Gardening Increases Vegetable Consumption in School-aged Children: A Meta-analytical Synthesis

Gail A. Langellotto[1] and Abha Gupta

ADDITIONAL INDEX WORDS. elementary school, middle school, childhood obesity prevention, SNAP-Ed, nutrition education, school garden, vote-counting, literature review

SUMMARY. Although a handful of published reports suggest that garden-based nutrition education programs are effective in increasing fruit and vegetable consumption, many of these studies have low statistical power because of small sample sizes and lack of long-term data. In this study, we used meta-analytical techniques to examine the efficacy of garden-based nutrition education programs for increasing children's nutrition knowledge, preference for fruit and vegetables, and/or consumption of fruit and vegetables. We confined our analysis to peer-reviewed studies that examined programs that were delivered to children in the United States. We looked at the relative impacts of garden-based nutrition education programs, compared with experimental controls (i.e., no nutrition education) and nutrition education programs without a gardening component. We compared the results of our meta-analysis with those of a vote counting analysis to illustrate the importance of repeated studies and quantitative analysis. In our vote counting analysis, the majority of the outcomes were nonsignificant in the control and nutrition education groups, but positive and significant for the gardening group. Our quantitative analysis of the impacts of gardening education programs on children's nutrition knowledge, preference for fruit and vegetables, and/or consumption of fruit and vegetables was limited by the small number of studies that reported the full suite of descriptive statistics needed to conduct a meta-analysis. Nonetheless, one striking and robust result emerged: gardening increased vegetable consumption in children, whereas the impacts of nutrition education programs were marginal or nonsignificant. We suggest two nonmutually exclusive hypotheses to explain our results: gardening increases access to vegetables and gardening decreases children's reluctance to try new foods. Our results suggest that gardening should be an integral component of wellness programs and policies. A historical lack of funding has impeded both the broader adoption of school gardens and rigorous research on the social, behavioral, and academic impacts of gardening on children. Recently, however, there has been an increase in federal support for gardening and garden-based research projects—a trend that we hope will continue and grow.

Behavioral and dietary lifestyles responsible for weight gain and obesity are often learned at an early age (Cooke, 2007). Children (particularly adolescents) who are overweight are more likely to be overweight or obese during adulthood (Dietz, 1998) and are at risk for a variety of physical and psychosocial complications during their lifetime (Ebbeling et al., 2002). Thus, it is troubling that the prevalence of obesity among children and adolescents in the United States has more than doubled between 1963–65 and 2007–08 (Ogden and Carroll, 2010).

Department of Horticulture, OR State University, 4017 Agriculture and Life Sciences Building, Corvallis, OR 97331

[1]Corresponding author.
E-mail: gail.langellotto@oregonstate.edu.

Although genetics are known to influence an individual's body mass index (BMI), environmental factors are thought to be largely responsible for rising obesity rates (Ebbeling et al., 2002; French and Stables, 2003). Creating environments where children are encouraged to be physically active and to choose nutrient-dense foods (such as fruit and vegetables) is thus often the focus of interventions that aim to promote healthy BMI and reduce the risk of childhood obesity (Stice et al., 2006).

Gardens and other sites of participatory food production are prime sites for such interventions. Gardens, in particular, can be used at a variety of educational sites as "learning laboratories" that may positively influence eating habits and increase physical activity in children. Specifically, children's willingness to taste vegetables (Morris et al., 2001), knowledge of nutrition (Morris et al., 2002), and preference for fruit and vegetables (Hermann et al., 2006; Lineberger and Zajicek, 2000) have been shown to be positively affected by garden-based educational activities. These results highlight the potential importance of garden-based activities to support a comprehensive nutrition education program.

Recently, there has been resurgent interest in educational gardens, prompted in part by high-profile calls for a garden in every school (Pollan, 2008) to foster an "edible education." Although educators may support the use of school gardens to promote healthy eating (Graham and Zidenberg-Cherr, 2005), lack of resources impedes the broader integration of gardens into school activities (Graham et al., 2005).

To effectively promote healthy eating habits via the use of school gardens, it is important to develop a thorough understanding of the efficacy of garden-based nutrition education programs. Although a handful of individual studies suggest that garden-based, experiential education activities are effective vehicles for increasing fruit and vegetable consumption and promoting healthy food choices in young children, many studies suffer from low statistical power because of small sample sizes and lack of long-term data (Robinson-O'Brien et al., 2009). In addition, because there is a practical limit to the number of servings of fruit and vegetables a child can consume per day, researchers studying the impact of school gardens on changes in fruit and vegetable consumption must be able to detect behavioral outcomes that are small in magnitude. Detecting such small changes requires a high degree of statistical power, which is often beyond the capability of a single study.

Meta-analysis offers a solution to the dilemma of low statistical power in individual studies by synthesizing the results of multiple independent studies that test the same hypothesis (Gurevitch and Hedges, 1993). Specifically, meta-analysis increases statistical power and reduces type II errors and is thus especially useful for summarizing experiments with low

sample sizes and/or weak treatment effects (Arnqvist and Wooster, 1995). An additional benefit of meta-analytical techniques is that they can quantify the magnitude of a treatment effect for individual studies included in the analysis, as well as calculate the overall magnitude and significance of the cumulative effect across all studies examined (Rosenberg et al., 2000).

We used meta-analytical techniques to test the hypotheses that, over time, participation in an educational garden program would increase students' knowledge of nutrition, increase students' preference for fruit and vegetables, and increase students' consumption of fruit and vegetables. Specifically, we tested the hypothesis that garden-based nutrition education programs have greater impact on measured outcomes (e.g., nutrition knowledge, fruit and vegetable preference, fruit and vegetable consumption) than traditional nutrition education programs.

To illustrate the importance of repeated studies and statistical power to answer these questions, we also present the results of a vote counting analysis. Vote counting synthesizes the results of multiple studies by counting the number of nonsignificant and significant outcomes for a particular question (i.e., do garden-based nutrition education programs increase vegetable consumption in children?). Together, these methods allowed us to address the relative efficacy of garden-based vs. more traditional nutrition education programs for changing knowledge, attitudes, and behaviors that support healthy weight management.

Materials and methods

LITERATURE REVIEW. We conducted a literature review by systematically searching Google Scholar (Google, Mountain View, CA) for various combinations of the words: intervention, fruit, vegetable, garden, nutrition, consumption, school, and youth. We excluded the significant body of gray literature that exists on these subjects, in the form of reports to funding agencies and working group articles, and concentrated our efforts on peer-reviewed publications. We repeated our search keywords in the PubMed (National Library of Medicine, Bethesda, MD) and Web of Knowledge (Thomson

Reuters, New York) databases, as well as in the *American Society of Horticultural Science* archives. When we found relevant peer-reviewed research studies or reviews (e.g., Delgado-Noguera et al., 2011; French and Stables, 2003; Robinson-O'Brien et al., 2009), we cross-referenced these articles for additional studies.

We confined our search to those studies that worked with children in kindergarten through grade 12, and that were conducted in the United States. To be included in our review, studies had to report at least one of five response variables: nutrition knowledge, preferences for fruit and/or vegetables, and/or consumption of fruit and/or vegetables.

The treatments within these studies were categorized according to the type of nutrition education program that served as the intervention: "control," "nutrition education," or "garden." Children in a "control" group were not exposed to any type of formal nutrition education program. Children in a "nutrition education" group participated in a nutrition education program that did not include a gardening component. Children in a "garden" group participated in a nutrition education program that also included a gardening component.

Given these restrictions, we assembled a data set of 20 studies that reported 66 observations (i.e., outcomes or results) for nutrition knowledge, fruit and vegetable preference, and/or fruit and vegetable consumption (Table 1). Even though we restricted our search to studies that were conducted from kindergarten through 12th grade, we only found studies that were conducted with students in kindergarten through grade eight.

DESCRIPTION OF STUDIES. All of the 20 included studies were quasi-experimental, in which the researchers first recruited an educational site (e.g., school, Boys and Girls Club, community garden, etc.) rather than directly recruiting children from across all possible sites. These types of experimental designs are called "quasi-experimental" because they lack a key element of randomized experiments: the random assignment of subjects to a treatment category. Only after cooperating sites were identified were students recruited to take part in a study.

Although the majority of studies included a control group that did not

participate in a nutrition education and/or gardening program, six studies (Heim et al., 2009; Hermann et al., 2006; Koch et al., 2006; Lineberger and Zajicek, 2000; Poston et al., 2005; Wright and Rowell, 2010) did not include a control.

The majority of the studies with a nutrition education program focused on increasing the consumption of healthy foods and/or decreasing the consumption of unhealthy foods. Increasing physical activity and/or decreasing sedentary activities were also included as an aspect of many of these programs. In the studies that had a garden treatment, gardening activities (e.g., planting, maintaining, harvesting) were integrated into a nutrition education program. Detailed descriptions of each study included in our analyses can be found in Table 1.

VOTE-COUNTING ANALYSIS. For the vote-counting analysis, we scored the significance (either positive or negative) or nonsignificance of each observation of a treatment category (e.g., control, nutrition education, and gardening) on a response variable (e.g., nutrition knowledge, preferences for fruit or vegetables, and consumption of fruit or vegetables). Some studies (e.g., Koch et al., 2006; O'Brien and Shoemaker, 2006) reported the effect of a treatment category on the combined preference for fruit and vegetables and/or combined consumption of fruit and vegetables. We included these as separate response categories from preference or consumption of just fruit or just vegetables.

For this analysis, observations within studies were recorded as significant when the probability value was less than or equal to 0.05, regardless of the type I error rate set by the studies' authors. Specifically, we scored the significance of the difference between pretest and posttest scores. If baseline data were not reported, we noted the significance of the difference between a control and treatment group at the end of a study. In our vote counting analysis, we separately considered changes in response variables between pretest and posttest measures from differences in response variables between an intervention (e.g., nutrition education, gardening) and a control.

A significant positive response (+) was recorded when the value of

Table 1. Characteristics of studies included in our analyses of the impact of nutrition education programs and gardening programs on children's nutrition knowledge, preference for fruit and/or vegetables, and/or consumption of fruit and/or vegetables. Studies are listed alphabetically.

Study[z]	Experimental design	Location	Grade(s) and study site	Curriculum used	Treatment categories included[y]	Response variables measured[x]	Curriculum description
Auld et al., 1999	Quasi-experimental, pre- and posttest with control. Children assigned to treatment category based upon whether they attended an intervention school or matched control school	Colorado	Second to fourth grades, school	Integrated Nutrition Project	C, NE	FC, VC	A total of 16 nutrition lessons, designed to support other classroom disciplines (e.g., science, math), were delivered by specially trained educators and classroom teachers. A total of six lunchroom lessons were delivered by parents. Lessons targeted preparing and eating food, as well as healthy consumption behaviors
Baranowski et al., 2000	Quasi-experimental, pre-, posttest, and follow-up with control A total of 16 schools were recruited for participation and then randomly assigned to treatment category	Southeastern United States.	Third to fifth grades, school	Gimme 5	C, NE	NK, FVP, FVC, FC, VC	Over 2 years, a total of 24 sessions (each lasting between 45 and 55 min) focused on increasing consumption of fruit, juices, and vegetables. Activities included the "Gimme 5 Rap," taste tests in the cafeteria, student goal setting, and newsletters sent home to parents
Davis et al., 2011	Quasi-experimental, pre- and posttest with control. Children assigned to treatment category based upon whether they were participating in the LA Sprouts program	Los Angeles, CA	Fourth to fifth grades, community garden	LA Sprouts	C, G	FC, VC	Each week, a 45-min cooking/nutrition education lesson and a 45-min hands-on gardening lesson were delivered at a community garden. Nutrition lessons focused on culturally relevant vegetables and snacks, eaten family style at a table in the garden. Gardening lessons allowed students to plant, maintain, and harvest fruit and vegetables. Lessons on composting, use of recycled materials and monthly visits to local farmers' market also included. The program ran for 12 weeks, with one lesson delivered each week

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Study[z]	Experimental design	Location	Grade(s) and study site	Curriculum used	Treatment categories included[y]	Response variables measured[x]	Curriculum description
Gortmaker et al., 1999	Quasi-experimental, pre- and posttest with control. Children assigned to treatment category based upon whether they attended an intervention school or matched control school	Baltimore, MD	Fourth to fifth grades, school	Eat Well and Keep Moving	C, NE	FVC	A 2-year program delivered by classroom teachers focused on decreasing consumption of unhealthy foods, increasing fruit and vegetable intake, reducing television viewing, and increasing physical activity
Heim et al., 2009	Quasi-experimental, pre- and posttest with no control	Minnesota	Fourth to sixth grades, Young Men's Christian Association	Delicious and Nutritious Garden	G	FP, VP	Over 12 weeks, children participated in garden-based activities twice per week. Taste tests, snack preparations, and parent newsletters were also included in the program. Garden-based activities included learning about the origins of food, plant parts, nutrient needs of humans and plants, environmental stewardship, MyPyramid for Kids, goal setting, and roleplaying
Hermann et al., 2006	Pre- and posttest within a single school, with no control	Oklahoma	Kindergarten to eighth grades, afterschool	Combination of Junior Master Gardener, Agriculture in the Classroom, USDA Team Nutrition	G	VC	Nutrition education, food preparation, food safety, physical activity, and gardening lessons delivered 1 d each week. Children were grouped according to grade for lessons (kindergarten–second grades, third–fifth grades, sixth–eighth grades). Focus on culturally relevant gardening and nutrition lessons (e.g., Native American crops and foods)
Koch et al., 2006	Quasi-experimental, pre-, mid-, and posttest, with no control. Study sites chosen based upon the Texas Agricultural Extension Service employees who volunteered to participate	Texas	Second to fifth grades, variable settings	Junior Master Gardener	G	FVP, FVC	A total of 12 activities, which focused on six concepts, were taught. The activities addressed issues such as dietary fiber, gardening, plant needs, and eating according to Food Pyramid guidance

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Lineberger and Zajicek, 2000	Quasi-experimental, pre- and posttest with no control	Texas	Third and fifth grades, school	Nutrition in the Garden	G	FP, VP	A total of 10 units, with 34 different activities were delivered to students by classroom teachers. Each activity took ≈20 min to complete, for a total of 680 min of curriculum
McAleese and Rankin, 2007	Quasi-experimental, pre and posttest with control. One control, one nutrition education, and one gardening school	Southeastern Idaho	Sixth grade, school	Nutrition in the Garden	C, NE, G	FC, VC	Children in the nutrition group participated in a 12-week nutrition education program. Children in the gardening group participated in hands-on gardening activities in a garden where a variety of vegetables and fruit were grown. Students made salsa from garden-grown produce, dried herbs, and developed a classroom cookbook inspired by the garden
Morris et al., 2001	Quasi-experimental, pre- and posttest with control. Follow-up survey also conducted	California	Fourth grade, school	Nutrition to Grow On	C, NE, G	NK, VP	A total of nine nutrition lessons were delivered in school. Included education on the Food Pyramid, physical activity, serving sizes, food labels, goal setting, and snack preparation
Morris et al., 2002	Quasi-experimental, pre- and posttest with control. Follow-up survey also conducted	California	Fourth grade, school	Nutrition to Grow On	C, NE, G	NK, VP, VC	A total of nine nutrition lessons were delivered in school. Included education on the Food Pyramid, physical activity, serving sizes, food labels, goal setting, and snack preparation

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O'Brien and Shoemaker, 2006	Quasi-experimental, pre- and posttest with control	Manhattan, KS	Fourth grade, afterschool	Junior Master Gardener	C, G	NK, FP, VP, FVC	Each week, children were served a healthy snack, were taught a gardening lesson, and gardened for 30 min. From mid-March to late May, students in the gardening group received ≈80 min of instruction from all program parts. Lessons touched on seed selection, edible plant parts, using the Food Pyramid, container gardening, and garden maintenance
Parmer et al., 2009	Quasi-experimental, pre- and posttest with control. At a single school, six classes were assigned to one of three groups. Two classes served as a control, two classes participated in Pyramid Café nutrition education lessons, and two classes participated in both Pyramid Café and Junior Master Gardener lessons	Alabama	Second grade, school	Pyramid Café	C, NE	NK, FP, VP, VC	Every other week, children received 1 h of nutrition lessons. Content of lessons not described in study, and curriculum currently out of print. However, lessons appear to focus on eating a balanced diet from across the food groups. The total length of time of the intervention was not given
				Pyramid Café and Junior Master Gardener	C, G	NK, FP, VP, VC	On alternating weeks, children received 1 h of gardening lessons and 1 h of nutrition lessons. Hands-on gardening activities included planting a variety of vegetable seeds. Students maintained garden and prepared a party confetti salad from garden-grown vegetables. The total length of time of the intervention was not given

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Perry et al., 1998	Randomized, controlled trial, pre- and posttest with control	St. Paul, MN	Fourth to fifth grades, school	5-a-Day Power Plus Program	C, NE	FC, VC	Nutrition education program included teacher-implemented classroom lessons and parent-led home activities. Food service staff increased variety and attractiveness of fruit and vegetables on the serving line and placed promotional signs in the cafeteria
Perry et al., 2004	Randomized, controlled trial, pre- and posttest with control. A total of 26 schools participated, 13 of which were delayed phase controls. Schools were randomly assigned to nutrition education or control group	St. Paul, MN	Fourth to fifth grades, school	Cafeteria Power Plus	C, NE	FC, VC	Interventions took place over 2 years and included daily activities and special events. Each school day, food service staff focused on the variety and appeal of fruits and vegetables in the lunch line and verbally encouraged students to eat more fruit and vegetables. Special events included a kick-off social marketing campaign, a midyear competition to see which class could eat the most fruit and vegetables at lunch, and a final event that demonstrated different meal and snack options that could be made with table grapes (*Vitis* sp.)

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Poston et al., 2005	Quasi-experimental, pre- and posttest with no control	Kansas	Third to fifth grades,	Professor Popcorn	NE	NK, VP	A total of five lessons, which range in length from 30 to 60 min. Lessons focused on teaching healthy eating, according to Food Pyramid guidance. Recipes, food safety, and physical activity also included in each lesson
			Boys and Girls Club	Junior Master Gardener			A total of eight lessons, ranging in length from 20 to 60 min. Lesson objectives included gardening, nutrition, botanical concepts
Ratcliffe et al., 2011	Quasi-experimental, pre- and posttest with control	San Francisco, CA	Sixth grade, school	Delicious and Nutritious Garden	G	NK, VP, VC	Over 13 weeks, students received 20 min of instruction on a science-based gardening concept, followed by 40 min of hands-on gardening experience. Students planted, maintained, and harvested vegetables and seeds. Composting and bed preparation also included in lessons. Students ate raw vegetables in the garden and harvested and prepared garden-grown vegetables in ethnically diverse meals. Garden-grown salad greens were served to the entire school. Parents, administrators, and teachers were invited to participate in garden work parties

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Reynolds et al., 2000	Quasi-experimental, pre- and posttest with control	Alabama	Fourth grade, school	High 5	NE	FC, VC	A 14-lesson curriculum was delivered by specially trained coordinators to teach the lessons and coordinate food service/parent activities. Lessons were 30–45 min in length and featured fruit/vegetable themed characters and cheers. Between lessons, High 5 d were observed, where children were challenged to eat 5 servings of fruit and vegetables and record what they ate. Parents and food service workers were encouraged to support greater fruit and vegetable consumption in students
SiegaRiz et al., 2011	Quasi-experimental, pre- and posttest with control. Study conducted across 42 public middle schools, half of which received the HEALTHY program and half of which were controls	Houston, TX; Portland, OR; Irvine, CA; Philadelphia, PA; Chapel Hill, NC; Pittsburgh, PA; San Antonio, TX	Sixth to eighth grades, school	HEALTHY	C, NE	FC, VC	The HEALTHY program targeted changes in the school food environment, via changes in what was served in the cafeteria, vending machines, and during in school parties. Targeted messages aimed to promote healthy eating away from school

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Study[z]	Experimental design	Location	Grade(s) and study site	Curriculum used	Treatment categories included[y]	Response variables measured[x]	Curriculum description
Wright and Rowell, 2010	Quasi-experimental, pre- and posttest with no control	Green Bay, WI	Kindergarten to fifth grades, school	Gardens Reaching Our World (GROW)	G	VC	A child-friendly salad bar (lower height) was installed in the school cafeteria. Students received two 30-min nutrition lessons, focused on the importance of eating fruit and vegetables, and salad bar etiquette. Salad bar pep rally kicked off program. Indoor gardening lessons (delivered over 73 d) connected the students' salad bar experiences with the concept of growing their own food

[z]Studies were found by searching three databases for the keywords: intervention, fruit, vegetable, garden, nutrition, consumption, school, and youth. We confined our search to studies performed in the United States, and with a target age group of kindergarten through grade 12. Data from these studies were used in a vote counting analysis, meta-analysis, or both.

[y]C = control, NE = nutrition education, G = gardening.

[x]NK = nutrition knowledge, FP = fruit preference, VP = vegetable preference, FVP = fruit and vegetable preference, FC = fruit consumption, VC = vegetable consumption, FVC = fruit and vegetable consumption.

the posttest was significantly greater than the pre-test value or when the value of the treatment group was significantly greater than the control. A significant negative response ($-$) was recorded when the posttest value was significantly less than the pretest value or when the value of the treatment group was significantly less than the control. Nonsignificant differences (Ø) were also noted. In one case (Baranowski et al., 2000), we qualitatively assessed the significance by examining reported least squared means and graphical data. In another case (Siega-Riz et al., 2011), we conducted a post hoc analysis of the reported data to determine the significance of the difference between pre- and posttest values, for both the control and the nutrition education treatment.

We counted up the total number of significant positive, negative, and null responses among studies that reported pre- and posttest data, as well as studies that reported differences between control groups and interventions. This allowed us to qualitatively analyze the relative effect of no education, nutrition education, and garden-based education on children's nutrition knowledge, preferences for fruit and/or vegetables, and consumption of fruit and/or vegetables.

Meta-analysis. We used meta-analytical techniques to quantitatively examine the changes in children's nutrition knowledge, preference for fruit and vegetables, and consumption of fruit and vegetables as a function of whether they participated in a nutrition education program or gardening program.

Meta-analytical techniques combine the results of multiple, individual studies to estimate the overall magnitude of the outcome across all studies. This overall outcome is known as an effect size. To calculate the effect size for an individual study, the mean, variance estimate, and sample size are required (Rosenberg et al., 2000). Thus, although we started with 20 studies and 66 observations in the vote counting analysis and when we removed those studies that did not report descriptive statistics, did not report pre- and posttest data (or the magnitude of the change between pre- and posttests), or whose data were not on a scale that was comparable to the other observations in our data set, we

Table 2. Effect size (Hedge's g) and variance for studies included in our meta-analysis of the effects of nutrition education and gardening programs on children's nutrition knowledge, preference for fruits or vegetables, and/or consumption of fruits or vegetables. These data were used to calculate the cumulative effect size (E^{++}) and associated statistics reported in the manuscript.

Study	Treatment category	Outcome variable	Hedge's g[z]	Variance[y]
Auld et al. (1999)	Control	Fruit consumption	−0.256	0.006
	Nutrition education	Fruit consumption	−0.141	0.006
	Control	Vegetable consumption	−0.126	0.006
	Nutrition education	Vegetable consumption	0.038	0.006
	Control	Fruit consumption	0.014	0.029
Davis et al. (2011)	Gardening	Fruit consumption	0.023	0.059
	Control	Vegetable consumption	−0.066	0.029
	Gardening	Vegetable consumption	0.000	0.025
Heim et al. (2009)	Gardening	Fruit preference	−0.008	0.022
	Gardening	Vegetable preference	0.033	0.022
Lineberger and Zajicek (2000)	Gardening	Vegetable preference	0.016	0.018
	Gardening	Fruit preference	0.005	0.018
	Control	Fruit consumption	−0.028	0.080
McAleese and Rankin (2007)	Nutrition Education	Fruit consumption	0.056	0.080
	Gardening	Fruit consumption	0.115	0.045
	Control	Vegetable consumption	−0.082	0.080
	Nutrition Education	Vegetable consumption	−0.0181	0.080
	Gardening	Vegetable consumption	0.122	0.045
O'Brien and Shoemaker (2006)	Control	Nutrition knowledge	1.018	0.108
	Gardening	Nutrition knowledge	−1.189	0.140
	Control	Fruit preference	0	0.095
	Gardening	Fruit preference	−0.361	0.120
	Control	Vegetable preference	0.248	0.096
	Gardening	Vegetable preference	0.327	0.119
Parmer et al. (2009)	Control	Nutrition knowledge	0.274	0.052
	Nutrition education	Nutrition knowledge	0.170	0.054
	Gardening	Nutrition knowledge	0.201	0.052
	Control	Fruit preference	−0.0104	0.051
	Nutrition education	Fruit preference	0.016	0.054
	Gardening	Fruit preference	0.005	0.051
	Control	Vegetable preference	−0.037	0.051
	Nutrition education	Vegetable preference	−0.016	0.054
	Gardening	Vegetable preference	−0.016	0.051
	Control	Vegetable consumption	−0.106	0.051
	Nutrition education	Vegetable consumption	0	0.054
	Gardening	Vegetable consumption	3.75	0.144
Ratcliffe et al. (2011)	Control	Nutrition knowledge	−0.025	0.032
	Gardening	Nutrition knowledge	0.429	0.021
	Control	Vegetable preference	−0.050	0.020
	Gardening	Vegetable preference	0.214	0.015
	Control	Vegetable consumption	−0.176	0.032
	Gardening	Vegetable consumption	0.238	0.020
	Control	Fruit consumption	−0.007	0.001
Siega-Riz et al. (2011)	Nutrition education	Fruit consumption	−0.003	0.001
	Control	Vegetable consumption	−0.006	0.001
	Nutrition education	Vegetable consumption	−0.004	0.001

[z]Hedge's g was calculated as the standardized difference between the pretest and posttest value of an outcome variable: $gi = \frac{(\overline{X}E - \overline{X}C)}{SD}$, where $\overline{X}E$ is the posttest mean, $\overline{X}C$ is the control mean, and SD is the pooled standard deviation.

[y]Variances (v_g) for each Hedge's g were separately computed for each comparison: $v_g = \frac{N^C + N^E}{N^C N^E} + \frac{g^2}{2(N^C + N^E - 2)}$, where N^C and N^E are the sample sizes of the pre- and posttest groups.

were left with only 9 studies and 46 observations (Table 2).

DATA EXTRACTION AND CALCULATION OF HEDGE'S g For each treatment category (e.g., control, nutrition education, and gardening) and each response variable (e.g., nutrition knowledge, preferences for fruit or vegetables, consumption of fruit or vegetables), means, standard deviations, and sample sizes were obtained directly from the text or tables. In cases where only the standard error was reported, the standard deviation was calculated by multiplying the standard error by $\sqrt{n}$.

As necessary, data were transformed so that all observations for a given response variable were on a common scale. For example, data for nutrition knowledge was scaled from 0 to 5.

Data for fruit and vegetable preferences was also scaled from 0 to 5. In one study (Siega-Riez et al., 2011), fruit and vegetable consumption was presented in grams, rather than servings. We used the transformations presented by Morgan et al. (2010) (one serving of vegetables = 75 g, one serving of fruit = 150 g) to convert this data from grams to servings. These scales were chosen because they required the least number of data transformations (i.e., several data sets were already reported on these scales). If data could not be transformed to a common scale, it was excluded from the meta-analysis.

For each observation included in the meta-analysis, an individual effect size (g_i) of a treatment on a response variable was estimated as the standardized mean difference between the pretest and posttest mean:

$$g_i = \frac{(\overline{X}_E - \overline{X}_C)}{SD},$$

where $\overline{X}_E$ is the posttest mean, $\overline{X}_C$ is the control mean, and SD is the pooled standard deviation. This effect size metric, known as Hedge's g (Hedges and Olkin, 1985), was calculated using MetaWin© statistical software version 2.0 (Rosenberg et al., 2000). Variances (v_g) for each Hedge's g were separately computed for each comparison:

$$v_g = \frac{N^C + N^E}{N^C N^E} + \frac{g^2}{2(N^C + N^E - 2)},$$

where N^C and N^E are the sample sizes of the pre- and posttest groups.

CALCULATING CUMULATIVE EFFECT SIZES AND CONFIDENCE INTERVALS. To establish the effect of control, nutrition education, and gardening treatments on our response variables, we calculated cumulative effect sizes and confidence intervals (CI) (Gurevitch and Hedges, 1993; Rosenberg et al., 2000). Once again, all calculations and statistical tests were conducted using the MetaWin© software program (Rosenberg et al., 2000).

The cumulative effect size (E^{++}) (Hedges and Olkin, 1985; Rosenberg et al., 2000) was calculated as:

$$E^{++} = \frac{\sum_{i=1}^{n} w_i g_i}{\sum_{i=1}^{n} w_i},$$

where g_i is the effect size for the ith study, and w_i is the weight (reciprocal of the sampling variance) for the ith study. A positive value of E^{++} suggests that the treatment had a positive effect on a given response variable, whereas a negative value of E^{++} indicates that the treatment had a negative effect on a response variable.

Bias-corrected bootstrapped 95% CI were calculated for each E^{++} from resampling tests generated from 999 iterations (Adams et al., 1997; Rosenberg et al., 2000). When the CI did not bracket zero, E^{++} was considered to be significantly different from zero (Rosenberg et al., 2000).

FAIL-SAFE NUMBERS. As with most reviews, it was difficult to ensure that the sample of studies used in the analysis was representative of all studies that have been conducted. Because studies that yield significant results may be more likely to be published than those with null results, it is important to factor in the "file drawer problem" of unpublished studies (Arnqvist and Wooster, 1995). One of the strengths of meta-analysis is that it offers quantitative methods to assess the magnitude of bias against studies showing a nonsignificant effect.

To address the issue of publication bias, we generated a fail-safe number for each E^{++} (Rosenthal, 1979) using the MetaWin© software program (Rosenberg et al., 2000). A fail-safe number represents the number of nonsignificant studies needed in an analysis to change a significant result into a nonsignificant one. Higher the fail-safe numbers confer greater credibility to a significant result.

Results

VOTE COUNTING. For pre- vs. posttest comparisons, qualitative analysis of the vote counting results revealed that the majority of the outcomes (26 out of 39) were nonsignificant (Table 3). This pattern held true for the control and nutrition education groups, but not for the gardening group. In fact, the gardening group exhibited the most significant outcomes (8), with increases reported in nutrition knowledge, preference for vegetables, fruit consumption, vegetable consumption, and the combined measure of fruit and vegetable consumption.

When comparing the control group to the nutrition education group or the control group to the garden group, a total of 12 out of 27 of the outcomes were nonsignificant (Table 4). In the remaining 15 observations, the measured response variable was always higher in the nutrition education or gardening group, relative to the control group.

Although the gardening group showed more positive significant responses (for pre- and posttest comparisons, as well as compared with the control group) compared

Table 3. Number of observations with significant or nonsignificant outcomes in our vote counting analysis of pre-vs. posttest comparisons, across seven response variables and three treatment groups.

| | Treatment group | | | | | | | | |
| | Control[z] | | | Nutrition education[y] | | | Gardening[x] | | |
Response variable	+[w]	−[v]	Ø[u]	+	−	Ø	+	−	Ø
Nutrition knowledge	0	0	2	1	0	1	2	0	2
Fruit preference	0	0	2	0	0	1	0	0	3
Vegetable preference	0	0	2	0	0	2	2	0	2
Combined fruit and vegetable preference	0	0	0	0	0	0	0	0	1
Fruit consumption	0	1	1	0	0	2	1	0	0
Vegetable consumption	0	2	1	0	0	3	2	0	0
Combined fruit and vegetable consumption	0	0	1	0	0	0	1	1	0
Total	0	3	9	1	0	9	8	1	8

[z]Children in a control group did not participate in a formal nutrition education or gardening program.
[y]Children in a nutrition education group participated in a nutrition education program that did not include a gardening component.
[x]Children in a gardening group participated in a nutrition education program that also included a gardening component.
[w]Positive outcomes (+) indicate that posttest values were significantly greater than pretest values, at a probability value of less than or equal to 0.05.
[v]Negative outcomes (−) indicate that posttest values were significantly less than pretest values, at a probability value of less than or equal to 0.05.
[u]Null outcomes (Ø) indicate no significant difference between pretest and posttest values, at a probability value of less than or equal to 0.05.

with the other groups, the large number of nonsignificant outcomes across all treatment groups made it difficult to interpret this data with confidence.

META-ANALYSIS. Participation in a nutrition education program resulted in a significant increase in nutrition knowledge [E^{++} = 0.15, CI = 0.05 to 0.22, df = 1, fail-safe number = 0 (Fig. 1)]. The control group also had a significant increase in nutrition knowledge [E^{++} = 0.23, CI = 0.04 to 1.02, df = 2, fail-safe number = 3.4 (Fig. 1)]. However, the gardening treatment experienced no significant increase in nutrition knowledge [E^{++} = 0.21, CI = −1.19 to 0.43, df = 2 (Fig. 1)].

The control treatment exhibited no significant changes in preferences for fruit [E^{++} = −0.01, CI = −0.01 to 0.00, df = 1 (Fig. 2A)] or vegetables [E^{++} = −0.01, CI = −0.05 to 0.11, df = 2 (Fig. 2B)]. Although the gardening treatment had no significant effect on preferences for fruit [E^{++} = −0.02, CI = −0.20 to 0.01, df = 3 (Fig. 2A)], it did have a significant effect on vegetable preference [E^{++} = 0.10, CI = 0.01 to 0.19, df = 1, fail-safe number = 0 (Fig. 2B)]. We did not have enough observations to quantify changes in vegetable preference or changes in fruit preference for the nutrition education treatment.

There was no significant impact of the control condition on changes in fruit consumption [E_{++} = −0.04, CI = −0.24 to 0.003, df = 3 (Fig. 3A)]. Unexpectedly, there was a marginally significant, negative effect of the nutrition education treatment on changes in fruit consumption [E_{++} = −0.02, CI = −0.14 to −0.002, df = 2, fail-safe number = 0 (Fig. 3A)]. The garden treatment resulted in a small, but significant increase in fruit consumption [E^{++} = 0.08, CI = 0.02 to 0.12, df = 1, fail-safe number = 0 (Fig. 3A)].

Neither the control condition [E^{++} = −0.03, CI = −0.14 to −0.01, df = 5, fail-safe number = 0 (Fig. 3B)] nor the nutrition education treatment [E^{++} = −0.002, CI = −0.0073 to 0.04, df = 2, fail-safe number = 0; (Fig. 3B)] had a significant effect on vegetable consumption. However, students participating in a garden-based program significantly increased their vegetable consumption [E^{++} = 0.42, CI = 0.07 to 2.07, df = 3, fail-safe number = 50.5 (Fig. 3B)].

Table 4. Number of observations with significant or nonsignificant outcomes in our vote counting analysis of posttest comparisons between control and nutrition education treatments, and control vs. gardening treatments, across seven response variables.

	Comparison					
	Control[z] vs. nutrition education[y]			Control vs. gardening[x]		
Response variable	+[w]	−[v]	Ø[u]	+	−	Ø
Nutrition knowledge	1	0	2	3	0	0
Fruit preference	0	0	1	0	0	0
Vegetable preference	1	0	1	2	0	0
Combined fruit and vegetable preference	0	0	1	0	0	0
Fruit consumption	3	0		0	0	1
Vegetable consumption	0	0	5	3	0	1
Combined fruit and vegetable consumption	2	0	0	0	0	0
Total	7	0	10	8	0	2

[z]Children in a control group did not participate in a formal nutrition education or gardening program.
[y]Children in a nutrition education group participated in a nutrition education program that did not include a gardening component.
[x]Children in a garden group participated in a nutrition education program that also included a gardening component.
[w]Positive outcomes (+) indicate that the nutrition education or gardening group was significantly greater than the control.
[v]Negative outcomes (−) indicate that the nutrition education or gardening group was significantly less than the control.
[u]Null outcomes (Ø) indicate no significant difference between the nutrition education or gardening group and the control.
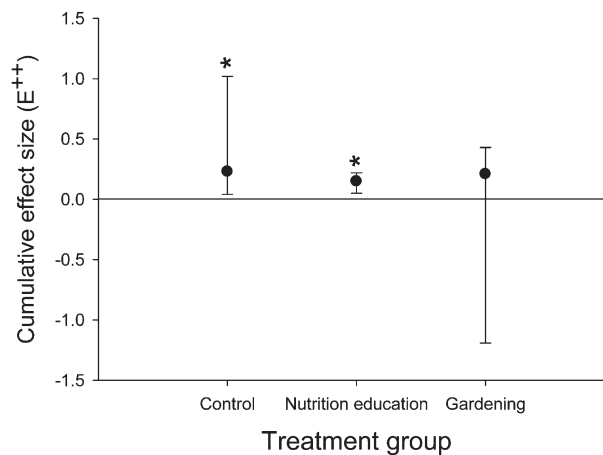

Fig. 1. Impact of control, nutrition education, and gardening treatments on changes in nutrition knowledge. Plotted points are the cumulative effect size (E^{++}), and bars represent upper and lower bias-corrected bootstrapped 95% confidence intervals (CIs). E^{++} was calculated as: $E^{++} = \sum_{i=1}^{n} w_i g_i / \sum_{i=1}^{n} w_i$, where g_i is the effect size for the ith study, and w_i is the weight (reciprocal of the sampling variance) for the ith study. CIs were calculated for each E^{++} from resampling tests generated from 999 iterations. When a CI intersects the zero line, the impact of a treatment is nonsignificant. Significant outcomes are marked with an asterisk (*).

Discussion

The vote counting analysis suggested that participation in a nutrition education program leads to an increase in nutrition knowledge. However, positive attitudinal (e.g., increased preference for fruit or vegetables) and behavioral changes (e.g., increased fruit or vegetable consumption) were primarily documented in the gardening programs.

Our meta-analysis documented some interesting outcomes. However, small sample sizes (ranging from two to six observations per analysis) at times limited our ability to draw inferences from the data. Specifically, where significant outcomes were found, they were often small in magnitude and vulnerable to charges of publication bias. For example, although we documented changes in nutrition knowledge within the
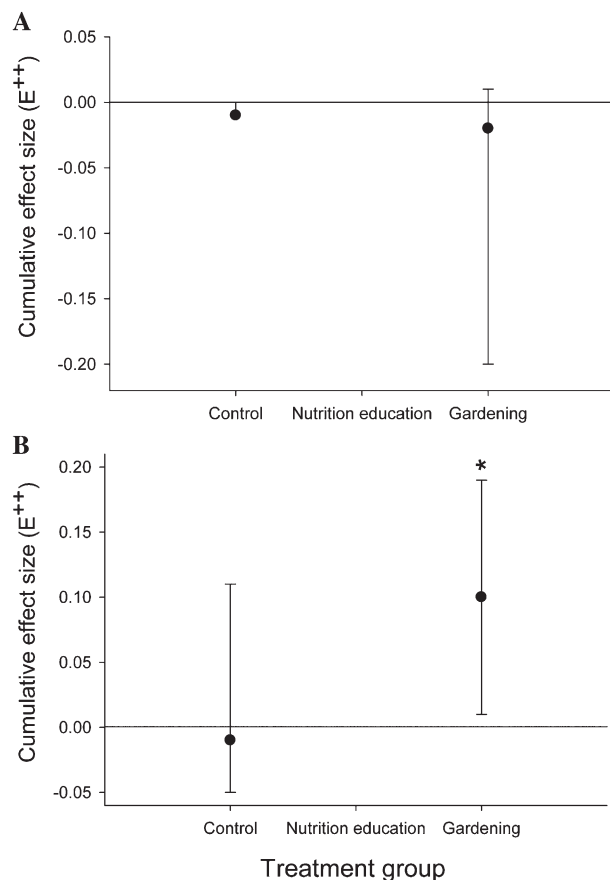
Fig. 2. Impact of control and gardening treatments on changes in preferences for (A) fruit and (B) vegetables. Sample size limitations precluded an analysis of the impact of the nutrition education treatment on preferences for fruit or vegetables. Plotted points are the cumulative effect size (E^{++}), and bars represent upper and lower bias-corrected bootstrapped 95% confidence intervals (CIs). E^{++} was calculated as: $E^{++} = \sum_{i=1}^{n} w_i g_i / \sum_{i=1}^{n} w_i$, where g_i is the effect size for the ith study, and w_i is the weight (reciprocal of the sampling variance) for the ith study. CIs were calculated for each E_{++} from resampling tests generated from 999 iterations. When a CI intersects the zero line, the impact of a treatment is nonsignificant. Significant outcomes are marked with an asterisk (*).

nutrition education treatment, the small effect size ($E^{++} = 0.15$) and small fail-safe number (0) suggests that this result should be interpreted with a degree of skepticism. We also documented a significant change in nutrition knowledge in the control group. The effect size for this pre- vs. posttest comparison was higher in magnitude ($E^{++} = 0.23$) and of greater credibility (fail-safe number = 3.4) compared to the result for the nutrition education group. Together, these results suggest that our meta-analysis of changes in nutrition knowledge may have been influenced by publication bias toward studies that report significant results and/or developmental changes in children's nutrition knowledge, over time.

Similarly, the small effect sizes and low fail-safe numbers associated with the impact of gardening on

preferences for vegetables [$E^{++} = 0.10$, fail-safe number = 0 (Fig. 2B)] and consumption of fruit [$E^{++} = 0.08$, fail-safe number = 0 (Fig. 3A)] suggest that these results should also be interpreted with caution. More data are needed to confidently assert that gardening programs increase preferences for vegetables and/or consumption of fruit.

To promote improved and more robust meta-analyses in the future, we encourage school garden researchers to report means, sample sizes, and measures of variance. In addition, we encourage researchers to report results using the common currency of servings of fruit and servings of vegetables. One especially well-designed and executed study (Gortmaker et al., 1999) reported a combined measure of servings of fruit and vegetables.

However, since it was the only study to report servings of fruit and vegetables, combined, we excluded it from our analysis since the data were not comparable to the larger data set.

In several regards, the result of the gardening treatment on vegetable consumption is the most robust result to come out of this meta-analysis. First, the effect size associated with the effect of gardening programs on vegetable consumption ($E^{++} = 0.42$) can be classified as a moderate effect (Cohen, 1962). In addition, the large fail-safe number (50.5) suggests that more than 50 additional, nonsignificant studies would have to be added to this data set to change the impact of gardening on vegetable consumption from significant to nonsignificant. By comparison, there were no significant, positive changes in fruit or vegetable consumption for the nutrition education treatment. Because participation in a garden-based educational program increases consumption of vegetables, public health and nutrition education programs would benefit from including gardening as a featured component of wellness programs and policies.

Although most of the studies did not detail what they grew in their gardens, it is reasonable to assume that the focus was on growing vegetables, rather than on fruit (in this context, we are referring to culinary fruit and not botanical fruit). Thus, it is not surprising that the most robust result of this study was the increase in vegetable consumption in children participating in a gardening program. This group's increase in fruit consumption, by comparison, was smaller.

We suggest two nonmutually exclusive hypotheses that might explain why gardening might promote greater vegetable consumption in children. First, gardening provides children with increased access to vegetables, and this increased access may result in greater consumption. Second, gardening can decrease a child's hesitance to try new foods by exposing children to a broad array of garden-grown vegetables. A study conducted by Birch et al. (1987) found that it takes between 10 and 15 exposures to a new food before a child will accept this new food into their diet. Of these 10–15 exposures, at least one has to be a taste. However, seeing, touching, planting, growing, and harvesting food are powerful and positive ways to expose children to vegetables or
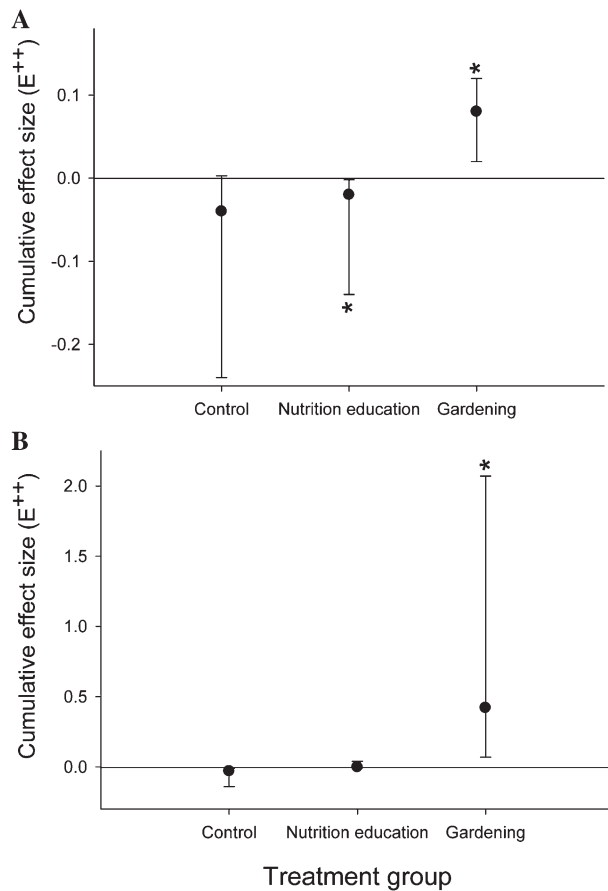
Fig. 3. Impact of control, nutrition education, and gardening treatments on changes in consumption of (A) fruit and (B) vegetables. Plotted points are the cumulative effect size (E^{++}), and bars represent upper and lower bias-corrected bootstrapped 95% confidence intervals (CIs). E^{++} was calculated as: $E^{++} = \sum_{i=1}^{n} w_i g_i / \sum_{i=1}^{n} w_i$, where g_i is the effect size for the ith study, and w_i is the weight (reciprocal of the sampling variance) for the ith study. CIs were calculated for each E_{++} from resampling tests generated from 999 iterations. When a CI intersects the zero line, the impact of a treatment is nonsignificant. Significant outcomes are marked with an asterisk (*).

fruit that they may not have had much experience with in the past. Coupled with the greater access to garden-grown vegetables, the mere act of gardening has the potential to both encourage and provide for vegetable consumption.

Based upon the results of this meta-analysis, where we found that gardening has a greater impact on vegetable consumption than other nutrition education programs, we advocate for greater funding for rigorous research of the social, behavioral, and academic impacts of school gardens on children. Garden programs have a history of being chronically underfunded (Graham et al., 2005; Phibbs and Relf, 2005). This lack of funding has impeded both the broader adoption of school gardens and research on the potential social, behavioral, and academic impacts of gardening on children (Phibbs and

Relf, 2005). Relatively few school garden studies have been supported by national grants. This makes it difficult to recruit, study, and track participants in a rigorous experimental study.

Another challenge to nutrition educators and school garden advocates has been working within the guidance of the Supplemental Nutrition Assistance Program Education (SNAP-Ed) program. SNAP-Ed is arguably the most ubiquitous program focused on obesity prevention, with a goal to increase the likelihood that low-income individuals, families, and children "will make healthy food choices within a limited budget" [U.S. Department of Agriculture (USDA), 2011]. However, current and historical guidance disallows the use of SNAP-Ed funds to pay for the basic tools and supplies needed to start or maintain a garden (USDA,

2011). Thankfully, the guidance for 2013 has been revised to allow for "the purchase of seeds, plants, and small gardening tools and supplies to assist in developing school and community gardening projects" (USDA, 2012).

In addition to the upcoming changes in SNAP-Ed guidance, other positive signs for the school garden movement include the relatively recent funding of the Delta Garden Study and the People's Garden Project. We hope that national support for garden-based educational programs and research will continue and grow, and suggest that researchers refer to the work of Phibbs and Relf (2005) for a list of common problems encountered in garden-based research projects, as well as suggestions for improving research on youth garden projects.

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