REVIEW

Farm to School Activities and Student Outcomes: A Systematic Review

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ABSTRACT

Farm to school programs (F2SPs) operate in 42% of school districts and are supported in part through federal and state policies as well as philanthropic funding. Although research evaluating the effects of farm to school–related activities on student outcomes is growing, a systematic review of the results and thus a synthesis of implications for future programming have not occurred. The primary objective of this systematic literature review is to summarize and evaluate studies on student outcomes associated with farm to school–related activities up to 1 September, 2017. Four databases spanning 4 research disciplines were used to identify full-text, English-language studies. Twenty-one studies were reviewed: 7 explicitly investigated F2SPs, and 14 evaluated the impact of school-based interventions that were relevant to activities reported in the 2013 and/or 2015 Farm to School Census. All of the F2SP studies ($n = 7$) and 85.7% of farm to school–related activity studies ($n = 12$) were multicomponent, and there was a wide variety of implemented intervention components across the reviewed studies. Results from F2SP and farm to school–related activity studies consistently show positive impacts on food and nutrition-related knowledge; most studies also suggest a positive relation between farm to school–related activities and healthy food selection during school meals, nutrition self-efficacy, and willingness to try fruits and vegetables. The impact of farm to school activities on fruit and vegetable consumption and preferences is unclear. The most common F2SP study limitations were study designs that preclude causal inference, outcome measurement with no reported or limited psychometric testing, lack of long-term outcome evaluation, and challenges related to quantifying intervention implementation. These findings underscore the need for more conclusive evidence on the relation between farm to school–related activities and changes in fruit and vegetable consumption. *Adv Nutr* 2020;11:357–374.

Keywords: farm to school, school nutrition, local foods, nutrition education, nutrition promotion, school gardens

Introduction

The National School Lunch Program (NSLP) provides low-cost or free lunches to >30 million children daily at a cost of $13.6 billion annually (1). Accordingly, farm to school programs (F2SPs) may represent both viable market opportunities for US food producers and mechanisms to promote healthy eating habits in children (2). F2SPs incorporate locally or regionally produced foods into school cafeterias and provide promotional activities or experiential learning to support nutrition education, including integrating food-related education into the regular, standards-based curriculum (2). In 2012, the USDA (3) established the Farm to School Program to help schools improve the health and wellness of their students and connect with local producers. The supporting legislation operationalizes F2SPs through a competitive grant process in which federal funds are awarded to support training, operations, planning, school garden development, partnership development, and otherwise implement F2SPs (4). In addition to this mandatory federal support, there has been a proliferation of state policies and programming for F2SPs (2) as well as philanthropic funding support (5).

The USDA conducted the Farm to School Census in 2013 and 2015 to better understand the prevalence of F2SP implementation and to identify needs for technical assistance (2). **Table 1** lists 17 farm to school activities included in the 2013 and/or 2015 Farm to School Census. Activities take place in the cafeteria (e.g., procurement and cafeteria promotions), the classroom (e.g., integrating nutrition and/or agricultural education into the standards-based educational curriculum), or outside the classroom (e.g., school gardens or farm visits). It is important to note that participating schools select the activities in which they

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Abbreviations used: F2SP, farm to school program; F2SRA, farm to school–related activity; FV, fruit and vegetable; NSLP, National School Lunch Program.

TABLE 1 Farm to school activity categories and corresponding activities from the 2013 and/or 2015 Farm to School Census

Category	Farm to school activities
Procurement	Local food procurement for school meals, snacks, à la carte or fundraiser foods
	Serving foods from school-based gardens or farms in cafeteria
	Working with local food producers to develop a new menu item using local foods
Integrated curriculum	Integrating farm to school concepts (e.g., agriculture and nutrition) into the academic standards-based curriculum
Experiential learning	Field trips to farms or orchards
	School garden or orchard activities
Promotion	Cafeteria food coaches to promote local food consumption
	Celebrating Farm to School Month
	Farmer visits to the school
	Hosting farm to school–related community events
	Incorporating Team Nutrition materials into farm to school activities[1]
	Local food promotions
	Offering taste tests of local foods or foods grown in school gardens/farms
	Smarter Lunchroom[2] strategies
Global	Evaluating changes in student acceptance and waste after implementing farm to school activities
	Generating media coverage of local foods being used in schools
	Training food service staff on farm to school or school gardens

[1]The farm to school category for the use of Team Nutrition materials will vary depending on which resource is used.
[2]Smarter Lunchroom techniques use behavioral economics principles to influence food behaviors by changing environmental behavioral cues without restricting choices.

participate, including the number, intensity, and duration. According to the 2015 Farm to School Census, the most common farm to school activities were serving locally procured foods in the cafeteria; promoting local foods produced at the school; conducting taste tests of local foods; visiting farms or orchards; and using Smarter Lunchroom strategies (6)—which, based on behavioral economics principles, aim to influence food behaviors by changing environmental behavioral cues without restricting choices—to encourage consumption of local foods (7).

One of the touted benefits of F2SPs is their ability to positively impact student outcomes. For example, educational and promotional activities in the classroom, garden, or cafeteria are purported to increase student knowledge about healthy foods, science, and/or agriculture, as well as strengthen gardening and cooking skills. These activities may also influence student preferences, attitudes, and self-efficacy toward vegetables, fruits, whole grains, and/or locally grown foods (8). Positive changes in student dietary behavior, such as improved vegetable and fruit consumption, are perhaps the most desirable potential F2SP student outcome (8). Increased intake of healthy foods may promote the reduction of childhood obesity, particularly if these foods displace consumption of less healthy, energy-dense foods. Increased intake of vegetables and other healthy foods during school lunch is also desirable because this may reduce plate waste, thus minimizing associated environmental consequences (9). In addition, farm to school activities are also purported to boost academic achievement, potentially promoting school attendance and improved test scores when nutrition and garden concepts are integrated into standards-based curriculums (8).

Although schools provide important opportunities to shape youth behaviors, school-based nutrition and health programs are associated with a variety of evaluation and implementation challenges, such as difficulties establishing random allocation of treatment groups (10); competing educational priorities (11); and the constrained budget, time, and staff of school systems (12, 13). In addition, there is significant heterogeneity among schools in their size, infrastructure, financial and human resources, and student demographics (14). Due to this complexity (14), multicomponent programs that are responsive to the specific needs of individual schools are common. Subsequently, the available school nutrition research often involves varying interventions and/or intervention doses across schools within the same study, and thus it is difficult to determine the success of individual interventions or programs (15–19).

The only existing literature review of F2SPs was published in 2008 (20). Joshi et al. (20) concluded that there were potential trends for behavioral impacts of F2SPs, but there were strong limitations to the available evidence. Perhaps the key limitation of the review by Joshi et al. (20) was that it included studies that were not peer-reviewed; at the time of their review, only 1 peer-reviewed article was available. Others have suggested that the available F2SP evidence is limited due to inconsistent measurement of program outcomes and intervention dosage or exposure (8). Most research included in the review by Joshi et al. (20) reported short-term outcomes instead of long-term health indicators, and few studies included a control group. Accordingly, the effectiveness of F2SPs is not understood.

Given the growth of F2SPs during the past decade, including federal, state, local, and philanthropic funding to support them, this research uses a systematic literature review to assess the impact of farm to school activities on student outcomes. Because limitations remain in the number of peer-reviewed literature on this topic, we include high-quality, peer-reviewed studies examining relevant cafeteria, garden, and other nutrition education interventions with the understanding that the available research on these F2SP-related activities may inform F2SP interventions.

Methods

The systematic literature review process was informed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2015 framework (21), and the review protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) database as CRD42017072814.

Eligibility and exclusion criteria

The search strategy aimed to identify peer-reviewed articles that assessed the effectiveness of F2SPs (i.e., interventions explicitly identified as F2SPs) and farm to school–related activities (F2SRAs; i.e., related school-based activities that might shed light on the effectiveness of F2SPs) on student outcomes. Student outcomes were broadly defined to include dietary intake, food selection, attitudes toward food (e.g., measures of food preference, taste ratings, and nutrition self-efficacy), food and nutrition knowledge, meal participation rates, student achievement, and health outcomes (e.g., anthropometric measures, biochemical indicators, and blood pressure). F2SP-related activities were defined as those listed in the 2013 and/or 2015 Farm to School Census (e.g., school gardens, school procurement of local foods, taste testing, Smarter Lunchrooms, farm field trips, farmer classroom visits, and integrated or educational curriculum). We only included articles studying kindergarten through 12th-grade students attending US schools participating in the NSLP. Studies were excluded if they focused on afterschool programs because these programs service only a fraction of the total school population, children attending these programs may not be representative of the overall school population, and not all afterschool programs are eligible for snack or supper provision by school nutrition programs. Given the small number of studies that explicitly addressed farm to school activities, all F2SP studies were included, whereas F2SRA studies were only included if they had a comparison group, as recommended by the Health Evidence Quality Assessment Tool (22). Commentaries, editorials, and systematic reviews were also excluded.

Information sources and search strategy

Four databases spanning biomedical sciences, education, economics, and general science (PubMed, ERIC, EconLit, and Web of Science) were searched for full-text, English-language publications published between January 2002 (the year in which the Farm Bill initiated the federal Fresh Fruit and Vegetable Program, a precursor to F2SP) and 1 September, 2017, by using keywords ("school meal" or "school cafeteria" or "school nutrition" or "farm to school" or "school food" or "school lunch" or "school breakfast" or "school classroom") *and* ("local procurement" or "local* foods" or "garden*" or "taste*" or "cook*" or "smarter lunchrooms" or "marketing campaign" or "promotion*" or "farm*" or "field trip" or "training" or "professional development" or "plate waste" or "student acceptance" or "curriculum" or "smart snacks" or "demonstrations" or "event"). (The asterisk was used at the end of key search terms to include any additional characters for a keyword search.) References of identified articles were further screened to identify additional studies. The search was completed in September 2017.

TABLE 2 Quality assessment criteria results for farm to school program and farm to school–related activity studies[1]

Criterion of study quality[2]	Farm to school program studies (*n* = 7)	Farm to school–related activity studies (*n* = 14)
Study design (0–2)	0.43 ± 0.53	2.00 ± 0.00
Sample size (0–1)	0.57 ± 0.53	0.93 ± 0.27
Metrics/measures (0–2)	1.29 ± 0.76	1.93 ± 0.27
Data analyses (0–2)	0.57 ± 0.53	1.79 ± 0.43
Intervention fidelity assessment (0–1)	0.43 ± 0.53	0.79 ± 0.43
Total quality assessment score (0–8)	3.29 ± 1.70	7.43 ± 0.51

[1]Values are means ± SDs. All explicitly farm to school studies were included, but only strong farm to school–related activities were included.
[2]Possible score range is provided in parentheses. Points were attributed as follows: research design—nonrandomized comparison group (1), randomized groups (2); sample size—sample size is too small (0), sample size is appropriate (1); metrics/measures—tool or tools are not valid or validity and reliability are not described (0), tools are valid but not reliable or reliability not described (1), valid and reliable tool or tools (2); data analysis—methods are inappropriate and inadequately described with enough detail to ensure reproducibility (0), methods are adequately described but may not be appropriate or methods seem appropriate but not fully described (1), methods are adequately described and appropriate (2); and assessment of intervention fidelity—not assessed (0), assessed (1). Total quality assessment score was derived through the sum of the 5 individual criteria. Total scores ≥3 were considered weak, scores of 4–6 were considered fair, and scores of 7–8 were considered strong.

Study selection and classification

Articles were screened for inclusion by ≥2 team members. Articles were assessed for eligibility by the first author and a team member. Discrepancies were resolved via a third team member. Studies were classified into 5 groups based on the F2SP-related activity investigated (as defined in Table 1): experiential learning, procurement, integrated curriculum/nutrition education, promotion, and global activities (global activities are comprehensive approaches that are relevant to the overall F2SP, such as using plate waste audits to improve farm to school interventions and/or seeking media exposure to promote farm to school programs). Study designs were cataloged according to definitions developed by the Academy of Nutrition and Dietetics (23).

Approach for evaluating relative quality and risk of bias

The Health Evidence Quality Assessment Tool (22) was adapted for farm to school activities and used to evaluate study quality. (See **Table 2** for specific quality scoring details.) At least 2 researchers assessed each eligible article and extracted relevant data independently and then met to reconcile their evaluations and data extractions. As noted in Table 2, points were assigned for 5 study characteristics derived from the Health Evidence Quality Assessment Tool (22): research design (0–2 points possible), sample size

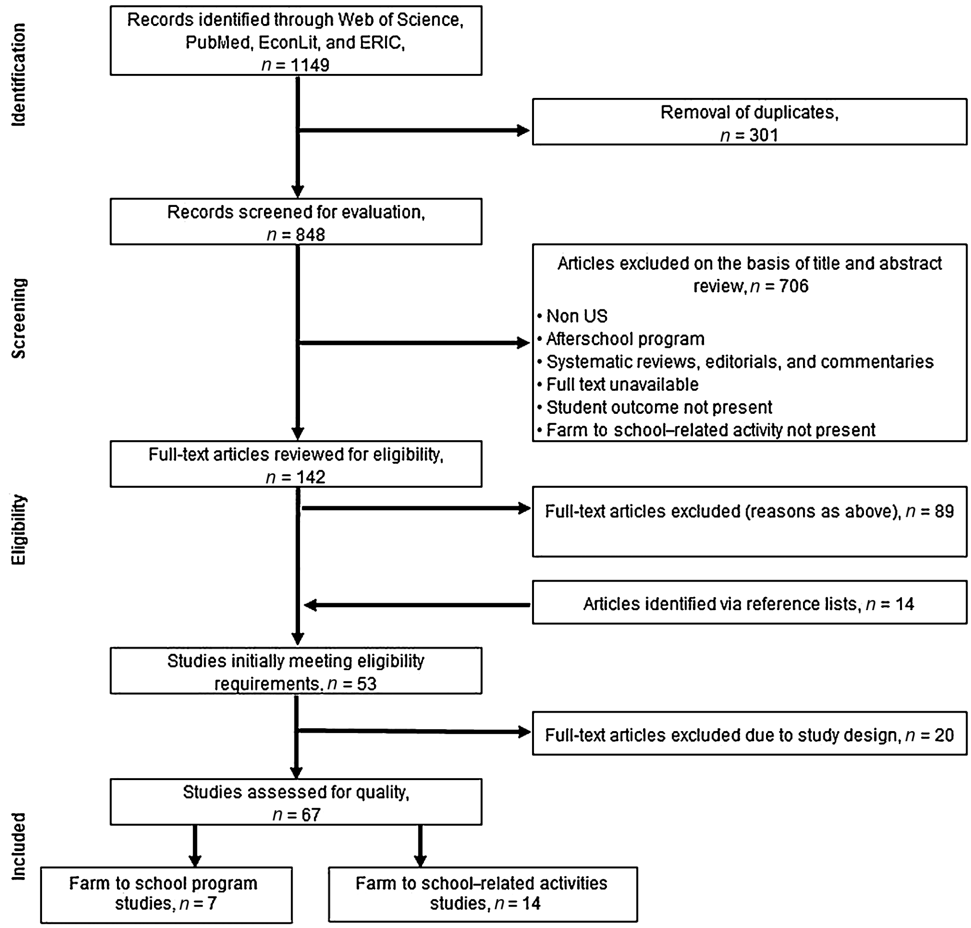

FIGURE 1 PRISMA flow diagram of the study selection and exclusion process. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

(0 or 1 point possible), data collection tools (0–2 points possible), data analysis (0–2 points possible), and assessment of intervention fidelity (0 or 1 point possible). Studies earning 0–3 points were classified as weak, those earning 4–6 points were classified as fair, and those earning 7–8 points were classified as strong. All explicitly F2SP studies were included in the synthesis of results, but only farm to school activity studies classified as strong were included (hereafter referred to as F2SRA studies).

Results

Figure 1 shows how the study selection and exclusion criteria determined the final set of articles we analyzed. Of the original 1149 identified articles, 142 were selected for full-text review, and an additional 14 manuscripts were identified after screening the reference lists from the studies reviewed in the primary search. Eighty-nine studies were initially excluded after full-text review, and an additional 21 papers were excluded from quality assessment due to study design limitations. Seven studies were included because they explicitly examined F2SPs; these were reviewed for quality but included regardless of their quality score. In total, 46 papers were assessed for quality; of which 30.4% (n = 14) were strong, 41.5% (n = 20) were fair, and 26.1% (n = 12) were weak. The remainder of this section focuses on the 14 studies evaluating farm to school-related activities that were assessed as strong as well as the 7 studies that explicitly examined F2SPs.

As shown in Table 2, F2SP studies were scored significantly lower than the F2SRA studies in the quality assessment criterion for study design and data analyses. An overview of the study design, intervention components, student outcomes, outcome measures/metrics, results, and farm to school implications for each included study is provided in **Table 3**. Of note, >85% of the included studies (n = 18) were multicomponent, meaning they featured more than 1 intervention. **Figure 2** illustrates the degree of overlap among the 6 farm to school activity categories and also further underscores the multicomponent nature of most included studies. Yet even within these components, there was much variation in the activities implemented so that even studies investigating the same farm to school activity category likely were evaluating very different student experiences.

TABLE 3 Summary of studies evaluating farm to school programs ($n = 7$) or farm to school–related activities ($n = 14$)[1]

First author (reference no.); year; population; location	QA score	Study design[2]	Farm to school–related objective	Intervention components (duration)	Outcomes (measurement method) and when measured	Results	Farm to school implications
Bontrager Yoder (24); 2015; 1877 3rd- to 5th-grade students in 11 schools; Wisconsin	Fair	Repeated cross-sectional study	To examine whether Farm to School can reduce FV waste over time	Local food procurement, Smarter Lunchrooms (this was a cross-sectional, secondary data analysis. Food items were categorized as local or nonlocal and placement)	FV consumption (digital photography quarter plate waste method) measured up to 5 times over 4 y	Where identified, locally sourced items were wasted more than conventionally sourced (+0.1 cups, $P < 0.0001$). Increasing prior farm to school years decreased waste (−0.02 cups, $P < 0.0001$)	Differences in local vs. nonlocal food packaging may influence consumption rates. Schools with more prior years of F2SP wasted less FV than schools with fewer years of F2SP
Bontrager Yoder (25); 2014; 1117 3rd- to 5th-grade students; Wisconsin	Weak	Noncontrolled trial	To assess the effectiveness of F2SPs in increasing students' FV consumption, knowledge, and attitudes	Nutrition education; local food promotion; local food procurement; taste tests; cooking demonstrations; V farm field trips (specific durations not provided)	Knowledge and attitudes (60-item survey), FV consumption (FFQ and lunch tray digital photography observation) collected at the start and end of the 2010–2011 academic year	Significant increases overall in knowledge (+1%), FV selection at lunch (+6%), and FV willingness to try scores (+1%, all $P < 0.001$); no change in overall dietary patterns	Farm to school programming improves mediators of FV consumption, although it does not lead to increases in overall consumption
Bristow (26); 2017; 1183 high school students; urban school district, St. Louis, Missouri	Weak	Noncontrolled trial	To determine if a locally grown sweet potato taste test and promotions will increase the selection of sweet potatoes	Taste testing (1 d); local food procurement (ongoing); local foods promotion (2 d during a 2-wk period)	Sweet potato selection (sales data) was measured on the same day that taste tests and promotions occurred	The number of servings of sweet potato selected increased from 0 at baseline to 4 at day of taste test to 24 servings 1 wk posttaste test ($P < 0.05$)	Promotions of local vegetables by taste testing are associated with increased consumption
Evans (18); 2012; 246 6–7th-grade students from 5 middle schools; Texas	Fair	Nonrandomized control trial	To test the influence of multicomponent programming on students' knowledge, attitude, preference for, and consumption of FV and also the effects of individual components on FV consumption	Integrated curriculum and nutrition education (4 lessons over 5 mo); school gardens (ongoing); farmer visits (1–2 over 5 mo); field trips (once); taste tests (3 over 5 mo); local food promotion (once/wk for 5 mo); local food procurement (once/wk for 5 mo)	FV motivation, self-efficacy, preference, and knowledge (survey); FV consumption (FFQ); pretest baseline measured in January 2009, and posttest measured in May 2009	Students exposed to 2 or more components decreased their preference for unhealthy foods (–1.05, $P < 0.01$), improved self-efficacy (1.97, $P < 0.01$), increased FV knowledge (0.57, $P < 0.01$), and increased FV servings/d consumed (0.96, $P = 0.01$), but there were no differences between intervention and comparison groups in FV motivation (0.64, $P = 0.26$) or preference (0.14, $P = 0.24$)	The treatment effect for exposure to only 1 component was limited to improvement in knowledge, but exposure to ≥2 also provided improvements in FV consumption and other nutrition attitudes
Jones (17); 2015; 15 elementary and 3 middle schools with ∼528 students per school; South Carolina	Fair	Nonrandomized control trial	To examine the impact of the first year of an F2SP on children's FV consumption	Local food procurement; school gardens; farm field trips; cooking demonstrations; promoting local foods (treatment duration is 1 school year but intensities are variable and unspecified. Exception: local food procurement—at least 2 fruits/vegetables per month)	FV consumption (digital photography Comstock plate waste method) data for treatment and control measured at the end of the school year, near or during the "South Carolina Grown Day"	4.5% more F2SP children tried V ($P < 0.05$); 3.0% fewer F2SP children tried F ($P < 0.05$). F2SP children consumed 0.11 additional servings of V ($P < 0.05$) but 0.07 fewer servings of F were consumed ($P < 0.05$)	Children in schools with an F2SP were more likely to try and consume V, but this was negatively related to trying and consuming F

(*Continued*)

TABLE 3 (*Continued*)

First author (reference no.); year; population; location	QA score	Study design[2]	Farm to school–related objective	Intervention components (duration)	Outcomes (measurement method) and when measured	Results	Farm to school implications
Moss (27); 2013; 65 3rd-grade students in 1 school; rural Illinois	Weak	Nonrandomized control trial	To test the effects of a farm field trip plus nutrition education on children's nutrition knowledge and FV consumption compared with nutrition education alone	Farm field trip (once in week 4), nutrition education (2 lectures of 30 min in weeks 2 and 3. Study duration: 4 wk)	Nutrition knowledge and FV consumption (22-item survey); pretest survey measured at week 1 and posttest survey at week 4	No relation was found between self-reported F and V consumption and participation on the farm field trip (statistics for nonsignificant findings not reported). Significant differences were found concerning knowledge of fiber ($\chi^2 = 11.6$, $P < 0.001$), vitamins and minerals ($\chi^2 = 4.4$, $P < 0.05$) among the nutrition only and nutrition + farm field trip group compared with the control	There is insufficient evidence that a farm field trip provides significant influence on FV consumption compared with nutrition education alone
Smith (28); 2012; 2130 6th-grade students; Michigan schools	Weak	Noncontrolled trial	To describe a multicomponent F2SP aiming to improve student FV consumption and knowledge	School gardens; cooking classes; farmer visits; nutrition education; local food procurement; taste tests; train food service staff; physical activity promotion (treatment duration is not provided; thus, no information is available about time lapse between baseline and postintervention)	FV consumption (not reported). Emphasis of study is on collaboration; thus, the timing of postintervention measurement is not reported	44.6% of students who did not consume at least 5 FV per day at baseline improved their consumption by at least 1 FV after intervention ($P < 0.001$)	Multicomponent F2SP may promote consumption of FV
Bates (29); 2015; 7th- through 12th-grade students; 2 schools in Provo, Utah	Strong	Crossover study	Examine the impact of serving fruit smoothies at school breakfast on daily fruit consumption	New product on menu (on the menu 13 out of 28 d of during-treatment data collection)	Selection and consumption (plate waste via quarter waste visual observation method) collected for 2–4 wk prior to the intervention and 4 wk during the intervention (68 d of data collection)	Students consuming ≥1 serving of whole fruit increased from baseline (4.3% to 45.1%; $P < 0.01$). Consumption returned to baseline levels when smoothies not offered	Students are more likely to consume smoothies than other fruit options, but this does not promote long-term behavior change
Blom-Hoffman (30); 2004; 91 kindergarten and 1st-grade students; underresourced urban school; northeastern United States	Strong	Cluster randomized trial	Examine the impact of a multicomponent nutrition program on nutrition knowledge and school lunch vegetable consumption	Nutrition education; taste tests; parent engagement; food coaches (class-room/knowledge/home component included a 5-wk intervention)	Nutrition knowledge (7-item survey) measured as pretest, posttest, and follow-up, vegetable consumption (visual observation using Comstock scale measured across 3 lunch periods during pretest, posttest, and follow-up)	Nutrition knowledge significantly higher in experimental group compared with control group ($P = 0.0001$), and the experimental group's knowledge scores were maintained at 1 mo later. There was no significant change in vegetable consumption (mean: 3.46% at pretest and 3.21% at posttest)	Multicomponent programs increase students' nutrition knowledge despite variable intervention integrity, but they will not have an impact on vegetable consumption

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TABLE 3 (*Continued*)

First author (reference no.); year; population; location	QA score	Study design[2]	Farm to school–related objective	Intervention components (duration)	Outcomes (measurement method) and when measured	Results	Farm to school implications
Bogart (31); 2014; 2997 7th-grade students in Los Angeles Unified School District; Los Angeles, California	Strong	Cluster randomized Trial	To test the impact of a multicomponent intervention, including healthy food promotion and sliced/snack-size FV, on NSLP participation and FV selection	Smarter Lunchrooms; taste tests; physical education; nutrition promotions; food coaches (January 2009–June 2012; 5-wk interventions in spring semesters)	Lunch participation (administrative data), FV selection (sales data). Administration and sales data were collected for intervention duration	15.3% increase in F selection ($P = 0.006$), 10.4% increase in lunches served ($P < 0.001$); 2.2% increase, but not statistically significant, in V selection ($P > 0.1$)	Multicomponent programming may influence students' meal participation and F selection decisions, but a more intensive intervention may be required to shape V decisions
Cohen (32); 2015; 968 students, 3rd through 8th grade; 2 urban low-income school districts in Massachusetts	Strong	Cluster randomized trial	Test the association of a chef intervention and Smarter Lunchrooms intervention on school food selection and consumption	Chef-enhanced meals (7 mo of total exposure); train food service staff (no specified duration); Smarter Lunchrooms (4 mo; started 3 mo in the Chef intervention for treated schools)	Selection and consumption of school meal components (individual food weights) data were collected in 6 d per school: 2 randomly selected nonconsecutive days for the baseline and 2 d in each of the 2 postintervention data collection periods	At 3 mo, V selection increased in chef vs. control schools (OR: 1.75; 95% CI: 1.36, 2.24). At 7 mo, V selection increased in the chef (OR: 2.54; 95% CI: 1.83, 3.54), Smarter Lunchrooms (OR: 1.91; 95% CI: 1.46, 2.50), and chef plus Smarter Lunchrooms (OR: 7.38; 95% CI: 5.26, 10.35) schools compared with the controls. Smarter lunchrooms alone had no effect on V consumption (OR: −10.7%; 95% CI: −23.8%, 2.4%), but consumption increased in chef (OR: 24.5%; 95% CI: 10.0%, 39.0%) and chef plus Smarter Lunchroom schools. At 3 mo, F selection did not increase in a statistically significant way in chef vs. control schools (OR: 1.46; 95% CI: 0.67, 3.21). Long-term F selection increased in the chef (OR: 3.08; 95% CI: 2.23, 4.25), Smarter Lunchroom, (OR: 1.45; 95% CI: 1.13, 1.87), and chef plus Smarter Lunchroom (OR: 3.10; 95% CI: 2.26, 4.25) schools compared with controls. Among students selecting F, consumption was higher in chef schools (OR: 0.17 cups/d; 95% CI: 0.03, 0.30), whereas the Smarter Lunchroom had no effect (OR: −0.00 cups/d; 95% CI: −0.13, 0.11)	Children may require repeated, long-term exposure to new foods in order to influence their selection and consumption behaviors. Chef interventions alone or in combination with Smarter Lunchrooms may improve selection and consumption of school meals

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TABLE 3 (*Continued*)

First author (reference no.); year; population; location	QA score	Study design[2]	Farm to school–related objective	Intervention components (duration)	Outcomes (measurement method) and when measured	Results	Farm to school implications
Folta (33); 2006; 880 elementary school students; Boston metropolitan area	Strong	Cluster randomized trial	Test the effectiveness of promotional messages on selection of legumes at school lunch	Nutrition promotion (30- to 60-s message promoting bean dishes played once a day for 1 wk over the public address system)	Lunch entrée selection (plate waste via visual observation)—every day a bean dish was served	There were no overall significant differences between intervention and control schools (OR: 0.93; 95% CI: 0.81, 1.07; $P = 0.31$). Students who received daily messaging were 2.47 times more likely (95% CI: 1.74, 3.53; $P < 0.001$) to select a bean dish compared with students in the control school	Messages alone were not enough to significantly influence behavior. However, the overall message dose may not have been strong enough to change behavior
Foster (34); 2008; 1349 4th- through 6th-grade students from 10 schools; mid-Atlantic region	Strong	Cluster randomized trial	To examine the impact of a multicomponent intervention on the prevention of overweight and obesity	Integrated curriculum (2 y); nutrition education (50 h of nutrition education per student/school year); nutrition promotions; parent education (various frequency: home and school association meetings; report card nights; weekly nutrition workshops); school nutrition policies (all food served was changed in the intervention schools for the 2 school years)	BMI (*z* scores), dietary intake (FFQ), collected at baseline (spring semester) and then after 2 y (spring semester)	Students in the intervention were 35% less likely to be overweight after 2 y (OR: 0.65; 95% CI: 0.54, 0.79; $P < 0.01$). There was no significant change in obesity prevalence (OR: 1.09; 95% CI: 0.85, 1.40; $P = 0.48$) or in dietary intake, expressed as total energy in kJ/d (OR: −104.27; 95% CI: −234.29, −25.73; $P = 0.12$); total fat in g/d (OR: −3.78; 95% CI: −8.59, 1.02; $P = 0.12$); F and V, *n* per day (OR: −0.04; 95% CI: −0.37, 0.30; $P = 0.82$)	A multicomponent program may decrease the prevalence of overweight children
Hendy (35); 2005; 346 1st-, 2nd-, and 4th-grade students; rural eastern Pennsylvania	Strong	Cluster randomized trial	Test effectiveness of a multicomponent intervention on FV preference and consumption	Smarter Lunchrooms; incentives for FV consumption; peer modeling (12 meals observed 3 d/wk; total intervention length not disclosed by authors)	Student FV consumption (plate waste via visual observation collected during intervention), FV preference (hedonic scoring interviews conducted 2 wk and 7 mo postintervention)	Significant association between reinforcement condition (F or V) and associated item consumption, but increases in V consumption were not sustained. Fruit preference ratings increased ($P < 0.02$) and V preference ratings also increased but did not reach significance ($P < 0.07$). FV preference returned to baseline 7 mo after intervention completion	Improving child choice and providing incentives may have an initial impact on food preferences and consumption, but these gains may not be sustained without additional intervention
Hoffman (36)[3]; 2010, 297 kindergarteners and 1st graders; urban northeastern United States	Strong	Cluster randomized trial	Examine the association of intervention components on student consumption of FV during school lunch over 2 y	Nutrition promotions; food coaches (2 y)	FV consumption (individual food weights), FV preference and knowledge (20-item and 9-item surveys); measurements collected each spring during the intervention	Significant increase in consumption of FV at end of year 1 (F = 18 g, $P < 0.001$; V = 7 g, $P < 0.01$) and of F at end of year 2 (F = 7 g, $P < 0.001$); no difference for V at end of year 2; no significant differences in FV preferences or BMI	Initial gains in FV consumption but no long-term gain in V consumption

(*Continued*)

TABLE 3 (*Continued*)

First author (reference no.); year; population; location	QA score	Study design[2]	Farm to school–related objective	Intervention components (duration)	Outcomes (measurement method) and when measured	Results	Farm to school implications
Hoffman (37)[3]; 2011; 297 kindergarteners and 1st graders; urban northeastern United States	Strong	Cluster randomized trial	Examine the impact of a multicomponent nutrition promotion intervention on student consumption, preference, and knowledge of FV, and on BMI over 3.5 y	Nutrition promotions; food coaches (2.5 y)	FV consumption (individual food weights), FV preference and knowledge (20-item and 9-item surveys), and BMI; measurements collected 5 times across 3.5 y (preintervention and each spring thereafter)	Student FV knowledge was 0.5 points ($P < 0.05$) higher than controls 3.5 y after intervention. No long-term impact on consumption, preferences, or BMI	Initial gains in FV consumption are difficult to maintain over the long term, but the impact on knowledge is more feasibly sustained
Perry (38); 2004; 1820 1st- and 3rd-grade students, 2 school districts; Minneapolis and Saint Paul, Minnesota	Strong	Cluster randomized trial	To determine if a cafeteria-based intervention would increase FV consumption	Nutrition promotion; Smarter Lunchrooms; taste tests; train food service staff (2 consecutive school years)	FV consumption (visual observation); measurements collected at the end of the intervention (after 2 y)	Significantly higher intakes of total consumed FV servings (0.14, $P = 0.03$) and fruits (0.17, $P < 0.01$); not statistically different intakes for fruit juice (–0.01, $P = 0.77$) or vegetables (–0.06, $P = 0.32$)	Cafeteria promotions are effective in creating modest FV consumption increases, but they may be more effective in concert with other interventions
Reynolds (39); 2000; 1698 4th-grade students from 28 schools	Strong	Cluster randomized trial	To test the association of a multicomponent dietary intervention on student FV consumption and psychosocial measures	Nutrition education; taste tests; Smarter Lunchrooms; train food service staff; parent outreach (2 consecutive school years)	FV consumption (24-h recall, plate waste via visual observation); psychosocial measures such as nutrition knowledge and self-efficacy (67-item questionnaire); questionnaire administered at baseline; 1- and 2-y measurements collected at least 1 mo after termination of that year's intervention	Significant difference in consumption of FV servings between groups at follow-up 1 (3.96 vs. 2.28 servings; $P < 0.0001$) and follow-up 2 (3.2 vs. 2.21 servings; $P < 0.0001$), but these 24-h recall outcomes were not able to be replicated via visual observation. The intervention groups had significantly higher nutrition knowledge scores at follow-up 1 and 2; intervention group self-efficacy scores were higher at follow-up 1 only (0.240 vs. 0.014; $P < 0.0004$)	Multicomponent nutrition education is associated with increased consumption of FV over the long term, but challenges with lunch time constraints may have limited impacts to out of school meals
Wells (19); 2015; 3061 2nd-, 4th-, and 5th-grade students in 49 low-income schools throughout the United States	Strong	Cluster randomized trial	To examine the effects of a school garden intervention on the science knowledge of elementary schoolchildren	School gardens; integrated curriculum (2 consecutive school years)	Nutrition and plant science knowledge (7-item questionnaire); survey administered at baseline and at 3 points during the intervention	Intervention group showed greater increases in knowledge (an increase from 3.2 out of 7 correct answers to 3.84; $P < 0.0001$). Schools with higher garden intervention fidelity experienced the highest increases in science scores (increased by 0.78; $P < 0.0001$)	A robust school garden intervention combined with integrated curriculum may lead to modest increases in science knowledge among low-income students

(*Continued*)

TABLE 3 (*Continued*)

First author (reference no.); year; population; location	QA score	Study design[2]	Farm to school–related objective	Intervention components (duration)	Outcomes (measurement method) and when measured	Results	Farm to school implications
Willi (40); 2012; 4363 6th-grade students; 42 middle schools throughout the United States	Strong	Cluster randomized trial	To test the association of a multicomponent intervention on cardiovascular disease risk in middle school students	Nutrition promotion; physical education; serving healthier options in cafeteria (2.5 consecutive school years)	Blood pressure, fasting blood lipids, BMI; measurements taken at baseline and end of study	No significant associations of blood lipids, BMI, or overall blood pressure; significant decrease in the occurrence of hypertension (from 13.8% to 8.3%) in non-Hispanic black males ($P = 0.0073$) and of hypertension (from 11.5% to 6.5%) in non-Hispanic white males ($P = 0.0370$)	A multicomponent program may not improve overweight/obesity or blood pressure overall, but it may reduce blood pressure in high-risk populations
Williams (41); 2016; 225 3rd- through 5th-grade students; New York City public schools	Strong	Cluster randomized trial	To test the impact of calorie labels and culturally appropriate nutrition promotions and nutrition education on snack purchases at school	Nutrition promotion; nutrition education (18 mo)	Snack selection (snack sales data); collected 1, 7, and 12 d after the intervention depending on the site	20% decrease in total kilocalories per snack ($P < .01$) postintervention; increase in number of healthy food sales from 8% to 36% ($P < 0.01$) and decrease in unhealthy foods from 51% to 36% ($P < 0.01$) postintervention	Culturally relevant nutrition education paired with calorie labeling may improve snack choices of students at school

[1]Studies that explicitly investigated F2SP are presented first, followed by studies that investigated farm to school–related activities. F, fruit; F2SP, farm to school program; FV, fruit and vegetable; NSLP, National School Lunch Program; QA, quality assessment; V, vegetable.
[2]Study designs were cataloged according to definitions developed by the Academy of Nutrition and Dietetics (23).
[3]There are data overlap between these 2 studies.

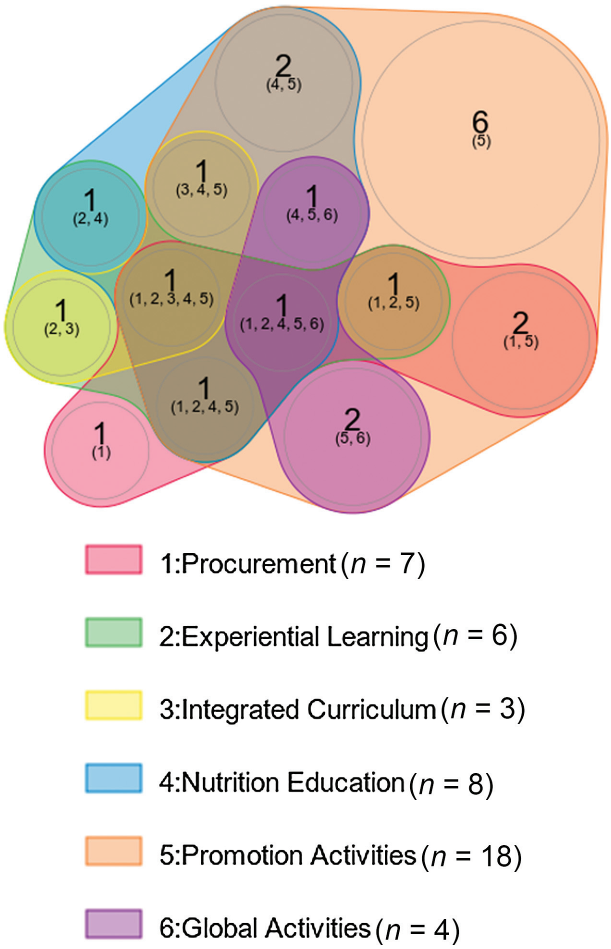

FIGURE 2 Euler diagram depicting the degree of overlap in farm to school activity categories investigated in the 21 included studies. Each farm to school activity category is numbered from 1 to 6 and is also identified by a color. The size of each circle states and is scaled according to the number of studies it represents. The set (or combination) of farm to school activity categories represented by each circle is listed in parentheses.

F2SP studies

All of the F2SP studies ($n = 7$) were published between 2012 and 2017. More than half of the studies ($n = 4$) included ≥1 elementary schools, and 42.9% ($n = 3$) included ≥1 middle schools. Nearly all ($n = 6$) of the studies were multicomponent, and most studies also incorporated local food procurement ($n = 6$). Local foods promotion ($n = 4$), taste tests ($n = 4$), nutrition education ($n = 3$), school gardens ($n = 3$), and cooking activities ($n = 3$) were also frequent intervention components. The majority of the F2SP studies ($n = 5$) assessed fruit and/or vegetable consumption. Nutrition-related knowledge ($n = 3$) was another common outcome measure. Noncontrolled trials ($n = 3$) and nonrandomized control trials ($n = 3$) were the most prevalent study designs. Four F2SP studies had weak quality assessment scores, and the remainder ($n = 3$) were scored as fair (Table 3).

Table 4 provides a summary of the relations between F2SP and student outcomes. Two F2SP studies had overall desirable findings regarding the impacts of F2SPs on student outcomes. Smith et al. (28) used a noncontrolled trial design to investigate the impact of school gardens, cooking classes, farmer visits, nutrition education, local food procurement, taste tests, and training food service staff on middle school student fruit and vegetable (FV) consumption. Students who were not consuming ≥5 servings of FV at baseline improved FV consumption following the multicomponent intervention. However, no information was provided about how dietary intake was measured or how the intervention impacted student FV consumption overall (28). In another noncontrolled trial, Bristow et al. (26) investigated the influence of local procurement, taste tests, and local foods promotion on student selection of sweet potatoes during school lunch. The number of locally grown sweet potato servings selected by the 123 high school students participating in school lunch increased from 0 at baseline to 4 at day of taste test and to 24 servings 1 wk posttaste test ($P < 0.05$) (26).

Two F2SP studies found undesirable or mixed outcomes as a result of F2SP interventions (Table 4). Using a repeated cross-sectional design, Bontrager Yoder et al. (24) investigated the impact of local food procurement on student FV waste. They found that more locally procured school lunch items were wasted compared with conventionally sourced foods (+0.1 cups, $P < 0.0001$). However, there were missing data regarding food sourcing and differences in how conventionally and locally procured food items were presented (packaged and sliced compared with not) that may have influenced these results. In addition, the number of prior years that schools participated in F2SPs was inversely related to plate waste (−0.02 cups, $P < 0.0001$) (24). A nonrandomized controlled trial by Jones et al. (17) investigated the impact of a multicomponent F2SP featuring local food procurement, school gardens, farm field trips, cooking demonstrations, and local food promotion. Results showed that 4.5% more children in the F2SP intervention group tried vegetables ($P < 0.05$) and consumed 0.11 additional vegetable servings ($P < 0.05$) compared with the control group. However, 3.0% fewer F2SP children tried fruit ($P < 0.05$) and consumed 0.07 less servings of fruit ($P < 0.05$) compared with the comparison students; the authors partially attribute this unexpected finding to differences in à la carte snacks that were offered during lunches at the intervention schools (17).

Three F2SP studies had at least some nonsignificant results (Table 4). In Bontrager Yoder et al.'s (25) noncontrolled trial, there were significant increases in knowledge of food, nutrition, and agriculture (+1.0%), FV selection at lunch (+6.0%), and willingness to try FV (+1.0%; all $P < 0.001$) after a multicomponent F2SP, but there was no change in overall FV consumption. The intervention included nutrition education, local food procurement, taste tests, and farm field trip components (25). Using a nonrandomized control study design, Evans et al. (18) tested the influence of multicomponent programming on students'

TABLE 4 Summary of the relations between farm to school activities and student outcomes[1]

Student outcome	Relation with farm to school activity: Desirable	No significant change	Undesirable	Inconsistent
Knowledge				
Nutrition	Reynolds (39), Hoffman (36),[2] Hoffman (37)[2], *Moss* (27), *Evans* (18)	—	—	—
Nutrition, food, and agriculture	*Bontrager Yoder* (25), Wells (19)	—	—	—
Motivation, FV	—	*Evans* (18)	—	—
Self-efficacy, FV	*Evans* (18), Reynolds (39)	—	—	—
WTT foods				
WTT, fruit	—	—	*Jones* (17)	—
WTT, FV	*Bontrager Yoder* (25)	—	—	—
WTT, vegetables	*Jones* (17)	—	—	—
Food preferences				
Fruit	Hendy (35)[3]	—	—	—
FV	—	Hoffman (36),[2] Hoffman (37),[2] *Evans* (18)	—	—
Unhealthy foods	*Evans* (18)	—	—	—
Vegetables	—	Hendy (35)	—	—
Meal participation	Bogart (31)	—	—	—
Meal item selection				
Entrée	—	—	—	Folta (33)
Fruit	Cohen (32), Bogart (31)	—	—	—
FV	*Bontrager Yoder* (25)	—	—	—
Healthy snacks	Williams (41)	—	—	—
Vegetables	Cohen (32), *Bristow* (26)	Bogart (31)	—	—
Consumption				
Fruit	Hendy (35),[2] Hoffman (36),[2] Bates (29)	—	*Jones* (17)	Cohen (32)
FV	Perry (38), *Evans* (18), *Smith* (28)	*Moss* (27), Hoffman (37)[2]	—	Reynolds (39)
Overall diet	—	Foster (34), *Bontrager Yoder* (25)	—	—
Vegetables	*Jones* (17), Hendy (35),[3] Hoffman (36)[3]	Blom-Hoffman (36)	—	Cohen (32)
Waste	—	—	—	*Bontrager Yoder* (24)
Anthropometric and physiologic				
Blood lipids	—	Willi (40)	—	—
Blood pressure	—	—	—	Willi (40)
BMI	—	Hoffman (36),[2] Hoffman (37),[2] Willi (40)	—	—
Obesity prevalence	—	Foster (34)	—	—
Overweight prevalence	Foster (34)	—	—	—

[1] All explicitly farm to school studies were included in this review, but only strong farm to school–related activities were included. Farm to school program studies are italicized. Studies are listed by first author name. FV, fruit and vegetable; WTT, willingness to try.
[2] Results were sustained in follow-up measures.
[3] Results were initially desirable but not significantly different at follow-up.

knowledge, attitudes, preference for, and consumption of FV. Intervention components included an integrated nutrition education curriculum, school gardens, farmer visits, taste tests, local food promotion, and local food procurement. Students exposed to $\geq$2 components decreased their preference for unhealthy foods (–1.05, $P < 0.01$), improved self-efficacy (1.97, $P < 0.01$), increased their FV knowledge (0.57, $P < 0.01$), and increased FV servings per day consumed (0.96, $P = 0.01$), but there was no difference between intervention and comparison groups in preference or motivation for eating FV. The farmer visit component had the largest treatment effect on FV consumption (+0.52 servings/d), followed by taste tests (+0.45 servings/d) and local food procurement (+0.42 servings/d), but these effect sizes were not statistically significant (18). Another nonrandomized control trial conducted by Moss et al. (27) investigated the impact of adding a farm tour in addition to nutrition education on children's nutrition knowledge and FV consumption. There was no relation between self-reported FV consumption and participation in the farm tour, but significant differences were found concerning knowledge of fiber ($\chi^2 = 11.697$, $P < 0.001$) and vitamins and minerals ($\chi^2 = 4.458$, $P < 0.05$) among the nutrition only group and nutrition plus farm tour group compared with the control group (27).

Studies featuring F2SRAs

All the F2SRA studies ($n = 14$) were published between 2000 and 2016. Most of the studies ($n = 11$, 78.6%) included $\geq$1 elementary schools, and 35.7% ($n = 5$) included $\geq$1 middle schools. Fruit and/or vegetable consumption was the most common outcome measure ($n = 8$, 57.1%), followed by fruit and/or vegetable selection ($n = 4$, 28.6%) and BMI-related outcomes ($n = 4$, 28.6%). All the included farm to school activity studies were of strong quality and consisted of cluster randomized trials ($n = 13$, 92.9%) and crossover studies ($n = 1$, 7.1%). Most F2SRA studies ($n = 12$, 85.7%) had multicomponent interventions, most commonly including nutrition promotion ($n = 9$, 64.3%), Smarter Lunchrooms strategies ($n = 6$, 42.9%), and nutrition education ($n = 5$, 35.7%). The complex nature of the multicomponent interventions made it difficult to parse out individual study results for each farm to school activity category. Subsequently, detailed study findings are only provided when study designs enable the isolation of individual farm to school activity impacts.

Experiential learning and procurement studies.

Although very common in F2SP studies, there was only 1 F2SRA study featuring an experiential learning intervention and 1 featuring a procurement intervention. Wells et al. (19) implemented a school garden intervention, which also included an integrated science curriculum component using a cluster randomized trial design. The intervention group showed greater increases in nutrition and plant science knowledge ($P < 0.0001$), and schools with higher measures of intervention fidelity experienced the highest increases in science scores ($P < 0.0001$) (19). Bates and Price (29) used a crossover trial design to investigate the impact of a new menu item, fruit smoothies, on fruit consumption during school breakfast. The number of students consuming ≥1 servings of whole fruit increased from baseline (from 4.3% to 45.1%; $P < 0.01$). Consumption returned to baseline levels when the smoothie was not offered (29).

Integrated curriculum and nutrition education studies.

Six studies featured nutrition education and/or an integrated curriculum, and all of them utilized a cluster randomized trial design. The majority (83.3%, $n = 5$) involved nutrition education, 1 study provided garden-based education (16.7%), and 2 studies integrated their education component into academic standards (19, 34). All 6 nutrition education and/or integrated curriculum studies were multicomponent and most frequently included nutrition promotions ($n = 5$) and/or taste tests ($n = 2$). Most study outcomes were desirable (Table 4), including improved knowledge (19, 30, 39), increased healthy snack selection (41), improved self-efficacy (39), and decreased overweight prevalence (34). There was 1 study with inconsistent findings for FV consumption (39). Two studies found no significant changes in vegetable consumption (30), dietary intake (34), and/or obesity prevalence (34).

Promotion studies.

The most common F2SRA in non-F2SP studies was promotion interventions ($n = 12$). Promotion interventions consisted of social marketing of healthy eating habits ($n = 7$), Smarter Lunchrooms ($n = 5$), taste tests ($n = 4$), and/or food coaches ($n = 4$). All non-F2SP studies featuring promotion components utilized a cluster randomized trial design ($n = 12$). Although most promotion studies ($n = 11$) were multicomponent, 2 studies were able to isolate the impact of a promotion intervention. Folta et al. (33) examined the impact of promotional messages delivered over the school public address system for bean dishes served at school lunch on bean selection. They found no overall significant differences between intervention and control schools in bean selection; however, the authors noted that there was unintended variation in the frequency of promotional message implementation among the interventional schools. Students who received daily promotional messages about legumes over the school intercom were 2.47 times more likely (95% CI: 1.74, 3.53; $P < 0.001$) to select a bean dish compared with students in the control school, suggesting that the intervention was most successful when it was delivered most frequently (33). A cluster randomized trial by Cohen et al. (32) examined the impact on schools that received Smarter Lunchroom interventions compared with schools that received Smarter Lunchrooms plus chef-enhanced meals ("chef" intervention) and with control schools. Both fruit selection and vegetable selection increased in the chef (respectively: OR: 3.08; 95% CI: 2.23, 4.25; and OR: 2.54; 95% CI: 1.83, 3.54), Smarter Lunchroom (respectively: OR: 1.45; 95% CI: 1.13, 1.874; and OR: 1.91; 95% CI: 1.46, 2.504), and chef plus Smarter Lunchroom (respectively: OR: 3.10; 95% CI: 2.26, 4.254; and OR: 7.38, 95% CI: 5.26, 10.354) schools compared with controls. Smarter Lunchrooms alone had no effect on consumption, but consumption increased in chef (0.17 cup fruit increase, 95% CI: 0.03, 0.30 cups/d; and 0.16 cup vegetable increase, 95% CI: 0.09, 0.22 cups/d) and chef plus Smarter Lunchroom schools (0.13 cup vegetable increase, 95% CI: 0.05, 0.19 cups/d); there were no significant changes in fruit consumption. However, note that these evaluations were completed 7 mo after exposure to the chef intervention and only 4 mo after Smarter Lunchrooms (32).

The remaining 10 promotion studies were all multicomponent and most frequently included nutrition education ($n = 4$), training food service staff ($n = 2$), and multiple types of promotion interventions ($n = 6$). Nine of these studies reported ≥1 desirable findings (Table 4): increased school lunch participation (31), improved nutrition knowledge (30, 37, 39), increased fruit selection (31), increased healthy food selection (41), improved vegetable consumption (35, 36), improved fruit consumption (35, 36), improved FV consumption (38), increased fruit preference (35), improved self-efficacy (39), and decreased overweight prevalence (34). Two multicomponent promotion studies had inconsistent results for FV consumption (39) or blood pressure (40). Seven multicomponent promotion studies had ≥1 nonsignificant results for vegetable selection (31), vegetable consumption (30, 37), fruit consumption (37), dietary intake (34), vegetable preference (35), FV preference (36, 37), blood lipids (40), obesity prevalence (34), and/or BMI (37, 40).

Global activities studies.
Although many studies included researcher-initiated plate waste studies, none of them tested the influence of plate waste measures on future selection, consumption, waste, or any other student outcome. There were 3 studies featuring global activities, which all consisted of training food service staff. All of the global activity studies were multicomponent and most frequently included taste tests ($n = 2$) and Smarter Lunchrooms ($n = 3$). All of the global activities studies were cluster randomized trials. Results consisted of increased nutrition knowledge (39), fruit selection (32), increased vegetable selection (32), increased FV consumption (38), and improved self-efficacy (39). Two studies reported inconsistent results for FV consumption (32, 39).

Common study strengths and limitations

The included studies shared some common limitations. The most common study limitations for F2SRA studies include outcome measurement with no reported or limited psychometric testing and challenges related to quantifying intervention implementation. In addition to these limitations, none of the F2SP studies utilized study designs that allow causal influence. Furthermore, intervention activities, frequency, and/or duration often varied within treatment groups. Few studies (18, 19, 33) adjusted for intervention provision variation in the analysis, and the number of children exposed to the intervention relative to the number of children receiving the intervention was rarely quantified (18, 19). Similarly, there was a large variance in the scope or dose of the provided farm to school activities. For example, the number of reported nutrition or gardening education lessons ranged from 2 lessons of unspecified duration (27) to 50 total hours of nutrition lessons (34), with many studies not reporting the number and/or duration of provided lessons, making it difficult to compare intervention effectiveness across studies. In addition, most studies failed to provide details about the theoretical underpinnings of the intervention, making it difficult to compare motivating and facilitating theoretical determinants and how they are addressed.

In contrast, several included F2SP and F2SRA studies did address intervention fidelity. Blom-Hoffman et al. (30) examined the impact of classroom nutrition education and lunchroom food coaches where researchers conducted unannounced integrity checks across 28% of the lessons and 21% of the lunches. The authors found high levels of lunchroom variability of food coaching and concluded that students increased nutrition knowledge despite implementation variability, but the variation may have contributed to the lack of significant impact on vegetable consumption. Wells et al. (19) included a variable for garden intervention fidelity, which was composed of the number of lessons delivered, number of FV plants planted, number of FV harvested, and number of ways students were exposed to the FV harvest. Other reported intervention fidelity measures included unannounced structured observations by research staff (36, 37), student interviews or self-report of intervention exposure (18, 36, 37), and/or teacher interviews or report of intervention exposure (18, 37).

Although most studies only assessed short-term interventions, 3 studies assessed outcomes after the intervention period ended and emphasized the importance of measuring longer-term outcomes to understand intervention impacts. Hendy et al. (35) examined the change in FV consumption and preferences before, during, 2 wk after, and 7 mo after an intervention in which children received nutrition promotion and positive reinforcement for eating FV. Increased FV consumption from baseline occurred during the intervention but was not measured at follow-up. FV preferences also increased at 2 wk postintervention from baseline, but they returned to baseline levels 7 mo later (35). Hoffman et al. (36) examined the longitudinal impact of a 2-y nutrition promotion and food coach intervention on student knowledge and FV consumption. FV consumption improved at the end of year 1, but at the end of year 2 only the increases in fruit consumption were sustained (36). Despite the fact that 1 y later there were no differences between intervention and control groups, there were persistent increases in children's knowledge across the 3.5-y time period (37). Reynolds et al. (39) investigated the impact of a multicomponent nutrition education and promotion program on student FV consumption at baseline, after the intervention, and 1 y postintervention. Children in the intervention group had significantly higher FV consumption after the intervention (3.96 servings for intervention compared with 2.28 servings for control, $P < 0.0001$) and 1 y later (3.20 servings for the intervention compared with 2.21 servings for control, $P < 0.0001$) (39).

Discussion

This study systematically assessed the relation between F2SP and F2SRA on student outcomes. There are few peer-reviewed studies that assess the impacts of farm to school activities on student outcomes, and these studies have significantly more limitations compared with other school-based food and nutrition studies, likely due to the emerging nature of this research area. Results from F2SP and F2SRA studies consistently show positive impacts on food and nutrition-related knowledge; most studies also suggest a positive relation between farm to school activities and healthy food selection during school meals, nutrition self-efficacy, and willingness to try FV. Yet, the studies included in this review had conflicting results on the relation between farm to school activities and FV consumption, as well as FV preferences. It is also important to note that studies identified as higher quality by the Health Evidence Quality Assessment Tool (22) presented little evidence that farm to school activities impact health outcomes such as BMI, blood lipid levels, and blood pressure. However, this review revealed a crucial gap of long-term assessments of farm to school activities.

All ($n = 7$) of the F2SP studies and 85.7% ($n = 12$) of the F2SRA studies were multicomponent, and there was a wide variety of implemented intervention components across the reviewed studies. The multicomponent nature of school nutrition interventions aligns well with the Whole School, Whole Community, Whole Child model (42) and the socioecological model (43), which both stress the interrelated sectors of influence required to influence behavior change and improve student health and academic outcomes. Although these holistic frameworks are most likely to stimulate behavior change, one of the main drawbacks of this multicomponent approach is the inherent difficulty of determining which elements work and which do not, necessitating school nutrition programs to replicate each intervention component in order to bring about desired results. Given the questionable feasibility of replicating these large, multicomponent interventions, as well as the limited time and resources of school staff, it is prudent to scale down interventions so that they are as efficient as possible. Future research of multicomponent F2SPs may consider scaffolding interventions as done by Cohen et al. (32) and/or incorporating intervention fidelity measurement into outcomes assessment as advised by Curran et al. (44) and exemplified by others (16, 18, 19, 45).

In addition to being multicomponent, F2SPs are broadly defined, allowing schools to tailor interventions to suit their needs, interests, and constraints. Although its loose definition likely appeals to schools, it yields much variation in program implementation, which adds to the challenges of assessing the efficacy of even the most commonly implemented farm to school activities. For example, local food procurement is the most frequently implemented F2SRA, with 77% of F2SP schools implementing it according to the 2015 Farm to School Census (7). Among the studies included in this review, the 6 F2SP studies with a local food procurement component included 1–6 additional components. Thus, it is unclear what role local food procurement played in the findings of these studies, relative to the other implemented components. There was only 1 strong-quality F2SRA study related to procurement. In this study, Bates and Price (29) reported improved fruit consumption after a new fruit smoothie was added to the breakfast menu. Although this is a strongly designed study and farm to school activities include working with local food producers to develop new menu items, Bates and Price's findings do not necessarily indicate that local food items will improve FV consumption. However, the study results do suggest the potential of well-accepted or more convenient FV menu items to improve dietary behaviors.

Promotions were the most commonly implemented F2SRA in the studies reviewed for quality assessment. Similarly, 3 of the top 5 activities reported by school districts in the 2015 Farm to School Census were promotions (7). The most common promotions investigated in F2SP studies were local food taste tests (18, 25, 26, 28) and local food promotions (17, 18, 25), whereas the F2SRA study promotions most frequently consisted of general nutrition promotion (i.e., social marketing of nutrition messages; (31, 33, 34, 36–38, 40), Smarter Lunchrooms strategies (31, 32, 35, 38, 39), and taste tests (30, 31, 38, 39). These F2SP promotion studies netted inconsistent and nonsignificant results, particularly for FV consumption. The F2SRA studies with positive FV consumption results tended to have intervention components that were not related to F2SP, such as providing incentives for FV consumption (35), student competitions for highest FV consumption (38), and school–chef partnerships to improve student acceptability of menu items (32). This suggests that the available evidence on the effectiveness of nutrition promotions may not be appropriate to interpret the effectiveness of promotions commonly used in F2SPs. In addition, the dietary assessment method used in some of the promotion studies (18, 34, 39) may not have been able to detect changes in dietary consumption. For example, Foster et al.'s (34) multicomponent intervention, which used an FFQ to assess dietary intake among 4th- to 6th-grade children, resulted in decreases in overweight prevalence among the intervention group relative to the controls, but there were no significant differences in dietary intake between the intervention and control groups even though the intervention was largely nutrition focused and had no child physical activity component. FFQ and diet screeners have higher cognitive difficulty and require more generalized memory recall compared with other dietary assessment techniques (46), and these limitations may be exacerbated when used with children (47, 48).

Another key finding of this review is the lack of high-quality studies evaluating experiential learning farm to school activities. Wells et al.'s (19) study evaluating the impact of a school garden integrated curriculum intervention was the only relevant study assessed as strong in quality. According to the 2015 Farm to School Census (7), approximately one-third of schools conducted student field trips to farms or orchards, which was the most commonly reported experiential learning activity in 2015. Moss et al. (27) concluded that there was no significant difference in self-reported FV consumption when a farm field trip was added to a nutrition education intervention; however, this study was rated as weak in quality. Additional strongly designed studies are needed to assess the impact of farm field trips, school gardens, and/or cooking activities in F2SPs.

The existing F2SP and F2SRA studies do not provide evidence of a link between nutrition education and improved FV consumption. It is unclear whether the lack of findings is due to the ineffectiveness of F2SPs or due to poor intervention fidelity, insufficient intervention dosage, and/or inadequate outcome measurement. In Struempler et al.'s (45) study of a 17-class childhood obesity prevention program, 98% of the increases in FV consumption occurred by class 10 of 17. This suggests that a series of classes may be required to achieve change in dietary behavior and supports the use of process evaluation to determine required intervention dose in order to conserve time and resources. Many F2SP and F2SRA studies in this review did not report intervention fidelity and/or quantify the duration and reach of specific intervention components, making it difficult to assess intervention dose adequacy. Without this information, it is also difficult to assess the feasibility of various F2SP implementation doses because most studies do not specify the original intended doses and actual implementation dose achieved. Three studies (18, 19, 33) included in this review reported intervention dose delivery at lower levels than were originally planned and reported only small or no significant change in outcome measures in the overall sample. However, there were significant dose–response relations among farm to school activity intervention implementation and science knowledge (19), nutrition knowledge (18), unhealthy food preference (18), FV self-efficacy (18), bean selection (33), and FV consumption (18).

One potential way to improve F2SP implementation fidelity, as well as the long-term sustainability of interventions, is to determine the impact of farm to school activities on academic outcomes because school staff may be more likely to adhere to intervention protocols if there are potential academic benefits (49). Although Joshi and Ratcliff (8) contend that F2SPs have the potential to influence academic achievement, only 1 study in this review assessed the relation between farm to school activities and an academic outcome (science knowledge) (19). However, there were 6 additional studies showing a positive relation between farm to school activities (30, 37, 39) or F2SPs (18, 25, 35) and nutrition-related knowledge, which suggests some potential for F2SPs to be leveraged to enhance academic achievement. The importance of linking F2SPs to academic achievements under the current educational policy climate (50) is likely why Ralston et al. (2) specified the integration of "food-related education into the regular, standards-based classroom curriculum" in a recent USDA report on F2SPs. Yet, only 3 of the 10 studies in this review that included an education component utilized an integrated curriculum. Similarly, the most commonly reported activities in the 2015 Farm to School census (7) were ones that take little or no instructional time and provide less intensive student experiences, suggesting that these interventions may be more feasible than classroom interventions. More research is needed to examine the impact and feasibility of farm to school classroom interventions that are integrated into the standards-based curriculum and also to examine the relation between F2SPs and academic outcomes.

Conversely, knowledge gains may not be a sufficient outcome from a health context. Nutrition knowledge may be a necessary step toward dietary behavior change, but knowledge increases alone are unlikely to elicit behavior change (51). Commonly utilized behavior change theories, including the health belief model (52) and the theory of planned behavior (53), suggest that outcomes such as self-efficacy and attitudes toward FV may be more appropriate behavior change intermediaries than nutrition knowledge. F2SP interventions aiming to influence children's dietary behaviors should consider implementing theory-based activities, including experiential learning opportunities (54), and corresponding evaluation metrics to determinants of desired behavior change, such as self-efficacy and food preference improvement.

This review addresses an important gap in the literature, and the findings of this review may inform the practice of the nearly 100,000 schools participating NSLP. Important strengths of this review include its interdisciplinary approach and its adaptation of a tested tool for quality assessment. However, we were unable to perform a meta-analysis due to the wide range of outcome measures and variation in metrics used. Due to the scant evidence on F2SP effectiveness, we included studies with school-based food and nutrition interventions encompassing F2SRA. However, some of these studies were only tangentially related to farm to school activities. In addition, one limitation of using the Health Evidence Quality Assessment Tool to assess paper quality is that it does not take the quality of the interventions into account. This omission from the quality assessment process makes it difficult to compare studies, particularly those with educational components, and their findings. Although F2SP studies had lower-quality research designs and perhaps a higher risk of biased study findings, they often had more intensive interventions compared with those implemented in the F2SRA studies. However, it is encouraging that there have been 7 peer-reviewed F2SP papers published since Joshi et al.'s (20) original review of F2SPs in 2008. Although these papers may have statistical and design limitations, the breadth and profundity of their interventions make important contributions to the overall understanding of F2SPs and the feasibility of school-based nutrition education, suggesting a need for continued publication of robust F2SP interventions even when they have methodological shortcomings.

Summary and recommendations for future research

There are few peer-reviewed studies on F2SPs. The available literature suggests a positive relation between farm to school activities and food and nutrition-related knowledge, as well as healthy food selection during school meals. The relation between farm to school activities and FV consumption is inconclusive, and there is no evidence that these activities significantly influence BMI, blood lipids, and/or blood pressure. Most F2SP interventions were multicomponent, making it difficult to isolate the impact of individual intervention components. Few implementation metrics were available, but their findings underscore the link between intervention integrity and student outcomes. Future research should incorporate robust process evaluation and thorough reporting of the psychosocial theories used, as well as investigate the impact of F2SPs over time.

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