Review

Meta-Analysis of Food Safety Training on Hand Hygiene Knowledge and Attitudes among Food Handlers

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ABSTRACT

Research has shown that traditional food safety training programs and strategies to promote hand hygiene increases knowledge of the subject. However, very few studies have been conducted to evaluate the impact of food safety training on food handlers’ attitudes about good hand hygiene practices. The objective of this meta-analytical study was to assess the extent to which food safety training or intervention strategies increased knowledge of and attitudes about hand hygiene. A systematic review of food safety training articles was conducted. Additional studies were identified from abstracts from food safety conferences and food science education conferences. Search terms included combinations of “food safety,” “food hygiene,” “training,” “education,” “hand washing,” “hand hygiene,” “knowledge,” “attitudes,” “practices,” “behavior,” and “food handlers.” Only before- and after-training approaches and cohort studies with training (intervention group) and without training (control group) in hand hygiene knowledge and including attitudes in food handlers were evaluated. All pooled analyses were based on a random effects model. Meta-analysis values for nine food safety training and intervention studies on hand hygiene knowledge among food handlers were significantly higher than those of the control (without training), with an effect size (Hedges’ g) of 1.284 (95% confidence interval [CI] = 0.830 to 1.738). Meta-analysis of five food safety training and intervention studies in which hand hygiene attitudes and self-reported practices were monitored produced a summary effect size of 0.683 (95% CI = 0.523 to 0.843). Food safety training increased knowledge and improved attitudes about hand hygiene practices. Refresher training and long-term reinforcement of good food handling behaviors may also be beneficial for sustaining good hand washing practices.

To be effective for reducing foodborne illnesses, food handler food safety training must increase motivation, improve attitudes, and increase the frequency of safe food handling practices, such as hand hygiene practices. The implied assumption is that such training leads to changes in behavior based on the knowledge, attitudes, and practices model (20). However, this model has been criticized by Ehiri et al. (22) and Griffith (33). Study results have indicated that increased knowledge does not necessarily lead to changes in behavior (14, 22, 55). Several studies on how training programs impact food safety behaviors within food production settings have been conducted. In most of these studies, researchers evaluated pre- and immediate post-intervention knowledge and behaviors among workers who attended food safety workshops (10, 16, 22, 23, 42). Clayton et al. (14) also concluded that training must involve a risk-based approach and that behavioral change will not occur merely as a result of training. The concept of risk is an important part of food hygiene training. Attitudes and company culture have an impact on behavior and therefore on foodborne outbreaks associated with food workers (67).

Targeted training and risk communication should be used to change food handlers’ behavior, implement safer food handling, and improve knowledge of food safety practices such as cross-contamination, temperature control, and personal hygiene (20).

Systematic reviews and meta-analysis methodologies have been developed to summarize the scientific evidence from the literature (21, 71). In systematic reviews, researchers collate empirical evidence that fits the prespecified inclusion criteria to answer a specific research question. Meta-analysis is the statistical combination and summarizing of results from multiple studies (34). The term “meta-analysis” was coined in 1976 in the social science literature (28). The term is derived from the Greek “meta” or “after” analysis, representing a form of summing up after obtaining the results (5). The meta-analysis approach addresses two main questions (48): (i) Is there support in the sampled population of studies that the interventions (i.e., food safety training and hand hygiene interventions) made a statistically significant difference in the outcome(s) (i.e., increase, decrease, or no difference in hand hygiene knowledge and attitudes)? (ii) If so, how large is the training effect? In addition to these questions, heterogeneity of results among the primary studies can be evaluated (65). When combined,
systematic review and meta-analysis can provide strong evidence for the effectiveness of interventions based on the best available data (68). Meta-analyses of the effects of hand hygiene on infectious diseases have revealed that hygiene education reduced the risks of diarrheal illness (2, 17, 24) and respiratory infections (2, 54). In the context of food safety, meta-analyses have only been recently used to integrate and synthesize food safety information (6, 30, 31, 51, 52, 58, 68, 69). To our knowledge, a meta-analysis comparing the effectiveness of food safety training or hand hygiene interventions with a group of food handlers has not been conducted. Analysis of food safety training or hand hygiene interventions (i.e., hand hygiene education) to increase knowledge and improve hand hygiene practices is important because hand hygiene is an important factor for reducing cross-contamination risks (67). The primary aim of this meta-analysis was to assess the extent to which food safety training or intervention strategies increase knowledge of and improve attitudes toward hand hygiene. The meta-analyses focused on evidence of any changes in hand hygiene knowledge scores, attitudes, and self-reported practices resulting from the interventions.

MATERIALS AND METHODS

Literature search and selection of studies. We conducted electronic searches based on the terms “food safety,” “food hygiene,” “education,” “interventions,” “hand washing,” “hand hygiene,” “practices,” and “behavior.” To optimize sensitivity, searches for both headings and text words in the title and abstract were conducted. A number of electronic databases associated with PubMed, Web of Science Citation Index, ProQuest, and Cochrane Library PubMed were searched. After the searches, titles and abstracts of the citations chosen were screened using the prespecified criteria to determine possible inclusion. The reviews by Campbell et al. (9), Egan et al. (20), and Medeiros et al. (44) were used as additional sources to identify early searches. Because of limited resources, we did not validate the selection process through the use of a second reviewer. In addition to the electronic searches, the authors manually searched key journals in the field, checked reference lists, and sought additional data from authors of published studies that were not readily available or published. Additional studies were identified from abstracts from food safety conferences and food science education conferences. All titles and abstracts (when available) were screened for eligibility. Additional data were sought from authors of published studies when appropriate data were not fully reported (4, 19, 56, 61).

Inclusion criteria. We defined food safety training and hand hygiene intervention as a planned process to provide information (i.e., hand hygiene knowledge) and to modify attitudes or behaviors (i.e., hand hygiene practices) through learning experiences to achieve effective performance (i.e., improvement in hand hygiene knowledge and practices). Hand hygiene interventions in this review included only educational materials such as information sheets (12), posters (3, 25), role playing (13), training manuals (3), videos (3, 13, 43, 62, 63), and demonstration of microbial plate counts (50). We included studies in which the authors evaluated hand hygiene knowledge, attitudes, and behavioral changes after food safety education and training or hand hygiene interventions were provided (Table 1). Studies that included reports of changes from pretraining to posttraining and intergroup differences in cognitive and affective outcomes also were included. Studies were excluded when no hand hygiene evaluations were carried out in the training programs. Several studies in which researchers assessed bacterial contamination on food handlers’ hands before and after training (10, 60) were not included in the meta-analysis because the study designs and outcome measures differed.

Data analysis. Tables 2 and 3 provide the data extracted from nine and five studies, respectively, included in the meta-analyses of hand hygiene knowledge and attitudes. Table 4 provides additional data from theoretical interventions such as the theory of planned behavior (46, 47) and health action model strategies (73).

Meta-analyses were conducted using comprehensive meta-analysis (CMA) software, version 2 (Biostat, Englewood, NJ). After reviewing and cataloging the information, the primary metric for the calculation of effect sizes is Hedges’ $g$, which examines the size of a relationship between two variables (15). Regardless of the interventions, to conduct the statistical analysis the effect sizes of all studies must be converted to one common type of measure. The effect size refers to the degree to which the hypothetical phenomenon (i.e., increase in hand hygiene knowledge and improved attitudes) is present in the population (i.e., food handlers). Because the data compiled in this review were from various studies conducted under different settings, a random effects model was used in the meta-analyses. The random effects model assumes that there is no common treatment effect for all included studies (36) and the treatment effects for individual studies are assumed to vary around the overall average treatment (18). It also represents a sample from a larger population of possible studies (26).

Calculation of effect sizes. In this meta-analysis, we used studies that included independent groups (control and intervened groups) and matched groups (pre- and posttraining tests). Because different studies with different intervention strategies were used to assess the outcome, the scale of measurement often differed among
<table>
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<th>Setting, location</th>
<th>Study design</th>
<th>Intervention</th>
<th>Sample size</th>
<th>Outcome</th>
<th>Reference(s)</th>
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<td>Lectures and demonstration techniques (e.g., microbial plate counts)</td>
<td>Control = 49; intervention = 41</td>
<td>Pre- and posttraining knowledge assessment</td>
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<td>Training program divided into 15 sessions: charts, flip charts, posters, motivational video films, role playing, demonstrations, puppet shows and handouts (included 30 small restaurant owners, 43 mobile food vendors, and 7 food handlers)</td>
<td>80</td>
<td>Pre- and posttraining knowledge assessment</td>
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<td>Pre- and posttraining evaluations</td>
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<td>Study design</td>
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<td>Sample size</td>
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<td>a</td>
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<td>Control and intervention groups with pre- and posttraining evaluations</td>
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<td>31</td>
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<td>Computer-based instruction</td>
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<td>f</td>
<td>Street food vendors, India</td>
<td>Pre- and posttraining evaluations (in this review, only the food handler group was included)</td>
<td>Training program divided into 15 sessions: charts, flip charts, posters, motivational video films, role playing, demonstrations, puppet shows and handouts (included 30 small restaurant owners, 43 mobile food vendors, and 7 food handlers)</td>
<td>80</td>
<td>Pre- and posttraining performance rating of good hygiene practices</td>
<td>13</td>
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TABLE 4. Characteristics of studies included in the meta-analysis of the effect of food safety training and behavioral interventions on hand hygiene attitudes

<table>
<thead>
<tr>
<th>Study index</th>
<th>Subgroup within study</th>
<th>Setting, location</th>
<th>Study design</th>
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<th>Sample size</th>
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<td>c i</td>
<td>Mushroom companies (including farms and packinghouses), USA</td>
<td>Control and intervention groups with pre- and posttraining evaluations; only track A packinghouse participants</td>
<td>Food safety educational lessons; management support and motivation; monetary incentive</td>
<td>73</td>
<td>Monitoring of hand washing compliance rate (after using bathroom)</td>
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<td>ii</td>
<td>Mushroom companies (include farms and packinghouses), USA</td>
<td>Control and intervention with pre- and posttraining evaluations; only track B (red company) packinghouse participants</td>
<td>Food safety educational lessons; management support and motivation</td>
<td>39</td>
<td>Monitoring of hand washing compliance rate (after using bathroom)</td>
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<td>iii</td>
<td>Mushroom companies (include farms and packinghouses), USA</td>
<td>Control and intervention with pre- and posttraining evaluations; only track B (green company) packinghouse participants</td>
<td>Food safety educational lessons; management support and motivation</td>
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<td>iv</td>
<td>Mushroom companies (include farms and packinghouses), USA</td>
<td>Control and intervention with pre- and posttraining evaluations; only track C packinghouse participants</td>
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<td>Monitoring of hand washing compliance rate (after using bathroom)</td>
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<td>d i</td>
<td>Restaurants, USA</td>
<td>Control and intervention groups</td>
<td>TPB interventions (incentive program; persuasive messages and reminders)</td>
<td>Control = 140; intervention = 83</td>
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<td>Restaurants, USA</td>
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<td>Control = 140; intervention = 51</td>
<td>Behavioral compliance scores</td>
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<td>iii</td>
<td>Restaurants, USA</td>
<td>Control and intervention groups</td>
<td>4 h of ServSafe food safety training</td>
<td>Control = 140; intervention = 94</td>
<td>Behavioral compliance scores</td>
<td></td>
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* TPB, theory of planned behavior.
studies. In those cases, the standardized mean difference (d index) effect size statistic was used (8). The mean differences were standardized by an estimate of the standard deviations of the measurements in the studies to remove the effect of the scale of measurements (29). Use of the d index is most appropriate for studies for which the means and standard deviations were reported for the control and intervened groups (7). Hedges’ g was then calculated to correct for bias from small sample sizes (8, 15).

For studies in which the researchers did not report the standard deviations but did report the results of a t test, the exact P value, or a pre- and posttest correlation (r), the effect size was calculated in CMA by inputting the means, sample sizes, and t, P, or r values. When critical data were not being adequately reported to allow for calculation of effect sizes and it was not possible to estimate the effect sizes, the study was excluded. Seven studies were excluded. When studies included more than one treatment, the group deemed most relevant (e.g., receiving food safety training or other relevant educational interventions) was included in the meta-analysis. When there was more than one treatment group, the treatment group that received the least amount of intervention (e.g., receiving standard training only) was used. Because the purpose of this meta-analytical study was to assess the effectiveness of food safety training for improving hand hygiene knowledge and attitudes, the inclusion of other treatments (e.g., monetary incentives) may falsely elevate or decrease the effect sizes. Behavioral interventions such as management support and provision of incentives are discussed below.

Assessment of heterogeneity. The $I^2$ statistic was used to estimate the variation (heterogeneity) in the results among the different food safety training studies of hand hygiene knowledge and/or practices. $I^2$ represents the percentage of the total variation in estimated effects across studies due to heterogeneity rather than to chance (38). Higgins et al. (35) considered $I^2$ values of 25, 50, and 75% as low, moderate, and high. Publication bias was assessed using the Begg and Mazumdar rank correlation and Egger regression. Evidence of publication bias was considered significant when a two-tailed P value of <0.10 was obtained for the Begg and Mazumdar test and when a P value of <0.05 was obtained for the Egger test (64). Correction for publication bias was determined using Rosenthal’s file drawer number (failsafe N) method (29).

RESULTS

Study selection. Nine studies with 465 participants were identified for inclusion in the meta-analysis. The search of databases provided 1,597 citations. Of these, 1,575 studies were discarded after screening for eligibility and adjusting for duplicates. The full text of 22 studies was examined in more detail. Some studies were excluded because they were focused on quantification of pathogenic bacteria before and after intervention (60) or reduction of the number of diarrheal cases (40) or not enough information was provided and we were unable to contact the author(s) (4, 19, 61). All nine studies that met the inclusion criteria were included in the meta-analysis of hand hygiene knowledge, and five of these studies were included in the meta-analysis of hand hygiene attitudes (Fig. 1).

Synthesis of results. The meta-analysis of food safety training and/or intervention effects on hand hygiene knowledge among food handlers was obtained from combining the nine studies in a forest plot (Fig. 2). The overall intervention and training effect was significantly higher than that of the control (without training or no intervention), with an effect size (Hedges’ g) of 1.284 (95% confidence interval [CI] = 0.830 to 1.738) providing strong evidence.
evidence that food safety training increases hand hygiene knowledge. The results of all the studies included in the meta-analysis (with the exception of study indexes 1 and 7, which overlap the mean effect size of 0) indicated a significant effect of food safety training or interventions (compared with the control) on increasing hand hygiene knowledge.

Five food safety training or hand hygiene intervention studies monitored hand hygiene attitudes and self-reported practices, with a summary effect size of 0.683 (95% CI = 0.523 to 0.843) (Fig. 3). The range of results derived from the individual studies was narrow, but the overall estimated effect size was smaller than the effect size for hand hygiene knowledge.

Cumulative forest plot. Figure 4 is a cumulative forest plot in which the first row is a meta-analysis of study index 1. The second row is a meta-analysis based on two studies (study indexes 1 and 2a), and so on. The last study to be added was study index 9; therefore, the point estimate and 95% CI shown on the line for this study is identical to that shown in the summary effect. With addition of each study, the point estimates shifted to the right and developed a more consistent pattern.

Meanwhile, the cumulative meta-analysis of the effect of training on hand hygiene attitudes showed how the body of evidence has shifted over time (Fig. 5). The effect shift reiterated that of some studies (14, 22, 55, 73) in which food safety training had a small effect on food handlers’ attitudes and behaviors. This result is possibly not surprising, given the substantial evidence on the effects of food safety training in behavioral research (14, 22, 55). From study index c onward, the effect size begins to diminish. This finding led us to the following questions: To what extent will food safety training result in improved hand hygiene attitudes? Does improved attitudinal change result in behavioral change? In addition to self-motivation, management support, peer pressure, and availability of facilities play crucial roles in good hand washing practices.

Social-cognitive models. Figure 6 shows the effect sizes of food safety training and the influence of cognitive-behavioral theory-based model strategies on hand hygiene attitudes. Study index c (i) (46, 47) with an effect size of 1.064 (95% CI = 0.779 to 1.350) and d (i) (73) with an effect size of 0.825 (95% CI = 0.496 to 1.115), which tested the effects of behavioral interventions (e.g., management support and incentive programs), revealed that a combination of standard training and social cognitive behavioral interventions resulted in the greatest effects for both studies. The authors believed that the incorporation of behavioral interventions improved hand hygiene attitudes by targeting individuals’ motivational systems. When relevant skills and knowledge (i.e., hand hygiene procedures) are present, appropriate environments (i.e., adequate hand washing time and facilities) and motivational support from supervisors and the team can lead food handlers to increase good hand washing practices. Nieto-Montenegro et al. (47) suggested that to increase the effectiveness of a training program, the

![FIGURE 3. Forest plot of the effect of food safety training or hand hygiene interventions on hand hygiene attitudes, with a random effects summary. FTF, face-to-face delivery training; CBI, computer-based instruction.](image)

![FIGURE 4. Cumulative meta-analysis of the effects of food safety training on hand hygiene knowledge. The summary effect size was reestimated each time a study was added. ST, standard training; PH, participatory hand washing training; FTF, face-to-face delivery; CBI, computer-based instruction.](image)
designer must first understand the food handlers’ behavior and how this behavior interacts with their beliefs and levels of knowledge. This understanding can be facilitated by use of theory-based models when developing educational materials (45). For example, the theory of planned behavior was used to improve hand washing behavior. To improve attitudes, we recommended that food safety training materials include why food safety and hand hygiene is important (e.g., by emphasizing that practicing good hand hygiene reduces the number of people that get sick). Soon and Baines (63) used case studies of Mason Jones and Kyle Allgood (victims of food poisoning) during food safety training to connect with audiences’ lifestyles (especially those with children), incorporate fear, and enhance perception of risks. Supervisors and managers of food handlers also should create an environment that encourages hand washing by displaying posters and reminders (in the workers’ native languages) and should act as role models. To improve subjective norms, the trainers should emphasize that managers, colleagues, health inspectors, and customers would want food handlers to properly perform hand washing behaviors. Perceived control can be improved by supplying adequate resources and reminding employees to perform the behaviors (53). Ehiri et al. (22) and Seaman and Eves (59) also recommended that food safety training research be based on models such as the health action model: “The health action model probably gives the most thorough description of factors that may influence behavior change following training.” A better understanding of the beliefs among food handlers about their adherence to appropriate hand hygiene guidelines may help intervention designers target specific components of the theory of planned behavior model for further improvement (63).

Publication bias. Publication bias among all studies was assessed graphically with funnel plots (Figs. 7 and 8). Both plots contained clusters, suggestive of publication bias. A clustering of larger or more significant studies appeared toward the top of the plot and generally clustered around the mean effect size. The base of the plot was weak or missing because smaller or negative-result studies were not included in the analysis. The funnel plots are asymmetric, with more studies toward the right (representing a larger treatment effect) and few toward the left. Statistical test results provided evidence of publication bias for the effects of food safety training or interventions on hand hygiene knowledge (Begg’s test, $P \approx 0.0005$; Egger regression, $P = 0.0057$). When there is no heterogeneity, the points are distributed evenly on either side of the summary effect (29). When more “positive” studies (i.e., studies with significant results) than “negative” studies (i.e., studies with insignificant results) are likely to be published, then review of the published literature may be biased toward a “positive” result. The statistical tests for hand hygiene attitudes reveal lower evidence of publication bias (Begg’s test, $P = 0.85$; Egger’s regression, $P = 0.59$).

Correction for publication bias. Publication bias can be corrected through a sensitivity analysis that allows an estimate of its potential impact on the conclusions using the failsafe $N$ method (29). The number of studies that would be required to remove an observed significant effect is estimated. The failsafe $N$ is 742, suggesting that more than

![FIGURE 5. Cumulative meta-analysis of the effect of food safety training on hand hygiene attitudes. FTF, face-to-face delivery; CBI, computer-based instruction.](image)

![FIGURE 6. Forest plot of the effect of food safety training and the influence of social-cognitive models on hand hygiene attitudes. ST, standard training; MS, management support; $s$, monetary incentive; TPB, theory of planned behavior interventions.](image)
700 studies with an effect size of 0 would need to be added to the meta-analysis before the effect would become statistically nonsignificant. We found only nine studies in which the effects of food safety training and intervention strategies on hand hygiene knowledge and practices among food handlers were evaluated; it is unlikely that nearly 700 studies were missed.

**Heterogeneity.** Evidence of heterogeneity was observed in hand hygiene knowledge scores ($I^2 = 36.32\%$, $P < 0.05$) and hand hygiene attitudes ($I^2 = 2.66\%$, $P < 0.05$). More than 35% of the heterogeneity in hand hygiene knowledge scores was due to variance between studies rather than to chance. Some possible sources of heterogeneity may be subject selection, baseline food safety knowledge, diversity in cultural backgrounds, and participant characteristics. For hand hygiene attitudes, $I^2$ was $2.66\%$, indicating that although the heterogeneity was highly significant, its effect was small.

**DISCUSSION**

This meta-analysis is the first to explore the effectiveness of food safety training and hand hygiene interventions for improving hand hygiene knowledge and attitudes. The results supported those of individual studies that indicated that training increases hand hygiene knowledge scores. Even though the meta-analysis revealed an increase in attitude scores (Fig. 3), results in four of the five studies were based on self-reported data. Self-reported data are susceptible to social desirability bias (32), a tendency of individuals to overestimate desirable traits or behaviors (e.g., hand hygiene practices) and underestimate undesirable ones to present themselves in a favorable light (27).

Despite the effectiveness of hand hygiene training for improving knowledge, this training may be less effective for motivating people to use good hand hygiene practices. Few studies in this meta-analysis included an assessment of retention over time of hand hygiene knowledge and behavioral change after the intervention. Some studies tested the knowledge scores and hand washing compliance rate after a certain posttraining period (1, 39, 47, 62). Future hand hygiene interventions and training programs should monitor the retention of knowledge and behavioral changes in hand hygiene practices over time. Larger studies coupled with longer follow-up studies or refresher training sessions should be conducted. Follow-up assessments can measure the impact of training over time (20). However, these studies may pose various challenges to
trainers and researchers. Fenton et al. (23) found that seasonal employees in the farming and food industry were more difficult to train because of rapid employee turnover. Pilling et al. (53) also faced a similar problem when food service establishments declined to participate because of the long time frame and the intrusive nature of data collection.

Environmental and motivational factors are integral to training sessions. Griffith (33) argued that behavioral change (i.e., the implementation of required hygiene practices) is not easily achieved and that consideration must be given to motivation, constraints, barriers, facilities, and cultural aspects. Future meta-analyses of the effects of continuous monitoring can be used to determine whether there are differences in the effects of training after a long posttraining period. However, on-site monitoring is costly and may not be feasible because of staff turnover. When continuous monitoring and refresher training courses are not feasible for certain operations, a combination of standard training and behavioral interventions may be the most advantageous and practical approach for both operations and food handlers.

When food handlers were divided into subgroups based on whether they received standard training, behavioral interventions, or standard training plus behavioral interventions (e.g., incentive rewards, management support, and reminders), the training effect was largest for participants that received both standard training and behavioral interventions (Fig. 6). Social cognitive components of the theory of planned behavior model and health action model can be targeted in educational interventions to improve behavioral intent. Managers and supervisors should emphasize the positive outcomes of hand washing (e.g., safe food, less recall, and more profit for the company and workers) and potential negative outcomes (e.g., foodborne illnesses, product recall and lost business, and possible retribution or bankruptcy). Supervisors and managers also should create an environment that encourages hand washing through the display of posters and reminders (in the workers’ native languages) (73) and should be role models for good hand hygiene. Food handlers should be constantly reminded of their crucial role in ensuring safe food for consumers because they are the food service–customer interface. Adequate hand washing facilities and time will encourage food employees to use good hand washing practices (53).

The results of the meta-analyses confirmed the efficacy of food safety training for increasing knowledge of and improving attitudes about good hand hygiene. However, the effect on attitudes was lower and based on self-reported practices. Knowledge retention and behavioral changes among food handlers should be monitored so refresher courses and targeted training can be designed and implemented. Meta-analysis can be used to integrate results from diverse studies and synthesize the information. However, publication bias may be present. Efforts to monitor human behavior are complex, and motivational, perceptual, and environmental factors must be taken into consideration (17, 49). Training sessions have been viewed as a one-time thing, and refresher training is often neither planned nor implemented (72). Refresher courses and follow-up training sessions, monitoring of hand hygiene practices for longer posttraining periods, and management support will impact hand washing practices. Detailed examination of monitoring over time and combinations of food safety training and social cognitive behavioral interventions will be beneficial.

Advantages. A systematic review assembles all relevant research done on a subject, trying to avoid the bias of the most influential publications (37). Meta-analysis also combines data across studies to estimate the treatment effects with more accuracy than can be accomplished with a single study (38). Policy-makers can use meta-analysis to make critical decisions.

Limitations. One of the main limitations of the present study is the language used, i.e., we included only studies published in English. Food safety training and/or intervention effects on food safety knowledge and practices may be addressed by a number of different kinds of studies. Negative results may have been published in languages other than English or might have not been published at all (37). For example, one Spanish study in which the researchers assessed the effectiveness of health training courses offered for food handlers in a health care district in Valencia was excluded (70). The outcomes reported in this systematic review and meta-analysis were taken from only part of the original studies. Because of insufficient data, our study excluded a number of otherwise eligible studies (4, 19, 41, 56, 57, 61, 62). Publication bias is always a concern in a meta-analysis. Research with significant results is more likely to be published than are studies with nonsignificant results (66). For some studies, calculations were carried out to obtain the effect sizes (Hedges’ g). The calculations may not be as precise as calculations made using the raw data (2).

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