Healthy Living Cambridge Kids: A Community-based Participatory Effort to Promote Healthy Weight and Fitness

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The objective of this study was to assess the impact of a community-based healthy weight intervention on child weight and fitness. Cambridge Public Schools (CPS) have monitored BMI and fitness annually since 2000. Annual increases of overweight and obesity from 2000 (37.0%) to 2004 (39.1%), triggered a multidisciplinary team of researchers, educators, health care, and public health professionals to mobilize environmental and policy interventions. Guided by the social-ecological model and community-based participatory research (CBPR) principles, the team developed and implemented *Healthy Living Cambridge Kids* (HLCK), a multicomponent intervention targeting community, school, family, and individuals. The intervention included city policies and community awareness campaigns; physical education (PE) enhancements, food service reforms, farm-to-school-to-home programs; and family outreach and "BMI and fitness reports". Baseline (2004) to follow-up (2007) evaluation design assessed change in children's weight and fitness status. A cohort of 1,858 K-5th grade children participated: 37.3% black, 14.0% Hispanic, 37.1% white, 10.2% Asian, 1.7% other race; 43.3% were lower income. BMI *z*-score (0.67–0.63 $P < 0.001$) and proportion obese (20.2–18.0% $P < 0.05$) decreased, and mean number of fitness tests (0–5) passed increased (3.7–3.9 $P < 0.001$). Whereas black and Hispanic children were more likely to be obese at baseline (27.0 and 28.5%, respectively) compared with white (12.6%) and Asian (14.3%) children, obesity among all race/ethnicity groups declined. Concurrent with a 3-year community intervention, modest improvements in obesity and fitness were observed among CPS children from baseline to follow-up. The CBPR approach facilitated sustaining policies and program elements postintervention in this diverse community.

INTRODUCTION

Across the United States (US), childhood obesity and unfitness continue to impact both the current and future health of our children. In 2005–2006, 30.1% of children and adolescents aged 2 through 19 years had high BMI ≥85th percentile and 15.5% had BMI ≥95th percentile (1). A meta-analysis of studies from 11 countries, including the United States showed a decline in pediatric aerobic performance since 1970 (2) and other US studies showed small decreases in physical activity and fitness, which varied by age and gender (3,4).

Given the limited success in stemming the childhood obesity epidemic by treating obesity in clinical settings (5) or targeting overweight students for intervention (6), school-based efforts often embraced a universal approach of preventing excess weight gain through "down-stream" child-centered education and behavior change approaches (7–10). Currently, there is growing emphasis on "up-stream" public health, environmental, and policy approaches that address the limited control that children have over their food and physical activity choices (11,12). Interventions of this nature are designed to tip the energy balance in favor of increased energy expenditure and/or decreased energy intake by providing access to appealing physical activity and/or healthy food choices, and may be more effective and sustainable than behavioral approaches alone (13–15). Whereas obesity prevention interventions often include efforts to increase physical activity, improving physical fitness is a less frequently reported outcome, though school and after-school programs have shown some success (16,17).

Published reports on broad-based interventions that incorporate community involvement are still limited, and most have not used participatory methods. Community-based participatory research (CBPR) provides opportunities to engage collaboratively with community partners and offers the potential for sustainability (18). Shape Up Somerville represents one of the few community obesity prevention interventions that utilized a CBPR approach (14). Nationally, there are calls for more

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communities to use stakeholder participation and partnerships to take action on addressing obesity through supporting healthy eating and active living efforts (10,12), but to date there are few studies that demonstrate the results of these efforts (13,19).

Today, the media and "obesity-watch" newsletters (i.e., www.rwjf.org/childhoodobesity/digestlist.jsp) are documenting that communities across the nation are initiating community- and school-level obesity prevention programs and are using "real world" measures based on routinely-collected data for evaluation and policy decision making. Given that these efforts are generally not considered research initiatives, their results remain locally based and not widely disseminated. As a result, there is little information in the literature for other communities hoping to adopt these approaches.

Our study helps to fill this gap in the literature by contributing to CBPR generally, and to help document the burgeoning grassroots childhood obesity prevention movement specifically, by describing a community-initiated, implemented, and evaluated healthy weight intervention, Healthy Living Cambridge Kids (HLCK). The evaluation used "real world" measurement to assess the impact of HLCK on child BMI and fitness outcomes. The intervention was implemented in an ethnically and socioeconomically diverse urban city. Our intent was to illustrate how a community can harness and increase grassroots capacity to mobilize interventions and evaluate their outcomes.

METHODS AND PROCEDURES

Setting

Cambridge, MA, is a dense city of 101,355 (20) north of Boston. At baseline (preintervention) in the 2003–2004 school year, 6,444 children were enrolled in 12 kindergarten-eighth (K-8th) grade schools and one high school in the Cambridge Public Schools (CPS). Despite its reputation as a wealthy college town, 64% of the students were nonwhite (38% African-American, 15% Hispanic, 10% Asian, and 1% other) and 41% were low-income. Almost one-third (33%) of children reported speaking a language other than English at home, and 50 countries of origin were reported—Brazil, Haiti, and Central American countries among the most common. Over the course of the study, enrollment in CPS declined to 5,599 children in 2006–2007 school year due to the transience of the population and trends toward transfer to private and suburban schools. Average daily attendance remained relatively constant at ~94% (21). According to the 2005 Middle School Health Survey (adapted from the Youth Risk Behavior Survey (22)), among 6th–8th grade children, 40.6% reported eating 5+ fruits and/or vegetables in the past 24 h; 64.7% reported watching ≤2 h of TV daily; and 40.5% reported meeting moderate and/or vigorous physical activity benchmarks (CPS, personal communication).

Study design

To evaluate the impact of the 3-year HLCK intervention (2005–2007), this longitudinal study assessed change in BMI and fitness among a cohort of children who were in kindergarten-fifth (K-5th) grade preintervention (baseline) in school year 2003–2004 (2004) to follow-up in year three of the intervention 2006–2007 (2007) when the children were in third-eighth (3rd–8th) grade. Children who would not have received the full three years of the intervention due to their age at baseline (grades 6–8) were excluded from the cohort. In addition, children excluded from the cohort were <5 years at baseline, >14 years at follow-up, or had special needs that precluded measurement. Process measures were collected throughout the implementation phase. BMI and fitness data were provided by CPS which routinely collects this information as part of the annual physical education (PE) curriculum without active parental consent. However, parents and children may opt out of the data collection at any time. The study protocol was approved by CPS administration and the Cambridge Health Alliance Institutional Review Board.

Community-based participatory research (CBPR) approach

The HLCK study is the result of 10 years of CBPR in Cambridge designed to develop and mobilize environmental and structural interventions within the community and school to promote healthy weight. The CBPR approach engaged community members in all aspects of the research process from research questions to design and implementation of the study and to analysis and dissemination (18). Our study involved a collaborative effort between members of The Healthy Children Task Force (Task Force) in Cambridge, including CPS, the Institute for Community Health, and the Cambridge Public Health Department. The Task Force is a multidisciplinary coalition of elected officials, educators, health care, and public health professionals, researchers, and parents that has provided a forum for collaboratively addressing children's health issues since 1990. In 2000, the Task Force prioritized healthy eating and active living and identified increasing "healthy weight" (BMI ≥5th and <85th percentile for age and gender (23)) and fitness among K-8th grade children as community goals. Task Force partners, both individually and through the institutions they represented, became involved in elements of both the intervention and the evaluation.

Intervention

The HLCK intervention developed in four phases: formative, developmental/pilot, implementation, and sustainability. These elements served as building blocks in one community's effort to address childhood obesity and promote healthy eating and active living.

Formative phase (1999–2001). Several steps initiated obesity prevention work. First, in 1999, CPS collaborated with research partners at Institute for Community Health to (i) develop a computerized data system to record annual height, weight, and fitness test score data and monitor, in aggregate, BMI percentiles and fitness status of K-8 CPS children, (ii) train PE teachers and school nurses in standardized anthropometry, and (iii) purchase standardized equipment for each school.

Second, Task Force partners created 5-2-1 guidelines based on national goals and emergent research to promote healthy weight. The 5-2-1 guidelines promoted decreasing energy intake by promoting eating five or more servings of low-energy fruits and vegetables daily (24); increasing energy expenditure by limiting inactive or sedentary time to 2 h or less of TV or screen time daily (25); and increasing moderate and vigorous physical activity to at least 60 min of age-appropriate physical activity on all or most days of the week (26). The 5-2-1 slogan served as an awareness campaign and provided goals for community-level interventions.

Third, formative research including community forums and parent input clearly identified that local families were interested in improvements to school meals and PE. Subsequently, Task Force partners were mobilized to seek grants, garner resources, and pilot healthy weight interventions.

Intervention development and pilot-testing phase (2001–2004). BMI data showed that CPS children had higher rates of overweight and obesity (BMI ≥85th percentile) than national rates (27) and several years of trend data showed an ~0.5% annual increase of high BMI occurred from 2000 (37.0%) to 2004 (39.1%) among K-8th grade children, suggesting a worsening in children's health.

In 2001, Task Force partners pilot-tested the use of individualized "BMI and fitness report cards" (BMI and fitness reports) on parents' awareness of their children's weight and fitness status and their intentions to take follow-up action (28). Based on positive results, CPS implemented BMI and fitness reports system-wide for grades K-8. Supports (follow-up phone calls, referrals for weight management) for parents of overweight and obese children were implemented by school nurses from Cambridge Public Health Department. Over time, family feedback led to adjustments in layout and language to improve the readability of the BMI and fitness reports.

Next, with additional grant dollars, a pilot-program in four elementary schools tested the feasibility and efficacy of using school-yard gardens, cafeteria taste-tests, and family education to promote fruit and vegetables. PE enhancement grants offered professional development for PE teachers and new gymnasium equipment in all schools.

Implementation phase (2005–2007). In 2005, HLCK was launched, representing the culmination of years of collaborative efforts and several successful grants. The original partnership expanded to include CitySprouts, a gardening organization, Cambridge Department of Human Service Programs, Cambridge Green Streets Initiative, and the Federation of Massachusetts Farmers' Markets. Funding came from the Department of Education Carol M. White Physical Education Program, USDA Community Food Projects, Blue Cross Blue Shield of Massachusetts, and the Massachusetts Department of Public Health.

The 3-year, multicomponent HLCK intervention continued to be guided by CBPR principles. In keeping with observations that successful interventions were more likely to use a conceptual frame and a comprehensive environmental and policy intervention approach (10) HLCK adapted the socio-ecological model (29) to target community, school, family, and individuals. **Figure 1** summarizes key components of HLCK implementation.

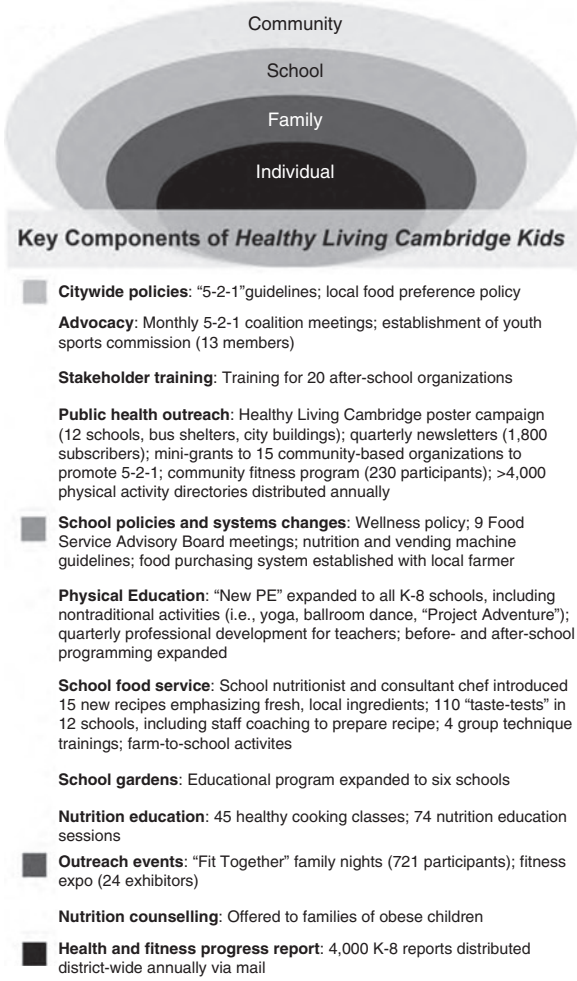

Figure 1 Key components of Healthy Living Cambridge Kids.

At the community level, implementation strategies were designed to provide policy support for healthy living choices such as a city council endorsement of the "5-2-1" guidelines and passage of a local food preference policy; to provide opportunities for community advocacy such as the 5-2-1 coalition and youth sports commission; to provide after-school providers training on implementing the policies; and to raise community awareness of the many resources available in the city to promote healthy eating and active living through a poster campaign, newsletters, 5-2-1 mini-grants, and directories of physical activities distributed to all school children.

At the school level, PE and food service policies, systems, and programs were implemented at all 12 K-8 schools similarly to improve access to appealing, appropriate physical activity opportunities, and healthy food choices for all children; school stakeholders were trained to implement new guidelines and policies; and PE programs such as Project Adventure and ballroom dancing, and innovative food service projects such

as new recipe and menu development and cafeteria taste-tests were developed to promote 5-2-1. School-yard garden programs were expanded to increase student awareness of and appreciation for locally-grown produce.

A school wellness policy http://www.cpsd.us/cpsdir/school_policies.cfm was developed as required by the WIC Reauthorization Act of 2004. School nutrition guidelines included restrictions on items sold in vending machines (30); limited access to a la carte foods; system-wide substitution of lower-sugar (<6 g sugar) (31) and/or higher-fiber (>2 g fiber) cereals, whole grain breads (50–100% whole grain), and low-fat yogurt without artificial colors, and products with trans fat were phased out. Principles to promote 5-2-1 were included for PE, recess, and snacks in the policy.

At the individual- and family level, strategies and policies were designed to increase the awareness of children and their families of each student's health risk due to their BMI or fitness test scores, and to provide skills and resources for addressing individual and family health risks and lifestyle choices through school-based family nights. Annual BMI and fitness reports noted results were not diagnostic and referred parents to pediatricians for follow-up. Fitness report distribution was followed by "Fit Together" family event nights, open to all families but specifically targeting families of obese children. In addition, receptive families were offered subsidized weight management counseling at a local family-oriented obesity management agency.

Evaluation measures/outcomes

Weight status. Individual weight status was assessed by BMI, calculated from height and weight measurements collected annually each spring by CPS PE teachers and school nurses who were trained as professionals each year with a standard protocol (32). As noted, all schools used the same equipment. Height was measured to the nearest 0.25 inch with a wall-mounted stadiometer (Seca 216 Accu-Hite, Snoqualmie, WA). Weight was measured to the nearest 0.2 lb with an electronic scale (Seca 216 Bellisima-digital, Snoqualmie, WA) in indoor clothing without shoes. Because CPS sent BMI and fitness screening results home to families and wanted to ensure accurate information, all student data was checked for outliers during data entry, and high and low data (BMI <5th or ≥95th percentile) were reviewed by school nurses familiar with the children. BMI *z*-scores and percentiles based on age and gender were calculated for each student from CDC growth charts (23). As in previous studies, BMI *z*-scores ≤−4 and BMI *z*-scores ≥5 were excluded from the analysis (33). Children were classified as: obese (BMI ≥95th percentile), overweight (BMI ≥85th and <95th percentile), healthy weight (BMI ≥5th and <85th percentile), and underweight (BMI <5th percentile) (34).

Fitness. Fitness was assessed by age- and gender-adjusted scores on five fitness tests completed annually in PE each spring: endurance cardiovascular test; abdominal strength test; flexibility test; upper body strength test; and an agility test. PE teachers were trained annually with testing and scoring protocols adapted from Amateur Athletic Union (35) and Fitnessgram (Cooper Institute, Dallas, TX (36)). Children's proficiency status (Participant, Attainment, Outstanding) was assigned for each test according to Amateur Athletic Union and Cooper Institute guidelines as described elsewhere (37). For each fitness test, children were considered "passing" if they achieved "Attainment" or "Outstanding". The mean number of fitness tests passed was calculated for each student (from 0 to 5 tests passed). Overall fitness was calculated where "passing" was defined as having "passed" all five tests and "not passing" was defined as having failed any one of the five tests. "Passing" or "not passing" the endurance cardiovascular "shuttle run" test score was also used independently because it has been correlated with obesity (37).

Personal measures. Gender, grade, age, race/ethnicity (black, Hispanic, Asian, white), and income status based on eligibility for free or reduced price school meals (free meals) under the National School Lunch Program were extracted from the school administration record system. Free meal eligibility was used as an indirect measure of family income status and was coded as a binary variable, lower income, or higher income (eligible or ineligible for free meals, respectively) (38).

Statistical analysis

Change in weight and fitness status was assessed using continuous and categorical classifications as described above. For analysis of continuous data, paired *t*-tests were utilized to determine changes in mean BMI *z*-score and the mean number of fitness tests passed between the baseline data collection point (2004) to the follow-up data collection point (2007) in the overall cohort and in samples stratified by gender, race/ethnicity, and socioeconomic status. For categorical data, McNemar tests were utilized to determine statistical significance of changes in the proportion of children in each BMI percentile category, and each dichotomous fitness category from baseline to follow-up both in the overall sample and in samples stratified by gender, race/ethnicity, and socioeconomic status. Percent change was calculated for descriptive purposes. P values <0.05 were considered statistically significant.

All analyses used SAS (version 9.1; SAS Institute, Cary, NC).

RESULTS

Results were compared for a cohort of K-5th grade children at baseline and after 3 years of intervention when these children were in grades 3–8th. Of the eligible cohort of 3,561 nondisabled K-5th grade children in 2004, the following numbers of children were excluded from the analytic sample: 95 children due to biologically implausible BMI *z*-scores; 5 children due to missing fitness data at baseline or follow-up; 1,603 due to missing data at follow-up in year 4. Approximately 1,260 children or ~79% of the missing data could be accounted for by annual cohort-specific student attrition rates (ranging from 4% to 12%) and 6% absenteeism rate from baseline to follow-up (21). We were unable to account for missing data from ~343 students or

Table 1 Baseline sample characteristics: K-5th grade, 2004

Characteristics	Mean (s.d.)
Age *n* = 1,858	7.7 (1.8)
BMI *z*-score *n* = 1,858	0.7 (1.1)
Fitness tests passed *n* = 1,618	3.7 (1.3)
	Number (%)
Gender *n* = 1,858	
Female	895 (48.2)
Male	963 (51.8)
Income status *n* = 1,856	
Lower income	803 (43.3)
Higher income	1,053 (56.7)
Race/ethnicity *n* = 1,858	
Asian	189 (10.2)
Black	685 (37.3)
Hispanic	260 (14.0)
White	693 (37.1)
Other	31 (1.7)
BMI percentile *n* = 1,858	
<5th	38 (2.1)
5th to <85th	1,133 (61.0)
85th to <95th	312 (16.8)
95th and above	375 (20.2)
Passed all fitness tests (overall) *n* = 1,858	
Passed	826 (44.5)
Failed	1,032 (55.5)

Table 2 Difference in BMI *z*-score from baseline (2004) to follow-up (2007)

	Mean (s.d.) 2004	Mean (s.d.) 2007	Difference from 2004 to 2007
Total sample *n* = 1,858	0.67 (1.06)	0.63 (1.03)	−0.04****
Gender			
Female *n* = 895	0.62 (1.04)	0.57 (1.02)	−0.05***
Male *n* = 963	0.72 (1.08)	0.68 (1.02)	−0.04
Income status			
Lower income *n* = 803	0.83 (1.09)	0.80 (1.04)	−0.03
Higher income *n* = 1,053	0.54 (1.02)	0.49 (1.00)	−0.05***
Race			
Asian *n* = 189	0.45 (1.06)	0.46 (0.96)	0.01
Black *n* = 685	0.87 (1.07)	0.82 (1.03)	−0.05**
Hispanic *n* = 260	0.94 (1.01)	0.89 (1.01)	−0.05
White *n* = 693	0.45 (1.02)	0.38 (0.99)	−0.07***

*$P < 0.10$; **$P < 0.05$; ***$P < 0.01$; ****$P < 0.001$

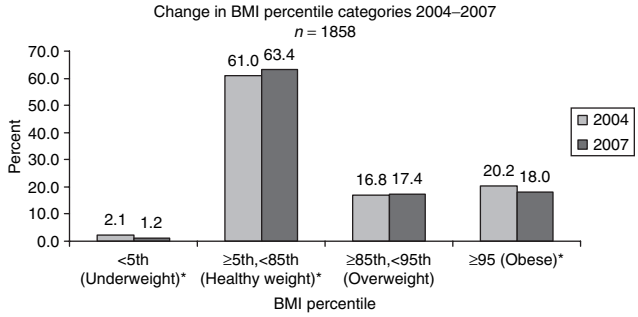

Figure 2 Difference in BMI percentile categories from baseline (2004) to follow-up (2007)

~11% (~4% per year). The final analytic sample includes 1,858 children (52% of the eligible cohort).

Baseline characteristics of the final sample are in **Table 1**. Mean age was 7.7 years, and 48.2% were female. White and black children were equally represented (37.1 and 37.3%, respectively), followed by Hispanic (14.0%) and Asian (10.2%). Nearly half (43.3%) were lower income. At baseline, the mean BMI *z*-score was 0.7 ± 1.1 s.d.. Twenty percent (20.2%) of the cohort was obese and 37.0% was obese or overweight (≥85th percentile). Approximately 30% (29.9%) of children passed all five fitness tests, with a mean of 3.7± 1.3 s.d. passed tests.

The final study sample differed significantly on several variables from the 1,703 eligible children who were missing data at follow-up. Mean age of children missing data was 9.1 years vs. 7.7 years in the study sample, children missing data were more likely to be Asian 13.0 vs. 10.2%; and less likely to pass all five fitness tests 26.4 vs. 29.9%. However, BMI *z*-scores were not significantly different.

Weight status

After 3 years of intervention, a significant decrease in mean unadjusted BMI *z*-score (−0.04, $P \leq 0.001$) was observed for the overall sample (**Table 2**). From stratified analysis, girls experienced a significant decrease (−0.05, $P < 0.01$); as did higher income children (−0.05, $P < 0.01$), and white (−0.07, $P < 0.01$) and black children (−0.05, $P \leq 0.05$).

Figure 2 compares unadjusted prevalence rates of weight status categories at baseline and follow-up, The prevalence of "healthy weight" increased significantly by 2.4% ($P < 0.05$) (**Table 3**), a 5% change. Children in all gender, race/ethnicity, and income groups experienced an increase in healthy weight. Conversely, the prevalence of underweight (<5th percentile) declined by −0.9 ($P < 0.05$), a −40% change over 4 years, with the impact most pronounced among boys, lower income, and Asian and black children. The prevalence of obesity decreased significantly 2.2% ($P < 0.05$), a −11% change, particularly among higher income children (2.1%; $P < 0.05$) and females (−2.7%; $P < 0.05$). By contrast, the prevalence of overweight did not change significantly over the course of the intervention, with most groups experiencing a modest increase in overweight status. Forty percent (40.1%) of children who were overweight in 2004 became healthy weight in 2007; 24% of children who were obese in 2004 became overweight in 2007. By contrast, 9.4% of children of healthy weight in 2004 became

Table 3 Difference in weight status percentile from baseline (2004) to follow-up (2007)

		Gender		Income status		Race/ethnicity			
	Total sample	Female	Male	Lower income	Higher income	Asian	Black	Hispanic	White
Weight status/year of data collection	*n* = 1,858 %	*n* = 895 %	*n* = 963 %	*n* = 803 %	*n* =1,053 %	*n* = 189 %	*n* = 685 %	*n* = 260 %	*n* = 693 %
Obese[a]									
2004	20.2	19.1	21.2	27.8	14.4	14.3	27.0	28.5	12.6
2007	18.0	16.4	19.5	25.7	12.3	9.5	24.1	27.3	11.3
Δ2004–2007	–2.2**	–2.7**	–1.7	–2.1*	–2.1**	–4.8*	–2.9**	–1.2	–1.3
Overweight[b]									
2004	16.8	16.0	17.6	18.3	15.6	16.4	18.5	16.5	14.9
2007	17.4	17.8	17.0	18.7	16.3	19.6	19.6	18.5	14.4
Δ2004–2007	0.6	1.8	–0.6	0.4	0.7	3.2	1.1	2.0	–0.5
Healthy weight[c]									
2004	61.0	63.1	59.0	51.7	68.1	66.1	52.3	54.6	70.4
2007	63.4	64.4	62.4	54.4	70.2	70.4	55.3	53.5	72.6
Δ2004–2007	2.4**	1.3	3.4**	3.3*	2.1*	4.3	3.0*	1.1	2.2
Underweight[d]									
2004	2.1	1.8	2.3	2.2	1.9	3.2	2.2	0.4	2.2
2007	1.2	1.5	1.0	1.3	1.2	0.5	1.0	0.8	1.7
Δ2004–2007	–0.9*	–0.3	–1.3**	–0.9**	–0.7	–2.7**	–1.2**	0.4	–0.5

[a]BMI ≥ 95th percentile for age and gender. [b]BMI ≥ 85th and <95th percentile for age and gender. [c]BMI ≥5th and <85th percentile for age and gender. [d]BMI <5th percentile for age and gender.
Difference in weight status percentile 2007–2004 *$P < 0.10$; **$P < 0.05$; ***$P < 0.01$; ****$P < 0.001$.

overweight in 2007; and 18.6% of overweight children in 2004 became obese in 2007.

Fitness

Fitness test scores improved significantly for all children from baseline to follow-up, irrespective of race/ethnicity or income status, and on all measures—mean number of fitness tests passed (3.7 (1.32 s.d.) to 3.9 (1.27 s.d.)); percent passing all five fitness tests from 29.9 to 44.5% (14.6% increase); and percent passing the endurance cardiovascular test from 52.6 to 66.6% (14.0% increase) (**Table 4**).

DISCUSSION

After 4 years, and concurrent with the implementation of a 3-year community-initiated healthy weight intervention, a cohort of economically and ethnically diverse urban children (K-5th grade at baseline) experienced a significant decrease in mean BMI *z*-scores ($P < 0.001$), and a significant decline in prevalence of obesity (20.2–18.0%; $P < 0.05$). If extrapolated to the current elementary student body of ~4,200, a decrease in the prevalence of obesity of 2.2% would result in ~93 fewer children who were obese at follow-up, or, for perspective, the equivalent of about four classrooms of children. In the context of other recently published community- or policy-based interventions, the decrease from baseline to follow-up of the unadjusted BMI *z*-score was similar or greater among our intervention cohort (−0.04) than reported in Economos *et al.* (−0.027 for female and −0.036 for male) (14) or in Foster *et al.* (0.07) (15). The studies were not equivalent: the length of intervention was shorter in both studies than in ours and the participants were of somewhat different grade levels, but the results are suggestive of the extent of change that can be expected from a multicomponent intervention in a diverse community. Likewise, although we cannot compare our BMI change results to a control group during the same time frame, CPS children historically experienced annual increases in high BMI (~0.5%) prevalence of 37.0–39.1% from 2000 to 2004 (cross-sectional data) that decreased concurrently with the full implementation of the HLCK intervention. The decline in BMI *z*-scores and obesity that we observed through this community-based initiative and evaluation is encouraging for other communities embarking on "grassroots" obesity prevention initiatives, and adds to the small body of literature on the potential impact of community- and policy-based approaches. The results also speak to the importance of long-term commitment of community and school resources and innovation necessary for influencing child physiological changes.

Table 4 Difference in fitness and endurance test from baseline (2004) to follow-up (2007)

		Gender		Income status		Race/ethnicity			
	Total Sample	Female	Male	Lower income	Higher income	Asian	Black	Hispanic	White
Test/year	*n* = 1,858 %	*n* = 895 %	*n* = 963 %	*n* = 803 %	*n* = 1,053 %	*n* = 189 %	*n* = 685 %	*n* = 260 %	*n* = 693 %
Fitness test[a]									
2004	29.9	31.0	28.9	26.0	32.9	31.2	25.8	31.5	32.6
2007	44.5	44.7	44.2	40.1	47.9	42.3	39.4	45.4	49.2
Δ2004–2007	14.6****	13.7****	15.3****	14.1****	15****	11.1**	13.6****	13.9****	16.6****
Endurance test[b]									
2004	52.6	55.2	50.2	46.6	57.3	49.7	48.0	49.2	59.0
2007	66.6	68.8	64.5	60.7	71.2	63.5	59.9	63.5	75.0
Δ2004–2007	14.0****	13.6****	14.3****	14.1****	13.9****	13.8***	11.9****	14.3****	16.0****

[a]Percent of children who passed all fitness tests. [b]Percent of children who passed cardiovascular endurance test.
Difference from percent passed in 2007 from 2004 *$P < 0.10$; **$P < 0.05$; ***$P < 0.01$; ****$P < 0.001$.

Although overall BMI *z*-score and obesity declined, overweight prevalence actually increased slightly, 0.6%, from 16.8 to 17.4%. This was largely a result of a shift of 88 children (23.5%) from obese at baseline to overweight in 2007, and 106 children (9.4%) from healthy weight at baseline to overweight in 2007. The overall trend, however, was in a positive direction—253 children shifted down one category of weight status compared with 185 children shifting up a weight category in the same time period.

Since there were local concerns that the HLCK obesity prevention work, which includes BMI and fitness reports, could unintentionally result in underweight, it was encouraging that the downward shift in BMI *z*-scores and obesity rates were not accompanied by an increase in underweight. In fact, underweight declined (2.1–1.2%) significantly, and the prevalence of healthy weight increased significantly from 61.0 to 63.4%. Results from Arkansas studies, which also included BMI reports, also did not report increase in underweight (39).

School and community policies and environmental interventions that increase access to healthy foods and physical activity have the potential to disproportionately benefit children and families who depend on school meals and school- or community-based physical activities. It is noteworthy then, that among the relatively high-risk HLCK cohort (63% nonwhite and 43% qualified for subsidized meals) children in all racial/ethnic and income groups experienced improvements in weight status. White and black, and higher income children experienced significant declines in overall BMI *z*-scores; and Asian and black children experienced statistically significant declines in obesity status. However, whereas the change in weight status was encouraging, black and Hispanic children continued to experience obesity at approximately twice the rate as white or Asian children (24.1 and 27.3%, respectively at follow-up, compared with 11.3 and 9.5%, respectively). This trend is consistent with national statistics (1). To further address racial/ethnic population-associated disparities will probably require CBPR approaches that are specific to each community.

Concurrent with the HLCKs initiative, age and gender-adjusted fitness test scores among the 2004 cohort improved significantly across all indicators, and for all racial/ethnic groups and income status groups. Although data from a comparable control group were not available, CPS children clearly benefited during this period through increased access to equipment, innovative PE and fitness programs, opportunities after school and trained PE teachers. Whereas other intervention studies have also found improvements in fitness, overall we found few studies that reported on fitness, and the methods were not always comparable.

The CBPR approach of engaging partners and incorporating local priorities and strategies leveraged resources, enhanced community capacity and built constituencies of support. This community-wide momentum facilitated the postintervention sustainability of many policies (i.e., city-wide local food preference and nutrition policies), systems changes (i.e., menu changes and BMI and fitness reports), and program elements (i.e., "New PE", school gardens, cafeteria taste-tests, and food service staff training). In addition, the surge of innovation and multilevel health interventions served to raise community expectations around children's health and quality of life.

New partnerships have emerged postimplementation of HLCK which we expect will support previous work and expand services in a similarly grassroots manner. For example, the School Health Program works with other city departments on health policies that affect children in both in- and out-of-school time, to provide consistent care. Health and literacy advocates are partnering on initiatives to reduce TV viewing among young children and among immigrant families, further supporting 5-2-1 goals. Health and recreation advocates are developing new playground guidelines and recreation policies that support physical activity and healthy snacks. Men's health and children's health advocates are working with

leaders in ethnic minority communities to tackle disparities in obesity and 5-2-1 behaviors. Local food advocates are laying the groundwork for a food policy council for Cambridge. BMI, fitness, and youth risk behavior data continue to be collected to monitor progress post-HLCK.

Strengths and limitations of study

The study had a number of unique strengths. The evolving nature of the intervention provides an opportunity to study a "real world" situation that is sustainable and can and is being replicated across the country. The study also demonstrates the success that a CBPR approach can have on local policy and practice. The use of "real world" measures helps validate the use of evaluative tools in community programming and finally, this is one of very few studies that showed a decrease in obesity and an increase in fitness. Other strengths of this research include the long length of the intervention, and the economically and ethnically diverse study cohort.

There are several limitations of this study. Given that the intervention described developed as a result of multiple participants' interest, creativity, and ingenuity, rather than as a deliberate research trial, HLCKs did not have a control community to compare relative rates of BMI *z*-score, weight status, and fitness change over time. Although we have historical data for comparison, without a control group it is unclear whether the positive change in BMI and fitness can be attributed to the 3 years of HLCK intervention or to a general secular change caused by the overall attention to the problem of obesity. In addition, due to missing data which we assume largely reflects children who moved out of district or were absent on the day the BMI scores were collected, the cohort that was followed was significantly different than the group for whom follow-up data was missing. It is therefore possible that the trajectory of results for the study cohort could have been different had these other students, who were more likely to be Asian, older, and/or less likely to pass all five fitness tests remained in the cohort. This fact potentially decreases the generalizability of the results. The measurement data were collected and entered by trained PE teachers, not researchers. However, as noted, CPS staff was trained annually to collect height, weight, and fitness data for surveillance and screening, and additional quality control procedures were in place. Whereas height and weight are objective measures, fitness testing may be more subjective and a measurement bias could have been introduced because the PE teachers both implemented elements of HLCK and collected fitness data. More study is required to understand the subjectivity of these tests and the reliability of the measures. The Youth Risk Behavior Survey data is anonymous and cannot be linked with the BMI and fitness data, thus we can only characterize the study population and not test the contribution of behavior to BMI or fitness statistical models. Because of the CBPR nature of the study, the intervention phases were not distinct, and the intervention built in momentum over time, making it difficult to define specific cut-points for pre- and postintervention data benchmarks.

In conclusion, the HLCK approach, with formative and developmental phases, culminating in a full implementation of community-relevant initiatives is probably typical of how many communities are addressing childhood obesity in their cities or towns. Community-based environmental- and policy-oriented approaches are being encouraged by national agencies and funders. Our positive results add to the short, but growing list of studies showing that "upstream" oriented, multidimensional interventions with children, schools, and communities can curb and potentially prevent obesity.

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DISCLOSURE

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REFERENCES

1. Ogden CL, Carroll MD, Flegal KM. High body mass index for age among US children and adolescents, 2003–2006. *JAMA* 2008;299:2401–2405.
2. Tomkinson GR, Léger LA, Olds TS, Cazorla G. Secular trends in the performance of children and adolescents (1980–2000): an analysis of 55 studies of the 20m shuttle run test in 11 countries. *Sports Med* 2003;33:285–300.
3. Adams J. Trends in physical activity and inactivity amongst US 14–18 year olds by gender, school grade and race, 1993–2003: evidence from the youth risk behavior survey. *BMC Public Health* 2006;6:57.
4. Malina RM. Physical fitness of children and adolescents in the United States: status and secular change. *Med Sport Sci* 2007;50:67–90.
5. Epstein LH, Valoski A, Wing RR, McCurley J. Ten-year outcomes of behavioral family-based treatment for childhood obesity. *Health Psychol* 1994;13:373–383.
6. Story M. School-based approaches for preventing and treating obesity. *Int J Obes Relat Metab Disord* 1999;23(Suppl 2): 43–51.
7. Thomas H. Obesity prevention programs for children and youth: why are their results so modest? *Health Educ Res* 2006;21:783–795.
8. Doak CM, Visscher TL, Renders CM, Seidell JC. The prevention of overweight and obesity in children and adolescents: a review of interventions and programmes. *Obes Rev* 2006;7:111–136.
9. Sharma M. School-based interventions for childhood and adolescent obesity. *Obes Rev* 2006;7:261–269.
10. Summerbell CD, Waters E, Edmunds L *et al*. Interventions for preventing obesity in children. *Cochrane Database Syst Rev* 2005;20:CD001871.
11. Carter RC. The impact of public schools on childhood obesity. *JAMA* 2002;288:2180.
12. Koplan JP, Liverman CT, Kraak VI (eds.). *Preventing Childhood Obesity*. *Health in the Balance*. The National Academies Press: Washington, DC, 2005
13. Veugelers PJ, Fitzgerald AL. Effectiveness of school programs in preventing childhood obesity: a multilevel comparison. *Am J Public Health* 2005;95:432–435.
14. Economos CD, Hyatt RR, Goldberg JP *et al.* A community intervention reduces BMI z-score in children: Shape Up Somerville first year results. *Obesity (Silver Spring)* 2007;15:1325–1336.
15. Foster GD, Sherman S, Borradaile KE *et al.* A policy-based school intervention to prevent overweight and obesity. *Pediatrics* 2008;121:e794–e802.

16. Gutin B, Yin Z, Johnson M, Barbeau P. Preliminary findings of the effect of a 3-year after-school physical activity intervention on fitness and body fat: the Medical College of Georgia Fitkid Project. *Int J Pediatr Obes* 2008;3 Suppl 1:3–9.
17. Reed KE, Warburton DE, Macdonald HM, Naylor PJ, McKay HA. Action Schools! BC: a school-based physical activity intervention designed to decrease cardiovascular disease risk factors in children. *Prev Med* 2008;46:525–531.
18. Israel BA, Parker EA, Rowe Z *et al.* Community-based participatory research: lessons learned from the Centers for Children's Environmental Health and Disease Prevention Research. *Environ Health Perspect* 2005;113:1463–1471.
19. Minkler M, Oetzel J, Duran B *et al*. What predicts outcomes in CBPR? In: Minkler M, Wallerstein N (eds.). *Community-Based Participatory Research for Health*. 2nd edn. John Wiley & Sons: San Francisco, CA, 2008, pp 371–392.
20. US Census. Cambridge's Page <http://factfinder.census.gov/home/saff/main.html?_lang=en> U.S. Census, 2000, Accessed March 2009.
21. Massachusetts Department of Education <http://profiles.doe.mass.edu/profiles/student.aspx?orgcode=00490000&orgtypecode=5&>. Accessed July 2009.
22. National Center for Chronic Disease Prevention and Health Promotion, Division of Adolescent and School Health Youth Risk Behavior Surveillance Survey. Healthy youth: YRBSS 2009 Questionnaires and Item Rationale. (Online). 2008 July 1 <http://www.cdc.gov/HealthyYouth/yrbs/questionnaire_rationale.htm> (cited 3 April 2009).
23. Centers for Disease Control and Prevention, CDC Growth Charts <http://www.cdc.gov/nchs/about/major/nhanes/growthcharts/>. Accessed March, 2009.
24. US Department of Agriculture. Nutrition and Your Health: Dietary Guidelines for Americans 2005. (Online). <http://www.health.gov/dietaryguidelines/dga2005/document/pdf/DGA2005.pdf> (cited 27 March 2009).
25. Hancox RJ, Milne BJ, Poulton R. Association between child and adolescent television viewing and adult health: a longitudinal birth cohort study. *Lancet* 2004;364:257–262.
26. US Department of Health and Human Services, Physical Activity Guidelines for Americans <http://www.health.gov/paguidelines/guidelines/summary.aspx>. Accessed March 2009.
27. Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999–2000. *JAMA* 2002;288:1728–1732.
28. Chomitz VR, Collins J, Kim J, Kramer E, McGowan R. Promoting healthy weight among elementary school children via a health report card approach. *Arch Pediatr Adolesc Med* 2003;157:765–772.
29. McLeroy KR, Bibeau D, Steckler A, Glanz K. An ecological perspective on health promotion programs. *Health Educ Q* 1988;15:351–377.
30. Action for Healthy Kids. Wellness Policy Tool. <http://www.actionforhealthykids.org/wellnesstool/index.php>. Accessed 2005.
31. WIC Regulations, Federal Register, Code of Federal Regulations, 7 C.F.R. Part 246. <http://www.access.gpo.gov/nara/cfr/waisidx_08/7cfr246_08.html>
32. Ikeda JP, Crawford P. *Guidelines for Collecting Heights and Weights on Children and Adolescents in School Settings*. Center of Weight and Health: University of California at Berkeley, CA, 2000.
33. Kim J, Must A, Fitzmaurice GM *et al.* Incidence and remission rates of overweight among children aged 5 to 13 years in a district-wide school surveillance system. *Am J Public Health* 2005;95:1588–1594.
34. Barlow, SE. Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight and obesity: summary report. *Pediatrics* 2007;120(Suppl 4):S254–S288.
35. President's Challenge. Physical Fitness Test. (Online). 2006 <http://www.presidentschallenge.org/educators/program_details/physical_fitness_test.aspx> (cited 27 March 2009).
36. Fitness Testing. Cooper Institute. <http://www.cooperinst.org/ftgmain.asp>. Accessed 20 September 2006.
37. Kim J, Must A, Fitzmaurice GM *et al.* Relationship of physical fitness to prevalence and incidence of overweight among schoolchildren. *Obes Res* 2005;13:1246–1254.
38. National School Meal Program. US Department of Agriculture. Food and Nutrition Service. <http://www.fns.usda.gov/cnd/governance/notices/iegs/IEGs04-05.pdf>. Accessed 10 July 2006.
39. Assessment of Childhood and Adolescent obesity in Arkansas <http://www.achi.net/current_initiatives/BMI_Info/Docs/2007/Results07/ACHI_2007_BMI_Online_State_Report.pdf>. Accessed March 2009.