A Community Intervention Reduces BMI *z*-score in Children: Shape Up Somerville First Year Results

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Abstract

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Objective: The objective was to test the hypothesis that a community-based environmental change intervention could prevent weight gain in young children (7.6 ± 1.0 years).

Research Methods and Procedures: A non-randomized controlled trial was conducted in three culturally diverse urban cities in Massachusetts. Somerville was the intervention community; two socio-demographically-matched cities were control communities. Children ($n = 1178$) in grades 1 to 3 attending public elementary schools participated in an intervention designed to bring the energy equation into balance by increasing physical activity options and availability of healthful foods within the before-, during-, after-school, home, and community environments. Many groups and individuals within the community (including children, parents, teachers, school food service providers, city departments, policy makers, healthcare providers, before- and after-school programs, restaurants, and the media) were engaged in the intervention. The main outcome measure was change in BMI *z*-score.

Results: At baseline, 44% ($n = 385$), 36% ($n = 561$), and 43% ($n = 232$) of children were above the 85th percentile for BMI *z*-score in the intervention and the two control communities, respectively. In the intervention community, BMI *z*-score decreased by −0.1005 ($p = 0.001$, 95% confidence interval, −0.1151 to −0.0859) compared with children in the control communities after controlling for baseline covariates.

Discussion: A community-based environmental change intervention decreased BMI *z*-score in children at high risk for obesity. These results are significant given the obesigenic environmental backdrop against which the intervention occurred. This model demonstrates promise for communities throughout the country confronted with escalating childhood obesity rates.

Key words: BMI, weight change, childhood obesity, community health, intervention

Introduction

Obesity, arguably one of the most serious public health threats today, is increasing at an alarming rate in children (1–6). The prevalence has risen as much as 3-fold over the past few decades, resulting in a staggering percentage of youth, up to 40%, who are overweight or at risk for overweight (1,7,8). Of particular concern are the disproportionate rates of obesity among racial and ethnic minority children (9). Given the intractable nature of the condition once it is established, proactive strategies that begin early in childhood are needed to support prevention of overweight (10–12).

Children have very little control over their food choices and physical activity options, particularly in the obesigenic environments of developed nations (13). Increasing portion sizes, easy access to highly palatable energy-dense foods, changing family dynamics, and technological advances that have reduced the need for daily physical activity all contribute to the problem (14,15). From a public health per-

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spective, individual behaviors must be addressed in the context of societal and environmental influences at the community level where children live (16,17).

Developing effective strategies to bring children into energy balance, through appropriate caloric intake and expenditure activities that support the achievement and maintenance of desirable weight, is an international mandate (18–20). Before-, during-, and after-school environments represent obvious and favorable settings for obesity prevention in children, particularly those at high risk (21–23). The potential to reach millions of children each day as they progress through these environments is enormous, as established channels for program administration and health communication already exist (24,25). Most obesity prevention studies have targeted school environments with modest success with respect to environmental, behavioral, and biological change (20,26). Only a handful of obesity interventions aimed at elementary and middle school children have been successful in modifying obesity risk over the short-term (27–30) or in slowing the increase in overweight and obesity (31). More unsettling is the fact that very few have demonstrated a reduction in overweight and obesity prevalence (18,32,33), while evidence of no benefit is much more common (20,34). Lack of success is most likely due to the narrow focus of the interventions, in that school time accounts for <50% of children's waking hours.

Studies of environmental approaches to obesity prevention in children are needed to address all of the daily influences on energy balance. No controlled studies, to our knowledge, have evaluated the effectiveness of multifaceted community-based changes on the prevention of undesirable weight gain in children. To begin to fill this gap, we conducted Shape Up Somerville (SUS)[1]: Eat Smart, Play Hard, one of the first collaborative community-based participatory research (CBPR) initiatives (35,36) designed to change the environment to prevent obesity in early elementary school age children. CBPR is a promising collaborative approach that combines systematic inquiry, participation, and action to address urban health problems (36). We partnered with community members of three culturally diverse urban communities to conduct a controlled trial to evaluate whether an environmental change intervention could prevent a rise in BMI *z*-scores in young children through enhanced access and availability of physical activity options and healthy food throughout their entire day.

Research Methods and Procedures

This CBPR study included the facilitation of a collaborative partnership with the communities in all phases of the research: identifying the problem, designing, implementing, and evaluating the intervention, and identifying how data would inform actions to improve health within the community (37). The intervention was a non-randomized controlled trial and included three communities studied over a 3-year period (September 2002 to August 2005). The data presented here are for the intervention period conducted over one school year (Pre: September/October 2003, Post: May/June 2004). Participants included children in grades 1 to 3 attending public elementary school in the three participating communities.

A required element of CBPR is that there must be established and ongoing relationships between key community-based organizations and the research entity (35,36). We chose Somerville as the intervention community because our relationship with that community met these criteria. Recruitment for control communities began during the Summer/Fall of 2002 by contacting school superintendents from several eastern communities in Massachusetts identified as eligible for participation based on socioeconomic status and racial-ethnic diversity. The study purpose and protocol were presented to four potential communities. The first two socio-demographically matched cities that could provide a written commitment to participate were chosen as control communities (Control 1 and Control 2) and did not receive any of the intervention components. We included two control communities to protect against the possibility that an intervention would be introduced in one of them during the study period. All three communities were cities outside of Boston and had similar community demographic characteristics, such as non-English speaking in the home (28% to 36%), median household income ($39,507 to $46,315), and percentage living below the poverty level (12.5% to 14.5%) (38,39). All schools within both control communities received $500 for each year of the study as incentive for participation.

School administrators from the three participating communities and the food service director and school nurse supervisor in Somerville signed a study contract/agreement. All 30 elementary schools in the three communities participated: 10 in intervention, 15 in Control 1, and 5 in Control 2. Subject recruitment and study procedures were approved and monitored by the Institutional Review Board at Tufts University. All investigators, staff, and data collectors completed training in Mandatory Educational Requirements for Human Subjects Protection. Parental informed written consent was obtained for all participating children. Of the 5940 children eligible, 1696 participated (631 in the intervention community and 1065 in the control communities). Figure 1 presents the flow of recruitment, the number of consented children, and the total number of children included in the analysis.

Intervention Program

Using a community participatory process, the intervention activities were developed to influence every part of an

[1] Nonstandard abbreviations: SUS, Shape Up Somerville; CBPR, community-based participatory research; CI, confidence interval.

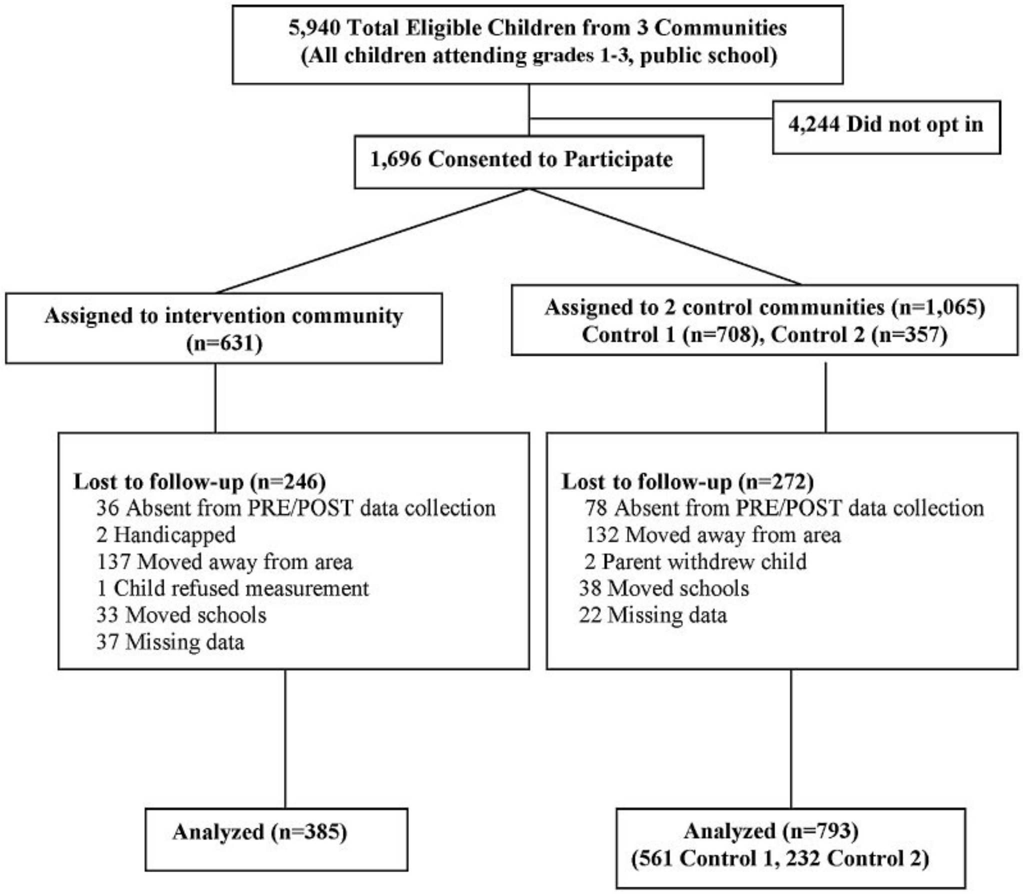

Figure 1: Flow diagram of recruitment and analysis.

early elementary schoolchild's day. To begin, we engaged a wide variety of community members from the four major language communities (Portuguese, Haitian-Creole, Spanish, and English), including a range of professionals, to work with us to design and plan the study. The interactions took several forms, including meetings, focus groups, and key informant interviews, and led to the formation of several SUS advisory councils that remained actively involved throughout the study. Through the implementation phase of the project, we conducted extensive outcome and process evaluation and documented participation and adherence to intervention elements. Table 1 outlines SUS intervention components (available at http://nutrition.tufts.edu/research/shapeup) designed to result in an increased energy expenditure of up to 125 kcal/d beyond the increases in energy expenditure and energy intake that accompany growth (40,41).

Specific changes within the before-, during-, and after-school environments provided a variety of increased opportunities for physical activity. The availability of foods of lower energy density, with an emphasis on fruits, vegetables, whole grains, and low-fat dairy, was increased; foods high in fat and sugar were discouraged. Additional changes within the home and the community, promoted by the intervention team, provided reinforcing opportunities to be more physically active and improved access to healthier food. Many groups and individuals within the community (including children, parents, teachers, school food service providers, city departments, policy makers, healthcare providers, before- and after-school programs, restaurants, and the media) were engaged in the implementation of the intervention. Process evaluation allowed us to document the extent of implementation of all activities during the study. For example, the in-school curriculum was implemented by 90 teachers in 100% of 1 to 3 grade classrooms (N = 81), reaching 1600 children. Within the community, SUS participated in or conducted 100 events and 4 parent forums. We trained 50 medical professionals on childhood obesity guidelines and current screening practices, and we recruited 21 restaurants to become SUS approved. Our two newsletters reached 811 families through 9 parent newsletters and 353 community partners through 6 community newsletters. A monthly media piece (11 months) reached over 20,000 subscribers each month. A total of 14 after-school programs implemented the after-school curriculum. Various community-wide policies were developed to promote and sustain

Table 1. Components of the SUS intervention

Before school	After school
Breakfast program	SUS after-school curriculum
Increase fresh fruits, low-fat milk, whole grains	Increase physical activity
Taste tests	Cooking lessons
Adult monitors	Promote healthy snacks
Walk to School Campaign	Farm trips
Walking to school bus	Professional development for program staff
Traffic calming tactics	Walk from school campaign (see Walk to school campaign)
Walking contests	**Home**
International Walk to School Day	Parent outreach and education
Safe routes to school maps	Bi-monthly newsletter
During school	Free and reduced coupons
Professional development (nutrition and physical activity) for all school staff	Family events
School health office	Parent nutrition forums
Anthropometric equipment	Child's "Health Report Card" mailed each year
Height/weight data collection	**Community**
School food service	SUS Community Advisory Council
Increase whole grains, fruits and vegetables, low-fat dairy	Ethnic-minority group collaborations
Healthier a la carte snacks	Support from local "community champions"
Monthly taste tests	Walking/pedestrian trainings
New vegetarian recipes	City Employee Wellness Campaign
Ice cream sold only one day/wk	"Farmers Market" initiative
New equipment to enhance food presentation	Local physician and clinic staff training
SUS classroom curriculum	SUS "approved" restaurants
10-minute daily "Cool Moves"	City ordinances on walkability/bikeability
30-minute nutrition and physical activity lesson ($\sim$1 week)	Annual SUS 5 K Family Fitness Fair
Fun and healthy giveaways	Regular local media placement
Enhanced recess	Monthly SUS column in the *Somerville Journal*
New play equipment/game cards	Collaborated on City of Somerville health events
School "wellness" policy development	Resource guides
School food service	Physical Activity Guide
Classroom environment	Healthy Meeting Guide
Physical education environment	Health Message Translations Booklet
Structured day environment	
After-school environment	
School health environment	
To/from school environment	

SUS, Shape Up Somerville.

change. These included a school wellness policy, new policies and union contract negotiations that led to enhancements of the school food service, expanded pedestrian safety and environmental policies, the adoption of a healthy meeting and event policy, and a city employee fitness wellness benefit. As part of the CBPR approach, we also helped the intervention community secure over $1.5 million from other funding sources to continue many of these intervention activities. This approach addressed the complex environmental influences on energy balance and ensured maximal reach within a population of children. Environmental and programmatic changes were also documented in the control communities.

Outcome Measures

BMI z-score. During the Pre and Post periods of the intervention year, height and weight were measured and used to calculate BMI *z*-score. Change in BMI *z*-score was the primary health outcome of the study. Both height and weight were obtained, in triplicate, without shoes, following the recommended procedures for children in school settings (42) and standard anthropometric measurement procedures (43). Height was measured to the nearest eighth of an inch using a portable stadiometer (Shorr Infant/Child/Adult Height/Length Measuring Board; Shorr, Olney, MD). Weight was measured in light clothing to the nearest 0.5 lb on a digital scale (Seca Bella model 840; Seca, Hanover, MD). BMI was calculated using an average of three body weight measures divided by an average of three height measures and converted to *z*-scores as recommended by the U.S. Centers for Disease Control and Prevention (44). In accordance with Centers for Disease Control guidelines, a *z*-score below the 5th percentile was considered underweight, a score between the 5th and 85th percentile was considered desirable, a score at or above the 85th percentile but below the 95th percentile was considered at risk for overweight, and a score at or above the 95th percentile was considered overweight (44). In cooperation with the school nurse at each school, trained study personnel measured the children in a private area such as the school nurse's office. If a common area was used, measurement areas were made private by using screens and/or adequate space separation. To obtain measurements from absent children, follow-up visits were made to most schools within a 2-week period.

Demographic and behavioral measures. In addition to basic child demographic information (sex, birth date, grade, ethnicity, primary language at home) collected at the time informed consent was obtained, a 68-item questionnaire written in the household language (English, Spanish, Portuguese, or Haitian Creole) was mailed to parents/caregivers during the Pre period with a postage-paid, pre-addressed return envelope. A reminder postcard was sent if the survey was not returned within 2 weeks. Non-respondents were sent a second survey 1 week later. Parents/caregivers were asked to report family socio-demographic information, such as education, age, ethnicity, and marital status; personal information, such as height and weight; and other information pertaining to the child, such as sports and physical activity involvement, dietary intake and restrictions, and television viewing. For parents who did not complete the baseline survey, a short survey that queried demographic information only was sent during the Post period.

Statistical Analysis

Variables for analysis derive from measurements obtained Pre and Post intervention. Of the 1696 subjects with completed consent forms (631 intervention and 1065 control), 1178 observations (385 intervention and 793 control) with both Pre and Post measures were included in our analytic sample. Of the 1178 participants, 733 also completed the survey of family information providing additional descriptive information (presented as percentages and mean ± standard deviation) on physical activity and nutritional behavior. Consistent with the study design, these behavioral measures were not included in the model to test the effect of the intervention on weight in the subject population. We performed independent *t* tests or χ^2 tests on all descriptive variables (Tables 2–4) to test for differences between the intervention and each control community. Significant differences ($p < 0.05$) are indicated.

To assess differences in the change in BMI *z*-score between the intervention and the two control communities, we used a multivariate model. Because subjects were not randomly assigned to treatment groups, the analytic approach had to account for the intraclass correlation or "clustering effect" that arises due to similarities among subjects who reside within a community. Although the three communities were chosen for their aggregate similarity, even small group differences between the intervention and control communities could have distorted the estimation of standard errors. For the current study, generalized estimating equations often used to account for clustering effects in data were not appropriate due to the small number of clusters. Instead, our model used an estimating procedure (PROC SURVEYREG; SAS Institute, Inc., Cary, NC) that allowed us to account for clustering effects in our data (45). Although designed for complex samples, this procedure can be used to compute standard errors while accounting for clustering in the data. The results reported here are conservative compared with those produced by the generalized estimating equations procedure. Furthermore, because no other interventions were introduced in either control community during the study period, we pooled the two control communities. We included child characteristics as identified in the original research design. The covariates included sex, age, ethnicity, grade, primary language at home, and the child's BMI *z*-score at baseline.

Dummy variables for each school ($N = 30 - 1$) were included in the regression to account for fixed-effects due to the child's school. These effects could include unmeasured differences in the consistency and enthusiasm of the support for the intervention among teachers and administrators, as well as differences in resources among neighborhood-based schools. The α-level was set at $p < 0.05$.

Results

Table 2 summarizes the children's demographics and pre-intervention weight measures by community. All communities were racially diverse, although distributions varied among them. Over one third (36% to 49%) of the children, when stratified by gender, were either at risk for overweight or overweight at pre-intervention. Table 3 displays selected

Table 2. Baseline (pre-intervention) demographic characteristics by community

	Intervention ($N = 385$)	Control 1 ($N = 561$)	Control 2 ($N = 232$)
Age (yrs)	7.92	7.34*	7.8
Mean (standard deviation)	(1.061)	(0.944)*	(1.047)
Grade (%)			
1	32.2	47.4*	43.5*
2	29.6	23.7*	25.4
3	38.2	28.9*	31
Ethnicity (%)			
White	49.6	37.8*	51.7
Black	7.5	25.1*	6.9
Hispanic	18.2	11.8*	22.8
Asian	9.1	2.3*	7.3
Other	15.6	23*	11.2
Non-English primary home language (%)	33	15.9*	35.3
Weight category (%)			
<85th percentile BMI	55.6	63.6*	56.9
85th to 95th percentile BMI	20	16.4	17.7
>95th percentile BMI	24.4	20	25.4

* Significantly different from intervention by *t* test (age) and χ^2 (all others).

children's behavioral information by community pre-intervention. Eating meals while watching television was common, with nearly 40% of children "sometimes" or "often" watching television while eating dinner. Close to one half of the parents reported that their child had a television set in their bedroom. In terms of meeting dietary recommendations, slightly more than half reported consuming the recommended amount of fruit and dairy per day, while 15% or fewer reported consuming the recommended amount of vegetables (46). Between 58% and 62% of parents reported that most days of the week their child participated in the school lunch program.

Table 3. Selected behavioral characteristics of children at baseline by community

	Intervention ($N = 231$) (%)	Control 1 ($N = 359$) (%)	Control 2 ($N = 143$) (%)
Dinner with TV often/sometimes	36.8	37.2	44.8
TV in bedroom	40.7	51.8*	55.4*
2 or more fruits/d	56.6	52.4*	48.6*
3 or more vegetables/d	14.0	10.1	12.8
3 or more dairy/d	50.4	56.0	55.2
Participates in school lunch	58.3	58.4	62.2
No. of sports or lessons/yr			
0	22.5	27.0	29.4
1–3	37.2	41.5	39.8
≥4	40.3	31.5*	30.8

* Significantly different from intervention by χ^2.

Table 4. Selected characteristics of the family at baseline by community

	Intervention	Control 1	Control 2
Marital status	$N = 231$	$N = 359$	$N = 143$
Never married	10.7	24.8*	13.4
Married	79.1	60.0*	73.2
Separated/divorced	9.8	14.7	13.4
Parent birthplace			
U.S. born mother	54.4	70.4*	57.0
U.S. born father	51.1	67.9*	54.7
Mother's education	$N = 222$	$N = 344$	$N = 137$
Less than high school	14.0	4.9	14.0
High school or equivalent	35.1	48.0	54.0*
Some or all college	34.2	41.0	27.7
Graduate school	16.7	6.1*	4.4*
Father's education	$N = 210$	$N = 327$	$N = 132$
Less than high school	14.8	13.2	11.4
High school or equivalent	37.6	55.7*	66.7*
Some or all college	30.5	25.1*	18.9
Graduate school	17.1	6.1	3.0

Values are percent.
* Significantly different from intervention by χ^2.

Approximately one fourth of children were not involved in any sports or physical activity lessons in the past year.

Table 4 describes family characteristics at baseline. Over 60% of the children lived in households with married parents. Most parents had at least a high school diploma or the equivalent; mothers were generally more educated than fathers. Many parents were born outside of the United States. Parent education was higher, on average, in the intervention community than in either of the control communities.

Table 5. Unadjusted pre- and post-intervention BMI z-score by community and sex

	Intervention ($N = 385$)		Control 1 ($N = 561$)		Control 2 ($N = 232$)	
	Female (n =190)	Male (n = 195)	Female (n = 298)	Male (n = 263)	Female (n = 117)	Male (n = 115)
Pre BMI z-score						
Mean years	0.782	0.918	0.617	0.777	0.679	1.132
SD	1.100	1.021	1.060	0.999	1.055	0.903
Post BMI z-score						
Mean	0.755	0.882	0.615	0.768	0.688	1.113
SD	1.070	1.022	1.065	0.995	1.055	0.926
Δ BMI z-score						
Mean	−0.027	−0.036	−0.002	−0.009	0.009	−0.018
SD	0.356	0.284	0.265	0.289	0.294	0.253

Pre, September/October 2003; Post, May/June 2004; Δ, Post − Pre; SD, standard deviation.

Table 5 shows the Pre and Post intervention BMI *z*-score measures and the mean change over the intervention period. Table 6 presents the impact of the intervention on the change in BMI *z*-score in the intervention and control communities. The average change in BMI *z*-score in the intervention community was −0.1307 [95% confidence interval (CI), −0.1836 to −0.0778; $p = 0.02$] compared with Control 1 and −0.1048 (95% CI, −0.1541 to −0.0555; $p = 0.02$) compared with Control 2 after controlling for baseline BMI *z*-score, sex, grade, age, race, primary language spoken at home, school, and community. When the controls were pooled, the average change in BMI *z*-score was −0.1005 in the intervention community compared with the control communities (95% CI, −0.1151 to −0.0859; $p = 0.001$), after controlling for the same covariates as above.

Baseline BMI *z*-score was included in the regression for two reasons. First, subjects with larger positive baseline BMI *z*-scores are likely to experience greater weight change than those who have normal, average, or low BMI *z*-score. Second, there is a general statistical problem with regression to the mean in a Pre/Post study design. Even if the intervention is not effective, a second measurement of BMI among a large group is likely to show some Post intervention change toward the mean score (i.e., lower Post score among children with higher initial weight). We found no significant effects due to sex, grade, age, ethnicity, and primary language spoken at home after adjusting for baseline BMI *z*-score.

We examined the influence of mothers' and fathers' education using a reduced dataset of 658 subjects for whom education information was complete. Neither was a significant predictor of BMI *z*-score change, and there were no significant differences in other covariates between the two regression models

Discussion

This study demonstrates that it is possible to address the alarming rise in the prevalence of overweight in children through a multifaceted environmental change approach that involves the community, schools, families, and students. Data from this study indicate a significant BMI *z*-score change in a population of high-risk early elementary school children. The significant effect size ($\beta = -0.1005$, $p = 0.001$), albeit modest, is important given the obesigenic environmental backdrop against which the intervention occurred.

The effect of the 8-month intervention period can be best understood by the example in Table 7, which shows the effect on a child at the 75th percentile BMI *z*-score and 50th percentile for height (44,47,48). This table demonstrates that, for this child, exposure to the intervention would decrease the expected weight gain by almost 1 pound, 0.8 and 0.9 lb for a boy and girl, respectively, assuming that the child was tracking at the 75th percentile BMI *z*-score and 50th percentile for height. The intervention effect is even

Table 6. Results of multiple regression model of change in BMI *z*-score pre- and post-intervention ($N = 1178$)

Variable	Control 1	Control 2	Control 1 + 2
Intervention (Somerville vs.)	−0.1307	−0.1048	−0.1005
	(0.0203)	(0.0235)	(0.0011)
Baseline BMI *z*-score	−0.0328	−0.0448	−0.031
	(0.3466)	(0.2204)	(0.1516)
Sex	0.00003	−0.0058	−0.0022
	(0.9963)	(0.4323)	(0.6475)
Grade	−0.0304	−0.0228	−0.0208
	(0.3389)	(0.5026)	(0.3249)
Age (months)	0.0013	0.0011	0.0007
	(0.5409)	(0.6276)	(0.6510)
Ethnicity	0.0009	0.0052	0.0027
	(0.0251)	(0.5024)	(0.3540)
Primary language spoken at home	0.0079	0.0076	0.0129
	(0.6279)	(0.6837)	(0.3255)
Constant	−0.0099	−0.0322	−0.0136
	(0.8986)	(0.6862)	(0.8277)

Values are coefficients (*p* values). Adjusted for all variables shown above plus the 30 participating schools

Table 7. Estimated intervention effect over 8 months on a child at the 75th percentile BMI *z*-score

	Boys			Girls		
	Baseline (8 years)	Without intervention (8 years 8 months)	With intervention (8 years 8 months)	Baseline (8 years)	Without intervention (8 years 8 months)	With intervention (8 years 8 months)
Height (inches)*	50.35	51.85	51.85	50.23	51.66	51.66
BMI†	17.00	17.40	17.17	17.27	17.70	17.45
Weight (lbs)‡	61.43	66.50	65.68	61.97	67.18	66.24
BMI *z*-score†	0.68	0.68	0.58	0.68	0.68	0.58
BMI *z*-score change		0.00	−0.09		0.00	−0.09
Weight change (lbs)		5.07	4.25		5.21	4.26
Intervention effect (lbs)		−0.82			−0.95	

* Height is 50th percentile at each age, baseline, and without intervention.
† BMI and BMI *z*-score are 75th percentile.
‡ Weight at baseline is calculated from baseline BMI and height (44,47,48).

more compelling when applied to a male and female child of 8 years of age with a BMI-for-age at the 85th percentile and a height at the 50th percentile at baseline: prevention of an additional weight gain of 1.1 lb in a male child and 1.3 lb in a female child and a drop below the at-risk-for-overweight category to the 82nd percentile.

This study should be put into the context of other published weight management and obesity prevention trials conducted on school children and adolescents (20,34). The few studies that have demonstrated successful obesity prevention fall on a continuum of approaches, from highly controlled, clinic-based, cognitive-behavior family-centered approaches to educational and coordinated school-based interventions (20,49). Clinical studies have focused on treatment of an already overweight population through a multifaceted team approach (49–51). Although this medical model has demonstrated success, it appears to be most appropriate for highly motivated, well-resourced parents with an overweight child who have access to comprehensive programming (49,50,52).

In the high-risk population of children participating in this study, ~20% were already overweight. This demonstrates the need for involvement in childhood obesity prevention and management far beyond the routine doctor's office visit. Although timely identification of obesity by primary care providers is a crucial step in management, several studies have shown that providers fail to identify up to one half of obese children (53,54).

Only a few school-based interventions, and no community-wide interventions, targeting changes in behaviors such as screen time, physical activity, and dietary intake have demonstrated success in obesity prevention (27–30,32,33). These studies have focused largely on children in the late elementary to middle school years. We targeted young children with an average age of 7.6 ± 1.0 years to evaluate the potential for prevention strategies early in life. Elementary school children have been affected more by the pediatric obesity epidemic than any other group or cohort. While U.S. obesity rates have doubled among 2- to 5- and 12- to 19-year-olds, they have tripled in the 6- to 11-year-old group (55). Similarly, in parts of Europe, the obesity rates have tripled in 7- to 11-year-olds (8,56). The most comprehensive school-based trial to promote health, the Child and Adolescent Trial for Cardiovascular Health (CATCH), reported many system-wide and behavioral changes, but no change in overweight outcomes (57). The Child and Adolescent Trial for Cardiovascular Health (CATCH), now the Coordinated Approach to Child Health, was recently shown to prevent an increase in risk of overweight in low-income schools with predominantly Hispanic children (31). Indeed, the school environment is a natural and worthy target for change, but without additional support from the home, community, and healthcare environments, learned behavior cannot be practiced and reinforced. The complex nature of the etiology of obesity demands far-reaching interventions that penetrate every aspect of a child's world.

Most comprehensive community-based interventions have focused on cardiovascular disease risk reduction, among them the Stanford Five-City Project and the Pawtucket Heart Health program (58,59). To our knowledge, no other comprehensive obesity prevention study has been fully embedded in the community. This community-based environmental change intervention, which involved partnering with an entire city to prevent obesity in early elementary schoolchildren, represents the next logical step in the childhood obesity research continuum (60). A key effort of our study entailed forming a community council, which guided the intervention development, implementation, and evaluation. We hypothesized that the SUS: Eat Smart. Play Hard CBPR intervention, which used key elements of other successful social change models (61), could make an impact on weight status. SUS intervened in multiple environments, using every aspect of the community that touches children and their families, to provide healthier dietary and physical activity opportunities while creating policies to promote sustained change. These intervention components, given the common infrastructure of school systems, before- and after-school programs, city governments, community organizations, and home environments, may be appropriate for a wide range of communities.

Community-based participatory research interventions have only recently made their way into the research literature, and the choice of analytic approach for data collected in these studies remains controversial. The data analysis plan for this study included a variety of methods to test the hypothesis and validate our findings. To assess differences in the change in BMI *z*-score between the intervention and the two control communities, we used the a priori multivariate model presented in Table 5. We also applied an alternative model that follows a more traditional approach for a longitudinal design by using a mixed effects model with the random effects at the individual level in which there are repeated measures for each subject. For the alternative model, individual variability at baseline was assumed to contribute to the magnitude of the treatment effect. It also approximately modeled the clustering effects of responses within communities and incorporated the effects of this clustering into the estimated standard errors. The effect of the intervention on BMI *z*-score change remained significant under this specification.

Limitations and Strengths of Study

A number of limitations, some of which relate to the nature of CBPR, balanced by several strengths of this study are noteworthy. The study was controlled, but not randomized. Although this is not considered optimal, CBPR requires an established and ongoing relationship with the community of interest. Assigning the intervention to Somerville enabled us to capitalize on an existing collaborative foundation and to execute our intervention within a relatively short time period of funding (3 years). Second, although the up-front investment required to build and extend relationships during the planning year was both time- and labor-intensive, once the intervention was launched and carried out, the cooperation and buy-in from the community were genuine and unwavering. As this program is disseminated, communities will need to establish a method of collaboration to replicate the intervention. A third limitation of the study is that we were able to measure and follow only a subset of the entire eligible population of children. The study required institutional review board approval and parental informed written consent on the children. Given the ethnic diversity, different languages spoken, unfamiliarity with research, and the age of the children, we were not able to gain consent for all eligible children in the three communities. Despite these difficulties, we recruited and retained a large sample of ethnic and racially diverse, high-risk children from three communities.

In summary, this study effectively decreased BMI *z*-score in a group of high-risk children through a community-based environmental change intervention. The effectiveness of a community-based model offers a step toward turning the tide on the enormous public health problem of childhood overweight and obesity. Comprehensive strategies that involve changes in multiple environments reinforced with policies that ensure healthy living are a viable and necessary direction for the future.

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