JOURNAL OF SCHOOL HEALTH

RESEARCH ARTICLE

School Gardens Enhance Academic Performance and Dietary Outcomes in Children

CLAIRE K. BEREZOWITZ, EdM[a] ANDREA B. BONTRAGER YODER, MM, PhD[b] DALE A. SCHOELLER, PhD[c]

ABSTRACT

BACKGROUND: Schools face increasing demands to provide education on healthy living and improve core academic performance. Although these appear to be competing concerns, they may interact beneficially. This article focuses on school garden programs and their effects on students' academic and dietary outcomes.

METHODS: Database searches in CABI, Web of Science, Web of Knowledge, PubMed, Education Full Text, Education Resources Information Center (ERIC), and PsychINFO were conducted through May 2013 for peer-reviewed literature related to school-day garden interventions with measures of dietary and/or academic outcomes.

RESULTS: Among 12 identified garden studies with dietary measures, all showed increases/improvements in predictors of fruit and vegetable (FV) consumption. Seven of these also included self-reported FV intake with 5 showing an increase and 2 showing no change. Four additional interventions that included a garden component measured academic outcomes; of these, 2 showed improvements in science achievement and 1 measured and showed improvements in math scores.

CONCLUSIONS: This small set of studies offers evidence that garden-based learning does not negatively impact academic performance or FV consumption and may favorably impact both. Additional studies with more robust experimental designs and outcome measures are necessary to understand the effects of experiential garden-based learning on children's academic and dietary outcomes.

Keywords: nutrition and diet; curriculum; child and adolescent health; school health.

Citation: Berezowitz CK, Bontrager Yoder AB, Schoeller DA. School gardens enhance academic performance and dietary outcomes in children. J Sch Health. 2015; 85: 508-518.

Received on January 22, 2014
Accepted on January 14, 2015

Among the issues facing public education are 2 competing trends. First, there is increasing emphasis in schools and districts across the country on academic performance as a measure of student outcomes, largely to align with federal and state legislation such as *No Child Left Behind* and *Race to the Top*.[1] Second, there is increasing emphasis on public health interventions in schools to improve children's health, including those to combat the problems of low fitness and excess obesity. Both have gained momentum, the former as a result of national performance initiatives and the latter as a result of data showing a decline in US children's nutritional status, with nearly one third now classified as overweight or obese.[2] Despite possible linkages between obesity and academic performance, proponents of both often appear to be in opposition: both compete for limited time and funding. Thus, this article aims to summarize existing knowledge of possible synergies between dietary and academic outcomes resulting from school-based interventions aimed at improving student health.

[a]Research Assistant, (cberezowitz@wisc.edu), Department of Nutritional Sciences and Department of Educational Psychology, University of Wisconsin-Madison, 1415 Linden Drive, Madison, WI 53706.

[b]Research Assistant, (abontrageryoder@gmail.com), Department of Nutritional Sciences, University of Wisconsin-Madison, 1415 Linden Drive, Madison, WI 53706.

[c]Professor Emeritus, (dschoell@wisc.edu), Department of Nutritional Sciences, University of Wisconsin-Madison, 1415 Linden Drive, Madison, WI 53706.

Address correspondence to: Claire K. Berezowitz, Research Assistant, (cberezowitz@wisc.edu), Department of Nutritional Sciences and Department of Educational Psychology, University of Wisconsin-Madison, 1415 Linden Drive, Madison, WI 53706.

This publication was supported by the Centers for Disease Control and Prevention's Community Transformation Grant (CTG) Program, which is made available through the Prevention and Public Health Fund of the Affordable Care Act (Board of Regents of the University of Wisconsin System: Grant Number 3597; PI: Sarah Van Orman, MD, MMM). The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the University of Wisconsin-Madison, the US Department of Health and Human Services or the Centers for Disease Control and Prevention.

Obesity is a public concern because obese children are more likely to be obese throughout their adult years, and are more likely than healthy-weight children to begin experiencing weight-related health complications at an earlier age.[3] Beyond the health risks, however, are negative associations of obesity with academic performance, suggesting that programs to address obesity may also address some issues related to academic performance. Cross-sectional data show that obese children have lower grades and standardized test scores, as well as more behavioral problems than their healthy-weight peers.[4-7] In one study, overweight seventh to ninth graders had a mean GPA that was 0.2 lower than healthy-body mass index (BMI) children and were twice as likely to have grades of less than 2.0 on a 4.0 scale.[8] Because obesity is linked to academic outcomes, it should be important to balance school-based programs that maximize both health and academic outcomes.

There is strong rationale for these associations between health and academic performance. Health may impact several pro-academic behaviors, such as school attendance and time spent on homework.[9] In addition, obesity can negatively impact social interactions, and this, in turn, has been associated with lower academic performance.[10] Previous reviews have examined school-based nutrition interventions, but have focused on school breakfast, noting mostly positive effects on outcomes supporting academic success.[9,11] Furthermore, reviews demonstrate that school nutrition programs effectively reduce hunger.[12-14] Therefore, studies relating to school meal implementation are not included in this article.

The history of nutrition-related public health programs in US schools is strongly tied to school meal programs. An estimated 52 million children aged 5-17 years spend significant time at school.[15,16] The National School Lunch Program (NSLP), first legislated in 1946, aimed to reduce nutritional deficiencies and "to encourage the domestic consumption of nutrition agricultural commodities and other food."[3] Later, the School Breakfast Program (SBP) was authorized in 1975 with the goal of providing "adequate nutrition," targeting those with high risk for a nutritional deficiency, such as children from low-income families.[3,17] Today, an average of 31 million children participate in the NSLP and about 10 million in the SBP each day.[3] NSLP participants consume an average of 35% of their daily energy at school; children participating in both meal programs may consume as much as half.[18] More recent school nutrition efforts include the national farm-to-school movement to bring more local fruits and vegetables (FV) into school cafeterias and classrooms. Thus, it would seem that school nutrition programs have considerable opportunity to positively influence student health.

In recent years, schools have begun exploring new opportunities to educate students on healthy dietary habits in addition to providing school meals. Health education has been part of school curricula for decades, and although a set of national standards published by the Centers for Disease Control and Prevention (CDC) exists,[19] we are not able to locate documentation of their use in schools. One such educational opportunity arises from the provision of school gardens, which has spread across the United States, supported by nonprofit organizations, grassroots organizing, and even federal funding.[20,21] Gardens have a history that began decades ago as a means of science instruction.[21,22] Today, gardens are also promoted as a means for children to increase exposure to FV, and thereby improve attitudes and preferences related to FV consumption. Loosely rooted in social cognitive theory, the premise is that exposure, attitudes, and preferences mediate FV consumption; moreover, the CDC promotes increased FV consumption as a strategy for reducing obesity prevalence.[23,24]

A few reviews published to date have focused on the unique effects of school-based interventions aimed at improving diet quality, with or without garden education, on student academic outcomes. Fewer still have focused exclusively on longitudinal, school-based interventions. This is understandable given the significant burden of time to undertake such interventions and evaluations. While the long-standing school programs are based on nutrition principles related to health, it continues to be challenging for schools to reconcile increasing academic accountability with public health programming. Concurrent with the increased emphasis on standardized test performance, programs involving school meals, nutrition education (NE), and school gardens have arisen to creatively address health concerns. If evidence exists that academic performance can be maintained or improved while implementing health-focused programs, they can be justified.

This article aims to collate findings with respect to school garden interventions that include measures of academic performance and/or FV consumption. To dissect these issues, this article is organized around 2 guiding questions: (1) Do interventions with school gardens change dietary outcomes or their predictors? (2) Do interventions with school gardens impact academic outcomes?

METHODS

Database searches for peer-reviewed publications were conducted in CABI, Web of Science, Web of Knowledge, PubMed, Education Full Text, ERIC, and PsychINFO as of May 2013. Keywords included various combinations of schools, academic performance/achievement, school performance, standardized test scores, cognitive function, nutrition education/intervention/programs, schools, farm-to-school, school gardens, and nutrition/dietary intervention, yielding 3731 records. Titles and abstracts were scanned for relevance to our stated aims with 155 identified as potentially relevant. Finally, studies were assessed for quality and content, and reference lists were checked for additional sources.

To be included, studies needed to be school garden interventions conducted during the school day, lasting at least 1 month, in the K-12 grade range, and include measures of academic performance and/or diet. Studies were excluded that were not school-based, were from non-Western cultures, were shorter than 1 month, or were not in English. The final set of papers, totaling 15 individual studies represented by 16 papers, lacked similar designs and measures, and thus, formal meta-analysis was not feasible.

RESULTS

Twelve studies measuring school gardens' effects on predictors of and/or actual FV intake met inclusion criteria (Table 1). Interventions comprised specifically designed garden curricula,[25,26] comparisons of NE lessons with and without gardening, or garden-based learning integrated into regular science classes. Interventions involved at least 9 lessons, with some lasting up to 4 months. One intervention compared outcomes for nongardening students with those in their first or second year of exposure to the program.[27] Half of the studies included fourth and/or fifth graders; 4 studies focused on younger grades, and 3 included more advanced grades. Cohort size ranged from 97 to almost 2000 students; most were in the 100-300 range. Cohort ethnicity ratios were included for half of the studies and varied greatly: 2 were "predominantly White," whereas the remaining 4 were 29-93% non-White, with 84% of 1 study's participants self-identifying as Hispanic. No studies specified whether participating schools were public or private, and only 1 study[28] specified whether participants were from urban or rural settings, although another[29] can be easily identified as urban. Geographic location also varied. Dietary outcome measures were either predictors of and/or reported FV intake. Studies assessing predictors of intake included measures of nutrition/dietary knowledge,[29-33] willingness to taste FV,[28,29,33,34] attitudes toward FV,[31,33,35] and preference for or choosing FV for meals or snacks.[27,28,29,31-33,36] All indicated statistically significant improvements in FV intake predictors. Seven studies measured self-reported FV consumption, but with nuanced interpretation due to the different tools. FV consumption results were mixed: 2 studies showed no change,[33,35] whereas 3 showed an increase[28,36,37] in FV consumption. The remaining studies focused only on vegetable consumption: 1 showed an increase in vegetable varieties consumed >1 time per month,[29] and the other showed gardeners more likely than nongardeners, including NE-only students, to choose and consume vegetables in the school lunchroom.[32]

Four studies, described in 5 papers, investigated academic outcomes in schools with garden-based interventions (Table 2). Two studies included third to fifth graders,[38,39] 2 included first to sixth graders,[40,41] and the other included only fifth graders.[42] Cohort sizes were 3769, 1197 (a subset of the larger cohort), 647, 196, and 119 students. Each employed an experiential school gardening curriculum as part of the intervention, which supplemented traditional classroom lessons. Intervention durations ranged from a 14-week gardening curriculum for 2 hours, once per week, to those implemented across 2 academic years. Three studies utilized level 1 of the same youth gardening curriculum developed by the Texas Agricultural Extension Service, designed to educate third to fifth graders about environmental science, health, horticulture, and nutrition.[43-45] Academic outcomes were measured by science, math, and in one case reading achievement test scores. Science achievement was assessed using a science achievement test based on the Junior Master Gardener curriculum;[38,42] math achievement was measured using the Texas statewide standardized test[39] or the Florida Comprehensive Achievement Test (FCAT).[41,46] The FCAT also assessed reading achievement.[41,46] Two studies[38,42] found significantly higher science achievement scores among gardeners compared with nongardeners, and the third[39] found no difference. When stratified by grade, fourth-grade gardeners showed increased science scores, but fifth-grade nongardeners had higher science scores, resulting in no overall difference.[39] The fourth study showed significant improvements in math test scores.[47]

DISCUSSION

This article is unique in that it examined school-based garden interventions that have the potential to influence both academic and health-related student outcome measures. Sixteen school garden intervention studies measured academic outcomes and/or FV consumption in children. Results indicated that these school-based garden interventions improved or maintained both FV consumption or mediators thereof and academic performance. Specifically, garden programs improved FV intake in 71% of studies measuring that outcome, and improved or showed no difference in academic performance in all 5 studies comparing gardening to nongardening students. Moreover, academic test scores improved or showed no change, regardless of the academic area assessed. However, this is a small collection of studies, and as such these findings should be considered preliminary.

Table 1. **Interventions Involving School Gardens With Dietary Outcome Measures**

Study	Participants	Design, Intervention	Outcomes: Fruit and Vegetable Intake Predictors	Outcomes: Measured Fruit and Vegetable Intake
Morris and Zidenberg-Cherr[30]	Sample size: N = 3 schools in 1 district; 3 classrooms per school; number of students not reported Age/grade: fourth grade Demographics: schools matched on student demographic profiles 8.4% African American 3% Asian American 17.2% Hispanic 66.5% White 25% FRPL	Design: quasi-experimental; nonrandom group assignment Intervention A: NE + G; 9 nutrition lessons, each including gardening component Intervention B: NE Control: no NE or garden Measures: pre/post nutrition knowledge questionnaire, vegetable preference survey	-Nutrition knowledge scores significantly higher at the treatment schools than at the control school -Results retained at 6-month follow-up	Not measured
Morris et al[34]	Sample size: N = 2 schools (1 intervention, 1 control); 3 classrooms per school Age/grade: first grade Demographics: schools matched for ethnicity and geographic location ethnicity: not reported %FRPL: not reported	Design: pilot study to assess feasibility of garden-based education and evaluation Intervention: NE + G; growing vegetables outdoors Control: no garden Measures: pre/post one-on-one student interviews to assess knowledge of, attitudes toward food	-Increased willingness to taste vegetables grown in the gardens	Not measured
Nolan et al[31]	Sample size: N = 4 schools; 141 students in 9 classrooms Age/grade: second to fifth grades Demographics: 47% male 84.4% Hispanic 3.5% African American 9.2% White 9.2% Other %FRPL: not reported 42.4% of households < poverty line per US Census Bureau data	Design: quasi-experimental (no control), to evaluate program impact of health education through gardening on children's knowledge about nutrition and attitudes toward fruit and vegetables. Intervention: Junior Master Gardener nutrition curriculum + school gardens Measures: pre/post (1) nutrition knowledge: 13-question multiple choice questionnaire; (2) preference for fruits and vegetables: modified FV preference questionnaire, modified; fourth, fifth graders; (3) snack choices	-Nutrition knowledge increased, pre- to post-test; impacted also by grade -FV preference increased from pre- to post-test	-Snack choices improved from pre- to post-test
Cotunga et al[27]	Sample size: N = 3 schools in 1 district; 359 students Age/grade: -Control: school A, fourth/fifth grades -Intervention: school B, fourth grade; first time in program; school C, all students, second time in program Demographics: -School A (control): 73% White -School B: 41% White -School C: 37% White ∼All schools: 34-38% FRPL	Design: quasi-experimental, nonrandom group assignment; cross-sectional, and longitudinal-by-design: analysis of new, first, second time exposures to compare school lunch vegetable selection with/without gardening and garden produce Intervention: garden education: classroom lessons, school vegetable garden visits to plant, tend, harvest; in-garden taste opportunities for vegetable tended and harvested; school B: first program exposure, school C: second program exposure Control (school A): no garden Measures: time-of-purchase lunch observations, 3 separate days: 1 day offered three fourth cup romaine salad from school garden, 2 days normal-vendor salads; test of proportions: choosing a salad	-Percent of students choosing a salad with garden-grown romaine: -Control: no change -School B: 11% increase, day 1 to 3 -School C: 39% increase, day 1 to 3	Not measured

Table 1. **Continued**

Study	Participants	Design, Intervention	Outcomes: Fruit and Vegetable Intake Predictors	Outcomes: Measured Fruit and Vegetable Intake
Lineberger and Zajicek[35]	Sample size: N = 5 elementary schools; 111 students Age/grade: third/fifth grades Demographics: ethnicity: not reported %FRPL: not reported	Design: quasi-experimental: volunteer participation of classrooms by teachers Intervention: Nutrition in the Garden activity guide; 10 units combining horticulture and nutrition; detailed background information for teachers. 34 total activities in 10 units, each ∼20 minutes Control: none Measures: pre/post attitudes to FV, FV questionnaire; FV behaviors, 24-hour recall journals	-Attitudes toward vegetable improved post-program; also toward FV snacks. Especially among females and younger students -No change in attitudes toward fruit	-FV consumption did not improve as a result of gardening -Very low FV intake at pre-test, maintained at post-test: estimated 2.0 servings/day
Meinen et al[28]	Sample size: N = 28 sites; 1796 unmatched pre/post surveys from N = 801 students, 995 parents Age/grade: parent surveys of second or younger graders; student respondents for third to seventh graders Demographics: "mostly White" 21% urban, 45% "urban cluster," 34% rural (per NHANES designation) 21% to > 70% FRPL: 7 sites, 51 + % 8 sites, 41-50% 13 sites, 21-40%	Design: quasi-experimental, prospective evaluation: volunteer intervention classrooms, with volunteer-identified comparison site/classroom Intervention: Got dirt? Gardening curriculum; average 4 months Control: no garden curriculum Measures: pre/post surveys: predictors of and consumption of FV (students, or parents for second-grade students/younger); teachers reported type of garden established, number of students participating, and start/end dates of garden project	Increased at post relative to pre: -trying new fruit -choosing fruit instead of chips/candy -choosing vegetables instead of chips/candy -trying new vegetables grown in the garden	Increased FV consumption as measured by parent (not student) report
Morgan et al[33]	Sample size: N = 2 schools; 127 students Age/grade: fifth to sixth grades Demographics: 54% boys Ethnicity: not reported %FRPL: not reported	Design: quasi-experimental: nonrandom group assignment Intervention: 10-weeks; group A, NE + G; group B, NE only Control: no NE, no garden Measures: pre/post FV knowledge; vegetable preferences (willingness to taste and taste ratings); FV consumption (24 hour recall)	-NE + G and NE-only students, relative to controls, showed higher overall willingness to taste vegetables, overall vegetable taste ratings -NE + G group better able to identify vegetables; more willing to taste capsicum, broccoli, tomato and pea; higher preference to eat broccoli and pea as a snack	-No change in fruit or vegetable intake
Parmer et al[32]	Sample size: N = 6 classrooms; 115 students total: 76 intervention (39 NE + G, 37 NE-only), 39 control Age/grade: second grade; NE + G 7.3 years, NE 7.3 years, Control 7.4 years Demographics: 70% male Ethnicity: not reported %FRPL: not reported	Design: quasi-experimental, nonrandom group assignment Intervention A, NE + G: 1 hour NE every other week + 1 hour gardening alternating weeks Intervention B, NE-only: 1 hour NE every other week Control: no NE or gardening Measures: pre/post FV knowledge, preference, consumption	-NE + G, NE-only students showed greater improvements in knowledge, taste ratings than control participants	NE + G group more likely to choose and consume vegetables in lunchroom than nutrition education-only or control groups at post-test

Table 1. **Continued**

Study	Participants	Design, Intervention	Outcomes: Fruit and Vegetable Intake Predictors	Outcomes: Measured Fruit and Vegetable Intake
Ratcliffe et al[29]	Sample size: N = 3 schools (2 interventions, 1 control); N = 236 students total: 170 intervention; 150 control Age/grade: sixth grade, 11-13 years Demographics: 22% African American 29% Asian American 9% Filipino American 30% Hispanic 3% Pacific Islander 7% White non-Hispanic/Other 22% English-Language Learner 35% overweight, per BMI 64% FRPL	Design: quasi-experimental Intervention: garden-based learning sessions integrated into regular science class, ~1 hour/week across 4 months, total 13 hours. Each session was ~20 minutes instruction (classroom or garden) + 40 minutes hands-on in-garden experiences. Garden activities were chosen to maximize students' exposure to vegetables and peer and adult modeling through cyclical garden activities (planting, tending, harvesting, preparing, consuming) Control: same health and science learning objectives, but no garden program Measures: pre/post vegetable knowledge, attitudes, and behavior through 2 self-administered surveys: Garden Vegetables Frequency Questionnaire (GVFQ); Taste Test	Self-administered surveys: -Increased ability to identify vegetables -Increased preference for vegetables -Increased willingness to taste vegetables -For all, gardeners > controls Taste test: -Increased varieties of vegetables tasted, gardeners > controls -No difference in willingness to taste vegetables between gardeners, controls	GVFQ: -Gardeners reported more vegetables varieties consumed > 1×/month, both for vegetables grown and not grown in school garden
Wang et al[36]	Sample size: N = 327 students Age/grade: fourth to fifth grades, followed into middle school Demographics: 27% White 21% African American 14% Hispanic 8% Asian American 31% mixed/other/unknown 39% low-income; 24% of fathers/male guardians had high school or less education	Design: 3-year prospective study Intervention: modifications to school food and dining; garden and cooking classes; lesson integration Control: none Measures: knowledge/attitudes (questionnaire); dietary behavior (3-day food diary); household information (parent questionnaire)	Students most exposed to the intervention showed a significantly greater increase in preference for fruit and green leafy vegetables, compared with students least exposed	-Most intervention exposure, increased FV intake ~0.5 cups -Least intervention exposure, decreased FV intake ~0.3 cups
McAleese and Rankin[37]	Sample size: N = 3 schools (2 interventions, 1 control); 99 students Age/grade: sixth grade, mean 11.1 years Demographics: Ethnicity "similar" across schools %FRPL "similar" across schools	Design: nonequivalent control group: 1 control + 1 experimental schools randomly assigned; second experimental school assigned based on garden availability Intervention: 12-week NE program; 1 with, 1 without garden activities Control: no NE or garden Measures: pre/post 3 × 24-hour recall workbooks	Not measured	-NE + G participants increased FV servings more than students in the two other groups -Significant increases in vitamin A, vitamin C, and fiber intake.

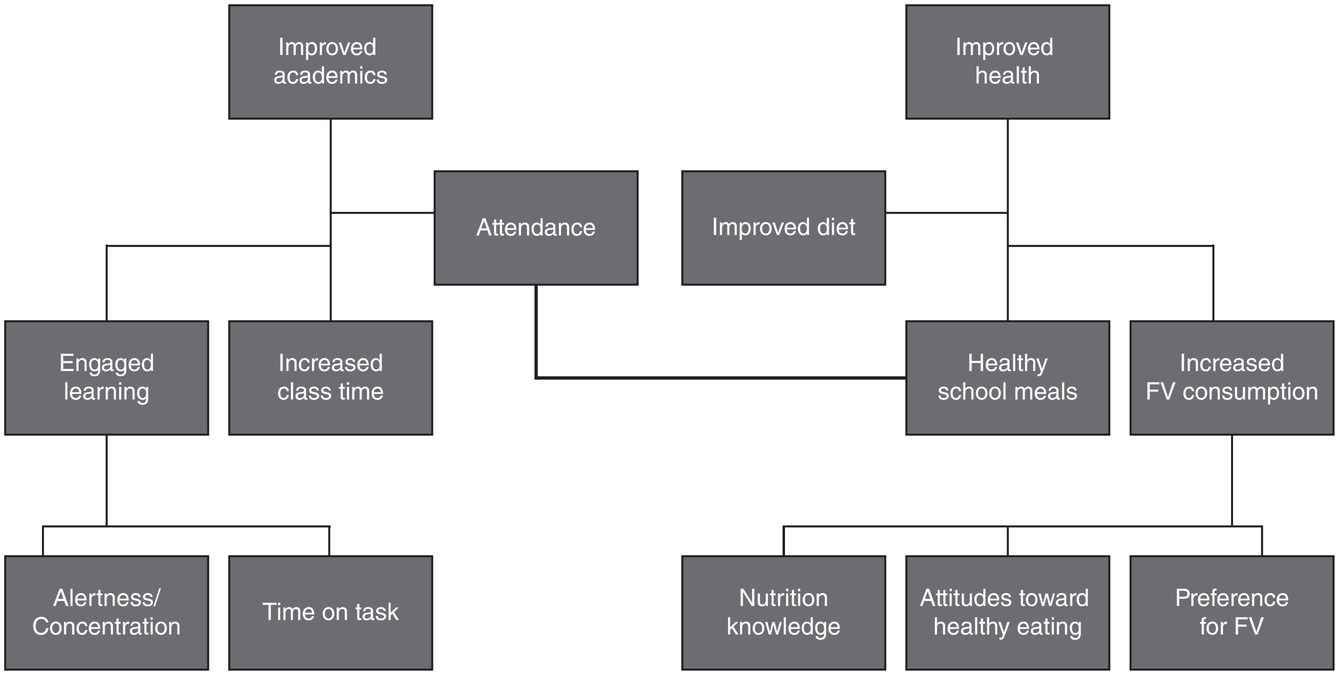
NE + G, nutrition education + garden; NE, nutrition education; %FRPL, percent of students eligible for free or reduced-price lunches; FV, fruit(s) and vegetable(s); BMI, body mass index.

Table 2. **Interventions Involving School Gardens With Measures of Academic Outcomes**

Study	Participants	Intervention/Design	Outcomes: Academic
Klemmer et al[38]	Sample size: N = 7 schools; N = 647 students: 453 intervention in 27 classes, 194 control in 13 classes Age/grade: third to fifth grades Demographics: 47% male Ethnicity: not reported % FRPL: not reported	Design: post-test only, quasi-experimental Intervention: garden activities integrated into science curriculum, alongside traditional classroom lessons Control: traditional classroom teaching Measure: science achievement test	-Intervention students scored significantly higher science achievement test scores than control students -Effect of grade: intervention most effective for third- and fifth-grade boys, fifth-grade girls
Pigg et al[39]	Sample size: N = 1 school; N = 196 students: 94 interventions, 102 controls Age/grade: third to fifth grades Demographics: Ethnicity: not reported % FRPL: not reported	Design: quasi-experimental, nonrandom group assignment; convenience sample Intervention: youth gardening curriculum taught by classroom teachers + traditional classroom math, science Control: traditional classroom math, science; no gardening Measures: pre/post Texas Assessment of Knowledge and Skills math achievement test	-Gardening students: no improvement in math scores; no significant difference in science sores from nongardening -Fourth-grade gardening students higher science scores than nongardening -Fifth-grade controls, higher math, science scores
Smith and Motsenbocker[42]	Sample size: N = 3 schools (1 intervention, 1 control classroom per school); N = 119 students: 62 interventions, 57 controls Age/grade: fifth grade Demographics: Ethnicity: majority African American % FRPL: not reported	Design: quasi-experimental, nonrandom group assignment Intervention: 14-week gardening curriculum (Junior Master Gardener; 2 hours, 1×/week) Control: no gardening curriculum Measure: pre/post 40-question science achievement test	-Intervention students' scores higher at post-test, versus no difference in control students
Hollar et al[40]	Sample size: N = 5 schools (4 interventions, 1 control); N = 1197 students (this is a subset of total cohort: those qualifying for FRPL; 974 intervention, 199 controls) Age/grade: 7.8 years Demographics: 68% Hispanic 9% Black 15% White 8% Other 100% FRPL	Design: 2 school years, quasi-experimental, nonrandom Intervention: Nutrition: modifications to school meal and extended-day snack menus: more high-fiber items, fewer high-glycemic items, lower total, saturated, and trans fats Health curriculum: nutrition and healthy lifestyle management program for elementary-aged children and adults, using materials from USDA Team Nutrition and The OrganWise Guys; FV gardens Physical activity: increased school-day physical activity opportunity: 10-15 minutes/day desk-side physical activity program, matched with core academic areas; structured physical activity during recess, for example, a walking club Control: comparison school "as usual" Measures: Florida Comprehensive Achievement Test (FCAT) reading, math scores	-Significant improvement in FCAT math scores, +22.3 intervention versus −3.0 control ($p = .001$) -Trend for improvement in FCAT reading scores, +5.7 intervention versus −1.2 control ($p = .08$)
Hollar et al[41]	Sample size: N = 5 schools (4 interventions, 1 control); 3769 students (full cohort of study by Hollar et al[40] above) Age/grade: 8 years Demographics: 50% Hispanic 33% White 8% Black 8% Other 31% FRPL	Design: described above Intervention: described above Control: described above Measures: third grade FCAT reading, math scores	-Statistically significant improvements in academic test scores, especially among low-income Hispanic and White children, observed in intervention versus control participants

FCAT, Florida Comprehensive Achievement Test; %FRPL, percent of students eligible for free or reduced-price lunches; USDA, United States Department of Agriculture; FV, fruit(s) and vegetable(s).

Figure 1. **An Illustration of Perceived Connections Between Health and Academic Success and Their Mediators**



Previous reviews focused on garden interventions linked to academic outcomes but were not limited to peer-reviewed literature as is this article.[43,48,49] Herein, 4 gardening interventions indicated that such programs support academic performance, with the most evidence demonstrated for science test scores; math and language arts scores improved to lesser degrees. Gardening program impacts with respect to children's FV intake also demonstrated positive effects. Moreover, teachers were generally found to report that gardens were a valuable teaching tool. Garden program studies also indicated an indirect, positive effect on children's social development. Overall, however, garden program studies lacked scientific rigor, and the inclusion criteria for this article yielded only a small set of studies. It is promising that the various studies were not discordant, but the small number of studies tempers the strength of this article.

A schematic to illustrate possible connections between academic and dietary inputs and outcomes is presented in Figure 1. Mechanisms for school nutrition interventions' effects on academic performance continue to be unclear. Healthier school meals may offer a long-term effect of improved nutrient intake and nutritional status, with positive effects on cognition; however, socioeconomic indicators also predict academic performance in addition to nutritional status.[11,13] We suggest, as have others, that academic outcomes may improve due to increased attendance and, consequently, increased instructional time.[44,45] It is possible that measures of pro-academic behaviors may better indicate students' potential for academic success: time on task, classroom behavior, creativity, and attitudes toward learning.[9]

Mechanisms to explain why gardening interventions specifically improve academic outcomes in students are similarly speculative. School garden programs broadly aim to improve children's dietary choices through improved knowledge of and attitudes toward FV; this is generally conceptualized using social cognitive theory.[23] However, this does not relate directly to academic outcomes. It is clear from protein-energy malnutrition-related literature that improving students' nutritional status improves academic outcomes,[12,45,50] but this effect is less apparent in students who are provided with adequate protein and energy.[9] School gardens may improve students' attitudes toward school itself—a byproduct of experiential education, rather than a primary objective of the program itself, because enhanced school engagement leads to improved academic outcomes. Gardens also may help students develop observational skills, and simultaneously provide an opportunity for students to integrate interdisciplinary content in the context of a living laboratory. Indeed, experiential learning opportunities like school gardens have been shown to increase student engagement. Christenson et al[51] define experiential learning as activities that enhance student learning through active participation. This type of learning has been shown to motivate students to dedicate time and energy to their learning, leading to more engaged students.[51]

While the degree of change in each of these studies is not large, it may help close the achievement gap between low- and adequate-income families.[40,41] Much like substantial dietary change is difficult to achieve, substantial academic achievement improvement is probably difficult to achieve without sustained changes to the learning environment. Although extensive attention has been given to improving academic performance by preventing protein-energy malnutrition,[9,11-14] excess nutrition and the resultant obesity also influence academic performance. As described above, the documented connections between obesity and academic performance indicate that healthier children are also better learners.[4-8] Nutrition education, meal offerings, and school gardens are also aimed at obesity prevention through improved diet quality as a result of increased knowledge, improved food options in the school setting, and improved choices throughout an individual's lifetime.

This article has limitations. Interventions were methodologically diverse. These garden interventions, like in earlier reviews, commonly identified incomplete methodological descriptions, use of a convenience sample, often a lack of a control group, and small cohorts.[49] These shortcomings limit between-study comparisons and definitive conclusions. As mentioned above, a major limitation is the small number of studies that met inclusion criteria. Indeed, previous reviews of both academic and nutritional/dietary outcomes cautioned against overly zealous affirmations of such interventions because the literature is scarce, albeit growing, particularly with regard to garden programs. Further work is needed using strong experimental designs with control groups, longitudinal analyses, and nonconvenience-sample cohorts.

Furthermore, few nutrition and garden interventions have measured academic performance. Among those that have, outcomes are difficult to compare due to diverse measurement tools. The recent national creation of the Common Core Standards may better facilitate academic outcomes assessment alongside health-oriented school programs. Legislators and school administrators are accustomed to utilizing standardized test scores and school grades for outcome comparisons, and the new standards may permit improved across-site academic outcome comparability. In addition, the Healthy, Hunger-Free Kids Act of 2010 legislated extensive changes in the NSLP and SBP nutrition aims,[52] and identified important evaluative outcome include children's improved health concurrent with the ongoing aims of improved academic performance.

No studies addressed instructional quality due to their limited scope, but it could be considered in this newer context. Aspects of academic performance such as time on task and classroom behavior, although vital to the school and learning environment, require much more time on the part of the investigator and/or teacher to quantify and qualify. These are important aspects to measure in future studies. Finally, cohort age ranges are limited, with most focusing on elementary students, suggesting a need for studies involving middle and high school students.

IMPLICATIONS FOR SCHOOL HEALTH

A review of 16 longitudinal school garden intervention studies show potential for school-based interventions to improve student academic performance, attendance, as well as mediators of FV intake, although the effects are small and most studies are quasi-experimental in nature. Schools may want to consider school gardens as a hands-on instructional tool to enhance science learning and to potentially improve long-term FV consumption. However, few studies met inclusion criteria, limiting the strength of these findings. More research is needed with a focus on comprehensive school garden interventions, including those involving school meal modifications, NE, and expanded opportunities for integrating school gardens into curricular instruction. Balancing scientific rigor with minimal disruption in the school day is a challenge, but one worth undertaking in order to ensure that educational systems/settings promote intellectual and physical health and development for all children.

REFERENCES

1. Sibley B, LeMasurier GC. Children's health and academic performance: elevating physical education's role in schools. *Int J Phys Educ*. 2008;45(2):64-82.
2. Ogden CL, Carroll MD, Curtin LR, Lamb MM, Flegal KM. Prevalence of high body mass index in US children and adolescents, 2007-2008. *JAMA*. 2010;303(3):242-249.
3. Institute of Medicine. *School Meals: Building Blocks for Healthy Children*. Washington, DC: The National Academies Press; 2010.
4. Datar A, Sturm R. Childhood overweight and elementary school outcomes. *Int J Obes*. 2006;30(9):1449-1460.
5. Judge S, Jahns L. Association of overweight with academic performance and social and behavioral problems: an update from the early childhood longitudinal study. *J Sch Health*. 2007;77(10):672-678.
6. Shephard RJ. Curricular physical activity and academic performance. *Pediatr Exerc Sci*. 1997;9(2):113-126.
7. Dwyer T, Sallis JF, Blizzard L, Lazarus R, Dean K. Relation of academic performance to physical activity and fitness in children. *Pediatr Exerc Sci*. 2001;13(3):225-237.
8. Mo-suwan L, Lebel L, Puetpaiboon A, Junjana C. School performance and weight status of children and young adolescents in a transitional society in Thailand. *Int J Obes Relat Metab Disord*. 1999;23(3):272-277.
9. Hoyland A, Dye L, Lawton CL. A systematic review of the effect of breakfast on the cognitive performance of children and adolescents. *Nutr Res Rev*. 2009;22(2):220-243.
10. Vaillancourt T, Brittain HL, McDougall P, Duku E. Longitudinal links between childhood peer victimization, internalizing and externalizing problems, and academic functioning: developmental cascades. *J Abnorm Child Psychol*. 2013;41(8):1203-1215.

11. Rampersaud GC, Pereira MA, Girard BL, Adams J, Metzl JD. Breakfast habits, nutritional status, body weight, and academic performance in children and adolescents. *J Am Diet Assoc*. 2005;105(5):742-743.
12. Taras H. Nutrition and student performance at school. *J Sch Health*. 2005;75(6):199-213.
13. Jyoti DF, Frongillo EA, Jones SJ. Food insecurity affects school children's academic performance, weight gain, and social skills. *J Nutr*. 2005;135(12):2831-2839.
14. Murray NG, Low BJ, Hollis C, Cross AW, Davis SM. Coordinated school health programs and academic achievement: a systematic review of the literature. *J Sch Health*. 2007;77(9):589-600.
15. National Center for Education Statistics - Digest of Education Statistics. Percentage of population 3 to 34 years old enrolled in school, by age group: selected years, 1940 through 2008. Available at: http://nces.ed.gov/programs/digest/d09/tables/dt09_007.asp. Accessed September 2, 2014.
16. National Center for Education Statistics - Digest of Education Statistics. Estimates of resident population, by age group: 1970 through 2009. Available at: http://nces.ed.gov/programs/digest/d09/tables/dt09_015.asp. Accessed September 2, 2014.
17. United States Department of Agriculture, Food and Nutrition Service. School Breakfast Program: Program History. Available at: http://www.fns.usda.gov/sbp/program-history. Accessed July 26, 2013.
18. Briefel RR, Wilson A, Gleason PM. Consumption of low-nutrient, energy-dense foods and beverages at school, home, and other locations among school lunch participants and nonparticipants. *J Am Diet Assoc*. 2009;109(suppl 2):S79-S90.
19. Centers for Disease Control and Prevention. National Health Education Standards. 2013. Available at: http://www.cdc.gov/healthyyouth/sher/standards/. Accessed May 22, 2014.
20. Ozer EJ. The effects of school gardens on students and schools: conceptualization and considerations for maximizing healthy development. *Health Educ Behav*. 2007;34(6):846-863.
21. National Farm to School Network. The Benefits of Farm to School. Available at: http://www.farmtoschool.org/Resources/BenefitsFactSheet.pdf. Accessed September 2, 2014.
22. Kohlstedt SG. ''A better crop of boys and girls'': the school gardening movement, 1890-1920. *Hist Educ Q*. 2008;48(1):58-93.
23. Roche E, Conner D, Kolodinsky J, Buckwalter E, Berlin L, Powers A. Social cognitive theory as a framework for considering farm to school programming. *Child Obes*. 2012;8(4):357-363.
24. Centers for Disease Control and Prevention. Recommended community strategies and measurements to prevent obesity in the United States. *MMWR Morb Mortal Wkly Rep*. 2009;58(RR07):1-26.
25. Wisconsin Department of Health Services- Division of Public Health- NPAOP, Wisconsin Department of Public Instruction, University of Wisconsin Extension. Got Dirt? Garden Toolkit for Implementing Youth Gardens. 2013. Available at: http://www.dhs.wisconsin.gov/physical-activity/FoodSystem/Gardening/GotDirt/index.htm. Accessed September 2, 2014.
26. Seagraves RL, Whittlesey L, Klemmer C, et al. *Junior Master Gardener: Level 1 Teacher/Leader Guide*. Bryan, TX: Texas A&M AgriLife Extension; 2005.
27. Cotugna N, Manning CK, DiDomenico J. Impact of the use of produce grown in an elementary school garden on consumption of vegetables at school lunch. *J Hunger Environ Nutr*. 2012;7(1):11-19.
28. Meinen A, Friese B, Wright W, Carrel A. Youth gardens increase healthy behaviors in young children. *J Hunger Environ Nutr*. 2012;7(2-3):192-204.
29. Ratcliffe MM, Merrigan KA, Rogers BL, Goldberg JP. The effects of school garden experiences on middle school-aged students' knowledge, attitudes, and behaviors associated with vegetable consumption. *Health Promot Pract*. 2011;12(1):36-43.
30. Morris JL, Zidenberg-Cherr S. Garden-enhanced nutrition curriculum improves fourth-grade school children's knowledge of nutrition and preferences for some vegetables. *J Am Diet Assoc*. 2002;102(1):91-93.
31. Nolan GA, McFarland AL, Zajicek JM, Waliczek TM. The effects of nutrition education and gardening on attitudes, preferences, and knowledge of minority second to fifth graders in the Rio Grande Valley toward fruit. *HortTechnology*. 2012;22(3):299-304.
32. Parmer SM, Salisbury-Glennon J, Shannon D, Struempler B. School gardens: an experiential learning approach for a nutrition education program to increase fruit and vegetable knowledge, preference, and consumption among second-grade students. *J Nutr Educ Behav*. 2009;41(3):212-217.
33. Morgan PJ, Warren JM, Lubans DR, Saunders KL, Quick GI, Collins CE. The impact of nutrition education with and without a school garden on knowledge, vegetable intake and preferences and quality of school life among primary-school students. *Public Health Nutr*. 2010;13(11):1-10.
34. Morris JL, Neustadter A, Zidenberg-Cherr S. First-grade gardeners more likely to taste vegetables. *Calif Agric*. 2001;55(1):43-46.
35. Lineberger SE, Zajicek JM. School gardens: can a hands-on teaching tool affect students' attitudes and behaviors regarding fruit and vegetables? *HortTechnology*. 2000;10(3):593-597.
36. Wang MC, Rauzon S, Studer N, et al. Exposure to a comprehensive school intervention increases vegetable consumption. *J Adolesc Heal*. 2010;47(1):74-82.
37. McAleese JD, Rankin LL. Garden-based nutrition education affects fruit and vegetable consumption in sixth-grade adolescents. *J Am Diet Assoc*. 2007;107(4):662-665.
38. Klemmer CD, Waliczek TM, Zajicek JM. Growing minds: the effect of a school gardening program on the science achievement of elementary students. *HortTechnology*. 2005;15(3):448-452.
39. Pigg AE, Waliczek TM, Zajicek JM. Effects of a gardening program on the academic progress of third, fourth, and fifth grade math and science students. *HortTechnology*. 2006;16(2):262-264.
40. Hollar D, Messiah SE, Lopez-Mitnik G, Hollar TL, Almon M, Agatston AS. Effect of a two-year obesity prevention intervention on percentile changes in body mass index and academic performance in low-income elementary school children. *Am J Public Health*. 2010;100(4):646-653.
41. Hollar D, Lombardo M, Lopez-Mitnik G, et al. Effective multi-level, multi-sector, school-based obesity prevention programming improves weight, blood pressure, and academic performance, especially among low-income, minority children. *J Health Care Poor Underserved*. 2010;21(suppl 2):93-108.
42. Smith LL, Motsenbocker CE. Impact of hands-on science through school gardening in Louisiana public elementary schools. *HortTechnology*. 2005;15(3):439-443.
43. Robinson-O'Brien R, Story M, Heim S. Impact of garden-based youth nutrition intervention programs: a review. *J Am Diet Assoc*. 2009;109(2):273-280.
44. Meyers AF, Sampson AE, Weitzman M, Rogers BL, Kayne H. School Breakfast Program and school performance. *Am J Dis Child*. 1989;143(10):1234-1239.
45. Murphy JM, Pagano ME, Nachmani J, Sperling P, Kane S, Kleinman RE. The relationship of school breakfast to psychosocial and academic functioning: cross-sectional and longitudinal observations in an inner-city school sample. *Arch Pediatr Adolesc Med*. 1998;152(9):899-907.
46. Hollar D, Messiah SE, Lopez-Mitnik G, Hollar TL, Almon M, Agatston AS. Healthier options for public schoolchildren program improves weight and blood pressure in 6- to 13-year-olds. *J Am Diet Assoc*. 2010;110(2):261-267.
47. Sibley BA, Ward RM, Yazvac TS, Zullig K, Potteiger JA. Making the grade with diet and exercise. *AASA J Scholar Pract*. 2008;5(2):38-45.

48. Blair D. The child in the garden: an evaluative review of the benefits of school gardening. *J Environ Educ*. 2009;40(2):15-38.
49. Williams DR, Dixon PS. Impact of garden-based learning on academic outcomes in schools: synthesis of research between 1990 and 2010. *Rev Educ Res*. 2013;83(2):211-235.
50. Florence MD, Asbridge M, Veugelers PJ. Diet quality and academic performance. *J Sch Health*. 2008;78(4):209-215.
51. Christenson S, Reschly A, Wylie C. *Handbook of Research on Student Engagement*. New York, NY: Springer; 2012:816.
52. Healthy, Hunger-Free Kids Act of 2010. Pub L No. 111-296, 124 Stat. 3183. US Congress; 2010:1-84.