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Review

Effectiveness of Food Handler Training and Education Interventions: A Systematic Review and Meta-Analysis

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ABSTRACT

Improper food handling among those working in retail and food service settings is a frequent contributor to foodborne illness outbreaks. Food safety training and education interventions are important strategies to improve the behaviors and behavioral precursors (e.g., knowledge and attitudes) of food handlers in these settings. We conducted a comprehensive systematic review to identify, characterize, and synthesize global studies in this area to determine the overall effectiveness of these interventions. The review focused on experimental studies with an independent control group. Review methods included structured search strategy, relevance screening of identified abstracts, characterization of relevant articles, risk of bias assessment, data extraction, meta-analysis of intervention effectiveness for four outcome categories (attitudes, knowledge, behavior, and food premise inspection scores), and a quality of evidence assessment. We identified 18 relevant randomized controlled trials (RCTs) and 29 nonrandomized trials. Among RCTs, 25 (64%) unique outcomes were rated as high risk of bias, primarily owing to concerns about outcome measurement methods, while 45 (98%) nonrandomized trial outcomes were rated as serious risk of bias, primarily because of concerns about confounding bias. High confidence was identified for the effect of training and education interventions to improve food handler knowledge outcomes in eight RCT studies (standardized mean difference = 0.92; 95% confidence interval: 0.03, 1.81; $I^2 = 86\%$). For all other outcomes, no significant effect was identified. In contrast, nonrandomized trials identified a statistically significant positive intervention effect for all outcome types, but confidence in these findings was very low due to possible confounding and other biases. Results indicate that food safety training and education interventions are effective to improve food handler knowledge, but more evidence is needed on strategies to improve behavior change.

HIGHLIGHTS

- Food safety training and education interventions improve food handler knowledge.
- There is low confidence that these interventions improve other food safety outcomes.
- Risks of bias were present for most study outcomes.
- Further research is needed on strategies that can change food handler behaviors.

Key words: Behavior change; Education; Food handlers; Food hygiene; Knowledge synthesis; Training

Food handlers working in restaurants and other food service settings (e.g., grocery stores) are a frequent source of foodborne illness *(39)*. For example, 17,445 (56%) foodborne illness outbreaks reported in the United States from 1998 to 2013 were associated with food prepared in a restaurant *(5)*. These outbreaks caused >140,000 illnesses, 4,427 hospitalizations, and 32 deaths, and the majority (77%) were caused by improper food handling practices and inadequate food worker health and hygiene *(5)*. These data are supported by previous observational studies, which have found that retail and food service workers frequently do not follow recommended safe food handling practices, such as adequate hand washing and food cooling practices *(12, 38, 80)*.

Food safety training and education interventions are essential to promote and enhance food safety practices among food handlers, with an aim of ultimately reducing the burden of foodborne illness associated with these settings. Numerous studies have been conducted to evaluate the effect of different training and education interventions on the food safety knowledge, attitudes, and behaviors of food handlers working in retail and food service establishments *(32, 92, 99)*. Two previous structured knowledge syntheses have been conducted to summarize the literature in this area *(92, 99)*. One meta-analysis study synthesized studies investigating interventions to improve hand hygiene outcomes *(92)*. The review identified nine relevant studies

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of various study designs and found that interventions were effective to improve food handler knowledge, attitudes, and behaviors *(92)*. Another systematic review descriptively summarized and evaluated the quality of 23 relevant studies reporting on a broader range of interventions in commercial and institutional food service settings *(99),* highlighting key study design and reporting characteristics of the included studies.

The purpose of this systematic review was to update and expand on previous work by identifying, characterizing, assessing the risk of bias, and synthesizing the global evidence on the effectiveness of different food handler training and education interventions in restaurants and other food service settings. This review includes an updated, comprehensive search for relevant evidence, no language restrictions, only the most reliable study designs to evaluate intervention effectiveness (those with an independent control group), multiple food safety outcomes, a risk of bias assessment using newly recommended tools from the Cochrane Collaboration, meta-analysis of results to identify average estimates of intervention effect, and a quality of evidence assessment to determine the level of confidence in each finding. Results can inform future research priorities, as well as recommendations for the design of future education and training interventions for food handlers.

MATERIALS AND METHODS

Review approach, question, and eligibility criteria. This review was conducted following Cochrane Collaboration guidelines for systematic reviews of interventions *(44),* and this article is reported in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines *(65)*. The review question was "What is the efficacy of different training and education interventions to improve the food safety knowledge, attitudes, and behaviors of food handlers working at retail and food service?"

The population, intervention, comparison, outcome, and study design framework was used to define the review scope and eligibility criteria *(2)*. The population of interest included studies evaluating interventions for food handlers (e.g., employees and managers) who prepare or serve food at restaurants and other food service premises (e.g., grocery stores), including institutions (e.g., schools and hospitals). Studies targeting consumers preparing food at home and food handlers at other stages of the food chain were excluded. We included studies evaluating the following types of interventions: training courses and workshops, educational messaging materials (e.g., posters and brochures), and other theory-based or motivational interventions (e.g., incentives and provision of resources). We included studies that compared the effectiveness of these interventions to any type of comparison group, including groups that received no intervention (i.e., negative control group), as well as those that received some type of standard or traditional intervention (i.e., positive control group). For example, some studies might have compared Web-based training with traditional in-person training, and these were included in this review, with the Web-based training group categorized as the intervention and the traditional intervention as a positive control group. Outcomes of interest included food handler knowledge, attitudes, and behaviors, as well as food premise inspection or audit scores. Relevant study designs included any experimental study with an independent control group, including randomized and nonrandomized designs. Uncontrolled before and after studies (i.e., single group and pre- and postcomparisons) were initially included in the larger review project but excluded from the analysis reported in this article due to their limitations in attributing changes in outcomes to the intervention *(6, 44)*.

Eligible sources of evidence included journal articles and grey literature (e.g., government research reports, dissertations and theses, and conference proceedings) published in any language. The review authors had capabilities to review in English, French, and Spanish, while translators were identified to translate articles in the following languages: Chinese, Korean, Persian, German, and Italian. For any other languages identified, we used Google Translate to obtain an approximate English language version of the article for review.

Search strategy. The search strategy was developed in collaboration with a librarian. A comprehensive search algorithm was developed by extracting key words and terms from 10 relevant articles and combining them into topic (e.g., "food safety" and "food hygiene"), population (e.g., handler* and employee*), intervention (e.g., intervention* and train*), and outcome (e.g., behavior* and knowledge) categories. The search was pretested in Scopus and then implemented on 22 January 2018 in eight bibliographic databases: Scopus, PubMed, CAB Abstracts, Food Safety and Technology Abstracts, PsycINFO, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Hospitality & Tourism Index, and ProQuest Dissertations & Theses. No publication date or other restrictions were imposed.

We also searched for grey literature documents (e.g., conference proceedings and research reports) in Google via a series of simple search strings (e.g., "food safety training research food handlers"). For these searches, the first 100 hits were searched *(14)*. A search verification strategy was used to ensure that no relevant articles were missed. This included hand searching the reference lists of all relevant articles identified in the review, as well as from five previously conducted literature reviews on the topic *(32, 63, 64, 92, 99)*. Full search details and algorithms are reported as Supplemental Material (Supplemental File S1).

Relevance screening and confirmation. All references identified in the search were uploaded to RefWorks (ProQuest LLC, Ann Arbor, MI), and duplicates were removed. References were then imported into the systematic review management program DistillerSR (Evidence Partners, Ottawa, Ontario, Canada) to facilitate the review process. References were first screened for relevance at the title and abstract level by using a structured form. The form contained one question to assess the reference's relevance to the review question and eligibility criteria. Potentially relevant references were then procured as full texts and confirmed for relevance by using a relevance confirmation and assessment form. Only studies that reported extractable outcome data suitable for meta-analysis were considered relevant at this stage. This form was also used to extract key characteristics from relevant articles, including publication details, study methods, and information on each of the population, intervention, comparison, outcome, and study design elements investigated. The relevance screening form was pretested on 50 abstracts prior to implementation, and reviewing proceeded when a kappa agreement for inclusion was >0.80. The relevance confirmation form was pretested on five articles to ensure clarity of the questions and consistent interpretation among reviewers.

Risk of bias assessment and data extraction. RCT studies were assessed for their risk of bias by using the Cochrane Collaboration's Version 2.0 tool *(45),* with different versions of the tool applied, depending on whether the study was individually or cluster randomized. Nonrandomized studies were assessed by using the "risk of bias in non-randomized studies of interventions" tool *(93)*. The tool guidelines suggest prespecification of important confounding domains that could influence participants' intervention and control group status *(93)*. We considered individual participant sociodemographics (e.g., age, gender, ethnicity, and previous food safety training) and food premise characteristics (e.g., size and operation type) as potential confounding factors that should be investigated and controlled for in relevant nonrandomized trials *(11, 37, 56, 59, 96)*. Both tools were applied at the outcome level (e.g., knowledge and behavior), so different risk of bias ratings were possible if studies reported multiple relevant outcomes.

Detailed quantitative results (i.e., outcome data) on the efficacy of interventions were extracted from each study by using a data extraction form. Relevant outcome types included dichotomous and continuous measures. Dichotomous measures were extracted as contingency tables (e.g., number of participants using or not using a behavior in intervention versus control groups), while continuous measures were extracted as mean difference comparisons. When such data were not available, other statistics were extracted (e.g., F values and t test values) that could be used to estimate an effect size *(21)*. When raw data for each participant was available, this information was extracted and used to calculate an effect size post hoc. The risk of bias assessment and data extraction forms were pretested on six articles each prior to implementation. A copy of all review forms used in this review is available as Supplemental Material (File S1).

Meta-analysis. Data were stratified into comparable subgroups for meta-analysis. Four outcome type subgroups were created: attitudes and risk perceptions, knowledge, behaviors, and food premise inspection scores. These subgroups were then divided according to the study design (RCT or nonrandomized trial) and type of control group investigated (negative versus positive control group). Given that studies used different measurement instruments and scales, we selected the Hedges' g standardized mean difference (SMD) measure as the primary effect size metric *(8)*. Studies that reported dichotomous outcomes were converted to a SMD, with the assumption that all studies were measuring the same overall outcome construct *(8)*. Negative outcomes (e.g., number of inspection violations) were reverse coded for analysis to ensure that positive score values corresponded with more desirable outcomes.

Some studies reported multiple intervention groups, and these were combined into one group for meta-analysis, where possible, by using the formula reported in Higgins and Green 2009 *(44)*. The data set also included some cluster randomized trials and nonrandomized trials with intervention allocation at the cluster level (i.e., food premises) and measurement of outcomes on individuals within the cluster (i.e., food handlers). Most of these studies did not adequately adjust for this clustering, which underestimates the standard errors *(102)*. To ensure that they received appropriate weight in the meta-analyses, effect sizes from these studies were adjusted by multiplying the standard errors by the square root of the design effect *(44)*. The design effect requires an estimate of the intracluster correlation coefficient (ICC); given that no studies in this review reported this value, we inputted a common value of 0.10, as recommended for attitude and behavior outcomes in the education sector *(84, 101)*. A sensitivity analysis was conducted to evaluate the impact of selecting a smaller (0.05) and larger (0.20) ICC value.

Within meta-analysis subgroups, some studies reported more than one relevant outcome measure. To account for these outcome dependencies, we calculated all meta-analysis models by using the random effects robust variance estimation (RVE) approach with a small sample adjustment *(42, 97)*. This approach adjusts the standard errors of effect sizes to account for dependent outcome measures. In cases in which it was not possible to estimate this model (due to small data subgroups), the "averaging of effects" approach was used instead, where multiple outcome measures from a study within the subgroup were combined to a single effect size per study *(83)*. In these cases, a conservative estimation of the correlation between outcomes within a study ($r = 1$) was used. The study variance in these random effects models was calculated by using the restricted maximum-likelihood estimator (REML). We also used this averaging of effects approach when producing all forest plot figures to improve conciseness and facilitate illustration of across-study effects.

Possible publication bias was assessed in meta-analysis subgroups with $\geq$10 studies by using Begg's rank correlation and Egger's regression tests and by visual examination of contour-enhanced funnel plots *(94)*. These tests evaluate whether there is an association between the effect size and a measure of the sample size of studies in a meta-analysis subgroup *(94)*. When statistically significant at the 0.05 level, the tests suggest that there could be publication bias in the meta-analysis subgroup, but significant results could also be due to other factors, such as heterogeneity and chance *(94)*. All analyses were conducted in R software Version 3.4.0 *(77)*; the RVE model was run by using the robumeta package and other analyses, including forest plots, were calculated by using the meta package *(35, 86)*.

Quality of evidence. We used a slightly modified version of the Cochrane Collaboration's grades of recommendation, assessment, development and evaluation (GRADE) approach to evaluate the overall quality of evidence of each meta-analysis finding *(41, 44, 85)*. GRADE determines the confidence that the calculated estimates of intervention effect are close to the true estimates. Four GRADE ratings were possible: high, moderate, low, and very low. Outcomes from both RCTs and nonrandomized trials started at a high rating, which was adjusted on the basis of an evaluation of five downgrading (risk of bias, heterogeneity, imprecision, indirectness, and publication bias) and three upgrading (large effect size, dose-response gradient, and underestimated effect) criteria *(41, 85)*. The risk of bias criterion was informed by the study risk of bias assessment ratings. The heterogeneity criterion was informed by the meta-analysis I^2 value and was considered significant if this was >60% *(46)*. Imprecision related to the total sample size across studies in a meta-analysis subgroup and the robustness of the results to sensitivity analysis. Indirectness related to whether studies measured population, intervention, comparison, outcome, and study design elements that were not specific to the review question (e.g., studies including a mix of consumers and food handlers in the population provide only indirect evidence specific to food handlers). Publication bias was informed by the publication bias tests described previously. The GRADE tool and a full description of the criteria used in this assessment are available as Supplemental Material (File S1).

RESULTS

Characteristics of relevant studies. From 2,990 unique citations screened for relevance, 261 full-text articles

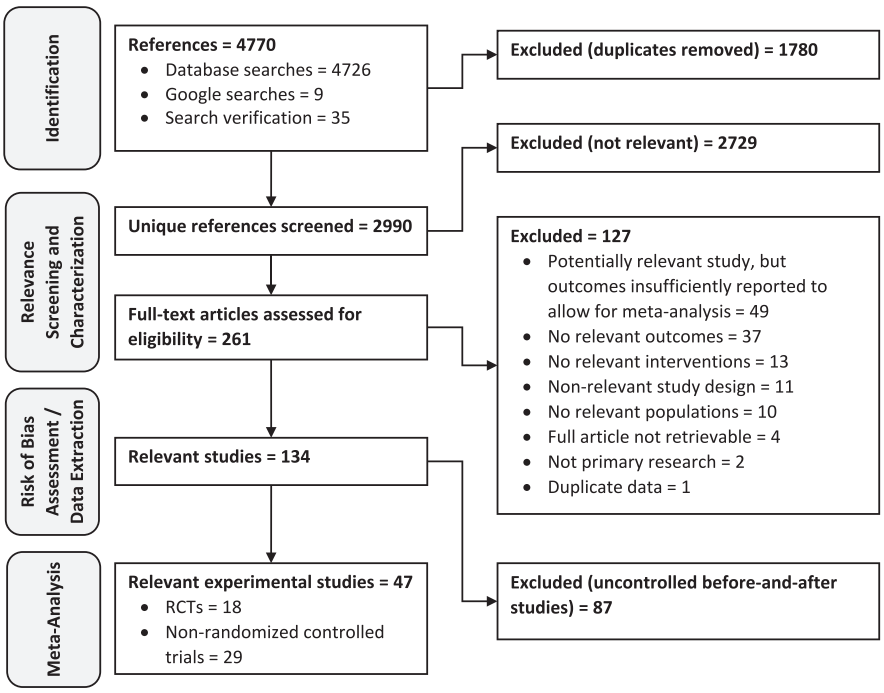

FIGURE 1. *Review flow chart.*

were considered potentially relevant and assessed for eligibility (Fig. 1). Of these, 127 were excluded for various reasons (Fig. 1), mostly because outcomes were insufficiently reported to allow for meta-analysis ($n = 49$), and another 87 were excluded because of a lack of an independent control group (i.e., uncontrolled before and after design). In total, 47 relevant experimental studies were identified (Fig. 1). The citation list, study level characterization data, risk of bias ratings, outcome data used for meta-analysis, and detailed GRADE ratings for all relevant studies are reported as Supplemental Material (File S2). The median publication year of relevant studies was 2010 (range, 1979 to 2017). Most studies were published as journal articles (75%) and in English (96%; Table 1). Most studies were conducted in North America (62%), used a nonrandomized design (62%), targeted a mix of food handler populations (47%), and included restaurants (34%), health care institutions (21%), and educational institutions (21%) as relevant food premises (Table 1).

The most commonly investigated type of intervention was training courses or sessions (66%), with in-person group training as the most frequently reported intervention component (Table 1). Interventions primarily covered at least two different food safety content areas (81%), with personal hygiene (87%) as the most frequently targeted construct (Table 1), while only four interventions focused on a single topic area (e.g., hand hygiene). Only 15% of studies reported that their intervention was informed by a theory of behavior change, and only 36% reported that participants were engaged in intervention development (Table 1). Most studies used a negative (i.e., no intervention) control group (87%). The most commonly reported outcome investigated was knowledge (68%), with questionnaires being the most frequently used data collection instrument (77%; Table 1). Most studies reported pretesting their instruments (62%), and most (79%) collected and reported baseline comparisons (i.e., pre- and postcomparison data in each group; Table 1). Nearly half of studies (47%) reported that the length of participant follow-up was longer than 1 month.

Risk of bias assessment. The risk of bias assessment results for RCTs and nonrandomized studies are shown in Tables 2 and 3, respectively. Among RCTs, the most frequently identified concern was possible risks of bias in the method of outcome measurement (high risk for 52% of outcomes), while a lack of complete description of the randomization process lead to "some concerns" for 44% of outcomes (Table 2). Among nonrandomized studies, most outcomes were rated as serious risk of bias overall (98%), primarily owing to concerns about potential confounding factors that could have explained the apparent intervention effects (Table 3). The method of outcome measurement also led to a serious risk rating for 33% of outcomes in these studies, while a lack of information about participation and attrition rates contributed to a "no information" rating for 42% of outcomes.

Meta-analysis. The meta-analysis results are shown in Table 4, with forest plots of each analysis reported in Figures 2 through 6. RCT studies suggested no significant effect of training and education interventions to improve food handler attitudes, behaviors, and food premise inspection scores (Table 4 and Figs. 2, 3, and 6). In contrast, nonrandomized trials suggested a small to moderate significant effect for attitudes and moderate to large effects for behaviors and inspection scores (Table 4 and Figs. 2, 3, and 6). In studies that compared training and education interventions to a negative control group (e.g., no training), both RCTs (SMD = 0.92, 95% confidence interval: 0.03, 1.81; $n = 8$ studies) and nonrandomized trials (SMD = 1.57, 95% confidence interval: 0.70, 2.44; $n =$

TABLE 1. *Characteristics of 47 relevant studies that investigated the effectiveness of food safety training and education interventions for food handlers working in retail and food service settings*

Characteristic	No.	%
Document type		
Journal article	35	74.5
Thesis or dissertation	12	25.5
Publication language		
English	45	95.7
Korean	1	2.1
Italian	1	2.1
Study region[a]		
North America	29	61.7
Asia and the Middle East	11	23.4
Europe	3	6.4
Africa	2	4.3
South America	2	4.3
Study design		
RCT	18	38.3
Nonrandomized trial	29	61.7
Food handler populations assessed		
Mix of food handlers	22	46.8
Employees only	12	25.5
Managers and operators only	9	19.1
Dieticians, nurses, and teachers	2	4.3
Volunteers	1	2.1
Not specified	1	2.1
Types of food premises investigated[b]		
Restaurants	16	34.0
Health care institutions	10	21.3
Schools, colleges, and universities	10	21.3
Grocery stores	4	8.5
Bars and cafes	3	6.4
Butcher shops	3	6.4
Special events and temporary food markets	3	6.4
Bakeries	2	4.3
Childcare facilities	2	4.3
Street food vendors	2	4.3
Other[c]	3	6.4
Not specified	9	19.1
Intervention type		
Training course or session	31	66.0
Multifaceted intervention	11	23.4
Messaging materials (e.g., posters)	4	8.5
Consulting service	1	2.1
Intervention components[b]		
In-person group training	25	53.2
Print media (e.g., posters and brochures)	16	34.0
Computer/Web-based training	9	19.1
In-person one-on-one training	8	17.0
Digital media (e.g., videos)	5	10.6
Provision of resources (e.g., thermometers)	4	8.5
Other[d]	3	6.4
Intervention content areas[b]		
Personal hygiene	41	87.2
Avoiding cross-contamination	37	78.7
Adequate cooking of foods	34	72.3
Time-temperature control	34	72.3
Avoiding food from unsafe sources	15	31.9
Not reported	6	12.8
No. of training sessions[e]		
1 session	19	46.3
2 or more sessions	11	26.8
Not reported	11	26.8
Total training time[e]		
Less than 1 day	14	34.1
1 Day or longer	12	29.3
Not reported	15	36.6
Intervention design and implementation characteristics[b]		
Delivery included facilitators or instructors	37	78.7
Informed by formative research	35	74.5
Members of target population engaged in development	17	36.2
Informed by a theory of behavior change	7	14.9
Type of control group[b]		
No intervention	41	87.2
Standard or traditional intervention	10	21.3
Relevant outcome types measured[b]		
Knowledge	32	68.1
Food premise inspection or audit scores	17	36.2
Behaviors, self-reported	13	27.7
Attitudes and risk perceptions	12	25.5
Behaviors, observed	9	19.1
Outcome data collection methods[b]		
Questionnaire	36	76.6
Participant observation	22	46.8
Health department inspection records	2	4.3
Pretesting of data collection instruments reported		
Yes	29	61.7
No	18	38.3
Baseline outcome measurements reported		
Yes	37	78.7
No	10	21.3
Postintervention follow-up time		
Immediately after	12	25.5
1 day to 1 month	6	12.8
Longer than 1 month	22	46.8
Not reported	7	14.9

[a] North American countries included United States ($n = 22$) and Canada ($n = 7$). Asian and Middle Eastern countries included India ($n = 3$), South Korea ($n = 3$), and Bahrain, Iran, Malaysia, Myanmar, and Saudi Arabia ($n = 1$ each). European countries included the United Kingdom ($n = 2$) and Italy ($n = 1$). African countries included Kenya and Nigeria ($n = 1$ each). Brazil ($n = 2$) was the only South American country.

[b] Multiple selections were possible for these questions, so answers may not add to 100%.

[c] Other premises included galley kitchens in navy ships, community-based adult-care facilities, and food banks ($n = 1$ each).

[d] Other intervention components included a professional consulting service, motivational site visits, and incentives ($n = 1$ each).

[e] These questions were tabulated only for studies that reported a training course or session component to their intervention ($n = 40$).

TABLE 2. *Summary risk of bias assessment for 18 relevant RCT studies that investigated the effectiveness of food safety training and education interventions for food handlers working in retail and food service settings*

Risk of bias domain/outcome type	No. of outcomes (studies)	No. (%)[a]		
		Low risk	Some concerns	High risk
Bias arising from the randomization process	25 (18)	13 (52)	11 (44)	1 (4)
Bias arising from the timing of identification and recruitment of individual participants in relation to timing of randomization[b]	12 (6)	8 (67)	0 (0)	4 (33)
Bias due to deviations from intended interventions	25 (18)	24 (96)	0 (0)	1 (4)
Bias due to missing outcome data	25 (18)	22 (88)	3 (12)	0 (0)
Bias in measurement of the outcome	25 (18)	12 (48)	0 (0)	13 (52)
Attitudes	3 (3)	0 (0)	0 (0)	3 (100)
Behaviors	3 (3)	0 (0)	0 (0)	3 (100)
Knowledge	11 (11)	11 (100)	0 (0)	0 (0)
Inspection scores	8 (8)	1 (7)	0 (0)	13 (93)
Bias in selection of the reported result	25 (18)	23 (92)	0 (0)	2 (8)
Attitudes	3 (3)	2 (67)	0 (0)	1 (33)
Behaviors	3 (3)	3 (100)	0 (0)	0 (0)
Knowledge	11 (11)	10 (91)	0 (0)	1 (9)
Inspection scores	8 (8)	8 (100)	0 (0)	0 (0)
Overall risk of bias rating	25 (18)	5 (20)	4 (16)	16 (64)
Attitudes	3 (3)	0 (0)	0 (0)	3 (100)
Behaviors	3 (3)	0 (0)	0 (0)	3 (100)
Knowledge	11 (11)	4 (36)	4 (36)	3 (27)
Inspection scores	8 (8)	1 (13)	0 (0)	7 (88)

[a] All percentages are calculated by using the total number of unique outcome assessments per risk of bias domain as the denominator.
[b] This bias domain was only assessed for cluster RCT studies ($n = 6$).

TABLE 3. *Summary risk of bias assessment for 29 nonrandomized controlled trial studies that investigated the effectiveness of food safety training and education interventions for food handlers working in retail and food service settings*

Risk of bias domain/outcome type	No. of outcomes (studies)	No. (%)[a,b]			
		Low risk	Moderate risk	Serious risk	No information
Bias due to confounding	45 (29)	0 (0)	1 (2)	44 (98)	0 (0)
Bias in selection of participants into the study	45 (29)	37 (82)	0 (0)	6 (13)	2 (4)
Bias in classification of interventions	45 (29)	35 (78)	6 (13)	4 (9)	0 (0)
Bias due to deviations from intended interventions	45 (29)	44 (98)	0 (0)	1 (2)	0 (0)
Bias due to missing data	45 (29)	23 (51)	2 (4)	1 (2)	19 (42)
Bias in measurement of outcomes	45 (29)	24 (53)	6 (13)	14 (31)	1 (2)
Attitudes	5 (5)	0 (0)	2 (40)	3 (60)	0 (0)
Behavior	13 (12)	0 (0)	4 (31)	9 (69)	0 (0)
Knowledge	20 (20)	19 (95)	0 (0)	0 (0)	1 (5)
Inspection scores	7 (7)	5 (71)	0 (0)	2 (29)	0 (0)
Bias in selection of the reported result	45 (29)	38 (84)	1 (2)	4 (9)	2 (4)
Attitudes	5 (5)	4 (80)	2 (20)	0 (0)	0 (0)
Behavior	13 (12)	11 (85)	0 (0)	1 (8)	1 (8)
Knowledge	20 (20)	16 (80)	0 (0)	3 (15)	1 (5)
Inspection scores	7 (7)	7 (100)	0 (0)	0 (0)	0 (0)
Overall risk of bias rating	45 (29)	0 (0)	1 (2)	44 (98)	0 (0)
Attitudes	5 (5)	0 (0)	0 (0)	5 (100)	0 (0)
Behavior	13 (12)	0 (0)	0 (0)	13 (100)	0 (0)
Knowledge	20 (20)	0 (0)	1 (5)	19 (95)	0 (0)
Inspection scores	7 (7)	0 (0)	0 (0)	7 (100)	0 (0)

[a] All percentages are calculated by using the total number of unique outcome assessments per risk of bias domain as the denominator.
[b] A fourth risk judgment was possible (critical risk) but was not assigned to any outcomes in this review.

TABLE 4. *Random effects meta-analysis models of the effectiveness of training and education interventions to improve food safety outcomes among food handlers working in retail and food service settings*[a]

Outcome type/control group type	Study design	No. of outcomes (studies)	Model type	Weighted avg SMD (95% CI)[b]	I^2 (%)	Egger's (Begg's) publication bias test *P* value	GRADE rating
Attitudes and risk perceptions							
No intervention	RCTs	3 (3)	REML	0.12 (−0.48, 0.72)	53	NA	Very low
	NRTs	14 (4)	REML	0.38 (0.06, 0.70)	59	NA	Very low
Behaviors							
No intervention	RCTs	5 (3)	REML	0.18 (−0.23, 0.60)	0	NA	Low
	NRTs	30 (12)	RVE	1.05 (0.27, 1.84)	88	0.074 (0.055)	Very low
Knowledge							
No intervention	RCTs	12 (8)	RVE	0.92 (0.03, 1.81)	86	NA	High
	NRTs	49 (17)	RVE	1.50 (0.70, 2.29)	93	0.004 (0.039)	Very low
Standard intervention	RCTs	23 (4)	REML	0.46 (−0.44, 1.36)	88	NA	Low
	NRTs	43 (3)	REML	0.21 (−0.23, 0.65)	5	NA	Very low
Inspection scores							
No intervention	RCTs	22 (8)	RVE	0.17 (−0.30, 0.64)	71	NA	Low
	NRTs	14 (7)	RVE	0.79 (0.16, 1.42)	74	NA	Very low

[a] SMD, standardized mean difference (Hedges' *g*); CI, confidence interval; RCTs, randomized controlled trials; REML, restricted maximum-likelihood estimator; NA, not applicable (insufficient data to perform this analysis); NRTs, nonrandomized controlled trials; RVE, robust variance estimation.

[b] SMD $>$ 0 indicates that the interventions have a positive effect on the outcomes of interest.

8 studies) found a significant, large effect on improving food handler knowledge (Table 4 and Fig. 4). However, significant heterogeneity was present in each subgroup ($I^2 =$ 86 and 93%, respectively). Among studies that compared enhanced training and education interventions to standard interventions (e.g., computer-based versus in-person training), no significant effect on food handler knowledge was identified among RCT and nonrandomized trial studies (Table 4 and Fig. 5).

The only high GRADE rating was for the effect of training and education interventions compared with a negative control group among RCTs (Table 4). All other RCT outcomes were rated as low or very low, and all nonrandomized trial outcomes were rated very low owing to a combination of concerns from risks of bias, significant heterogeneity, imprecision, and possible publication bias.

Sufficient data were available in two meta-analysis subgroups of nonrandomized trials to assess possible publication bias (Table 4). In both cases, statistical tests were significant or borderline significant at the 0.05 level, suggesting possible publication bias. Fourteen (30%) studies applied the intervention at the cluster level (e.g., food premise) and measured outcomes on individual food handlers within these clusters. Of these, only one study appropriately accounted for the clustered nature of the data in their analysis. We adjusted the standard errors of the other 13 studies by using an estimate of the ICC value of 0.1. The sensitivity analysis of using other ICC values of 0.05 and 0.2 indicated minimal impact on most meta-analysis findings (see File S2). The only meta-analysis estimate that changed substantially with differing ICC values was the RCT attitude outcome, although it remained not statistically significant in all cases. As a result of this finding, the GRADE rating for this outcome was adjusted downward for imprecision.

DISCUSSION

This review summarizes the global evidence on the effectiveness of training and education interventions to improve food handler attitudes, knowledge, behaviors, and food premise inspection scores. One-quarter of all relevant studies were master's theses or doctoral dissertations that were not subsequently published as peer-reviewed journal articles. This is a potential concern, given that previous research has consistently found that published studies are more likely to report positive or statistically significant findings compared with unpublished studies *(30)*. Additional research is needed to explore why studies do not get published in this field. Most studies were conducted in the United States and Canada (62%), with few studies conducted in Europe and other regions. Further research on food handler interventions in these regions is warranted, as the effectiveness of such interventions may be influenced by national cultures, policies, and practices *(72)*. Despite extensive language translation efforts, we identified only two relevant studies in languages other than English. However, it is possible that additional relevant articles in other languages may exist on this topic but were not indexed in the bibliographic databases searched in this review.

Most of the investigated interventions were training courses or sessions or were multifaceted interventions with training-based components, and few studies investigated the effects of educational materials or other types of motivational interventions (e.g., provision of resources or incentives). Future experimental research in this area should

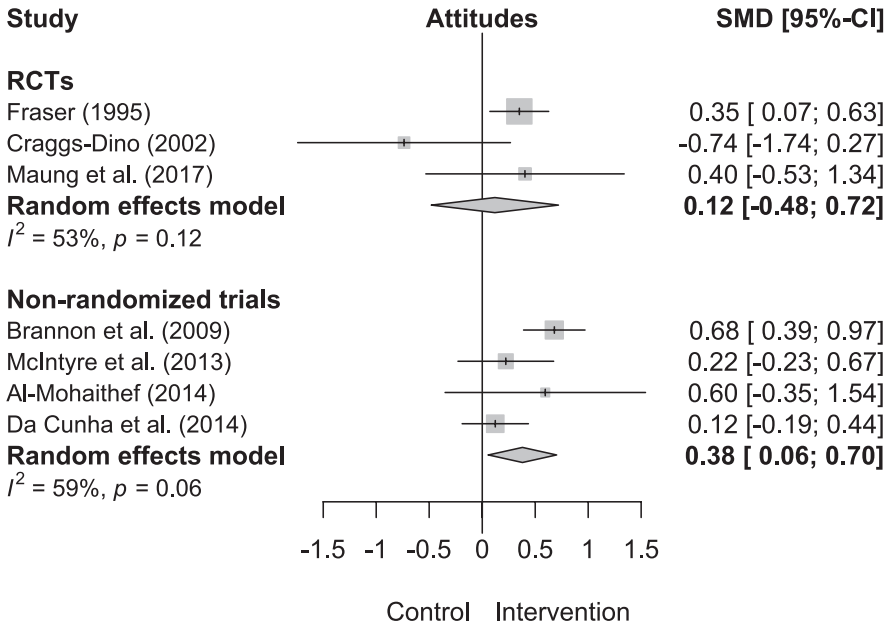

FIGURE 2. *Forest plot of a random effects meta-analysis of the effectiveness of education and training interventions to improve food handler attitudes. SMDs in this figure were calculated by using the averaging of effects approach and REML variance estimator. CI, confidence interval.*

investigate the effects of broader types of interventions for food handlers, including those that influence the work environment, culture, and policies *(11, 15, 40, 72)*. Additional studies evaluating such interventions have been published and shown to be effective by using uncontrolled before and after designs *(19, 50, 107),* but there is a need to further investigate these effects by using RCT designs. Of studies investigating training-based interventions, only 27% reported that the training consisted of at least two sessions. Only one of these studies reported a possible dose-response relationship, finding that food handlers who completed more training sessions had higher knowledge scores *(24),* while two studies found that knowledge scores were lower with increased time since training *(24, 62)*. Future experimental research should investigate whether increasing the number of training sessions, including regular retraining over time, can improve and sustain food handlers' attitudes, knowledge, and behaviors toward food safety.

Only 38% of relevant studies used an RCT design. RCTs provide the most reliable evidence on intervention effectiveness because the random treatment allocation process balances confounding factors across groups *(6,*

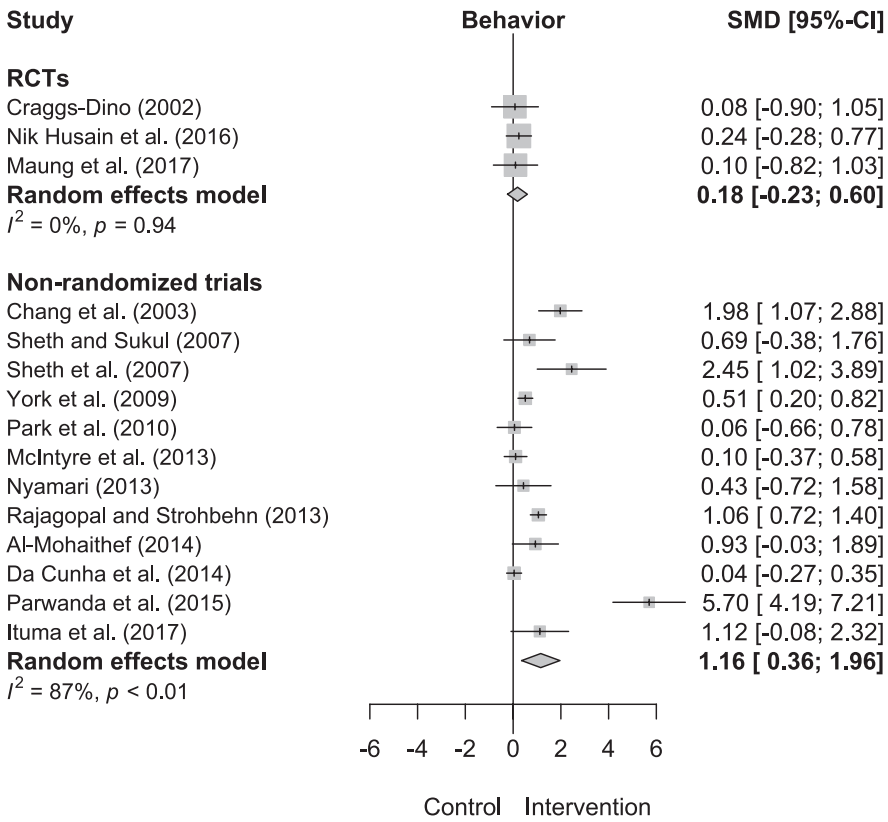

FIGURE 3. *Forest plot of a random effects meta-analysis of the effectiveness of education and training interventions to improve food handler behaviors. SMDs in this figure were calculated by using the averaging of effects approach and REML variance estimator. CI, confidence interval.*

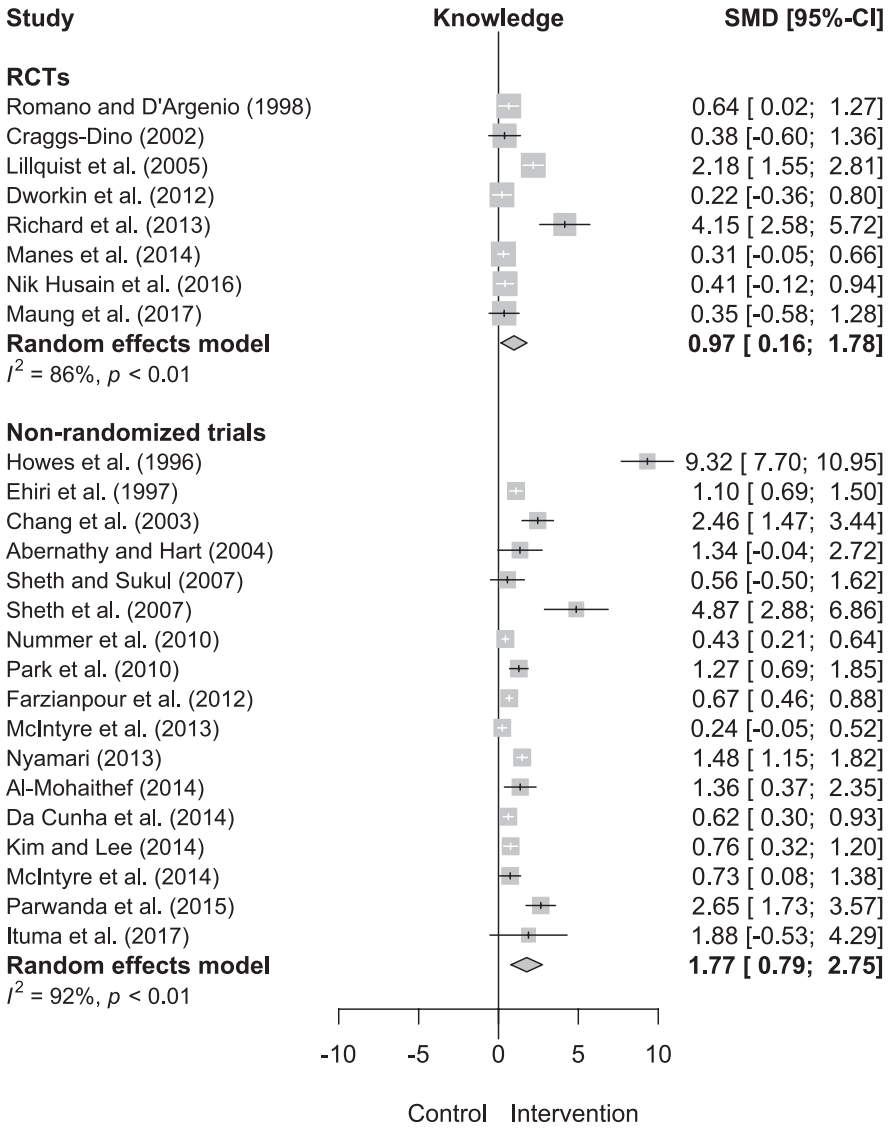

FIGURE 4. *Forest plot of a random effects meta-analysis of the effectiveness of education and training interventions, compared with no intervention, to improve food handler knowledge. SMDs in this figure were calculated by using the averaging of effects approach and REML variance estimator. CI, confidence interval.*

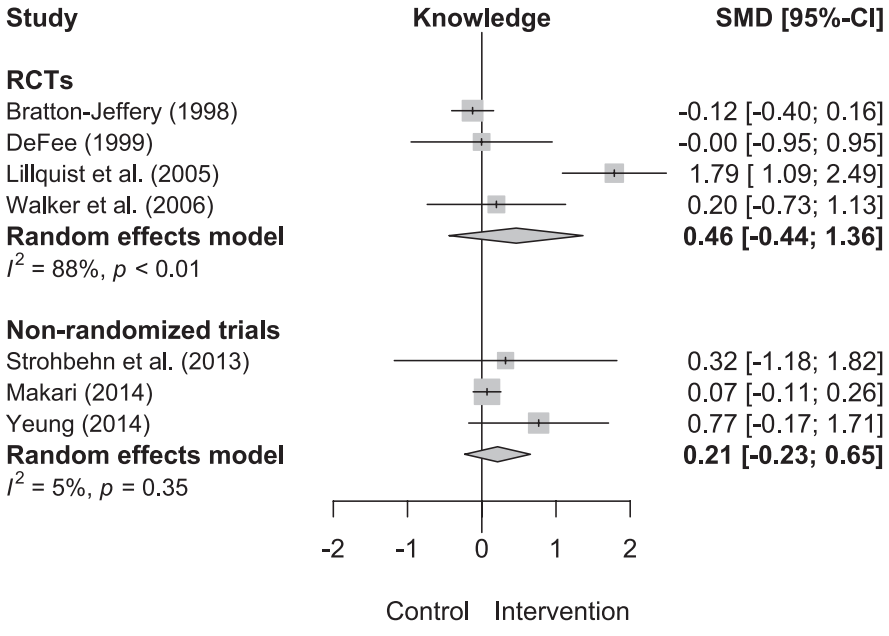

FIGURE 5. *Forest plot of a random effects meta-analysis of the effectiveness of education and training interventions, compared with a standard intervention, to improve food handler knowledge. SMDs in this figure were calculated by using the averaging of effects approach and REML variance estimator. CI, confidence interval.*

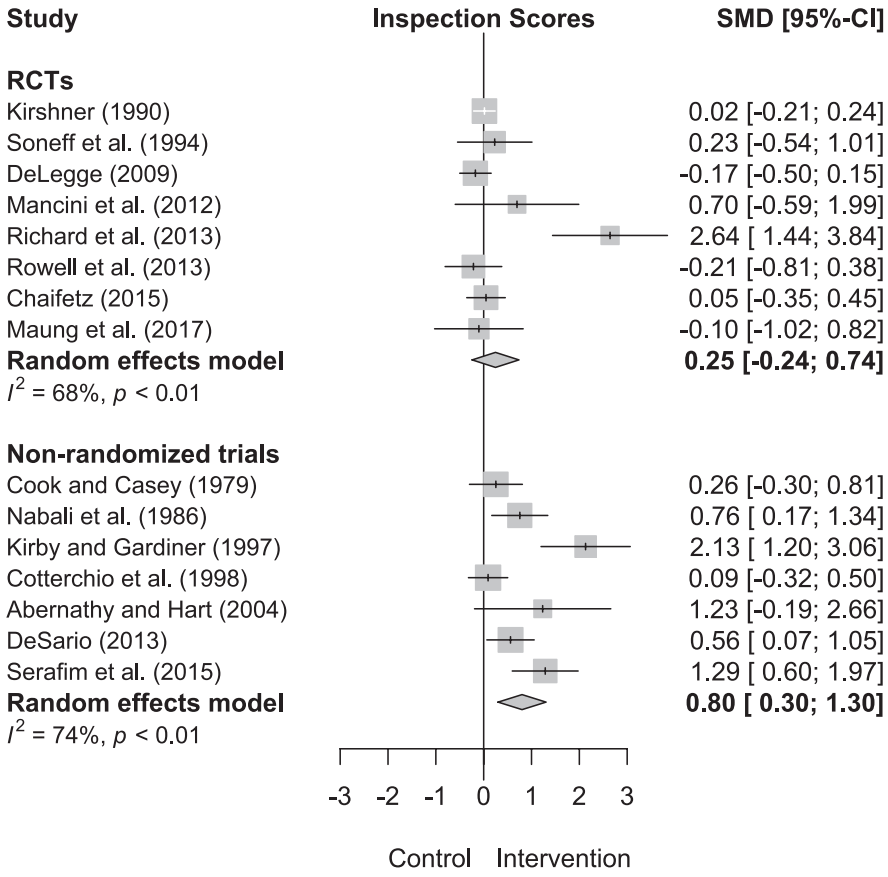

FIGURE 6. *Forest plot of a random effects meta-analysis of the effectiveness of education and training interventions to improve food premise inspection scores. SMDs in this figure were calculated by using the averaging of effects approach and REML variance estimator. CI, confidence interval.*

44). However, "some concerns" were noted for several of the RCT studies in this review because of a lack of a full description of the randomization process. It is important to describe clearly how randomization was conducted (e.g., computer-generated numbers) and how the intervention or control group status was assigned to participants, because inadequate randomization or concealment of this status from participants can lead to selection bias in the study, which can influence study outcomes *(73)*.

Several of the nonrandomized trials used a retrospective design or compared groups that were naturally exposed or not exposed to an intervention (e.g., food safety training policy change), so they did not involve active investigator allocation of intervention and control groups. Although randomization may not have been possible in these settings, investigators could have mitigated possible confounding bias by designing their study to investigate and control for confounding factors. For example, confounding can be controlled by restricting study eligibility to participants that all have the same value of the confounder (e.g., same age group or no previous food safety training for all participants) or by adjusting for important confounders through analysis (e.g., multivariable models) *(93)*. However, only one relevant study used this approach *(47)*. For this reason, nearly all nonrandomized study outcomes were rated as serious risk of bias. Another frequent risk of bias in both RCTs and nonrandomized trials was the method of outcome measurement. Subjective, self-reported measures, such as attitudes and behaviors, were considered vulnerable to bias owing to participant knowledge of their intervention group status. Similarly, observed behaviors and inspection scores were also considered to be at risk of bias if assessors were potentially aware of and not blinded to the intervention group status, which was rarely reported among relevant studies. Both situations have been shown to lead to exaggerated or biased intervention effect estimates *(48, 73)*. We therefore recommend that future RCTs in this field aim to use evaluated measurement tools (e.g., questionnaires) with documented validity and reliability to minimize bias and to ensure that outcome assessors are blinded to the intervention group status when measuring observed outcomes, such as behaviors and inspection scores.

Attitudes are an important precursor to behavior change *(3),* and previous research has found that food handlers' with more positive food safety attitudes and risk perceptions are more likely to implement safe food handling behaviors *(106)*. However, among RCTs, we found no significant effect of training and education interventions on either of these outcomes, although there were only three relevant studies investigating each outcome. For the attitude outcome, two of the RCT studies, which investigated an informational booklet and a training course and brochures *(36, 60),* found a positive intervention effect, while the other, which investigated a training course *(23),* found no effect. For the behavior outcome, all three studies found no significant effect *(23, 60, 69)*. In contrast, nonrandomized trials suggested a significant positive effect for both outcomes, with a much larger effect size for behaviors. It is difficult to measure self-reported outcomes, such as attitudes, in a way that is not susceptible to bias *(45),* which, along with possible confounding factors in the nonrandomized trials, may explain the difference in results between the

two study designs. Similarly, most of the behavior outcomes were measured via self-reports compared with independent observations, which tend to be inaccurate due to social desirability bias *(25, 29)*. There was also substantial variability in how attitude and behavior outcomes were defined and categorized across studies, with many only reporting overall or composite measures. It is possible that dividing these into more specific constructs (e.g., perceived susceptibility and severity of illness for attitudes and the clean, cook, chill, and separate constructs for behavior) could provide a more informative assessment of intervention effectiveness *(67)*. Further research is necessary to investigate additional ways to enhance food handler attitudes and behaviors through training and education interventions.

Both RCTs and nonrandomized trials found that training and education interventions are effective to improve food handler knowledge, with a large average effect size identified in both data sets. A range of different types of interventions were investigated among these studies, including provision of comic books and brochures, info sheets, training courses, and multifaceted approaches that incorporated theory-based training, resources, posters, and motivational site visits *(23, 31, 55, 59, 60, 69, 79, 81)*. We identified high GRADE confidence in the RCT findings, while the nonrandomized trial estimates are likely to be exaggerated due to the aforementioned risks of bias. These results support and reinforce the importance and effectiveness of public health initiatives that require certified and trained food handlers at retail and food service premises to enhance their food safety knowledge *(16, 98)*. However, although previous research has shown that knowledge is generally a good predictor of food handlers' behaviors, it is not the only factor that is important to achieve behavior change in this population *(106)*. Therefore, additional research is necessary to investigate how food handler interventions can affect other important behavioral determinants (e.g., social influences and self-efficacy) and to investigate how changes in knowledge can lead to sustained changes in food safety behaviors.

In contrast, no effect on food handler knowledge was identified among a smaller number of studies that compared enhanced versus standard interventions. These studies tended to investigate computer- or online-based training courses compared with traditional in-person courses. The results suggest that there is currently no evidence to indicate that any one type of educational or training intervention is superior to another to improve food handlers' knowledge. However, computer- or online-based interventions may be more cost-efficient compared with live instruction approaches, without compromising efficacy. A previous systematic review in the health care sector identified a number of training approaches that are effective to enhance various learning outcomes in the context of continuing professional education, including case-based learning, simulations, practice, feedback, and repetition *(7)*. This is supported by the only RCT study in this subgroup that reported a significantly positive effect, finding that training that incorporated active participation was more effective than traditional passive instruction *(55)*. Future research to investigate the comparative cost-effectiveness of different types of enhanced training and education approaches for food handlers is warranted.

Similar to attitude and behavior outcomes, we found a contrast between RCTs and nonrandomized trials for the effectiveness of food handler education and training interventions to improve food premise inspection scores, with the former showing no effect overall, and the latter a significant positive effect. However, among the RCTs, two of the eight studies found a strong intervention effect, and both investigated interactive, customized, and on-site training approaches *(58, 79)*. Most health departments conduct routine inspections of retail and food service establishments to evaluate food safety compliance. Although these assessments provide a snapshot of regulatory compliance and an indicator of food safety process controls in the establishment, there is inconsistent evidence on their relationship to food handler outcomes (e.g., knowledge) and the risk of foodborne disease transmission *(13, 51, 76, 103)*. Therefore, these outcomes may provide only indirect evidence on the effectiveness of food safety interventions targeted at food handlers, which could explain the lack of a consistent effect identified in RCTs, while the significant effects reported in nonrandomized trials may be attributable, at least partially, to confounding factors, such as differences in food handler characteristics (e.g., demographics and prior training status), establishment characteristics (e.g., size), or those performing the inspections across intervention groups *(22, 43, 51, 53)*.

One of the limitations of this review is the possibility that some relevant missing articles were not identified by the search. However, we attempted to mitigate this through a comprehensive search, including searches for grey literature and implementation of a verification strategy. Another possible limitation relates to the inclusion of grey literature studies, which could have design or other flaws, given that they have not been through a formal peer review process. However, previous research indicates that the main reason for nonpublication of health-related research is that the study was never submitted for publication, and this is due to a myriad of reasons, including a lack of interest or time, unimportant or negative results, fear of rejection, and poor study quality, among other reasons *(91)*. Further, although we did not empirically test for the effects of grey literature on the results of this review, given the small number of studies in each subgroup, we did not observe any notable differences in risk of bias on the basis of whether a study was published or not. The publication bias assessment on two subgroups suggests that smaller studies with nonsignificant findings may be missing from the published literature for these outcomes, but other explanations for these findings cannot be ruled out (e.g., risks of bias, heterogeneity in effects across studies, or chance) *(94)*. A related concern is that many potentially relevant articles ($n = 49$) were excluded owing to a lack of extractable outcome data. A new "Consolidated Standards of Reporting Trials" reporting guideline has been developed for RCTs of social and psychological (e.g., behavior change) interventions, and we encourage future authors in this field to report their findings in accordance with these international guidelines *(66)*.

To properly account for the weight of cluster RCTs and nonrandomized trials of a similar design in meta-analysis, we adjusted the standard errors of these studies via a design effect that required an assumption on the ICC value within these studies. The ICC measures the amount of variation in the study outcomes that is due to between-cluster effects (e.g., differences in food premises) compared with within-cluster effects (e.g., differences in food handlers within a food premise). The sensitivity analysis showed that meta-analysis results were mostly robust to the choice of ICC value. The only finding that was noticeably affected (RCT attitudes outcome) had only three studies, was downgraded in the quality of evidence assessment as a result, and its overall statistical significance was not affected. Significant heterogeneity was identified in several of the meta-analysis outcome subgroups. This heterogeneity could be due to various factors, including differences in risks of bias (e.g., confounding), intervention and population characteristics, or study methodology (e.g., outcome measurement instruments) across studies. Finally, the GRADE ratings were calculated by using the Cochrane Collaboration's approach to estimate the amount of confidence to place in each of the meta-analysis findings, which can support future research and decision making in this area, but requires some judgment to determine appropriate grading criteria.

This systematic review found strong evidence that training and education interventions are effective to improve food handlers' food safety knowledge. These results support the importance of mandatory food handler training and certification programs and other related initiatives. In contrast, inconsistent evidence was identified for other outcomes (food handler attitudes, behaviors, and premise inspection scores). Further research is needed to determine the effectiveness of different approaches to achieve food handler behavior change, including the evaluation of more innovative and complex interventions (e.g., theory-based approaches and motivational and reinforcement strategies). Confidence in effective strategies for behavior change would also benefit from additional RCT studies, cost-effectiveness comparisons of different interventions, and studies outside of North America, which would contribute to the ongoing challenge of improving food safety in retail and food service settings.

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SUPPLEMENTAL MATERIAL

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