Playgrounds Without Borders: Methods For A Playground Environmental Intervention Among U.S. Schoolchildren

J LeMaster, T Matisziw, J McElroy, C Nilon, S Sayers, S Stanis

Abstract

Background: Playground environmental interventions that increase children’s moderate-to-vigorous physical activity (MVPA) have not been adequately tested among low-income and minority children. Schools are key venues for environmental interventions because they reach children from all socioeconomic groups. Some issues remain unclear: whether these interventions benefit low-income and minority U.S. children; whether increases in MVPA at school are matched by increases outside school; whether benefits last beyond the immediate post-intervention period; and how children’s school and neighborhood environments affect their response to the intervention. Methods: Evaluation/study design: quasi-experimental intervention study, using both longitudinal and cross-sectional measurements during seven-day measurement sessions pre-intervention, immediately after intervention inception and every six months thereafter. Intervention: Walking/nature trails enhanced with fixed play equipment designed to stimulate activity directly on playgrounds and indirectly in local parks, trails and neighborhoods. Two schools will receive intervention early (Fall 2011) and two late (Spring 2012). Setting and population: 283 fourth-grade children and their parents (>50% of whom will be from low-income families) from four under-resourced elementary schools in a mid-western, mid-sized city. Measures:

Pre- and post-intervention: MVPA measured using geographically-linked accelerometers (indicating location and intensity of MVPA) and cross-sectionally using SOPARC methods to quantify the proportion of 4th graders playing actively on school playgrounds; qualitative interviews with children (cognitive mapping, photo-elicitation); questionnaires including secondary aim outcomes, family socioeconomic data and parent perceptions regarding neighborhood environments; children’s height and weight

Post-intervention only: focus group discussions with children and parents

Analysis:

Quantitative outcomes: hierarchical longitudinal data analysis, testing intervention effects as the interaction between study condition and time;

Qualitative outcomes: identification and iterative review of codes and themes, using a grounded theory approach to identify cross-cutting concepts that characterize interview and discussion responses.

Conclusion: This study will contribute to the prevention of childhood obesity nationally by developing, implementing and documenting an approach to assess the effects of community-developed environmental playground interventions using geographically attributed, longitudinal accelerometer data, cross-sectional SOPARC place-based data and qualitative interview data.
Several environmental intervention studies conducted among European schoolchildren report increases in playground-based activity [1-7]. Environmental strategies have most often included provision of game equipment and use of playground markings [2-8]. The most successful of these studies distributed game equipment rather than making permanent changes to playgrounds, and included both environmental and educational components, making it difficult to assess the effect of environmental changes [2,7]. Recent systematic reviews of randomized intervention studies to increase schoolchildren’s physical activity (PA) found none that examined the effect of an environmental intervention alone [9,10]. Verstraete reported that provision of game equipment coupled with an educational component in Belgian schools increased PA during recess[7]. Another study among preschool children in Belgium, which provided game equipment and/or playground markings, led to no change in accelerometer-measured PA during recess[8]. No playground environmental intervention studies have tested for effects of environmental interventions on children’s daily PA in their broader neighborhood environments beyond the playground, and none have been specifically tailored to needs of low-income or minority children[9-11]. Overall, the evidence suggests a state of equipoise regarding effects of environmental interventions on PA, especially for studies designed for low-income children that integrate the possible confounding effects of their home, neighborhood, and social environments.

PA interventions implemented on school playgrounds may increase the proportion of available playtime at school in which children participate in moderate to vigorous physical activity (MVPA), i.e., active play[9,11,12]. Some issues remain unclear: a) how such interventions can be tailored to benefit low-income and ethnic minority children in the U.S. (since the majority have been conducted in Europe and not specifically among minority students), b) whether increases in PA at school are accompanied by increases outside school, c) whether benefits last beyond the immediate post-intervention period, and d) to what extent children’s social and physical neighborhood environments influence their response to the intervention.

To investigate these issues, a school-based, environmental intervention is being conducted to promote increases in MVPA through modification of school playground environments in Columbia, MO. The overall goal of the study is to evaluate whether children’s interaction with their school and neighborhood environments increases PA, and to use these results to inform local advocacy efforts to prevent obesity among low-income and minority children. It is hypothesized that physical activity will increase more among children from schools that receive the intervention earlier and over a longer duration than in those from schools receiving it later over shorter durations.

**METHODS**

Overview: This study will determine the effect of a playground environmental intervention on school recess MVPA% (percent of available time spent engaged in MVPA); before- and after-school MVPA (minutes of available time spent in MVPA outside of school); open space MVPA (minutes of MVPA that take place in any outdoor open spaces); and the proportion of schoolchildren who are active on school playgrounds. We are using a quasi-experimental design, recruiting elementary schoolchildren (grade 4 in academic year 2010/2011) and their families from four elementary schools, each comprised of approximately 50% ethnic minority or low-income students. Two schools will receive the intervention in Fall 2011 and two in Spring 2012. These children provide longitudinal, repeated measures of location and activity every 6 months in the form of geographically attributed accelerometry records. These data will be integrated in a Geographic Information System (GIS) to assess children’s interaction with different types of environments. Children’s caregivers (parents or guardians) will provide information via questionnaires about the child’s (and family’s) demographic and socioeconomic background and regular participation in physical activity programming across the mid-western U.S. city in which the study is taking place. Qualitative methods (photo-elicitation interviews) will be used post-intervention to further assess children’s perceived access to and reasons for use of particular school playground and neighborhood open spaces (parks, trails, streets) for activity. Qualitative semi-structured interviews will also be used post-intervention to assess how children and their caregivers perceive the processes used to design and implement the playground intervention at their school. Finally, during each measurement period school-based methods (SOPARC) will be used to measure children’s cross-sectional PA on playgrounds during recess[13,14]. The study has been reviewed and approved by the Health Sciences Institutional Review Board of the University of Missouri.
PARTICIPANTS

Intervention schools proposed for the current project were selected by Columbia Public Schools (CPS) administrators in collaboration with academic and community partners. Table 1 displays demographic characteristics of students at participating and non-participating Columbia elementary schools. Participants will be 283 fourth grade students and their caregivers (parents or guardians). Selected schools have a disproportionately high ethnic minority and low-income population that has continued to increase since 2004. Table 1 also displays selected socio-economic characteristics (U.S. Census, 2000) for the neighborhoods within the attendance boundaries of area schools.

In the participant recruitment phase, families are initially contacted via a study brochure sent home with students by each child’s teacher. Parents or caregivers indicate approval for their child to participate in the study through written informed consent in addition to the child’s written assent. Principals at each school consent on behalf of the school for school-based System for Observing Play and Recreation in Communities (SOPARC) observations of groups of children on the school playgrounds, all of whom are unidentified in these observations. Recruitment of minority and low-income children is monitored using demographic data publicly available from the school district’s website, i.e., families’ self-identified ethnicity and numbers of students participating in reduced or free school lunch programs. No individual is excluded from participation in the study due to racial or ethnic origin or socioeconomic status; rather, the goal is to maximize recruitment of minority children and caregivers from participating schools.

FIGURE 1

Table 1: Schoolchildren’s characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Participating Schools</th>
<th>Non-participating Schools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total enrollment (N)</td>
<td>21,983</td>
<td>20,193</td>
</tr>
<tr>
<td>Minority students (N, %)</td>
<td>2,982 (14)</td>
<td>2,691 (13)</td>
</tr>
<tr>
<td>Low-income* students (N, %)</td>
<td>5,677 (26)</td>
<td>5,344 (26)</td>
</tr>
<tr>
<td>Total persons (N)</td>
<td>8,296</td>
<td>7,666</td>
</tr>
<tr>
<td>Minority population (N)</td>
<td>1,696</td>
<td>1,546</td>
</tr>
<tr>
<td>Families below poverty (N, %)</td>
<td>984 (15)</td>
<td>925 (15)</td>
</tr>
<tr>
<td>Households without vehicles (N, %)</td>
<td>567 (8)</td>
<td>538 (8)</td>
</tr>
<tr>
<td>Adults over 25 without high school/GED (N)</td>
<td>1,450 (4)</td>
<td>1,450 (4)</td>
</tr>
</tbody>
</table>

*Students receiving federally-funded free or reduced price lunches (2000 Census)

INTRODUCTION

Social ecological models are widely used by numerous agencies providing recommendations to promote activity and reduce obesity, and are considered the most promising strategy to organize efforts to change health behaviors in the U.S. population[15,16]. These models increasingly provide the conceptual framework for environmental interventions [1,17,18]. Social ecological models explain how a person’s social and physical environment interacts with the person’s physiological and psychological characteristics to limit or promote behavior change [19-21]. They postulate that to effect behavior change, interventions must address barriers to change in each environmental dimension [20,21]. Evaluations using a social ecological model ideally measure children’s outcomes in multiple dimensions, because changes in one environment dimension may affect other dimensions and related outcomes in each. Using this process may increase the social and cultural validity of the intervention for low-income families, reducing disparities between them and higher-income families[22-26]. Table 2 shows the social ecological conceptual model implemented in the current study, depicting how environmental interventions alter multiple dimensions of children’s physical and social environment.

FIGURE 2

Table 2: Social Ecological Model and related intervention elements

<table>
<thead>
<tr>
<th>Environmental Level/Dimension</th>
<th>Barrier</th>
<th>Intervention Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interpersonal (perception, family content)</td>
<td>Child perceives that playground equipment is uninteresting</td>
<td>Equipment installed that is designed with participation from kids who use it</td>
</tr>
<tr>
<td>Interpersonal/cultural (school, neighborhood content)</td>
<td>Low-income kids unaware of local city parks and walking trails</td>
<td>Safe, stimulating play-spaces are inaccessible (e.g. too far)</td>
</tr>
<tr>
<td>Physical (built and natural)</td>
<td>School intervention stimulates kids to use playground equipment</td>
<td>Stimulation kick-designed</td>
</tr>
<tr>
<td>Policy (laws and rules)</td>
<td>School playground after school hours not supervised</td>
<td>Signage placed at playgrounds</td>
</tr>
</tbody>
</table>

The core PA intervention component of the study is a nature/walking trail at each school with student-designed, fixed play equipment along the trails to stimulate active play on the playground and suggest use of parks and trails before and after school. Children congregate and are most active in playgrounds areas with installed play equipment[27]. Renovation of playgrounds, playground art and equipment all increase activity among older elementary school children[3-5,7,28,29]. Activity is often greater when trails link different features (e.g. equipment) in parks and playgrounds[30,31]. While children from low-income families tend to live closer to schools and more often walk for transportation[32], lack of recreational facilities in their
neighborhoods limits their activity[33]. In Columbia, a network of trails has been designed and built to promote active transportation, including walking/biking to school. This study will assess whether a playground intervention that increases active play on playground trails may therefore increase use of other local trails and parks after school.

The intervention is implemented using a community-organizing approach that engages caregivers and children, as well as school and community leaders. This approach builds on the social capital and experience gained from prior Robert Wood Johnson Foundation “Active Living” projects conducted in the area[34]. Further, this approach exemplifies participatory research, which “seeks to ensure community representation and ownership of the questions to be asked, the methods to be used, and ultimately the interpretation and application of research results”[35]. By using a participatory design approach, study investigators and community partners together seek to help each school’s children and caregivers take ownership of the project and tailor it to the school’s unique context and their perceived needs. Using a similar approach, a Wyoming “Active Living” partnership found self-reported use of community trails increased by twenty-fold[36]. In this study, post-intervention focus groups will be conducted to explore participating children’s and caregivers’ perceptions about the process.

During the planning process at each school, caregiver-led trail planning committees obtain input from students, caregivers, teachers, and community-based organizations representing local residents. This input is used to design and install trails and active play stations using locally available materials and volunteer labor donated by caregivers, local residents, and businesses. The scope of the project is limited in scale so that it is feasible to build it quickly using locally available resources, i.e., over one to two weekends. Children provide input by drawing pictures of equipment they think will be “fun to play on” both this year and the next. The final design is also American Disabilities Act compliant and meets the school district’s pre-established safety criteria. The play stations stimulate children’s after-school activity: for example, during the single-school pilot project (data not presented here), planning committees installed a climbing feature made of truck tires adjacent to a walking trail, similar to features and trails used in local parks. To further stimulate students’ after-school activity, school playgrounds remain accessible any time schools are not in session (after school and weekends) through a joint-use agreement with Columbia Parks and Recreation. Prior playground observational studies suggest that this could increase use of the playground trails even more[37].

**STUDY MEASURES**

Timeline: Fourth grade participants wear accelerometers to measure activity intensity and Global Positioning System (GPS) recorders (Qstarz BT1300S) to measure geographic location simultaneously for 10 days. A full week of school days and two weekends are measured. Measurements take place in Spring and Fall months having similar outdoor temperature and weather conditions. Children are given one-on-one orientation to the devices. Printed instructions on proper positioning and maintenance of the devices (i.e. nightly charging) are provided to both students and their caregivers. To reduce the risk of data loss, study staffs collect equipment at the beginning of the school day to charge the devices and download data. These are returned to the students before lunch or recess, fully charged. Post-baseline measurements will be made immediately post-intervention within the first month after the playground intervention is completed at each school to assess short-term response to the intervention, and every 6 months thereafter for the duration of the study.

Individual children’s physical activity (longitudinal cohort-based): Accelerometry is employed to collect information on children’s activity given that self-report activity questionnaires have generally proven inaccurate[38]. In this study, activity is measured with single-plane accelerometers since they are known to produce similar activity estimates to multi-plane instrumentation[39] (Actigraph, Pensacola, FL). These objectively and reliably measure physical activity for children of different gender, age, and race/ethnicity[40]. Children wear the accelerometer at all times except when sleeping, swimming or bathing. To obtain one week of continuous observations, physical activity is recorded as activity counts over 5-sec epochs. Epochs can then be aggregated to estimate overall energy expenditure per minute. A minute of moderate-to-vigorous physical activity (MVPA*min⁻¹) is categorized as any minute with > 3 metabolic equivalents (METs) per minute [41]. METs are a measure of activity intensity. Trost’s energy expenditure prediction equation can be applied to convert counts to METs, providing an appropriate characterization of children’s energy expenditure at moderate-vigorous intensity[42]. Because there is no consensus on the best formula for converting counts to METs[43], general physical...
activity (GPA) will be recorded as counts/min. The number of counts and minutes of MVPA can then be calculated for any type of temporal or spatial grouping (e.g., before school, during recess, PE class and lunch breaks, after school and weekends) using accelerometer data. MVPA% can then be defined as the proportion of recess minutes classified as MVPA. Minutes when the child reports not wearing the device will be excluded from subsequent analysis. Periods with more than 20 zero-count minutes, strongly indicative of non-adherence, are also removed from analysis[44]. A study “measurement day” is defined as the time interval when 95% of children have count data. Alhassan has developed a data-driven approach to determine the minimum number of minutes of accelerometer wear needed to adequately represent a day of activity. Their approach exploits the Spearman correlation between total counts during increasingly longer periods of time and average counts/min over the entire day. The minimal significant correlation value +0.8 indicating the lower limit of duration of the measurement day. Analysis days when activity was measured for less than this period of time can then be safely excluded[44].

Playground-based physical activity (cross-sectional, school-based): The collective physical activity of children at each school during recess can be used as a measure of the effect of the intervention at the school level. In our study, the proportion of children actively playing in each area of the playground is directly observed throughout the data collection periods. A modified version of the System for Observing Play and Recreation in Communities (SOPARC) is employed to measure the proportion of children who are sedentary, walking or vigorously active in different areas of the playground [13,14]. SOPARC was selected because it includes separate assessments of physical activity among children of differing race/ethnicity. Trained research assistants (RAs) observe playgrounds during lunch recesses when children are engaged in free play. RAs count the number of children who are either sedentary (lying, standing still sitting or squatting), moderately active, or vigorously active in each of the pre-determined target areas in the playground. Target areas are defined based on the layout of natural activity zones (e.g., blacktop, swings, soccer field). Observers systematically rotate through the playground target areas recording the gender and activity level of the youth. Periodically two observers simultaneously scan a target area to check for inter-rater reliability.

Activity geo-location: GPS devices record the location of children’s activities in their outdoor environments. To ensure children’s safety, GPS data is recorded on the device but cannot be actively transmitted. QStarz BT-1300s GPS recorders (QStarz International Co. Ltd, Taipei, Taiwan, R.O.C.) were selected for use given that they are small and lightweight (22 g) enabling continuous, inconspicuous wear on a lanyard throughout the day. The recorders had a battery life which, coupled with recharging at night by the school children and at school by the study staff, provide sufficient collection capabilities. Although 4 days of accelerometer data collection is adequate to reliably sample children’s movements[45], in this study GPS records are acquired for 10 days per child to allow for days of poor data collection (e.g., cloud cover, failure to wear the device). Accelerometer and GPS receivers are synchronized to start collecting data at the same time.

Qualitative Observations: Because quantitative physical activity data may not explain why and how children use (or do not use) different features in their school and out-of-school environment, two qualitative techniques (photelicitation and focus group interviews) will be applied immediately post-intervention in conjunction with accelerometer and GPS data collection to better understand how caregivers and children perceive the children’s school and neighborhood environments.

During photelicitation data collection, children will use digital cameras to take photographs depicting where they engage in physical activity [46–48]. Brief interviews will be conducted with the children in which the photographs will be discussed (e.g., where they went and why, where they did not go and why). By associating the timestamp of the digital photographs to corresponding GPS records, pictures and interview data will be linked to specific locations (i.e., participatory photo mapping). Interviews will be digitally recorded, transcribed and analyzed as qualitative outcomes, to examine children’s perceptions of their environment and the intervention.

Post-intervention focus group discussions will be used to understand how the environmental context in which the activity takes place impacts outcomes at each site[49]. After intervention inception at each school, a focus group discussion using the “World Café” or a similar format will be conducted to obtain caregivers’ and children’s thoughts about participatory processes used to plan and construct the playground intervention at their school as well as the
influence of school staff and the broader school and neighborhood environment in which the intervention was set. During a World Café discussion[50], small groups of participants rotate among discussion tables. A specific topic is discussed at each table, and participants rotate until all groups have visited all tables and responded to all topics. Questions will be based on group process theory, which posits that functional groups are “microcosms of society” that must be effectively organized to develop a shared vision and achieve their goals[51,52]. To assess caregivers’ perceptions of the wider context of the school and neighborhood environment, questions regarding supportiveness (or otherwise) of the school’s physical and social environment, access to parks and exercise facilities, changes in related local policies or built environment and access to community-based programs are included. To maximize participation of minority groups, all caregivers and children from low-income families will be individually contacted to invite them to this event. If these families do not attend, attempts will be made to contact them by phone or in person to review responses from families who did attend and obtain their feedback.

Survey Data: The caregivers of all 4 th graders will provide self-report questionnaire-based data at baseline. To minimize respondent burden and maximize participation, questionnaire completion time will be limited to 15 minutes or less. Questions will include demographics; caregiver’s perception of their child’s physical activity and engagement with neighbors; caregiver’s estimates of their own physical activity using the short version of the International Physical Activity Questionnaire[53]; perceptions about the physical environment of their school and neighborhood including availability for walking and cycling, safety from traffic and crime; and satisfaction with their access to school and neighborhood facilities[54,55].

**ANALYTIC METHODS**

Matching GPS and accelerometer data: Linking GPS and accelerometer data is an important step in analyzing the location and intensity of children’s out-of-school activity. Coupling these two different sources of data can facilitate assessment of the effect of intervention in different environments and populations [56-58]. In the current study, time-stamped accelerometer measurements (collected at 5 second epochs) are matched to the GPS records (collected at 5 second intervals) to which they correspond. Our team has worked extensively to derive and verify techniques for identifying and correcting spurious GPS points (e.g., those caused by signal drift) as well as compensating for missing GPS records in an effort to maximize the amount of accelerometer data that can be associated with a location. For example, at the start of a child’s activity each day, GPS records may be lost during GPS start-up and initial signal acquisition. Later in the day, records may be dropped or distorted if the GPS unit’s signal becomes occluded (e.g., when moving under tree cover or entering/leaving buildings). In our pilot study, empirical support for interpolation of missing GPS records for durations of signal loss beyond 60 seconds did not lead to a significant increase in the number of accelerometer measurements that could be matched to GPS points for analysis. Most periods of GPS signal loss longer than 60 seconds were in fact, much longer (indicating the child was not wearing the device or it was turned off). Therefore interpolation of missing GPS data points was found to be unnecessary and is not performed in the current study.

Geographic Information Systems (GIS) Analysis of GPS and Accelerometer Data: Publicly and commonly available layers of geographic information for the Columbia, MO, study site and its surrounding region (Boone County) were acquired to facilitate applicability of the analysis framework to other areas. These data include property parcels, building footprints, roads, public lands (parks and trails), locations of other recreational venues such as pools, gyms, community centers, schools, and other locations children may frequently visit (e.g. stores, restaurants). To identify other environments that may be suitable for physical activity, imagery from the U.S. Department of Agriculture National Agricultural Imagery Program was classified to create a GIS layer delineating different types of land use and cover[59,60]. From the many types of landuse/landcover that were delineated, focus was limited to several general classes of landuse most related to this study’s objectives. These include areas delineated as ‘Park’, ‘Institutional building’, ‘Institutional outdoor space’, ‘Other open space’, and ‘Water’.

Next, the GPS-accelerometer matched data were converted into point features and overlaid with the selected landuse classes to attribute each point with the type of environment in which it occurred. \( \text{Children's residences are geo-coded from addresses provided by caregivers and verified using the child’s GPS records. We identified a set of potential activity opportunities accessible on the observed routes between} \)
each student’s home and school (e.g., parks within 5 minutes’ walk along a road route) in the GIS. Identification of this opportunity set serves as a baseline by which a child’s access to opportunities for physical activity and the degree to which these places are actually used can be better evaluated. Further, this may help identify factors that constrain access to or influence student choice of activities (e.g., lack of sidewalks, hours of operation, crime). Routes to and from school will be assessed to measure total minutes per day (or subdivisions of a day, e.g., before and after school) spent in contact with different categories of geographical features, proportion of available time in each child’s time budget spent in such spaces, and intensity of activity (counts) when children are in contact with a particular type of feature. Spatial indices factoring in cost of movement are also being developed to help explain and characterize children’s activity and its distribution across space.

Longitudinal data analysis: These analyses will be conducted using SAS version 9.2 (SAS Institute, Inc., Cary, NC). The main unit of analysis will be each child’s physical activity measured over 10 days each semester. For accelerometer-based analyses, longitudinal data analyses will be conducted using hierarchical mixed models[61,62]. Prior studies using accelerometer data examined the distribution of residuals and found that standard assumptions of normality and constant variance were well satisfied, and that clustering effects within schools were very weak, i.e., intra-class correlation (ICC) = 0.017 (unpublished data). Thus, normal theory methods will be utilized for analysis of the accelerometer outcomes. Additionally, appropriate transformations will be employed to adjust for deviations from this assumption. The primary analysis of the accelerometer data will consist of a two-way analysis of covariance comparing early vs. late intervention schools, defining a between-group factor and “time” as a within-subject repeated factor. An interaction term between these factors (group-X-time) will be included to test whether the change in physical activity differed between the early vs. late groups (intervention group effect). The analysis model is provided below:

Let $Y_{ijt}$ denote a seven-day accelerometer-based outcome (MVPA) for student $i$, in intervention group $j$, from school $k$, at time $t$. A general expression for ANOVA type model described in section 7.a is then given by

\[
Y_{ijt} = \mu + \tau_i + \gamma_j + (\tau \gamma)_{ij} + \Sigma_{jk} + \delta_k + \epsilon_{ijt} \tag{1.1}
\]

where $\mu$ is the overall mean MVPA, $\tau$ and $\gamma$ are the main effects for time and intervention group, respectively, $\tau \gamma$ is the group by time interaction, $\Sigma$ a vector of student-specific covariates, $\delta_k$ the random effect for school, and $\epsilon_{ijt}$ the random error component (if needed). The $\epsilon_{ijt}$ are assumed to be tri-variate normal with mean zero and covariance structure $\Sigma_{ijt} \sim N(0, \Sigma)$ independent of $\delta_k$. It is possible to include $t = 0$ in $\epsilon_{ijt}$ or include baseline MVPA in $X_j$ as both models provide an estimate of the mean pre-to-post change. Except for the refinements of a possibly unstructured $\Sigma$ and the inclusion of the random school effect the model is a standard ANCOVA model for repeated measurements.

To estimate intervention dose effects (duration of intervention), the group factor will be replaced with each child’s exposure to the intervention represented by daily attendance at a post-intervention school as a continuous variable. For each outcome the intra-correlation coefficient will be calculated to determine if a random effect needs to be added to the model to account for dependencies due to nesting of students within a common school environment. An appropriate residual correlation matrix will be used to account for repeated physical activity measurements for each child. Since this study will not randomize schools, all models will be adjusted for demographic or selected variables as covariates, such as BMI or GIS-based indices indicating access to public open spaces. Because weekday and weekend activities may differ qualitatively, they will be accounted for separately. Analytic weights will be employed to account for differences in the amount of data that each child provides (e.g. the inverse of the variance of minutes the accelerometer was worn each day). As a secondary analysis, possible moderation of treatment effects for longitudinal-cohort physical activity outcomes will be assessed using interaction tests between study group and each potential moderator. Of most interest will be to test whether intervention effects differ for children of different income-level, race/ethnicity and between genders.

Though extremely valuable as sources of information, accelerometer and GPS data are subject to a number of caveats. For instance, data can be corrupted or lost due to lost or damaged units, children not wearing the units, or staff not properly downloading and charging the unit between children. Data missing due to these effects will be attributed...
to random and non-informative processes. Although unlikely, if missing data due to instrument loss or student relocation is substantial (>10% of observations) multiple imputation will be used to test the sensitivity of the complete-data models, using statistical methods to incorporate uncertainty into the analysis[63,64]. The SAS procedures MI and MIANALYZE provide the computational tools. In addition to significance levels, appropriate summary statistics along with 95% confidence intervals will be reported for all study outcomes. To inform future studies, simple effect sizes defined as the mean change in each group’s outcomes divided by a naïve estimate of the pooled standard deviation for that outcome will be reported.

School-based, cross-sectional activity: Since these measurements will be performed on groups of children (rather than individuals), this outcome will be the proportion of children active in the schoolyard on a given day. Comparisons will be performed as with the accelerometer data and data will be analyzed using a binomial distribution and the logit function in generalized linear models (SAS events trials syntax). This approach will allow for the incorporation of repeated measurements for each schoolground. A generalized estimating equation will be used to accommodate dependencies due to repeated observation of same playground[62]. Otherwise, the same analytic design as described above for longitudinal data will be employed, but at the class level only.

Power analyses: A simulation study of the mixed model described above using accelerometer data from our prior studies in the study city was conducted. Since accelerometer-based MVPA% during recess and lunch breaks is the most proximate outcome to the intervention, the simulation was based on this outcome. In previous studies analyzing accelerometer data[Sayers SP, LeMaster JW, Thomas IM, Petroski GA, Ge B. unpublished data], it was found that children’s pre-intervention MVPA% during recess and lunch breaks was 67% (SD 17%), that within-child correlation for data measured 1 week apart was 0.56, and inter-class correlation (ICC) comparing activity between children within schools was very weak (0.02). Several assumptions were required to conduct the simulation: that within-child correlation is considerably less when activity is measured further apart (approximately 0.2-0.3); that within-school correlation is greater due to clustering effects of classes playing together at recess (approximately 0.05); that the variance of MVPA% is constant=289 (=17^2) and that a meaningful change in MVPA% immediately post-intervention (T1) in the early intervention group (EG) is ½ SD (12.7% increase from baseline) and ¾ SD six months later (T2); and that the probability of type 1 error will be 5%. For the late intervention group (LG) schools we assume there will be no change from T0 to T1 and ½ SD from T1 to T2. The diagram below depicts these assumptions. “Int” indicates the timing of the intervention.

Figure 4

Given these assumptions, recruitment of a cohort of 160 students (for longitudinal data analysis) would have 90% power for the T0 to T1 contrast within the EG and for the T1 to T2 contrast within the LG, and over 95% power to detect an overall short-term gain (the mean change in activity from T0 to T1 in EG and T1 to T2 in LG (effect of intervention duration) and approximately 84% power to detect an EG vs. LG difference immediately post-intervention at Time 1 (between group effect). Using identical outcomes and a similar environmental intervention, Verstraete found a similar change in MPVA% pre- vs. post-intervention[7]. Other environmental intervention studies have likewise reported increasing intervention dose effects as children’s exposure to the intervention accumulates [1,2].

QUALITATIVE ANALYTIC METHODS

All interviews will be recorded, transcribed verbatim and imported by source into NVivo Version 9.0 software (QSR International, Cambridge, MA) for content analysis using a grounded theory approach; that is, a common code book will be developed by reviewing a small representative portion of the data (1 of each type of discussion or interview). Each interview will then be independently coded by 2 faculty or other study staff, and codes compared to assess inter-rater agreement and achieve consensus. Emerging codes (single ideas identified by participants) will be organized and themes (larger ideas that summarize groups of codes) in NVivo to facilitate extraction of quotations to which codes and themes relate. Codes and themes will be reviewed iteratively throughout the study to identify cross-cutting themes that characterize participants’ overall responses by gender, race/ethnic group, and school.
DISCUSSION

This study will contribute to the prevention of childhood obesity nationally by developing, implementing and documenting an approach to assess the effects of community-developed environmental playground interventions using geographically attributed, longitudinal accelerometer data, cross-sectional SOPARC place-based data and qualitative interview data. The study fills an important gap in the existing literature by evaluating an environmental intervention designed for (and by) low-income children and their families to affect PA-related behavior; will measure a cohort of children longitudinally as well as cross-sectionally; and will examine the influence of multiple dimensions of low-income children’s social and physical environments on their response to the intervention. Additionally, these results will provide vital information to local and regional policy-makers whose aim is to reduce obesity among U.S. children.

In an Institute of Medicine review of environmental PA interventions, reviewers cited as a general weakness the reliance of environmental intervention studies on cross-sectional evaluations (with different children) rather than longitudinal evaluations of the same children[15]. The current study addresses this weakness by examining cross-sectional changes in children’s PA as a group in each school (using SOPARC methods), and also using a longitudinal design, combining accelerometers with global positioning system (GPS) recorders to help identify where, when and how much each child is active. This ability to link information about children’s activity with the activity’s geographic context will allow us to better understand how children respond to PA interventions while facilitating dissemination of this information to agencies advocating for changes in the built environment. Our study thus provides measurement capabilities not previously used in longitudinal intervention studies investigating the effect of environmental interventions on schoolchildren’s activity.

Here, a population-based approach is implemented: recruiting schoolchildren from schools provides the optimal window on their activity. Firstly, all children must attend school; second, because they spend so much time there during the day, schools provide an optimal opportunity to promote activity and for children to be active. The mixed methods approach will facilitate interpretation and understanding of the effects (if any) of social determinants of health on children’s response to the intervention (via caregiver questionnaire data); provide measures of activity intensity and duration (accelerometer-based data) as well as its location (GPS data) and the integration of all of these; and how children’s interaction with their particular school and neighborhood contexts affect intervention response (photo-elicitation interviews and focus group discussions). The study will therefore lay the foundation for a future cluster-randomized intervention study to determine the effect of such environmental interventions on schoolchildren’s physical activity across a range of school contexts. The results will also be of use to playground planners and designers in local schools and local governments, to help them build “habitats” where children prefer to be active.

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