STUDY PROTOCOL

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Evaluation of the Little Rock Green Schoolyard initiative: a quasi-experimental study protocol

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Abstract

Background Evidence suggests that access to green schoolyards may facilitate vigorous play and lead to increased physical activity, which could lead to improved academic outcomes and reduce excess childhood weight gain. Greener schoolyards can also provide additional outdoor amenities that help the community at large. The Little Rock Green Schoolyard Initiative, a program aiming to promote outdoor learning and play in two of the city's community schools, provides a natural experiment to evaluate the role of such interventions. This article presents the protocols and study plans that will be used to evaluate this community-led initiative on several outcomes including physical activity, sleep quality, use of schoolgrounds, and perceptions of the school environment. Administrative datasets will be used to assess exposure to green schoolyard improvements on academic achievement, attendance, and disciplinary referrals during elementary school.

Methods Data will be gathered in two community schools where the green schoolyard improvements are taking place and in two demographically-matched comparison schools located elsewhere within the Little Rock School District. Data will be collected before, during, and after the green schoolyard improvements go into effect. Physical activity and sleep quality will be measured using actigraphy. Physical activity will also be assessed through direct playground observations during recess and outside of school hours. During the final year of the study, administrative data will be assembled and evaluated using difference-in-differences estimation and synthetic controls, two causal inference methods from the program evaluation literature.

Discussion The study is designed to provide new insights into the design, implementation, and evaluation of playgrounds among schoolchildren, especially those who are at risk of developing severe obesity during their elementary school years. The research herein will develop empirical data, elucidate potential mechanisms, and practical experience for future study, policymaking, and health services.

Keywords Green space, Physical activity, Accelerometry, Childhood obesity, Green schoolyards, Child health, Quasi-experiment, Environmental strategies

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Background

The Little Rock Green Schoolyard Initiative has an initial focus on two elementary schools. The initiative is supported with a training and technical assistance grant from the National League of Cities and the Children and Nature Network. The aim is to transform the grounds of these two schools into nature-filled greenspaces that are conducive to outdoor learning and provide better opportunities for physical activity during and after school hours. Site modifications that address drainage issues, renovations to activate existing greenspaces, improvements to fencing that facilitate easier access to green areas, and the addition of landscape plants to provide shade and improve air quality are among the planned green space improvements.

The initiative is part of Little Rock Community Schools. Community schools engage members of the surrounding community to help ensure children have what they need to succeed (see Fig. 1). Using the community schools model, several critical needs were identified around school greenspace. These were: (1) opportunities for outdoor learning; (2) improved outdoor play experiences; and (3) safe, welcoming spaces for the community to connect with nature outside of school hours. The two schools initially targeted for green schoolyard improvements

serve lower-income, predominantly African American communities. Each school is centrally located in a walkable neighborhood, but residents in these neighborhoods have limited access to city parks within walking distance.

A growing literature on the health benefits of greener environments suggests that physical activity/play, air quality, sleep, and social behaviors are intertwined pathways that may protect against excess weight gain as well as promote psychological well-being and learning [1–12], hence the necessity of this work. Long term, programs like the Little Rock Green Schoolyard Initiative may improve health equity because the neighborhoods surrounding these schools are disproportionately affected by cardiometabolic conditions linked to inadequate physical activity and obesity.

The goal of this study is to take advantage of this community-led effort to understand the pathways through which green schoolyard improvements can improve health, academic outcomes, and community well-being (see Fig. 2). Specifically, the aims of the study are as follows:

1. Assess the impact of a community-led green schoolyard intervention on environmental and behavioral pathways to greater and more vigorous physical activity.
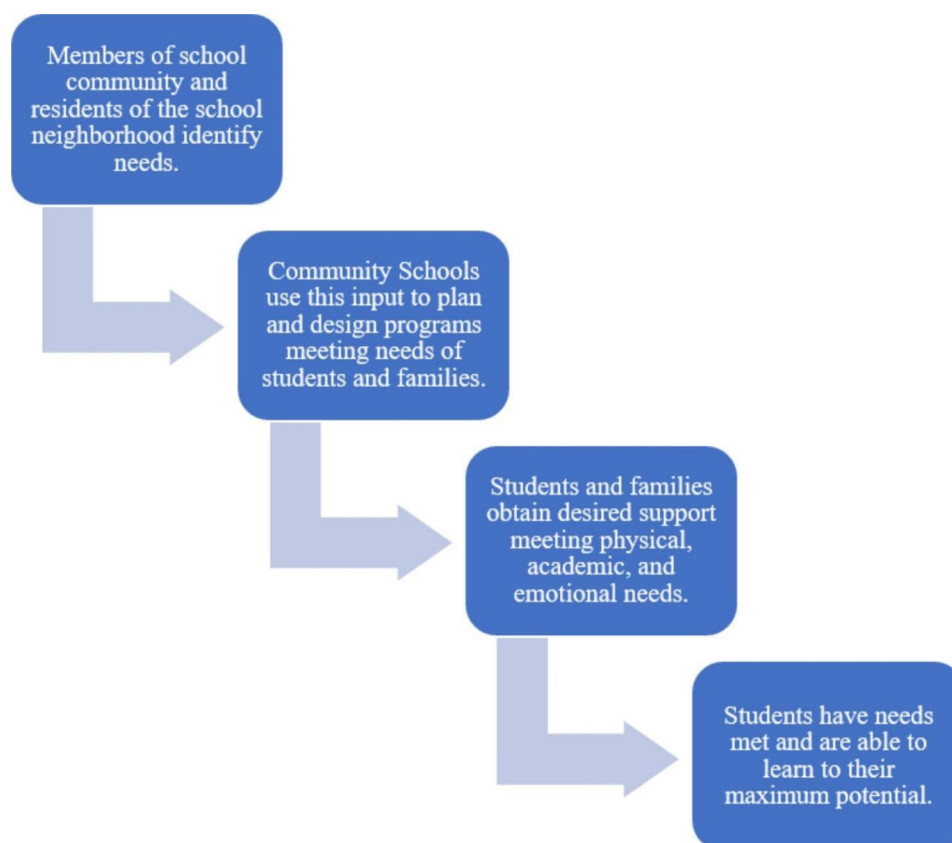
Fig. 1 Overview of the community school model
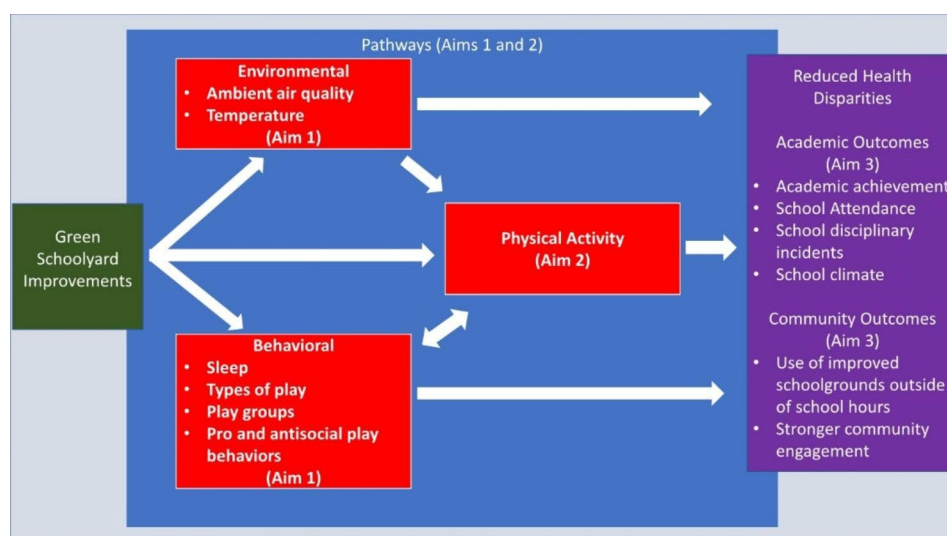
Fig. 2 Conceptual model used to develop the aims of this study

2. Determine the effect of greenspace improvements on physical activity among children in communities at high risk for cardiometabolic outcomes.
3. Identify the impact of greenspace improvements on academic and community-use outcomes of high importance to community- and school-level decision makers.

The study has an additional secondary aim, which is to characterize community- and school-level barriers that, if addressed, would amplify the impact of future school greenspace interventions.

Methods

The study involves a pre-post-comparison design. Data will be collected on outcomes related to the pathways presented above in Fig. 2 before, during, and after the green schoolyard transformations from children in the program schools and in comparable (demographically-matched) non-program schools within the Little Rock School District. The study is designed to understand how these pathways work in combination and whether greener schoolyards influence patterns of play in ways that improve opportunities for physical activity among children who are at greater risk for developing severe obesity. Community- and school-level barriers to implementation of the green schoolyard intervention will also be identified to inform future initiatives. Table 1 summarizes data collection activities (described in more detail below) over the four-year study period.

Schoolground characteristics and use

Research assistants and the study team will systematically observe recess during the fall and spring of each academic year. Observations will be conducted using the System for Observing Play and Leisure Activity in

Youth (SOPLAY) [13] and will assess activity, social context and environmental factors contributing to the quality of recess. With SOPLAY, members of the study team visually scan pre-determined target sections of the playground and record the number of persons engaged in various levels of physical activity at a given point in time [14–16]. Interobserver reliability will be regularly assessed. Observation days will be simultaneous between intervention and control school pairs and be conducted on a minimum of two school days within each fall and spring semester. Additional data collected on school-ground characteristics will be as follows:

a. After-hours schoolyard observations using the SOPLAY protocol will also be conducted during weekend days and on randomly selected days during the summer, and non-academic term consistent with previous school-based observation protocols [16–18].

b. Fine particulate matter ($PM_{2.5}$) will be collected using sensors (Purple Air-II-SD, PurpleAir LIc, Utah, USA) that will be placed in the schoolyards of participating schools. The use of such monitors has been evaluated previously [19–24]. They are calibrated and highly correlated with each other, providing an expectation of validity when making comparisons of measures between and among the same Purple Air-II-SD monitors placed at different schools. Data will be collected on a continual basis and will be gathered periodically through storage on an SD card to provide $PM_{2.5}$ data that can be linked temporally to the accelerometry data (described below) and to the playground observation data. These data will also be used to assess potential reductions in exposure to $PM_{2.5}$ due to the greening of the school yards

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Table 1 Summary of data collection measures by academic year (AY) and season[a]

Data collection activity	Baseline AY 1			Implementation AY 2			Post-implementation AY 3 and AY 4		
	Fa	Sp	Su	Fa	Sp	Su	Fa	Sp	Su
Aim 1: Assess the impact of a community-led green schoolyard intervention on environmental and behavioral pathways to greater and more vigorous physical activity.									
Accelerometry (sleep)[b]	X	X		X	X		X	X	
Social behaviors at recess (SOCARP)[c]	X	X		X	X		X	X	
Air quality/temperature	X	X	X	X	X	X	X	X	X
BMI measurement[d]	X	X		X	X		X	X	
Aim 2: Determine the effect of greenspace improvements on physical activity among children in communities at high risk for cardiometabolic outcomes.									
Accelerometry (physical activity)[b]	X	X		X	X		X	X	
Schoolground observations at recess (SOPLAY)	X	X		X	X		X	X	
Physical activity at recess (SOCARP)[c]	X	X		X	X		X	X	
BMI measurement[d]	X	X		X	X		X	X	
Aim 3: Identify the impact of greenspace improvements on academic and community-use outcomes of high importance to community- and school-level decision makers.									
School climate surveys	X	X		X	X		X	X	
After-hours schoolground observations (SOPLAY)	X	X	X	X	X	X	X	X	X
Passive monitoring of schoolground use	X	X	X	X	X	X	X	X	X
Retrospective analysis of administrative data on academic achievement, discipline, and attendance							X[e]	X[e]	X[e]
Secondary Aim: Characterize community- and school-level barriers that, if addressed, would amplify the impact of future school greenspace interventions.									
Teacher/staff interviews	X	X		X			X		

[a] Su = summer, Fa = fall, and Sp = spring; SOCARP = System for Observing Children's Activity and Relationships During Play, SOPLAY = System for Observing Play and Leisure Activity in Youth

[b] Accelerometry for physical activity and sleep are listed separately by aim but are measured simultaneously

[c] Collected during the same direct observation sessions

[d] Measured when accelerometers are fitted, used to assess differences in playground behaviors and physical activity by weight status in Aims 1 and 2

[e] Final post-implementation year (AY 4)

comparing pre- and post-implementation levels to those in the corresponding comparison schools.

c. Temperature will also be tracked over time. Changes in land surface temperature and density of addition of greenness can be estimated over time using Landsat images from the US Geological Survey in Google Earth Engine and compared.

Data collection involving schoolchildren. School climate surveys, accelerometry, and recess observations will occur twice per year: once during the fall and again in the spring. At each data collection point, child/parent dyads will be recruited to participate in the following study activities.

d. *School climate surveys*: Consented/assented children in grades 3 to 5 will complete a short school climate survey covering the domains of engagement, safety and school environment using validated questions from the US Department of Education's National Center on Safe and Supportive Learning Environments [25]. Participating children in kindergarten through grade 2 will not complete the climate survey because the survey questions are not designed for this younger age group.

e. *Accelerometer/Physical activity (and sleep) assessment*: Student total day, school day, and recess

physical activity will be measured using GT9X accelerometers (ActiGraph, Pensacola, FL, USA) worn on the waist. Students will be asked to wear the devices on the hip for 7 days for 24 h per day except for water-based activities with parents reporting out-of-bed times and when the monitor is removed in accordance with existing protocols [26–30]. While consensus on processing 24-hour accelerometry data in children has yet to be established [31], waist placement is selected due to the established validity for estimating time spent in moderate-to-vigorous physical activity (MVPA) in children [32] and the ability to assess sleep duration in combination with reported sleep times [33]. For days not directly observed by research assistants, school start, and end times will be reported by the school, and recess times will be reported by classroom teachers daily with a sub-sample of recess periods observed by research assistants. Primary activity outcomes will be time spent in MVPA during the recess period, total school day and the total day in addition to total sleep time. Accelerometers will not be GPS capable due to the hesitancy of the target population to participate in research and parent unease with the location tracking of children.

f. *Biometric measures*: Children will be measured for height, weight, and waist circumference when the accelerometers are fitted. Height will be measured using a free-standing portable height rod (0044-0392-0 M, Detecto, Webb City, MO, USA). Weight will be measured using a personal scale (BF-689, Tanita, Arlington Heights, IL, USA) The measurement of waist circumference will occur via tape measure (BalanceFrom Body Tape Measure, Ontario, CA, USA) using standard World Health Organization procedures and internationally recommended cut points [34]. The fittings and measurements will take place in a private-setting within each of the schools (e.g., nurses office) and will follow current protocols for body mass index (BMI) measurement in Arkansas public schools [35].

BMI will be calculated as (weight in pounds) ÷ (height in inches)^2 × 703. Because recent findings caution against the use of BMI z-scores in analyses of samples with severely obese children [36–38], we will use $\%BMI_{95}$ defined as the ratio of BMI to the 95th percentile on the sex-specific BMI for age reference charts. Freedman and colleagues [38] showed that measures relative to the 95th percentile are more strongly correlated with other measures of adiposity than BMI z-scores and are correlated comparably to z-scores across the full distribution of children. Weight classifications used in the study will also be based on the Centers for Disease Control and Prevention sex- and age-specific BMI growth charts and will include underweight (BMI ≤ 5th percentile), normal weight (5th percentile ≤ BMI < 85th percentile), overweight (85th percentile ≤ BMI < 95th percentile), and obese (BMI ≥ 95th percentile). Those in the obese classification will further be assigned to class I obesity ($100\% \leq \%BMI_{95} < 120\%$), class II obesity ($120\% \leq \%BMI_{95} < 140\%$), and class III obesity (determined by the smaller of $\%BMI_{95} \geq 140\%$ of the 95th percentile or a BMI of 40) [39]. Finally, the assessment of waist circumference will enhance these BMI-based measures by allowing abdominal obesity to be measured. Abdominal obesity heightens the risk for insulin resistance and cardiovascular disease, among other detrimental physiological effects [40–42].

g. *Direct observations of target children during recess*: The SOPLAY protocol described above is used to measure the amount of different levels of physical activity in pre-determined target areas of the schoolground. A similar observation protocol, the System for Observing Children's Activity and Relationships During Play (SOCARP) [43] will be modified and used to assess the activity of consented/assented children during recess. In our case, the target children are those participating in the accelerometry component of the study and for whom BMI and waist circumference will be measured. SOCARP is a validated protocol to measure physical activity levels on a single child in timed intervals [44]. The observers record information about activity types, social group size, and social interactions that can be used to assess occurrences of pro-social and anti-social behaviors before and after the greenspace enhancements [15, 45, 46]. We are also interested in whether these behaviors vary by gender and by weight status.

In preparation for the recess observations and data collection, the study team developed R Shiny apps to collect the recess observation data. These apps take advantage of the open-source R software environment [47]. Separate apps are designed specifically for the playground observations during recess, observations outside of school hours, and individual recess observations of assented children. The apps are best used on a tablet computer with a local R installation or on mobile (iOS/iPadOS or Android) devices with one of the observers wearing a backpack server (a laptop in a backpack that is running R Shiny Server software and a battery-powered travel router). We anticipate releasing these apps under the open-source GNU General Public License (GPL) version 3 and making them available on GitHub after we have refined them in the field and have developed documentation to facilitate their use by other research groups.

Administrative data on academic achievement, attendance, and disciplinary incidents. During the final year of the study, we plan to obtain administrative educational data to evaluate the green schoolyard initiative in terms of academic achievement, attendance, and disciplinary referrals.

h. Academic achievement will be measured in terms of standardized test scores on math and English language arts (ELA) in 3rd through 5th grade. The actual tests used to assess children will vary during our study period causing scales of raw scores to differ over time depending on the test used. To address changes in testing, we will standardize the raw math and ELA scores by grade and year to obtain z-scores for use as the outcome.

i. Attendance will be measured as the fraction of days present at school to total school days.

j. Following earlier work using the discipline component of the Arkansas Department of Education (ADE) administrative data [48], we will measure total disciplinary infractions along with three subgroupings:

    i. Aggressive behavior infractions: Offenses such as fighting, bullying, student assault, or staff assault.

    ii. Misconduct infractions: Actions disruptive to the learning environment, such as disorderly conduct, insubordination, truancy, and vandalism.

    iii. Other infractions: Incidents related to contraband items and miscellaneous offenses including those that fall under the "other" category within the ADE data.

There is evidence of disparities in disciplinary enforcement. Schoolchildren from communities of color are charged with infractions at higher rates than non-Hispanic white children both nationally [49] and in Arkansas [48]. The difference in differences and synthetic control methods used in the statistical analyses described below are robust to this issue.

Implementation measures. The primary implementation constructs of fidelity, dose, reach, satisfaction, and context will be assessed from multiple sources [50]. Implementation monitoring will follow the Consolidated Framework for Implementation Research (CFIR) to systematically assess factors influencing implementation [51]. Qualitative and quantitative implementation data will be collected from multiple sources including record examination, observations, surveys, and interviews. These detailed assessments will help to understand the various influences on effectiveness, which is particularly important due to the distinctiveness of each site and the community influences beyond the control of the research project. Interviews will be conducted with key stakeholders including principals, teachers, and staff. Nurses and school counselors will be included to examine potential unintended consequences of the green schoolyards on injuries and student mental health. Interviews will be conducted using the CFIR Interview guide [52].

Study population

Inclusion criteria

The study population includes elementary school-aged children in participating schools, their parents, and educators (including teachers, administrators, and other school staff). The children will range from 4 years of age (Kindergarten) to 12 years of age (5th grade). Most children will be 5 to 11 years old, but the 4 to 12-year-old age range specified enables for children that enter kindergarten early or late or repeat a grade to qualify for this research. Parents and educators will vary in age.

Exclusion criteria

Children, parents, and educators not attending or affiliated with one of the participating schools will not be eligible to participate.

Recruitment efforts will be coordinated and approved via the participating elementary schools and will occur multiple times per year during each of the four years of the study.

Recruitment efforts. IRB-approved recruitment flyers and signage will be used to recruit parent/child dyads. We will ask participating schools to include recruitment flyers along with other school and community interest information routinely being sent home to parents in student folders/backpacks and to distribute electronic versions of the flyer through routine electronic communications going to parents. We also plan to distribute flyers at school events attended by parents such as back-to-school nights, parent-teacher conferences, and PTA meetings. Signs will be placed in car-rider lines and near school entrances. IRB-approved invitations will be sent to educators with a request to participate in the CFIR interviews.

Our goal is to recruit up to 240 dyads (up to 10 per grade per school) at each of the planned data collection points. We will attempt to retain dyads for repeated observation over time but anticipate some degree of student turnover in these schools given that many families served by these schools face residential and job insecurity necessitating moves. Given the aims and scope of the study, we will not be retaining children who are no longer enrolled in the participating elementary schools due to a school transfer or to completion of the 5th grade.

Data analysis

The data collection plan for physical activity outlined above will provide adequate power to detect meaningful effects. Using an alpha of 0.05 and power of 80%, we calculated the minimum detectable difference between two parallel groups in the primary outcome of MVPA during recess. In pilot data from several Arkansas elementary schools, the average time children spent in MVPA was 40.4% with a standard deviation of 18.7%. Assuming MVPA before the green schoolyards program, the minimum detectable difference would be 6.8% of recess time which is equal to or greater than previous interventions to increase recess physical activity [53]. Given the recruiting target N=240) and a daily recess time of approximately 40 min as mandated by state legislation, we will have adequate power to detect anything greater than about a 3-minute difference in MVPA or 15 min per week.

Given the ability to collect baseline data, we can employ strong quasi-experimental designs to estimate the impact of the greener schoolyards on the pathway outcomes, the measurement of which are described above. We propose a difference-in-differences (DID) estimation to assess the program effects. DID is an established approach for causal inference in program and policy evaluations involving public health interventions [54]. We will assess whether our data meet the assumptions required to draw

valid causal inferences from DID designs and will conduct balancing tests for similarity in pre-implementation characteristics between children in the program and comparison schools. If necessary, we will modify our design to estimate DID regressions from matched samples to improve pre-implementation balance [55]. Robust standard errors will be clustered by cohort within school.

Additional sensitivity analyses to better understand interactions between the pathway outcomes and to assess robustness of findings from the DID estimations will include mixed-effects models [56] to assess differences in the trajectory of the measured pathway outcomes between children in program and non-program schools. This will help determine whether the green schoolyard program differentially effects physical activity among children with an unhealthy weight status. Structural equation models to correct for correlated and unobserved effects in the errors [57] that could jointly determine physical activity and sleep are also appropriate for these data. Continual progress is being made on empirical methods to strengthen causal inferences in program evaluations [58].

The administrative data being used to assess academic achievement and discipline will contain elementary schools across the state allowing us to employ the synthetic control method. The use of synthetic controls [59–61] has been identified as one of the most important innovations for program and policy evaluation in recent years [58, 62]. In short, a "synthetic" control elementary school will be constructed to correspond to each program school. The construction of the synthetic control is a weighted average of schools that did not undergo greenspace renovations. The synthetic control approach will provide an estimate of the program effect for each of the two program schools. Inference about this effect is accomplished through a series of placebo tests wherein the true estimate of the program effect is compared to the distribution of program effects that results when the analysis is repeated for each non-program school and its synthetic control. It is also customary to test sensitivity of the estimated program effect to the inclusion/exclusion of control units from the set used by the algorithm to form the synthetic control. As noted above, we expect disparities in disciplinary instances due to differences in enforcement. These methods, DID, and synthetic controls are robust to this issue allowing us to estimate valid average program effects.

To analyze implementation, in contrast to deductive empirical studies which test an a priori hypothesis, analysis for this aim will take an inductive approach [63]. Investigator experience and systematic data collection will be integrated into a comprehensive case study analysis. Quantitative data will be summarized for each implementation construct, and thematic analysis will be utilized to analyze all qualitative data [64]. A primary concern of many critics of qualitative research is a lack of rigor [65, 66]. The credibility of the research will be strengthened through triangulation by including multiple data sources (i.e., administrators, teachers, students) and multiple methods (i.e., interviews and observations). These multiple sources will help to eliminate single source bias. Triangulation will serve as confirmation in addition to providing a holistic portrayal of the process of implementation [67].

Discussion

The purpose of this research is to positively impact the lives and health of students, staff, and school communities by providing revamped and expanded green outdoor places for learning, playing, and engaging the community. A systematic review of experimental studies exploring the impact of schoolyard greening indicated favorable effects for physical activity and socioemotional health in children [68]. Not all greening/nature based interventions on childhood activity are found to be positive, some data show a decrease in moderate-vigorous physical activity when natural materials are added to a playground [69]. Similar to this natural experiment, previous work has shown the beneficial effects of green schoolyard renovations in low-income urban children by promoting higher levels of utilization, increased perception of safety, and more prosocial interactions [45]. The study herein helps address the limitations stated by Bohnert and colleagues by incorporating control/comparison schools and employing both observational and child level, via actigraphy, physical activity assessment methods [45].

Potential risk(s) of this research is the specific timing of program activities, changing administrations at the city and school level as well as potential adoption of greening programs at comparison schools is beyond the control of the study team. However, this study of the Little Rock Green Schoolyard Initiative provides an opportunity for a strong quasi-experimental design using demographically-matched comparison schools to answer important research questions and fill knowledge gaps in the literature on how greener schoolyards influence behaviors that reduce health disparities.

We anticipate that the Little Rock Green Schoolyard Initiative will be a new model for other schools to adopt and implement due to its potential to lessen health disparities, improve academic outcomes, and add a desirable area of recreation for the local community. Other regions with similar demographics can learn, modify, and benefit from this work. Future assessment of other demographics as well as specific mechanisms are necessary to evaluate the results of the Little Rock Green Schoolyard Initiative.

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List of Abbreviations

BMI	Body mass index
DID	Difference-in-differences
MVPA	Moderate-to-vigorous physical activity
$PM_{2.5}$	Fine particulate matter
SOPLAY	System for observing play and leisure activity in youth
SOCARP	System for observing children's activity and relationships during play

Authors' contribution
MRT, EKH, and KAW co-designed the project. MJB and MRT drafted the manuscript. EKH and KAW contributed to manuscript revision. All authors read and approved the final manuscript.

Data Availability
Not applicable as this article does not present data.

Declarations

Ethics approval and consent to participate
Ethical approval for this study has been received by the University of Arkansas for Medical Sciences Institutional Review Board (Protocol #274741). Informed consent will be obtained from all children and their parent/guardian. All methods will be carried out in accordance with relevant guidelines and regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

References

1. Hartig T, Mitchell R, de Vries S, Frumkin H. Nature and health. Annu Rev Public Health. 2014;35:207–28.
2. Lanza K, Alcazar M, Hoelscher DM, Kohl HW. Effects of trees, gardens, and nature trails on heat index and child health: design and methods of the Green Schoolyards Project. BMC Public Health. 2021;21(1):98.
3. Seo MY, Kim SH, Park MJ. Air pollution and childhood obesity. Clin Exp Pediatr 2020;63(10):382–8.
4. Zhang Y, Chen Z, Berhane K, Urman R, Chatzi VL, Breton C, et al. The dynamic relationship between asthma and obesity in Schoolchildren. Am J Epidemiol. 2020;189(1):583–91.
5. Astell-Burt T, Feng X, Kolt GS. Does access to neighbourhood green space promote a healthy duration of sleep? Novel findings from a cross-sectional study of 259 319 Australians. BMJ Open. 2013;3(8):e003094.
6. Monzon AD, Patton SR, Koren D. Childhood diabetes and sleep. Pediatr Pulmonol. 2022;57(8):1835–50.
7. Tillmann S, Tobin D, Avison W, Gilliland J. Mental health benefits of interactions with nature in children and teenagers: a systematic review. J Epidemiol Community Health. 2018;72(1):958–66.
8. van Dijk-Wesselius JE, Maas J, van Vugt M. A comparison of children's play and non-play behavior before and after schoolyard greening monitored by video observations. J Environ Psychol. 2022;80:101760.
9. Liu J, Green RJ. The effect of exposure to nature on children's psychological well-being: A systematic review of the literature. Urban For Urban Green. 2023;81:127846.
10. Raney MA, Daniel E, Jack N. Impact of urban schoolyard play zone diversity and nature-based design features on unstructured recess play behaviors. Landsc Urban Plan. 2023;230:104632.
11. Rahai R, Wells NM, Evans GW. School greenspace is associated with enhanced benefits of academic interventions on annual reading improvement for children of color in California. J Environ Psychol. 2023;86:101966.
12. Zare Sakhvidi MJ, Mehrparvar AH, Zare Sakhvidi F, Dadvand P. Greenspace and health, wellbeing, physical activity, and development in children and adolescents: An overview of the systematic reviews. Curr Opin Environ Sci Health. 2023;32:100445.
13. McKenzie TL, Marshall SJ, Sallis JF, Conway TL. Leisure-time physical activity in school environments: an observational study using SOPLAY. Prev Med. 2000;30(1):70–7.
14. Poulos A, Wilson K, Lanza K, Vanos J. A direct observation tool to measure interactions between shade, nature, and children's physical activity: SOPLAY–SN. Int J Behav Nutr Phys Act. 2022;19.
15. Raney MA, Hendry CF, Yee SA. Physical Activity and Social Behaviors of Urban Children in Green Playgrounds. Am J Prev Med. 2019;56(4):522–9.
16. Yu H, Kulinna PH, Mulhearn SC. The Effectiveness of Equipment Provisions on Rural Middle School Students' Physical Activity During Lunch Recess. J Phys Act Health. 2021;18(3):287–95.
17. Singletary CR, Weaver G, Carson RL, Beets MW, Pate RR, Saunders RP et al. Evaluation of a comprehensive school physical activity program: be a Champion! Eval Program Plann. 2019;75:54–60.
18. Baker EA, Elliott M, Barnidge E, Estlund A, Brownson RC, Milne A, et al. Implementing and evaluating Environmental and Policy Interventions for promoting physical activity in rural schools. J Sch Health. 2017;87(7):538–45.
19. Awokola BI, Okello G, Mortimer KJ, Jewell CP, Erhart A, Semple S. Measuring Air Quality for Advocacy in Africa (MA3): Feasibility and Practicality of Longitudinal Ambient PM2.5 Measurement Using Low-Cost Sensors. Int J Environ Res Public Health. 2020;17(19):7243.
20. Feenstra B, Papapostolou V, Hasheminassab S, Zhang H, Boghossian BD, Cocker D, et al. Performance evaluation of twelve low-cost PM2.5 sensors at an ambient air monitoring site. Atmos Environ. 2019;1:216:116946.
21. Mukherjee A, Stanton LG, Graham AR, Roberts PT. Assessing the utility of low-cost particulate matter sensors over a 12-Week period in the Cuyama Valley of California. Sensors. 2017;17(8):1805.
22. Gupta P, Doraiswamy P, Levy R, Pikelnaya O, Maibach J, Feenstra B, et al. Impact of California fires on local and regional air quality: the role of a low-cost sensor network and satellite observations. GeoHealth. 2018;2(6):172–81.
23. Karch D, Brito J, Sievwright J, Nayet C, Parsons M, Jones K, et al. Small Air Quality Sensor Applications to Improve Community Engagement in Western Canada. Poster Present Adv Citiz Sci Alta Chang Perspect Break Barriers; 2018.
24. Li J, Mattewal SK, Patel S, Biswas P. Evaluation of nine low-cost-sensor-based particulate matter monitors. Aerosol Air Qual Res. 2020;20(2):254–70.
25. Home | National Center on Safe Supportive Learning. Environments (NCSSLE) [Internet]. [cited 2023 Mar 8]. Available from: https://safesupportivelearning.ed.gov/.
26. Katzmarzyk PT, Barreira TV, Broyles ST, Champagne CM, Chaput JP, Fogelholm M, et al. The International Study of Childhood obesity, Lifestyle and the Environment (ISCOLE): design and methods. BMC Public Health. 2013;30:13:900.
27. Migueles JH, Cadenas-Sanchez C, Ekelund U, Delisle Nyström C, Mora-Gonzalez J, Löf M, et al. Accelerometer Data Collection and Processing Criteria to assess physical activity and other outcomes: a systematic review and practical considerations. Sports Med Auckl NZ. 2017;47(9):1821–45.
28. Runacres A, MacKintosh KA, Chastin S, McNarry MA. The associations of physical activity, sedentary time, and sleep with V˙O2max in trained and untrained children and adolescents: a novel five-part compositional analysis. PLoS ONE. 2023;8(3):e0275557.
29. Bergmann GG, Gaya AR, Silva LR, da Cruz JH, de Motta B, Ferreira TC. GD, 24-Hour Movement Guidelines: descriptive study with overweight and obese low-income children. J Mov Health. 2023;20(2).
30. McPhee PG, Di Cristofaro NA, Caldwell HAT, Proudfoot NA, King-Dowling S, MacDonald MJ et al. Physical activity trajectories in early childhood: investigating Personal, Environmental, and participation factors. Med Sci Sports Exerc. 2023.

31. Gao Z, Liu W, McDonough DJ, Zeng N, Lee JE. The Dilemma of Analyzing Physical Activity and Sedentary Behavior with Wrist Accelerometer Data: Challenges and Opportunities. J Clin Med. 2021;10(24):5951.

32. Evenson KR, Catellier DJ, Gill K, Ondrak KS, McMurray RG. Calibration of two objective measures of physical activity for children. J Sports Sci 2008;26(14):1557–65.

33. Barone Gibbs B, Kline CE. When does sedentary behavior become sleep? A proposed framework for classifying activity during sleep-wake transitions. Int J Behav Nutr Phys Act. 2018;15(1):81.

34. Xi B, Zong X, Kelishadi R, Litwin M, Hong YM, Poh BK et al. International Waist Circumference Percentile Cutoffs for Central Obesity in Children and Adolescents Aged 6 to 18 Years. J Clin Endocrinol Metab. 2020;105(4):e1569-1583.

35. BMI Height and Weight Measurement Training Manual [Internet]. ACHI. [cited 2023 Mar 8]. Available from: https://achi.net/library/bmi-height-weight-manual/.

36. Woo JG. Using body mass index Z-score among severely obese adolescents: a cautionary note. Int J Pediatr Obes IJPO Off J Int Assoc Study Obes. 2009;4(4):405–10.

37. Freedman DS, Berenson GS. Tracking of BMI z scores for severe obesity. Pediatrics. 2017;140(3):e20171072.

38. Freedman DS, Butte NF, Taveras EM, Lundeen EA, Blanck HM, Goodman AB, et al. BMI z-Scores are a poor indicator of adiposity among 2- to 19-year-olds with very high BMIs, NHANES 1999–2000 to 2013–2014. Obes Silver Spring Md. 2017;25(4):739–46.

39. Skinner AC, Perrin EM, Moss LA, Skelton JA. Cardiometabolic risks and severity of obesity in children and young adults. N Engl J Med. 2015;373(14):1307–17.

40. Lewitt MS, Baker JS. Relationship between abdominal adiposity, cardiovascular fitness, and biomarkers of cardiovascular risk in british adolescents. J Sport Health Sci. 2020;9(6):634–44.

41. Krekoukia M, Nassis GP, Psarra G, Skenderi K, Chrousos GP, Sidossis LS. Elevated total and central adiposity and low physical activity are associated with insulin resistance in children. Metabolism. 2007;56(2):206–13.

42. Gurnani M, Birken C, Hamilton J. Childhood obesity: causes, consequences, and management. Pediatr Clin. 2015;62(4):821–40.

43. Ridgers ND, Stratton G, McKenzie TL. Reliability and validity of the System for Observing Children's Activity and Relationships during Play (SOCARP). J Phys Act Health 2010;7(1):17–25.

44. Zarrett N, Abraczinskas M, Cook BS, Wilson D, Roberts A. Formative Process Evaluation of the "Connect" Physical Activity Feasibility Trial for Adolescents. Clin Med Insights Pediatr. 2020;14:1179556520918902.

45. Bohnert AM, Nicholson LM, Mertz L, Bates CR, Gerstein DE. Green schoolyard renovations in low-income urban neighborhoods: benefits to students, schools, and the surrounding community. Am J Community Psychol. 2022;69(3–4):463–73.

46. Prewitt SL, Rosselli C, Rosselli A. Physical activity and social interactions of Rural Elementary Children during recess. J Phys Act Res. 2019;4(2):114–7.

47. Team RC. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Httpwww R-Proj Org. 2016.

48. Cuadros-Meñaca A, Thomsen MR, Nayga RM Jr. School breakfast and student behavior. Am J Agric Econ. 2023;105(1):99–121.

49. Girvan EJ. Towards a problem-solving approach to addressing racial disparities in school discipline under anti-discrimination law. U Mem Rev. 2019;50:995.

50. Saunders RP. Implementation monitoring and process evaluation. Sage Publications; 2015.

51. Damschroder LJ, Aron DC, Keith RE, Kirsh SR, Alexander JA, Lowery JC. Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. Implement Sci. 2009;4(1):1–15.

52. Damschroder LJ, Reardon CM, Widerquist MAO, Lowery J. The updated Consolidated Framework for implementation research based on user feedback. Implement Sci 2022;17(1):75.

53. Parrish AM, Chong KH, Moriarty AL, Batterham M, Ridgers ND. Interventions to Change School recess activity levels in children and adolescents: a systematic review and Meta-analysis. Sports Med Auckl NZ. 2020;50(12):2145–73.

54. Wing C, Simon K, Bello-Gomez RA. Designing Difference in Difference Studies: best Practices for Public Health Policy Research. Annu Rev Public Health. 2018;1:39:453–69.

55. Qian Y, Nayga RM Jr, Thomsen MR, Rouse HL. The Effect of the Fresh Fruit and Vegetable Program on Childhood obesity. Appl Econ Perspect Policy. 2016;38(2):260–75.

56. Garrett MF, Laird NM, Ware JH. Applied longitudinal analysis. Hoboken NJ Wiley-Intersci; 2004.

57. Greene WH. The econometric approach to efficiency analysis. Meas Prod Effic Prod Growth. 2008;1(1):92–250.

58. Athey S, Imbens GW. The state of applied econometrics: causality and policy evaluation. J Econ Perspect. 2017;31(2):3–32.

59. Abadie A, Gardeazabal J. The economic costs of conflict: a case study of the Basque Country. Am Econ Rev. 2003;93(1):113–32.

60. Abadie A, Diamond A, Hainmueller J. Synthetic control methods for comparative Case Studies: estimating the Effect of California's Tobacco Control Program. J Am Stat Assoc. 2010;105(1):493–505.

61. Abadie A, Diamond A, Hainmueller J. Comparative politics and the synthetic control method. Am J Polit Sci. 2015;59(2):495–510.

62. Bouttell J, Craig P, Lewsey J, Robinson M, Popham F. Synthetic control methodology as a tool for evaluating population-level health interventions. J Epidemiol Community Health. 2018;72(8):673–8.

63. Creswell JW, Poth CN. Qualitative inquiry and research design: choosing among five approaches. Sage publications; 2016.

64. Braun V, Clarke V. Using thematic analysis in psychology. Qual Res Psychol. 2006;3(2):77–101.

65. Marshall C, Rossman GB. Designing qualitative research. Sage publications; 2014.

66. Sandelowski M. Rigor or rigor mortis: the problem of rigor in qualitative research revisited. Adv Nurs Sci. 1993;16(2):1–8.

67. Sandelowski M. Triangles and crystals: on the geometry of qualitative research. Res Nurs Health. 1995;18(6):569–74.

68. Bikomeye JC, Balza J, Beyer KM. The impact of Schoolyard Greening on Children's physical activity and Socioemotional Health: a systematic review of experimental studies. Int J Environ Res Public Health. 2021;18(2):535.

69. Brussoni M, Ishikawa T, Brunelle S, Herrington S. Landscapes for play: Effects of an intervention to promote nature-based risky play in early childhood centres. J Environ Psychol. 2017;54:139–50.

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