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Original article

A Multimodal Counseling-Based Adolescent Physical Activity Intervention

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A B S T R A C T

Purpose: National guidelines recommend adolescents achieve 60 minutes of moderate-to-vigorous physical activity (MVPA)/day, yet few adolescents meet these guidelines.
Methods: We piloted a novel quasi-randomized physical activity intervention to promote adolescent's use of their surrounding built environment among 30 intervention and 30 control overweight/obese adolescents aged 10–16 years living in greater Boston from 2013 to 2015. Location-specific MPVA was measured by accelerometry and global positioning system for three one-week periods (Time 1 [T1], Time 2 [T2], and Time 3 [T3]). One month after T1, intervention participants received individualized counseling on how to use their surrounding built environment to increase MVPA, and control participants received standard-of-care lifestyle modification counseling; both groups received their T1 physical activity data. T2 assessment occurred the week after the counseling visit and T3 assessment 3–4 months later. The main outcome was change in average daily minutes of MVPA; the secondary outcome was meeting national MVPA guidelines. Multivariable modeling accounted for covariates (baseline MVPA, body mass index, age, sex, race/ethnicity) and clustering by study group and town.
Results: Among the 60 adolescents recruited, 55 (92%) completed data collection. Short-term (T2) intervention effects included increased average MVPA of +13.9 minutes intervention versus −.6 minutes control ($p < .0001$). Differential increase in mean daily MVPA was sustained at T3 (9.3 minutes more in intervention group; $p = .0006$). The proportion of adolescents in the intervention group who achieved 60 minutes/day of MVPA increased from 11% (T1) to 21% (T2), whereas declining (7%–0%) among controls.
Conclusions: Individualized counseling about the built environment can help increase MVPA among overweight and obese adolescents.

IMPLICATIONS AND CONTRIBUTION

Most youth do not achieve recommended daily levels of physical activity. Prior adolescent physical activity interventions have not utilized the built environment for activity promotion. This article reports on a successful intervention using combined geographical information system-global positioning systems —accelerometry mapping technology to encourage adolescents to use their surrounding built environment to improve physical activity.

One third of U.S. adolescents are either overweight or obese [1]. Insufficient physical activity, along with dietary factors, plays an important role in weight status. National guidelines, including those of the American Academy of Pediatrics, recommend that all children and adolescents achieve 60 minutes of moderate-to-vigorous physical activity (MVPA) a day [2,3], yet physical activity

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levels decrease as children age and less than one adolescent in 10 in the United States meet these guidelines [4,5]. Prior pediatric physical activity interventions with objectively measured physical activity have had limited effect, resulting on average in a 4-minute daily increase in walking or running [6].

The built environment, defined as all human-made surroundings that provide the setting for human activities, has been shown in cross-sectional analyses to be associated with adolescent physical activity and obesity [7–9]. Time spent in parks, playgrounds, and sidewalks is associated with increased walking and MVPA among adolescents [7,10]. Despite this, few studies have empirically tested using the built environment to impact physical activity. To the best of our knowledge, no study has tested counseling adolescents on how to use their surrounding built environment to increase physical activity, and obesity interventions have yet to explore the impact of incorporating built environment counseling into physical activity promotion. We conducted the Children's Use of the Built Environment (CUBE) study [11], a controlled trial testing whether a novel multimodal physical activity intervention that includes global positioning systems (GPS) tracking and counseling on use of the built environment could increase daily MVPA among overweight and obese adolescents. The study had 2 hypotheses: the CUBE intervention would increase (1) adolescents' daily MVPA and (2) the number of adolescents achieving the recommended 60 minutes of daily MVPA. This article reports on the preliminary efficacy of the CUBE study intervention.

Methods

We conducted the CUBE study among 30 intervention and 30 control adolescents aged 10–16 years, residing in low- and middle-income towns within greater metropolitan Boston. Adolescents with an age- and sex-specific body mass index (BMI) at or above the 85th percentile, having no health conditions limiting ambulation, and followed at an academic outpatient community health center in eastern Massachusetts were recruited starting in the fall of 2013 over one year. Details of the study rationale, design, and methods have been published previously [11] and are briefly reviewed here. This study was approved by the Partners HealthCare Institutional Review Board, which oversees all hospital- and patient-affiliated research occurring within the Partners HealthCare network in Massachusetts.

Design

A quasi-randomized, unblinded, controlled study design with participants sequentially assigned 1:1 to a study group was chosen to account for known seasonal effects on built environment use in adolescents and to ensure an equal distribution of study group participants enrolled during each study season [7,12]. Time 1 (T1, baseline) data were collected for each participant for one week at study enrollment starting in October 2013 (Figure 1). Time 2 (T2) measurements occurred 1 month after T1, with data collected for one week. A third week of data (T3) were collected approximately 3–4 months after T2. The intervention occurred before T2 data collection.

Intervention

The CUBE intervention aimed to increase adolescent physical activity by testing the American Academy of Pediatrics recommendation that pediatric obesity counseling incorporate the built environment to achieve physical activity goals [2,13]. Intervention participants and a parent or guardian participated in a 30-minute team meeting with a pediatrician, during which they received feedback on their baseline average daily MVPA level. In this visit, intervention participants also received individualized counseling based on their T1 data on how to increase their daily physical activity using their specific surrounding built environment, including geocoded physical activity data displayed on color maps and color charts that classified their built environment use as mean daily MVPA and sedentary time spent in specific land use categories, including parks, playgrounds, home, school, streets, and sidewalks. The maps and charts were reviewed with the participant and parent/guardian at the team meeting and then provided to intervention participants. The participant and pediatrician also decided on a physical activity goal, which the subject agreed to achieve two to three times per week and which involved a new use of the surrounding built environment. Intervention participants received weekly text message and/or phone call reminders about their agreed on goal after their team meeting. Adolescents in the intervention group also received a physical activity promoting gift valued under $5 at T2, along with financial incentives ($5 to the subject and $10 to the family) for meeting their agreed on built environment goal and competed for a prize valued at several hundred dollars for the participant achieving the greatest increase in MVPA over the course of the study. In a parallel study visit, control participants received a handout reviewed in-person containing feedback on their average daily T1 MVPA level along with standard-of-care diet and physical activity recommendations.

Measures

Physical activity. The primary outcome, MVPA, was measured by accelerometry to obtain a valid, objective measure of physical activity. Participants were asked to wear the GT3X accelerometer (ActiGraph LLC, Ft. Walton Beach, FL) on a belt over the hip during waking hours for 7 days at Times 1, 2, and 3. Physical activity data were collected every 30 seconds. Thresholds specific to adolescents classified sedentary time as $<$100 activity counts per minute and MVPA as $\geq$2,296 counts per minute [14,15]. A valid day was defined as $\geq$4 hours (240 minutes) of time-matched accelerometer and GPS wear time, with nonwear defined as $>$60 minutes of consecutive zeros (by accelerometry) with a spike tolerance of 2 minutes, consistent with prior studies combining GPS and accelerometer data [16–18]. Participants were required to have three or more valid days of data for study inclusion. Each participant's daily MVPA was calculated using the total minutes at or above the MVPA threshold, divided by the number of valid study days. Although at least four valid days have been recommended for estimating physical activity levels, these recommendations are based on studies using only accelerometers, and collecting combined accelerometry-GPS data are known to produce lower data yields [16–18]. Only two participants in the study provided less than four valid days of data for one of the data collection periods, and a sensitivity analysis with these participants removed did not change results (results in the following section).

Primary outcome. The primary outcome was the change in mean daily MVPA, measured over one week.

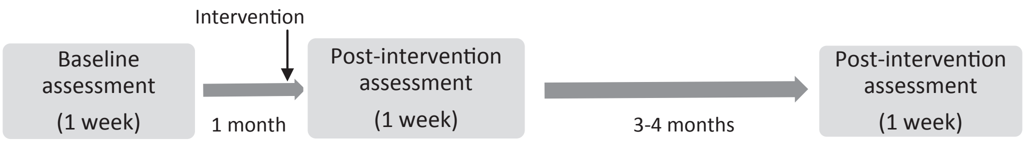

Figure 1. CUBE study data collection periods.

Secondary outcome. The secondary outcome was the number of participants achieving on average the recommended 60 minutes of daily MVPA over one week.

Location. Global positioning systems (GPS) recorded subject location every 30 seconds. Participants wore a GPS receiver (QStarz BT-1000XT; QStarz International Co., Ltd., Tapei, Taiwan) on a belt alongside the accelerometer for each of the three data collection periods. Accelerometer and GPS data were merged based on date/time stamps and collapsed into 1 minute epochs. Motorized travel data (>25 km/hour, as recorded by GPS receiver) were removed before analyses. To determine location, merged data were imported into ArcGIS (ESRI, Redlands, CA) and, following previously described protocol were hierarchically assigned a land use category known to be associated with adolescent physical activity (home, school, playground, park, street and sidewalk, and other) [7,12]. Daily sedentary time and minutes of MVPA were calculated for each land use category. Location data were used in this study only to map baseline physical activity patterns and inform physical activity counseling and not to measure change in outcomes.

Anthropometrics. Standing height and weight were measured after a standardized protocol by trained research staff at T1 and T3 using a stadiometer (SECA, Hanover, MD) and digital scale (LifeSource MD, San Jose, CA), respectively, with participants wearing indoor clothing, pockets emptied, and shoes removed. Measurements were taken in duplicate then averaged. BMI percentiles were calculated using the 2000 Centers for Disease Control and Prevention age- and sex-specific growth charts [19].

Covariates. Self-reported age (date of birth), sex, race/ethnicity, home address, along with parent-reported highest level of parental education were collected for each participant at study entry.

Statistical analyses

Baseline data were described using descriptive statistics. Study group parameters were compared using the *t* test or Mann–Whitney *U* test for ordinal data and using the chi-square or Fisher's exact tests for categorical data, based on data normality. The primary outcomes, change in mean daily minutes of MVPA from T1 to T2 and T1 to T3, were first calculated using Mann–Whitney *U* test, and adjusted estimates of MVPA at T2 and T3 were then derived using generalized linear modeling, accounting for baseline MVPA, BMI, age, sex, race/ethnicity, and parental education, and clustering by town of residence. Longitudinal analysis assessing for differences in the primary outcome by study group over time was assessed using proc mixed with time entered as a class variable to compare step functions, adjusting for sex, race/ethnicity, BMI, parental education, and town of residence. For the secondary outcome, owing to a small sample size and zero values, we report the number of participants achieving the recommended 60 minutes of daily MVPA as descriptive statistics. A subanalysis was conducted for the primary outcome, where the first day of data were removed from each participant to account for potential differences in data collection start times. Daily temperatures and weather conditions were compared by study group during each study period. A two-tailed significance level of .05 was set a priori for all statistical analyses.

Results

Sixty adolescents were enrolled in the study, of whom 55 (92%) completed the study and provided valid data at all three collection periods (Figure 2). Baseline demographic and study sample characteristics are presented by group in Table 1. There were no significant differences between the study groups in any of the collected variables at baseline, including age, sex, BMI, MVPA, or sedentary time. There were no differences in daily temperatures or weather conditions by study group during T1, T2, or T3 (data not shown). Adolescents wore the accelerometers for an average of 10.7 hours per day. The mean number of days of combined location–based physical activity data collected were 7.5 (±1.7) in T1, 7.2 (±2.2) in T2, and 6.8 (±1.6) in T3.

Outcomes

Change in moderate-to-vigorous physical activity. The mean change in mean daily MVPA from T1 to T2 was +13.9 minutes for adolescents in the intervention group (median, +10.7; interquartile range [IQR], −14.7 to +21.4) and −.6 minutes for controls (median, −1.9; IQR, −14.1 to +3.7; $p = .0001$). In a sensitivity analysis including only participants with four or more days of data during each data collection periods, results were similar (mean change in mean daily MVPA from T1 to T2 of +14.2 minutes for intervention participants vs. −.7 minutes for controls). In the adjusted model, intervention adolescents had a 17.1 minutes greater T2 mean daily MVPA than controls (43.8 vs. 26.7 minutes, $p < .0001$). In a subanalysis where the first day's data were removed, the change in mean daily MVPA from T1 to T2 remained greater in the intervention group (14.4 ± 24.1 minutes) compared with controls (−1.4 ± 8.6 minutes), $p < .001$.

The mean change in mean daily MVPA from T1 to T3 was +7.7 minutes for intervention adolescents (median, +6.3; IQR, −31.1 to +11.8) and +.5 minute for controls (median, −.1; IQR, −22.7 to +4.1; $p = .02$). Adjusted estimates showed a 9.3-minute greater mean daily MVPA at T3 in intervention participants compared with controls (38.0 vs. 28.7 minutes, $p = .0006$). In longitudinal analysis, the difference in mean daily MVPA between study group remained significant over time ($p = .005$; Figure 3).

Change in meeting 60 minutes/day of moderate-to-vigorous physical activity. At baseline, three (11%) adolescents in the intervention group and two (7%) in the control group met the 60 minutes/day of MVPA guidelines. At T2, six (21%) intervention participants met the 60 minutes/day recommendation,

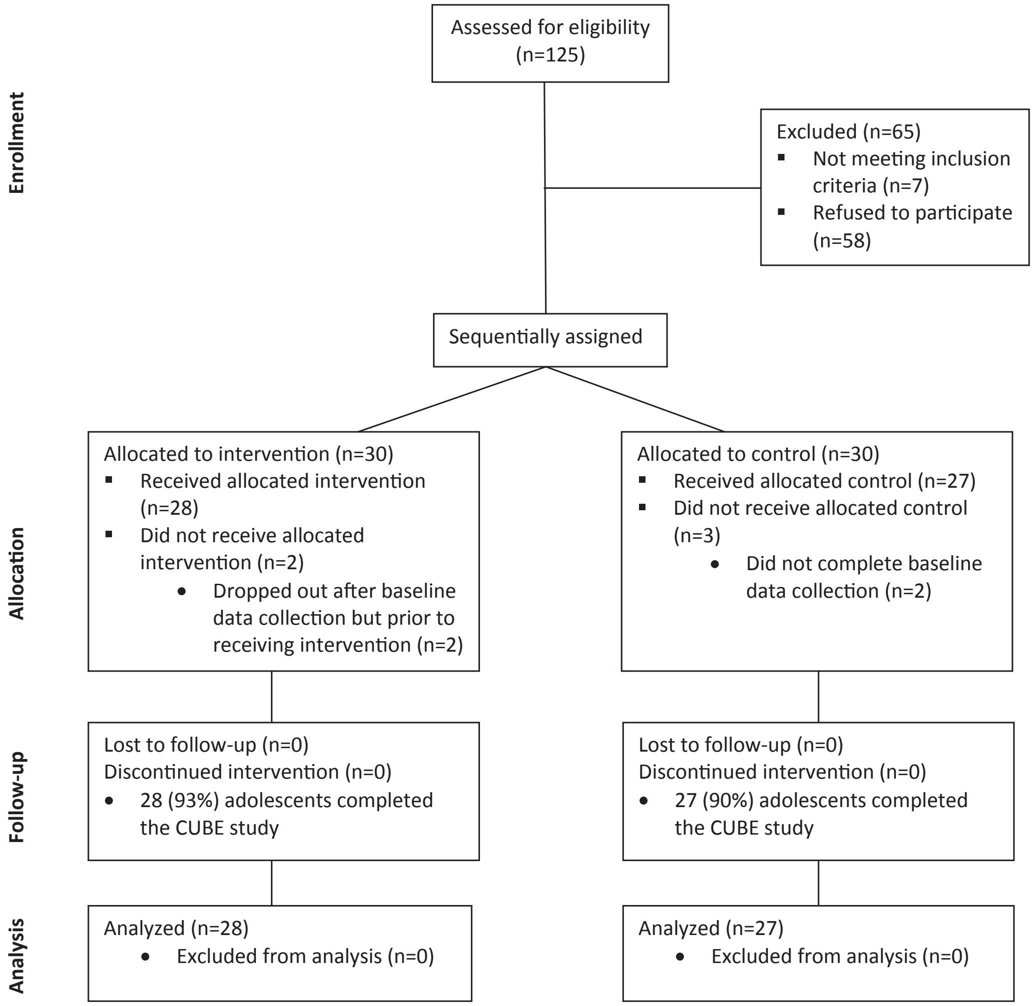

Figure 2. CONSORT (Consolidated Standards of Reporting Trials) diagram showing the flow of the participants through each stage of the CUBE study.

compared with none in the control group. At T3, five (18%) adolescents in the intervention group and two (7%) in the control group met the recommendations.

Change in sedentary time. The mean change in mean daily sedentary time was +5.8 (±86.3) minutes for adolescents in the intervention group and +11.1(±73.9) minutes for controls (p = 1.0) from T1 to T2 and −4.4 (±91.3) and −22.9 (±75.6) minutes from T1 to T3 (p = .5), respectively. In adjusted models accounting for covariates and baseline sedentary time, there were no differences by study group in sedentary time at T2 (p = .4) or T3 (p = .09).

Discussion

In this physical activity intervention among overweight and obese adolescents, we demonstrated that a multimodal physical activity program incorporating best practice approaches in obesity interventions with a novel emphasis on counseling adolescents in a pediatric office setting on how to use their surrounding built environment was effective at increasing both daily MVPA and the number of adolescents who meet physical activity guidelines. On average, adolescents who were taught built environment use skills increased and sustained their daily MVPA by 9.3 minutes per day over the control condition. This represents a 29% increase in their baseline daily MVPA level and, if achieved on a population-wide level, could have far-reaching health benefits for youth beyond weight control, including reducing the risk for adult cardiovascular disease, asthma, cancer, and overall mortality.

In incorporating the built environment into physical activity and obesity counseling, this study taps into an underutilized resource that has potential for promoting and sustaining daily physical activity. To our knowledge, this study is the first to report on a physical activity intervention in adolescents that tests the potential of counseling on built environment use. The built environment is an ubiquitous surrounding infrastructure that has many potential benefits as a platform for physical activity, including being: (1) universally available to all children and adolescents; (2) available every day and throughout the day; (3) available at low or no cost and without a required membership (such as are required for gym memberships or sports clubs); (4) a permanent infrastructure which will remain in place after the study's conclusion (different from study-sponsored games, after-school, and sporting activities); and (5) availability throughout the life course, promoting lifelong healthy habits.

Table 1
Comparison of study sample characteristics between groups at baseline (n = 60) in Massachusetts, 2013

	Intervention	Control	*p* value
Age, years	11.6	12.2	.1
Race/ethnicity, %			.6
White	50	43	—
Black	10	4	—
Hispanic	27	33	—
Asian	6	3	—
Multi/other	7	17	
Male, %	53	53	1.0
BMI percentile, mean	94	94	.8
MVPA, mean minutes/day	32	26	.2
Sedentary time, mean minutes/day	416	418	.9
Total wear time, mean minutes	1,870	1,865	1.0
Parental education, %			.7
High school or less	30	37	—
Associates degree or college	54	60	—
Graduate education or beyond	13	3	—
Missing	3	0	—

BMI = body mass index; MVPA = moderate-to-vigorous physical activity.

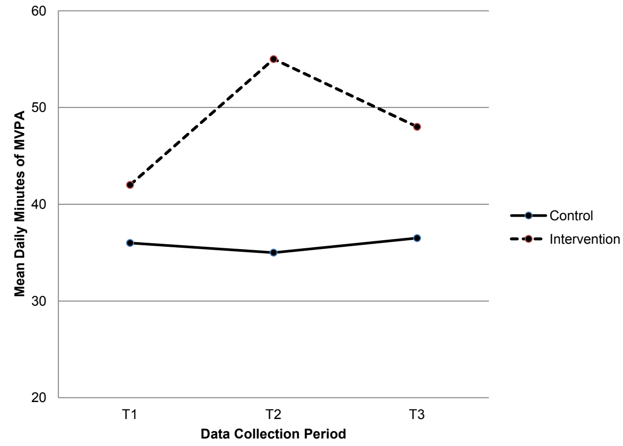

Figure 3. Longitudinal analysis of MVPA over time by study group.

Prior physical activity interventions have had a limited effect on adolescents' overall activity levels. A recent systematic review and meta-analysis by Metcalf et al. [6] that included youth younger than 16 years and assessed accelerometer-measured physical activity outcomes found that physical activity interventions have only a small effect, resulting approximately in an additional 4 minutes of walking or running per day. Few prior pediatric interventions, and no pediatric obesity interventions, have incorporated the built environment, and these have been among younger children and have had more limited success in increasing daily MVPA. In a pilot walking school bus study in Texas, in which children were randomized to participate in a program where children walked to school accompanied by an adult chaperone, MVPA increased by 7 minutes a day [20]. This study included younger elementary school–aged children, and the primary outcome was frequency of active travel to school not MVPA. Structurally, the Texas and CUBE studies are also very different; whereas the Texas study tested an instituted program, our study tested a counseling approach. Unlike in the walking school bus program where mode, time, and route of travel were predetermined, in our study, it was left up to the subject to decide how, when, where, and how often to use the built environment, two fundamentally different approaches to physical activity promotion, targeting different developmental stages. The hope for adolescents participating in the CUBE study is to have them develop lifelong skills in navigating and leveraging their surrounding architecture and urban planning infrastructures to augment their daily physical activity. Such knowledge, if adapted to other towns or cities where adolescents later reside, may promote lifelong physical activity habits.

Limitations of this study include a relatively small sample size conducted in a single pediatric office setting with unknown generalizability to other populations or pediatric health care settings and unknown sustainability of the physical activity outcomes beyond 4 months. The study was not designed to address changes in BMI, and the long-term impact on weight change is unknown. Intervention participants had slightly higher baseline physical activity levels than controls, possibly making intervention participants more motivated to increase their physical activity, though baseline differences did not meet statistical significance, and we controlled for baseline levels in our analyses. The intervention included multiple components common to obesity interventions, including financial incentives and text messaging, in addition to counseling adolescents on built environment use. These factors, which represent a best practice approach in pediatric obesity interventions, may have contributed to the outcome, though prior studies despite using these components have had limited success at increasing physical activity, suggesting a direct added benefit to counseling on built environment use. The use of financial incentives, although modest, may also limit the real-world feasibility of instituting this study's approach widely across pediatric office settings and the long-term sustainability of the behavior. We provided feedback to control participants on their objectively measured physical activity levels, an enhancement beyond basic lifestyle modification counseling typically provided to control participants, feedback which we felt was ethically appropriate, yet may have decreased the true effect size of the intervention. Although we proved the concept of incorporating built environment counseling into obesity care to be feasible and effective, the methods required for data cleaning and data analysis for objective location and physical activity data, including data synthesis, reduction, and geographical information system analysis, are complex and necessitate a sizeable amount of skilled human labor and time, typically a minimum of several hours per subject. Although this study's methods may not presently be scalable for population-wide delivery, technological advances in mobile health technology and machine learning will likely make the data complexities more manageable in the future [21].

The strengths of the study include its use of objectively measured physical activity and location data, high retention rate with 92% of enrolled participants completing the study, and efficacy. Counseling overweight and obese adolescents on using the built environment for physical activity promotion was effective and highly impactful at increasing MVPA, with physical activity behavior changes that appear to be sustained up to four months.

This physical activity intervention that included counseling on using the surrounding built environment improved physical activity levels among overweight and obese adolescents. In addition, adolescents who received the intervention were more likely to achieve recommended daily levels of physical activity. The promising results of this study should now be replicated in a larger study aimed at determining the feasibility of implementing personalized built environment counseling among a large population, the value added to traditional obesity care, and the effectiveness of this approach at improving longer term physical activity and obesity outcomes.

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