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RESEARCH ARTICLE

Physical Activity and Social Behaviors of Urban Children in Green Playgrounds

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Introduction: Nature exposure is associated with many wellbeing benefits. However, the influence of green space on the physical activity and social behaviors of children is not completely understood. The purpose of the study was to complete a stepwise impact evaluation of a large-scale playground greening project at a Title 1 elementary school in Los Angeles, California.

Methods: Physical activity and social interaction data were collected with direct observation and accelerometers pre-, immediately post-, and 4 months post-greening at control (students enrolled=393) and experimental (students enrolled=538) locations from 2016 to 2017. Effects of relevant variables on recess behavior were analyzed with linear mixed models in 2018.

Results: Zone popularity and recess behaviors did not change for control students during the study ($p>0.05$). Areas replaced by green space became the most popular for experimental students who transitioned from traditional playground games/sports to tag/chasing, gymnastics, climbing/jumping, and creative play. The percentage of students observed as sedentary decreased by 10.0% (95% CI=4.9%, 15.0%) at 4 months, $p=0.003$. Vigorous activity participation increased pre to post at the individual (48.5%, 95% CI=29.1%, 67.9%, $p<0.001$) and population level (41.2%, 95% CI=27.3%, 55.1%, $p=0.003$) and remained higher than pre-greening at 4 months ($p<0.05$) for girls in the experimental group only. The moderate to vigorous physical activity differential between green space and hardscape was greater for fifth graders than all other grades, $p=0.002$. Student physical and verbal conflict rates decreased below pre-greening rates after 4 months for the experimental group, $p<0.001$.

Conclusions: Results suggest that adding green space to asphalt-covered schoolyards helps expose children to nature, increases daily activity levels, and promotes social wellbeing in sex- and age-dependent ways.

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INTRODUCTION

Multiple studies have shown that physical activity (PA) is positively related to health and academic performance.[1–4] Unfortunately, more than 80% of Los Angeles, California, children do not meet the federal PA guidelines.[5] Physical inactivity has been linked to lower SES, poor neighborhood safety, a lack of green space, and peer bullying.[5–9] In part because of inactivity, 32%–36% of Los Angeles children living in low-income urban neighborhoods are obese and more than 6% report fair or poor health status.[7,8]

Nature exposure has been related to multiple physical, mental, and social health benefits.[9–18] Natural elements in play spaces appeal to children with diverse play preferences and may subsequently contribute to playground cohesiveness and decreased bullying during recess, as suggested through retrospective surveys and post-greening behavioral mapping.[19–25] In addition, depending on playground design, children can accumulate up to 40% of their recommended moderate to vigorous physical

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activity (MVPA) minutes at recess.[26–28] However, results from cross-sectional studies that quantify activity levels in green spaces are equivocal. For example, some studies show that students are more likely to be sedentary on paved sport courts and solid surfaces and more likely to be engaged in MVPA in grassy areas within a single playground,[19,29] whereas other studies show that step count and the percentage of students engaged in MVPA is similar between schoolyards with large differences in green space.[20,30] Green space tends to appeal more to girls and asphalt with painted lines tends to favor boys and students who are already meeting the PA guidelines through sport.[19,31,32] Interestingly, some studies demonstrate that boys are more active than girls in school[19] and neighborhood[18] green space and others demonstrate that MVPA is either not different between sexes or higher for girls in urban green space.[14,33]

Results from the aforementioned studies suggest that the influence of playground greening is not completely understood. In addition to inconsistent findings, a majority of previous studies evaluating the impact of green space use acute population-level momentary sampling techniques and have not included a control location.[10,13,14,19–22,29,34] No study has examined a stepwise impact of school playground design changes or determined whether PA rates persist over time for individual students. Studies comparing sex-specific and age-group PA levels in green schoolyards are also lacking.

The purpose of this study is to identify the relative impact of a large-scale playground greening project at a Title I elementary school in Los Angeles, California. The study specifically aims to determine the short- and long-term impacts of playground greening on MVPA levels and on antisocial interactions during unstructured recess periods.

METHODS

Study Population

The study was a nonrandomized, controlled trial with cluster sampling that was conducted from 2016 to 2017. Two Title I elementary schools in the Los Angeles Unified School District with baseline enrollments of 393 (control) and 538 (experimental) students were selected based on proximity, playground square footage, baseline playground design, and existing plans for large-scale greening renovations at one site. A total of 437 students (355 experimental; 82 control) participated in one or more individual data collection methods described below. Appendix Table 1 provides a breakdown of subject demographics in relationship to study participation.

At baseline, the following zones were present at both locations: kickball, basketball, volleyball, four-square, dodgeball, tetherball, handball, open field, and non-designated space near buildings. Zone number (control=18, experimental=21) and location were held constant throughout the study. In summer 2016 in the experimental location, ≅21,000 square feet of asphalt distributed in four playground zones were replaced by green space. Changes included (1) introduction of trees, mulch, and boulders in two zones; (2) replacement of one asphalt field with grass and trees; (3) replacement of another asphalt field with an outdoor classroom (decomposed granite floor, mulch and plant border, and log seating).

Measures

Recess-specific playground behavior was assessed for a period of 2 weeks prior to (pre-greening), immediately after (post-greening), and again 4 months after greening (follow-up). At both locations, two separate 20-minute recess periods were held in the morning and afternoon according to grade level (first to third grades and fourth and fifth grades).

PA and social interactions were assessed with two recess-context validated observation tools: System for Observing Play and Leisure Activity in Youth (SOPLAY) and System for Observing Children's Activity and Relationships During Play (SOCARP).[35,36] Researchers achieved a Cronbach α inter-rater agreement of 98.2% for combined SOPLAY and SOCARP measurements during training exercises, which met previously established reliability criteria.[22,35] SOPLAY includes systematic scans of individuals and contextual factors within predetermined target zones. During a scan, activity level of individuals (sedentary, walking, or vigorous) and predominant activity mode were recorded. SOCARP simultaneously records a target child's activity level, social group size, activity type, and social interactions.

During each data collection phase, a total of 55–65 population-based SOPLAY observations representing one to three daily scans every recess period were completed for every zone at both locations. Scans were repeated during a single recess period after the entire playground had been surveyed and only if researchers noted significant student migration between zones.

PA and social behavior data via 4-minute target child observations (SOCARP) extrapolated to 20 minutes was collected from a pool of recruited subjects at recess pre- (control: n=70, experimental: n=236), immediately post- (control: n=49, experimental: n=171), and 4 months post-greening (control: n=48, experimental: n=188).

At the experimental location, minutes spent sedentary or engaged in light-, moderate-, or vigorous-intensity PA were assessed pre- (n=83, first to fourth grades), immediately post- (n=143, first to fifth grades), and 4 months post-greening (n=146, first to fifth grades) using a triaxial accelerometer, Actigraph GT3X+. The GT3X+ accelerometer has been previously validated for measurement of PA levels of children in elementary school playgrounds.[37,38] Students wore accelerometers attached to a belt around the waist all day for 5 consecutive school days during each study phase. Wear time was validated, and accelerometer data scored with ActiLife, version 6.0 software using student-specific recess time filters and the Freedson Children (2005) algorithm for METs, cut points, and MVPA.[39] Combination of observation and accelerometer data collection methods allowed for specific and reliable analysis of behavior.[40]

All procedures received approval from the Los Angeles Unified School District Committee for External Research and the Occidental College IRB.

Statistical Analysis

Data from repeated scans of the same zone or child on the same day were averaged across observations to obtain activity profiles. Similarly, individual accelerometer data were averaged across the week during each study phase. Students with <3 days of accelerometer data were excluded from analysis. All statistical analyses were conducted in 2018 using SPSS, version 24 and significance level was set a priori at $p<0.05$. For the accelerometry and SOCARP data, intention-to-treat protocol was adopted, and baseline data entered when post- or follow-up data were missing. Linear mixed models were used to determine main and interaction effects of condition, study phase, sex, grade, and surface type on play behaviors. Study phase was specified as the repeated variable and observation zone and subject ID were specified as random factors for population- (SOPLAY) and individual-level (SOCARP and accelerometer) data respectively to control for their associated intraclass correlation. Linear mixed models have been shown to be an appropriate tool for analyzing longitudinal data with missing values, correlated data, and unequal variances.[41–43] Relationships between activity levels and social interactions (e.g., group size, time spent in prosocial or antisocial behavior) were identified with Pearson correlation.

RESULTS

Zone popularity was influenced by location and study period ($F[2, 4483]=7.80$, $p<0.001$). Pre-greening, zone popularity was similar between locations ($p>0.05$). In order of decreasing popularity, girls preferred handball, non-designated space with seating, and open space whereas boys preferred handball, four-square/dodgeball, and open space. The least popular zones were kickball and basketball for girls and non-designated space with seating and volleyball for boys. The distribution of control students remained stable across study phases ($p>0.05$). Conversely, the number of experimental students increased in areas replaced by green space, the degree of which differed by sex. In open space, the relative number of girls increased from 16.0% to 28.2% (12.2% change, 95% CI=9.3%, 15.1%) and the relative number of boys increased from 10.9% to 17.1% (6.2% change, 95% CI=0.3%, 12.1%) pre- to post-greening whereas the number of girls and boys decreased in handball and four-square/dodgeball zones. Green open space was the most popular zone on the playground at follow-up, hosting 24.1% and 15.7% of all girls and boys, respectively.

Pre-greening, students participated in traditional playground games (e.g., handball, kickball, tetherball, four-square) whereas tag/chasing, gymnastics (e.g., handstands, cartwheels), climbing/jumping, and creative play were the most popular activities after greening. The number of girls participating in gymnastics increased from 0.8% to 54.1% and the number participating in tag/chasing increased from 2.0% to 28.2% in open space post-greening. The number of boys participating in tag/chasing in open space increased from 3.2% to 54.3%.

The number of students observed in sedentary ($F[2, 4483]=4.11$, $p=0.003$), moderate ($F[2, 4483]=4.89$, $p=0.003$), and vigorous ($F[2, 4483]=3.78$, $p=0.005$) activity was influenced by location and study phase (Table 1). The highest percentages of sedentary students were located in handball (55.8%, 95% CI=53.5%, 58.2%),

Table 1. Population Activity Levels by Location

Location	Aggregated SOPLAY results, mean % (95% CI)						
	Pre-greening[a]	Post-greening	4-month follow-up	Percent change pre to post	Percent change pre to follow-up	Absolute change pre to post[b]	Absolute change pre to follow-up[b]
Control							
Sedentary	55.2 (51.9, 58.3)	55.0 (53.6, 56.4)	57.7 (55.9, 59.5)	n/a	n/a	n/a	n/a
Moderate	31.7 (29.1, 34.3)	30.8 (29.4, 32.2)	30.0 (28.5, 31.5)	n/a	n/a	n/a	n/a
Vigorous	13.2 (11.7, 14.6)	12.6 (11.4, 13.8)	12.3 (10.7, 13.9)	n/a	n/a	n/a	n/a
Experimental							
Sedentary	53.8 (50.5, 57.1)	**46.2 (44.2, 48.2)**	**48.5 (46.4, 50.7)**	−13.7 (−9.1, −18.2)	−10.0 (−4.9, −15.0)	−8.0 (−5.3, −10.6)	−5.5 (−2.7, −8.3)
Moderate	33.2 (30.6, 35.9)	**37.6 (35.8, 39.4)**	36.0 (34.1, 37.9)	17.8 (9.8, 25.8)	n/a	4.8 (2.5, 7.2)	n/a
Vigorous	13.0 (11.4, 14.6)	**16.2 (14.8, 17.6)**	**15.5 (14.0, 16.9)**	33.0 (18.0, 47.9)	28.2 (11.1, 45.2)	3.1 (1.5, 4.8)	2.3 (0.6, 4.0)

Note: Boldface indicates statistical difference relative to pre-greening ($p<0.05$).
[a]Baseline values were not different between control and experimental locations ($p>0.05$).
[b]The number of students out of 100 whose activity level at any given time is different relative to baseline.
n/a, not applicable; SOPLAY, System for Observing Play and Leisure Activity in Youth.

Table 2. Population Activity Levels by Surface Type

Sex	Aggregated SOPLAY results, mean % (95% CI)			
	Hardscape	Green space	Percent difference	Absolute difference[b]
Girls				
Sedentary	58.5 (55.2, 61.7)	**48.0 (45.6, 50.3)**	−18.7 (−14.8, −22.6)	−11.0 (−8.6, −13.5)
Moderate	28.8 (26.7, 30.9)	**35.3 (32.7, 38.0)**	21.6 (12.2, 30.9)	6.1 (3.4, 8.7)
Vigorous	12.8 (10.9, 14.6)	**16.7 (14.5, 19.0)**	52.1 (24.6, 79.6)	5.0 (2.0, 7.9)
Boys				
Sedentary[a]	47.7 (46.1, 49.3)	**40.8 (38.3, 43.3)**	−14.6 (−8.6, −20.5)	−7.3 (−4.6, −10.1)
Moderate[a]	37.5 (36.3, 38.7)	**42.6 (40.4, 44.7)**	16.7 (9.5, 23.9)	5.8 (3.3, 8.3)
Vigorous	14.8 (13.3, 16.2)	16.6 (14.5, 18.7)	n/a	n/a

Note: Boldface indicates statistical difference relative to hardscape ($p<0.05$).
[a]Significantly different than opposite sex for same surface ($p<0.05$).
[b]The number of students out of 100 whose activity level at any given time is different relative to hardscape.
n/a, not applicable; SOPLAY, System for Observing Play and Leisure Activity in Youth.

kickball (53.3%, 95% CI=50.0%, 56.6%), and volleyball (52.7%, 95% CI=48.0%, 57.4%) areas independent of study phase, location, or sex. Pre-greening sedentary counts at both locations were lowest in the basketball courts (41.0%, 95% CI=35.1%, 46.9%) and open space (39.4%, 95% CI=34.5%, 44.3%). The percentage of experimental girls observed in vigorous activity was higher than pre-greening at post (percentage change=41.2%, 95% CI=27.3%, 55.1%, $p=0.003$) and follow-up (percentage change=38.5%, 95% CI=23.3%, 53.6%, $p<0.05$). Vigorous activity participation did not change for boys ($p>0.05$). Regardless of sex, more experimental students were active in green space compared with hardscape areas ($F[1, 2282]=7.13$, $p<0.001$; Table 2).

SOCARP observations of experimental students revealed an interaction effect between grade X surface type ($F[4, 998]=9.48$, $p=0.002$). Fifth graders spent less time (1.2−1.7 minutes) engaged in MVPA on hardscape during recess than all other grades. Although there was a general trend for greater MVPA minutes on green space relative to hardscape, green space MVPA minutes were only significantly different between surfaces for fifth grade students (mean difference=1.8, 95% CI=1.6, 2.1, $p=0.001$).

Accelerometer analysis revealed main effects of study phase and sex for minutes spent sedentary (study phase: $F[2, 325]=20.70$, $p<0.001$, sex: $F[1, 325]=73.45$, $p<0.001$) and engaged in MVPA (study phase: $F[2, 325]=15.92$, $p<0.001$, sex: $F[1, 325]=50.26$, $p<0.001$) at the experimental location. Playground greening resulted in an individual decrease in sedentary time and corresponding increase in MVPA independent of sex (Table 3). Boys spent fewer minutes sedentary during recess (mean difference=2.2, 95% CI=1.8, 2.6) and more minutes in MVPA (mean difference=2.0 min, 95% CI=1.6, 2.4). Girls, but not boys, increased time in vigorous PA ($F[2, 325]=20.46$, $p<0.001$; mean difference pre to post=1.0, 95% CI=0.6, 1.4; mean difference pre to follow-up=0.8, 95% CI=0.4, 1.2). Although sedentary minutes were lower than baseline at follow-up for all grades, significant differences were only recorded for first (mean difference=1.6, 95% CI=0.7, 2.5) and fourth graders (mean difference=2.5, 95% CI=1.4, 3.5, $F[8, 325]=4.32$, $p<0.001$).

Antisocial behavior recorded through SOCARP was affected by location and study phase ($F[2, 998]=10.28$, $p<0.001$). Physical and verbal conflict rates decreased below pre-greening rates after 4 months at the

Table 3. Individual Activity Levels Recorded by Accelerometer

Activity level	Minutes during 20-minute recess, mean (95% CI)				
	Pre-greening	Post-greening	4-month follow-up	Percent change pre to post	Percent change pre to follow-up
Sedentary	8.8 (8.2, 9.4)	**6.5 (6.1, 6.9)**	**7.2 (6.8, 7.6)**	−19.2 (−11.4, −27.0)	−12.4 (−6.8, −18.1)
Light	2.2 (2.0, 2.4)	2.2 (2.0, 2.4)	2.1 (2.0, 2.2)	n/a	n/a
MVPA	9.4 (8.8, 10.0)	**11.3 (10.9, 11.7)**	**11.1 (10.7, 11.5)**	19.2 (10.9, 27.6)	12.1 (4.7, 19.6)

Note: Boldface indicates statistical difference relative to pre-greening ($p<0.05$).
MVPA, moderate to vigorous physical activity; n/a, not applicable.

Table 4. Physical and Verbal Conflict Rates

Location	Number of antisocial interactions during 20-minute recess, mean (95% CI)				
	Pre-greening[a]	Post-greening	4-month follow-up	Percent change pre to post	Percent change pre to follow-up
Control	3.6 (3.2, 4.0)	2.9 (1.5, 4.3)	3.2 (2.6, 3.8)	n/a	n/a
Experimental	3.5 (2.5, 4.5)	4.6 (3.0, 6.2)	**1.8 (1.0, 2.6)**	n/a	−50.9 (−18.6, −83.2)

Note: Boldface indicates statistical difference relative to pre-greening ($p<0.05$).
[a]Baseline values were not different between control and experimental locations ($p>0.05$).
n/a, not applicable.

experimental location (Table 4). Prosocial interactions at both locations were positively correlated with the amount of time spent in small groups (two to four students; $r=0.26$, $p<0.001$). Playground greening resulted in a significant decrease in minutes spent alone (mean difference= −2.2, 95% CI= −1.7, −2.7, $p<0.01$) and a significant increase in the number of minutes spent in small groups (mean difference=1.7, 95% CI=0.9, 2.6, $p<0.01$).

DISCUSSION

The current study tracked student PA and social interaction behaviors prior to and after a large-scale greening project in a low-income urban school. Following the replacement of asphalt with grass, trees, and other natural features, elementary school students spent less time sedentary and participated in more collaborative play with peers during recess. Notably, students traditionally at higher risk of not meeting PA guidelines, girls and older students, benefited the most from green space exposure as evidenced by zone selection and relative persistent changes in PA participation.

Activity levels increased immediately after greening and remained higher than baseline at the experimental location throughout the study. Results show that students accumulated an additional 20–30 MVPA minutes per week during standard recess periods alone. New recess-specific MVPA totals approach 40% of that recommended by federal guidelines. Interactions with the greened playground outside of recess time (e.g., before school, after school, during physical education) would add to this total.

Interestingly, MVPA changes recorded for individual girls were largely due to an increase in vigorous-intensity activity. Prior to renovations, the highest and lowest number of girls were located in handball and basketball courts, respectively. The greatest percentage of sedentary students was observed sitting on benches watching or waiting for their turn in handball courts, whereas the greatest percentage of active students was observed playing basketball. Green zones provided new opportunities for engagement in non-sport activities like gymnastics, tag, and climbing, activities often characterized by frequent bouts of vigorous intensity.

The higher activity levels recorded for both sexes in green space is in line with schoolyard data collected in Australia[19] and Denmark[29] and neighborhood data collected in the United Kingdom.[34] However, unlike the current study, the relationship between green space and vigorous-intensity activity was greater for boys in United Kingdom neighborhoods. It is possible that these neighborhoods include large areas of green space designed for sport, which appeal more to boys. Indeed, another study[14] that employed similar methods reported no sex difference in MVPA minutes accumulated in urban green space.

Some studies have shown that the impact of green space on PA participation decreases with age.[13,18,21] However, in the current study, data collected for first to fifth graders suggest the opposite. Students who started the study as fourth graders initially participated in the lowest MVPA levels and experienced the greatest change in activity levels after playground greening. At follow-up, activity levels were no longer different between grades. Study discrepancy may be related to the age of students being compared. For example, in Bates et al.,[21] first to fourth grades were compared with fifth to eighth grades and in Janssen and Rosu,[13] the youngest subjects were in the sixth grade. In middle school, activity habits may be more established and less influenced by changes in the environment. There are also age group differences in voluntary and mandatory time spent outdoors.

Similar to conclusions made by other researchers, behavioral changes measured in the current study may be the result of greater and more enjoyable opportunities for creative free play, more age-appropriate options, and subsequently a decrease in boredom and an increase in intrinsic motivation.[11,23,24,44] Indeed, the introduction of green space changed how playground space was used. Prior to greening, the greatest playground square footage was devoted to kickball/baseball and open fields, areas which, when combined, regularly hosted less than 25%

of the student population. The asphalt field surrounded by track lanes in the middle of the experimental playground was primarily used as a thoroughfare to other playground areas. Outside of the asphalt field, students engaged in traditional playground games with the use of school-provided activity balls and game rules learned in physical education. Four months after greening, open space locations that had been replaced by grass, trees, and logs were the most popular areas on the playground, which coincided with decreased use of standard equipment as more and more students chose to play tag/chasing games, to climb and jump, or to practice gymnastics. Researchers and school staff noted that students frequently worked together in small groups to create new games and pretend scenarios when located in green space. Examples included building human nests with mulch and leaves, attempting to avoid fire represented by the ground as one walked/ran along one log and jumped to another, and playing a version of hide and seek combined with capture the flag using trees and boulders as protection. The climbing and jumping associated with navigating through the log seating in the outdoor classroom and between the trees and boulders randomly placed throughout the yard could contribute to motor skill development in the areas of balance, coordination, and agility.[11,45] Additionally, opportunities for imaginative play during unstructured recess can increase the acquisition of important developmental skills, such as communication, negotiation, cooperation, sharing, problem solving, and coping.[46] Higher verbal and physical conflict rates immediately post-greening followed by significantly lower antisocial interactions at 4 months relative to baseline, may suggest that it takes time for children to learn how to navigate new spaces with peers and that ultimately, social skill development occurs with prolonged green space exposure. Indeed, in one study, caregivers and teachers reported less teasing/bullying at 20 and 32 months after green schoolyard renovation.[21]

This study has multiple strengths. The longitudinal nature, incorporation of a control location, and multiple data collection strategies allowed for specific analysis of PA context on the elementary school playground before and after green space renovations. Conclusions were possible at both the individual and population levels. Additionally, simultaneous comparisons were made between hardscape and green space, between sexes, and between grades.

Limitations

Because data were collected at a single experimental location, results may not be applicable to schools with different student demographics or design features. Because of low parental consent for individual SOCARP observations at the control location, representation in the control sample was limited. Additionally, behavior data related to yard supervisor–student interactions were not collected. However, researchers noted that some supervisors limited movement on asphalt when they believed student safety was at risk. Similarly, the influence of instructor guidance during physical education or afterschool programs on zone preference and activity choices at recess was not evaluated.

CONCLUSIONS

The evidence supporting a direct relationship between nature exposure and childhood wellbeing is mounting. However, in urban low-income neighborhoods, contact with nature is often minimal. The results from this study confirm that adding green space to existing asphalt-covered schoolyards is one mechanism by which to expose children to nature, increase daily MVPA levels, and promote social wellbeing in sex- and age-dependent ways. Complementary studies are needed to explore how much additional green space can be incorporated into school playgrounds to further narrow the activity gap between sexes without decreasing preferred activity options on hardscape.

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SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found in the online version at https://doi.org/10.1016/j.amepre.2018.11.004.

REFERENCES

1. Coe DP, Peterson T, Blair C, Schutten MC, Peddie H. Physical fitness, academic achievement, and socioeconomic status in school-aged youth. *J School Health.* 2013;83(7):500–507. https://doi.org/10.1111/josh.12058.
2. Lambourne K, Hansen DM, Szabo AN, et al. Indirect and direct relations between aerobic fitness, physical activity, and academic achievement in elementary school students. *Ment Health Phys Act.* 2013;6(13):165–171. https://doi.org/10.1016/j.mhpa.2013.06.002.
3. Liang J, Matheson B, Kaye W, Boutelle K. Neurocognitive correlates of obesity and obesity-related behaviors in children and

adolescents. *Int J Obes (Lond).* 2014;38(4):494–506. https://doi.org/10.1038/ijo.2013.142.
4. Raney M, Henriksen A, Minton J. Impact of short duration health & science energizers in the elementary school classroom. *Cogent Educ.* 2017;4(1):1399969. https://doi.org/10.1080/2331186X.2017.1399969.
5. Los Angeles County Department of Public Health. Key Indicators of Health by Service Planning Area. Los Angeles, CA: Office of Health Assessment and Epidemiology. http://publichealth.lacounty.gov/ha/docs/2015LACHS/KeyIndicator/PH-KIH_2017-sec%20UPDATED.pdf. Published 2017. Accessed May 30, 2018.
6. Henriksen PW, Rayce SB, Melkevik O, Due P, Holstein BE. Social background, bullying, and physical inactivity: national study of 11- to 15-year-olds. *Scand J Med Sci Sports.* 2016;26(10):1249–1255. https://doi.org/10.1111/sms.12574.
7. Los Angeles County Department of Public Health. 2015 Los Angeles County Health Survey. Los Angeles, CA: Office of Health Assessment and Epidemiology. www.publichealth.lacounty.gov/ha/LACHSDataTopics2015.htm#Child. Published 2016. Accessed May 30, 2018.
8. Los Angeles County Department of Public Health. Parks and Public Health in Los Angeles County: A Cities and Communities Report. Los Angeles, CA: Office of Health Assessment and Epidemiology. http://publichealth.lacounty.gov/chronic/docs/Parks%20Report%202016-rev_051816.pdf. Published 2016. Accessed May 30, 2018.
9. Almanza E, Jerrett M, Dunton G, Seto E, Pentz MA. A study of community design, greenness, and physical activity in children using satellite, GPS and accelerometer data. *Health Place.* 2012;18(1):46–54. https://doi.org/10.1016/j.healthplace.2011.09.003.
10. Barton J, Sandercock G, Pretty J, Wood C. The effect of playground- and nature-based playtime interventions on physical activity and self-esteem in UK school children. *Int J Environ Health Res.* 2015;25(2):196–206. https://doi.org/10.1080/09603123.2014.915020.
11. Chawla L. Benefits of nature contact for children. *J Plan Lit.* 2015;30(4):433–452. https://doi.org/10.1177/0885412215595441.
12. Flouri E, Midouhas E, Joshi H. The role of urban neighbourhood green space in children's emotional and behavioural resilience. *J Env Psychol.* 2014;40:179–186. https://doi.org/10.1016/j.jenvp.2014.06.007.
13. Janssen I, Rosu A. Undeveloped green space and free-time physical activity in 11 to 13-year-old children. *Int J Behav Nutr Phys Act.* 2015;12:26. https://doi.org/10.1186/s12966-015-0187-3.
14. Klinker CD, Schipperijn J, Christian H, et al. Using accelerometers and global positioning system devices to assess gender and age differences in children's school, transport, leisure and home based physical activity. *Int J Behav Nutr Phys Act.* 2014;11:8. https://doi.org/10.1186/1479-5868-11-8.
15. Kuo M, Browning MHEM, Penner ML. Do lessons in nature boost subsequent classroom engagement? Refueling students in flight. *Front Psychol.* 2018;8:2253. https://doi.org/10.3389/fpsyg.2017.02253.
16. Lovasi GS, Schwartz-Soicher O, Quinn JW, et al. A. Neighborhood safety and green space as predictors of obesity among preschool children from low-income families in New York City. *Prev Med.* 2013;57(3):189–193. https://doi.org/10.1016/j.ypmed.2013.05.012.
17. MacNaughton P, Eitland E, Kloog I, Schwartz J, Allen J. Impact of particulate matter exposure and surrounding "greenness" on chronic absenteeism in Massachusetts public schools. *Int J Environ Res Public Health.* 2017;14(2):207. https://doi.org/10.3390/ijerph14020207.
18. Sanders T, Feng X, Fahey PP, Lonsdale C, Astell-Burt T. The influence of neighborhood green space on children's physical activity and screen time: findings from the longitudinal study of Australian children. *Int J Behav Nutr Phys Act.* 2015;12:126. https://doi.org/10.1186/s12966-015-0288-z.
19. Dyment JE, Bell AC, Lucas AJ. The relationship between school ground design and intensity of physical activity. *Children's Geographies.* 2009;7(3):261–276. https://doi.org/10.1080/14733280903024423.
20. Anthamatten P, Brink L, Lampe S, et al. An assessment of schoolyard renovation strategies to encourage children's physical activity. *Int J Behav Nutr Phys Act.* 2011;8:27. https://doi.org/10.1186/1479-5868-8-27.
21. Bates CR, Bohnert AM, Gerstein DE. Green schoolyards in low-income urban neighborhoods: natural spaces for positive youth development outcomes. *Front Psychol.* 2018;9:805. https://doi.org/10.3389/fpsyg.2018.00805.
22. Brink LA, Nigg CR, Lampe SM, et al. Influence of schoolyard renovations on children's physical activity: the Learning Landscapes Program. *Am J Public Health.* 2010;100(9):1672–1678. https://doi.org/10.2105/AJPH.2009.178939.
23. Hyndman B. Where to next for school playground interventions to encourage active play? An exploration of structured and unstructured school playground strategies. *J Occup Ther Sch Early Interv.* 2015;8(1):56–67. https://doi.org/10.1080/19411243.2015.1014956.
24. Parrish A-M, Yeatman H, Iverson D, Russell K. Using interviews and peer pairs to better understand how school environments affect young children's playground physical activity levels: a qualitative study. *Health Educ Res.* 2012;27(2):269–280. https://doi.org/10.1093/her/cyr049.
25. Rung AL, Mowen AJ, Broyles ST, Gustat J. The role of park conditions and features on park visitation and physical activity. *J Phys Act Health.* 2011;8(suppl 2):S178–S187. https://doi.org/10.1123/jpah.8.s2.s178.
26. Ridgers ND, Stratton G, Fairclough SJ. Physical activity levels of children during school playtime. *Sports Med.* 2006;36(4):359–371. https://doi.org/10.2165/00007256-200636040-00005.
27. Bohn-Gettler CM, Pellegrini AD. Recess in primary school: the disjuncture between educational policy and scientific research. In: *Justice, Conflict and Wellbeing.* New York, NY: Springer; 2014:313–336. https://doi.org/10.1007/978-1-4939-0623-9_12.
28. Committee on Physical Activity and Physical Education in the School Environment, Food and Nutrition Board, Institute of Medicine. Kohl HW, Cook HD, eds. *Educating the Student Body: Taking Physical Activity and Physical Education to School.* Washington, DC: National Academies Press, 2013. https://doi.org/10.17226/18314.
29. Andersen HB, Klinker CD, Toftager M, Pawlowski CS, Schipperijn J. Objectively measured differences in physical activity in five types of schoolyard area. *Landsc Urban Plan.* 2015;134:83–92. https://doi.org/10.1016/j.landurbplan.2014.10.005.
30. Martensson F, Jansson M, Johansson M, et al. The role of greenery for physical activity play at school grounds. *Urban For Urban Green.* 2014;13(1):103–113. https://doi.org/10.1016/j.ufug.2013.10.003.
31. Blaes A, Ridgers ND, Aucouturier J, Van Praagh E, Berthoin S, Baquet G. Effects of a playground marking intervention on school recess physical activity in French children. *Prev Med.* 2013;57(5):580–584. https://doi.org/10.1016/j.ypmed.2013.07.019.
32. Ridgers ND, Fairclough SJ, Stratton G. Twelve-month effects of a playground intervention on children's morning and lunchtime recess physical activity levels. *J Phys Act Health.* 2010;7(2):167–175. https://doi.org/10.1123/jpah.7.2.167.
33. Rainham DG, Bates CJ, Blanchard CM, et al. Spatial classification of youth physical activity patterns. *Am J Prev Med.* 2012;42(5):e87–e96. https://doi.org/10.1016/j.amepre.2012.02.011.
34. Wheeler BW, Cooper AR, Page AS, Jago R. Greenspace and children's physical activity: a GPS/GIS analysis of the PEACH project. *Prev Med.* 2010;51(2):148–152. https://doi.org/10.1016/j.ypmed.2010.06.001.
35. 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. https://doi.org/10.1123/jpah.7.1.17.
36. Saint-Maurice PF, Welk GJ, Silva P, Siahpush M, Huberty J. Assessing children's physical activity behaviors at recess: a multi-method approach. *Pediatr Exerc Sci.* 2011;23(4):585–599. https://doi.org/10.1123/pes.23.4.585.
37. Ojiambo R, Konstabel K, Veidebaum T, et al. Validity of hip-mounted uniaxial accelerometry with heart-rate monitoring vs. triaxial accelerometry in the assessment of free-living energy expenditure in young children: the

IDEFICS Validation Study. *J Appl Physiol.* 2012;113(10):1530–1536. https://doi.org/10.1152/japplphysiol.01290.2011.
38. Sasaki JE, John D, Freedson PS. Validation and comparison of ActiGraph activity monitors. *J Sci Med Sport.* 2011;14(5):411–416. https://doi.org/10.1016/j.jsams.2011.04.003.
39. Freedson P, Pober D, Janz KF. Calibration of accelerometer output for children. *Med Sci Sports Exerc.* 2005;37(11 suppl):S523–S530. https://doi.org/10.1249/01.mss.0000185658.28284.ba.
40. Ruiz RM, Tracy D, Sommer EC, Barkin SL. A novel approach to characterize physical activity patterns in preschool-aged children. *Obesity.* 2013;21(11):2197–2203. https://doi.org/10.1002/oby.20560.
41. Verbeke G, Molenberghs G. *Linear mixed models for longitudinal data. Springer Series in Statistics.* New York, NY: Springer; 2000. https://doi.org/10.1007/978-1-4419-0300-6.
42. West BT, Welch KB, Gałecki AT, Gillespie BW. *Linear Mixed Models: A Practical Guide Using Statistical Software.* New York, NY: Chapman & Hall/CRC; 2014. https://doi.org/10.1201/b17198.
43. Wu L, Tong H, Keiding N, et al. *Mixed Effects Models for Complex Data.* New York, NY: Chapman & Hall/CRC; 2009. https://doi.org/10.1201/9781420074086.
44. Stellino MB, Sinclair CD. Intrinsically motivated, free-time physical activity. *J Phys Educ Recreat Dance.* 2008;79(4):37–40. https://doi.org/10.1080/07303084.2008.10598162.
45. Fjortoft I. Landscape as playscape: the effects of natural environments on children's play and motor development. *Child Youth Environ.* 2004;14(2):21–44. www.jstor.org/journal/chilyoutenvi. Accessed May 30, 2018.
46. American Academy of Pediatrics. The crucial role of recess in school. *Pediatrics.* 2013;131(1):183–188. https://doi.org/10.1542/peds.2012-2993.