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Title: Food safety policies and their effectiveness to prevent foodborne diseases in catering establishments: a systematic review and meta-analysis

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Abstract

Despite being largely preventable, foodborne diseases continue to be of major concern worldwide. Research has shown that interventions relying on food handling training programs and standard food safety practices have a direct impact on food handler's knowledge and attitudes. However, to date, evidence on the effectiveness of policies in reducing microbial count in food is sparse and inconclusive. This systematic review and meta-analysis aims to summarize the evidence on the potential of food safety policies in catering establishments as a means to prevent foodborne diseases. A search for relevant publications was conducted in PubMed, Scopus, CENTRAL, ProQuest, CINAHL and ERIC databases. Retrieved studies were summarised in terms of context, population, outcome, methodology, risk of bias and intervention type. Eight studies were included in the qualitative analysis and the meta-analysis. Food safety interventions were associated with a statistically significant microbial reduction of 28.6% (95% CI: -30.6% to -26.7%). Four subgroup analyses were conducted: by type of microorganism screened, by sample origin, by type of food establishment, and by sample collection time post-intervention. Microbial reductions were consistent across each of the subgroups. Findings suggest that policies such as programs based on the Hazard Analysis and Critical Control Points (HACCP) could be effective strategies to prevent foodborne diseases from occurring in foodservice establishments at the end of the food supply chain. However, the underlying evidence suffers from risk of bias and more randomized controlled trials and controlled before-and-after studies are needed in this field.

Keywords: Food safety; Food policy; Training; Foodborne disease; Microbial assessment; HACCP

1. Introduction

Foodborne diseases (FBDs) are a public health problem in many countries. According to Havelaar and colleagues (2015), contaminated food is responsible for up to 600 million foodborne illnesses and an estimated global burden of up to 33 million disability-adjusted life years in 2010. In addition, FBDs put an economic strain on countries by reducing national economic productivity, and by damaging trade and tourism. For example, it has been estimated that unsafe food costs low and middle income countries USD 95 billion in lost productivity each year (Jaffee, Henson, Unnevehr, Grace, & Cassou, 2019).

Improving hygiene practices and implementing food safety interventions is critical to ensure good public health and food security and to strive for better livelihoods, economic development and mutually beneficial commerce between countries.

A number of public health preventative measures exist to avoid problems in food hygiene and food safety throughout the food production chain. This study focuses on interventions targeting the meal preparation or 'plate' stage of the food chain continuum, which typically focuses on food handlers in the catering industry and, sometimes, consumers. Underlying many of these interventions are food safety systems, like the *Codex Alimentarius* (or "Food Code") and the Hazard Analysis and Critical Control Points (HACCP) (FAO & WHO, 2006).

Interventions targeting meal preparation are the focus of a number of academic publications as well as documents published by governments and intergovernmental organizations. Many studies have specifically looked at the behaviour changes in food handlers following their participation in food safety, food hygiene and food preparation training courses (Barrett & Riggins, 2011; Gautam, 2015; Seaman & Eves, 2008). This has led to a series of literature reviews measuring knowledge, attitudes and practices of foodservice employees as efficacy markers of educational programs in reducing the burden of FBDs (Reynolds & Dolasinski, 2019; Soon, Baines, & Seaman, 2012; Young, Greig, Wilhelm, & Waddell, 2019; Young, Waddell, Wilhelm, & Greig, 2020; Young et al., 2015; Zanin, da Cunha, de

Rosso, Capriles, & Stedefeldt, 2017). However, such reviews do not report the impact of behaviour change on reduction of risks for FBDs as they do not include microbial assessments of food-related samples (Saxena, Bharagava, Kaithwas, & Raj, 2015). This is a significant gap in the evidence to inform policy-making in this field, as it cannot be given for granted that better knowledge or enhanced attitudes decreases the burden of FBDs. More importantly, available systematic reviews do not provide a quantification of this potential impact.

This systematic review and meta-analysis aims to close these gaps by measuring the impact of food safety interventions in reducing microbial counts in commercial and institutional catering settings. The findings from this review may be used to inform decision-making in the field of food safety and health, especially around the expected impact of policy implementation or enforcement.

2. Material and methods

The study was conducted as a systematic review and meta-analysis of studies investigating the effectiveness of food safety and hygiene policy-based interventions preventing FBDs. This study followed the “Preferred Reporting Items for Systematic Review and Meta-Analyses” (PRISMA) guidelines (Moher, Liberati, Tetzlaff, & Altman, 2009). The research question was developed using the PICO framework and standard methodology approaches were applied as per the recommendations of the Cochrane Handbook for Systematic Reviews of Interventions (CHSRI) (Higgins & Green, 2011). A copy of the PRISMA checklist and the PICO framework are available in the Appendix Tables 1 and 2.

2.1. Data sources and search strategy

Titles, abstracts, keywords and, when available, full text of documents from six databases were systematically searched in March 2020 including PubMed (Medline), Scopus, the Cochrane Central Register of Controlled Trials (CENTRAL), ProQuest, the Cumulative Index of Nursing and Allied Health Literature (CINAHL), and the Education Resources Information Center (ERIC). These databases were

selected because of their scope of coverage across disciplines in nutrition, life, social, health and biomedical sciences. Terms used in the search algorithm included PICO-identified keywords for topic (e.g. "food safety", foodborne, "food contamination*"), intervention (e.g. HACCP, "hazard analysis and critical control point*", "food safety training*") and outcome of interest ("aerobic plate count*", "microbial analys*"). Manual search of the reference lists of included studies was also performed to retrieve and include relevant articles that had not previously been identified during the database search, a strategy commonly referred to as snowballing (Ababio, Taylor, Swainson, & Daramola, 2016; Charalambous, 2011; Han Acikel et al., 2008; Hart, 1997; Lim, Choi, Kang, & Kwak, 2013; Maung et al., 2017; Pivarnik et al., 2013; Young et al., 2019). The full search strategy is available in the Appendix Table 3.

2.2. Inclusion and exclusion criteria

Studies included in the analysis had to match the previously outlined PICO framework and fulfil a number of eligibility criteria. First, they had to evaluate the effect of a food safety and hygiene training program. Second, the target population should be composed of foodservice employees and food handlers who prepare or serve food at restaurants or other food distribution services, like grocery stores, rather than consumers preparing food at home or handlers working at other stages of the food chain. Third, the outcome variable in included studies should consist of the amount of microbial contamination (in colony forming units (CFU)) detected in samples of either food, surfaces or food handler's hands. Fourth, studies should report before and after intervention microbial counts or mean differences between pre- and post-program CFU collections. Finally, studies included should restrict their setting to food establishments specialised in supplying the end of the food chain continuum (e.g. restaurants).

CFU is a common microbiology technique used to estimate the number of viable microorganisms in a sample (Sieuwerts, De Bok, Mols, De Vos, & Van Hylckama Vlieg, 2008). Considering most studies identified during the search reported CFU, articles reporting microbial counts in Most Probable

Number (MPN) only were excluded as the scientific literature modelling the relationship between MPN and CFU approach suggests these measures are not interchangeable and comparing them could induce intra-sample variability (Cho et al., 2010; Gronewold & Wolpert, 2008). Preference was thus given to studies using CFU.

Records that fulfilled all inclusion criteria were included in the meta-analysis. Eligible sources of evidence included journal articles as well as dissertations and theses. No language restriction was established and native speakers along with online translation services supported the assessment of studies published in languages other than English. Only studies focusing on member countries of the Organization for Economic Co-operation and Development (OECD) were included in the analysis, as this group of countries is relatively similar in terms of policies and socio-economic characteristics, therefore maximizing cross-study homogeneity, and ensuring resulting policy implications apply more broadly.

2.3. Study selection

Following the exclusion of duplicate records, a screening of the titles and abstracts against the inclusion criteria was carried out. Full-texts of articles were scanned when insufficient information was provided in their abstracts to conclude on selection status. Reasons for excluding studies were documented in the PRISMA diagram (Figure 1).

2.4. Data extraction

For each study, qualitative data were extracted in terms of study characteristics such as setting, population, intervention type, sample details and main outcomes. Mean microbial counts (in CFU) before and after intervention implementation were collected for different categories to inform subgroup analyses. Subgroups were defined on the basis of type of microorganism screened, sample origin, food establishment type and sample collection time.

2.5. Risk of bias

The Risk of Bias In Non-randomized Studies of Intervention (ROBINS-I) tool was used in this study (Sterne et al., 2016). ROBINS-I focuses on assessing the internal validity of a study and includes signalling questions that inform and lead to an overall risk of bias (ROB) judgement. ROBINS-I views each study as an attempt to emulate a hypothetical pragmatic randomised trial and covers seven domains - confounding, participant selection, intervention classification, deviation from the intended interventions, missing data, outcome measurement and selection of which results to report – through which bias might be introduced (Sterne et al., 2016). Between three and eight signalling questions were used to assess the risk of bias in each domain. The risk of bias in each domain were then combined to produce an overall risk of bias that could be either low, moderate, serious or critical. A study was considered at low ROB if it was ranked low for all domains; at moderate ROB if it was ranked at low or moderate ROB for all domains; at serious ROB if it was ranked serious in at least one domain; and at critical ROB if it was ranked critical in at least one domain. A full copy of the tool, including the rating criteria for each domain, can be accessed in the Appendix Table 4.

2.6. Statistical analysis

As a first step in the analyses, calculations were performed to standardize data from different studies. Six out of eight studies reported values in log₁₀CFU whilst for the remaining two, conversions from CFU to log₁₀CFU were performed for same-scale comparison (Hart, 1997; Roy et al., 2016). CFUs measured before and after intervention were described as means in all but one study, from Soriano and colleagues (2002) (Soriano, Rico, Moltó, & Mañes, 2002). In the latter study, because findings were reported as ranges, mid-point numbers of each range were computed and summed to obtain mean values that could be used in the meta-analysis. In order to include the results from Cenci-Goga et al. (2005) in the meta-analysis, the numbers tabulated as “<2.48” or “<3.48” in the study were replaced in this review by the values 2.47 and 3.47 respectively as this is the most conservative option (Cenci-Goga, Ortenzi, Bartocci, Codega De Oliveira, et al., 2005).

In this review, all included studies reported continuous outcomes where the effect measure of interest is the difference in mean counts for before and after intervention groups. The difference is used to estimate the amount by which a food safety and hygiene intervention modifies the outcome.

For each study, group-specific standard deviations (SD), when available, were used to calculate the standard error of the mean for each group. These were in turn used to calculate the SD of the mean difference, using standard approaches detailed in the CHSRI (Higgins & Green, 2011). As per the recommendations in Cochrane's handbook, zero-cell counts like null standard error values, which caused computational errors in the analysis, were replaced by a value of 0.001 (Higgins & Green, 2011). Whenever essential summary measures such as SDs were not reported in an article, missing values were imputed using available SDs from studies considered as similar in design, sample size and sample investigated (Weir et al., 2018).

Studies on food safety interventions tend to report at least two data points: one for the mean microbial count before the implementation of the intervention and at least one for the mean microbial count after intervention application. To obtain a single comparable outcome value to quantify the effect of introducing a food safety measure in food establishments, the relative percent change of the pre- and post-intervention microbial mean counts was computed. This construct was used throughout this review, and is henceforth referred to as effect size or effect estimate.

For almost all eligible studies, multiple related variables of interest were examined and thus, more than one effect estimate was reported per sample collected. For example, in Cenci-Goga et al., the screening of each food sample resulted in the identification and quantification of up to five different microorganism types per extract collected (Cenci-Goga, Ortenzi, Bartocci, Codega De Oliveira, et al., 2005). To illustrate the type of data collected from included studies, an excerpt of the raw data extraction table is shown in the Appendix Table 5.

When studies reported data for multiple outcomes of interest (e.g. microbial count by microorganism type, sample origin, food establishment type and latest sample collection time), results for each outcome were considered as an independent study. To conduct a meta-analysis with multiple dependent effect sizes, a traditional approach averaging the effect sizes per study was used to handle this dependency (Moeyaert et al., 2017). In practice, for the main meta-analysis, the average of all different effect estimates and the average of their corresponding standard errors were computed for each study, resulting in a single averaged estimate and a single standard error per study.

In order to account for effect sizes based on larger sample sizes and to minimize the sampling variance of the average effect, the inverse of the variance was computed and used as a weight in a fixed-effect model (Moeyaert et al., 2017).

The 'metan' package in Stata version 16.0 was used to run a meta-analyses of effect estimates with their corresponding standard errors (Harris et al., 2010).

In accordance with Cochrane guidelines (Higgins & Green, 2011), heterogeneity was assessed through different methodologies. Visual inspection of forest plots and the funnel plots were used to identify systematic heterogeneity across studies and to check for the presence of publication bias. The I^2 statistic was used to quantify the percentage of variation across studies that is due to heterogeneity. The I^2 statistic was chosen as it is not affected by the number of studies considered.

In the subgroup analyses, meta-analyses were first stratified by microorganism type (coliforms, fecal coliforms, *Staphylococcus aureus*, total bacteria, *Enterobacterales*, moulds and yeasts), by sample origin (food, food handler's hands and food-contact surfaces), and then by type of food establishment (university: restaurant, canteen, café; food catering facilities: foodservice establishment, restaurant; care facilities: hospitals, RCCIs, assisted-living or long-term care centres). A final subgroup analysis was conducted by time at which the latest sample was collected post-intervention (≤ 1 month; 2-9 months; 1+ year). In the subgroup meta-analysis, for studies collecting

several corresponding samples and hence reporting multiple effect estimates for the same category, the average of group-specific effect sizes and that of their standard errors were calculated to obtain a single value for both effect size and standard error per study.

Further sensitivity analyses were performed by repeating the main meta-analysis but using a random-effects model instead of fixed-effects, and excluding studies with larger weights.

3. Results

3.1. Study selection

The database search identified 1602 records with eight additional records retrieved via hand searching (snowballing). Following the removal of duplicates (n=469), 1138 articles were screened for title and abstract leading to the further exclusion of 1028 studies. A total of 110 records remained to be assessed for full-text eligibility, which led to the exclusion of 102 records. Reasons for excluding full-text articles included unsuitable setting (n=40), missing outcome measure (n=29), missing intervention (n=19), unsuitable food supply stage (n=7), unclear or missing intervention and outcome (n=3), unsuitable design (n=2) and unclear intervention timeframe (n=1). Eight studies were included in the qualitative analysis and, given that Cochrane guidelines consider this as a sufficient number of studies, in the quantitative meta-analysis. The PRISMA diagram illustrating the selection process is shown in Figure 1.

[Figure 1 around here] - Figure 1. PRISMA diagram describing the selection process

3.2. Study characteristics: qualitative review

Table 1 summarizes the included articles. The eight studies eligible for systematic review were published between 1997 and 2016, and were carried out in the United States (n=3); Spain (n=2); Italy (n=1); Korea (n=1); and Portugal (n=1) (Cenci-Goga, Ortenzi, Bartocci, Codega De Oliveira, et al.,

2005; Garayoa, Yáñez, Díez-Leturia, Bes-Rastrollo, & Vitas, 2016; Hart, 1997; Lim et al., 2013; Pivarnik et al., 2013; Roy et al., 2016; Soares, García-Díez, Esteves, Oliveira, & Saraiva, 2013; Soriano et al., 2002). Only one journal article was published in a foreign language (Korean) (Lim et al., 2013).

All studies had quasi-experimental uncontrolled before-and-after (UBA) research designs. Most of the articles (n=6) surveyed populations composed of food handlers (Cenci-Goga, Ortenzi, Bartocci, De Oliveira, et al., 2005; Garayoa et al., 2016; Lim et al., 2013; Roy et al., 2016; Soriano et al., 2002). The remaining studies looked at foodservice and residential childcare institution (RCCI) staff and managers (Hart, 1997; Pivarnik et al., 2013; Soares et al., 2013).

Six of the eight studies implemented HACCP-based food safety control trainings for foodservice personnel, of which one study also evaluated hand disinfection as a food hygiene measure (Soares et al., 2013). The two remaining studies assessed handwashing and minimal-text food safety posters (Garayoa et al., 2016; Roy et al., 2016).

All eight studies used microbial counts as main outcome of interest and compared samples collected post-intervention with those collected prior the intervention, under 'business as usual' circumstances (Cenci-Goga, Ortenzi, Bartocci, De Oliveira, et al., 2005; Garayoa et al., 2016; Hart, 1997; Lim et al., 2013; Pivarnik et al., 2013; Roy et al., 2016; Soares et al., 2013; Soriano et al., 2002).

Follow-up time between baseline and after-intervention sample collection ranged from 2 weeks to 19 months across seven of the studies, with a median of approximately 2 months and an average of 5 months. The remaining study had a particularly short follow-up period with samples collected immediately after the handwashing event (Garayoa et al., 2016).

All included studies (n=8) screened for either Aerobic Plate Count (APC) or Total Plate Count (TPC), both of which identify counts of total bacteria, also known as aerobic microorganisms. All articles used comparable methodologies for microbiological assessment of samples, although four studies performed microbial analysis using plating kits that were different from the standard agar technique

(Hart, 1997; Lim et al., 2013; Pivarnik et al., 2013; Roy et al., 2016). Further details on the studies included in the analysis are provided in Table 1.

[Table 1 around here] - Table 1. Baseline characteristics of studies included in the qualitative analysis

3.3. Risk of bias within studies

The risk of bias was considered either low or moderate for six of the seven domains included in the ROBINS-I approach. However, the potential risk of bias due to confounding had to be ranked as critical for all the studies as no study was carried out as randomized controlled trials, which is common for these type of public health interventions. Overall, the risk of bias was thus considered critical. Following standard practice, and to test the potential impact of the risk of bias, the analyses were complemented by an extensive set of sensitivity analyses (see Section 3.8). Further information on each study, including the reasons behind the ROBINS-I ratings are reported in an overview risk of bias plot (Figure 2) and in the Appendix Table 6.

[Figure 2 around here] - Figure 2. Risk of bias assessment plot using the ROBINS-I tool

3.4. Results of individual studies

A summary of the results from each individual study included in this meta-analysis is provided in Table 2. The median sample size for studies included in this systematic review was 235 samples per article, including from food, kitchen surfaces or food handler's hands. The number of effect estimates extracted from each study ranged from 1 up to 111.

[Table 2 around here] - Table 2. Summary results of the eight included studies in the meta-analysis

3.5. Results of the meta-analysis

Overall, the implementation of a food safety training program amongst food establishment staff was estimated to reduce the microbial count by 28.6% on average (95% CI: -30.6% to -26.7%) (Figure 3).

[Figure 3 around here] - Figure 3. Meta-analysis of the effect of introducing a food safety intervention on microbial counts detected in samples collected from food establishments

3.6. Subgroup analyses

Throughout the following subgroup analyses, studies were pooled along different subgroups and hence individual studies could contribute multiple estimates to the pooled effects. In the subgroup analysis by type of microorganisms identified, microbial count reduction was highest for *Enterobacterales* (-71.7%; 95% CI: -81.6% to -61.8%) and lowest for *S. aureus* (-5.1%; 95% CI: -9.1% to -1.09%). The results obtained from this stratification are shown in Table 3.

[Table 3 around here] - Table 3. Meta-analysis of the effect of introducing a food safety intervention on microbial counts detected in samples collected from food establishments, by microorganism type

As shown in Table 4, swabs from hands and food-contact surfaces showed respectively the highest (-44.7%; 95%CI: -45.8% to -43.5%) and lowest (-22.6%; 95%CI: -25.2% to -20%) relative percent changes in microbial counts pre- and post-intervention.

[Table 4 around here] - Table 4. Meta-analysis of the effect of introducing a food safety intervention on microbial counts detected in samples collected from food establishments, by sample origin

A third subgroup analysis was conducted by food establishment type from where samples were collected. Results from this analysis are shown in Table 5. Food catering facilities had the highest (-33.3%; 95%CI: -44.4% to -22.1%) relative reduction in microbial counts after implementation of food safety measures, compared to catering facilities and universities.

[Table 5 around here] - Table 5. Meta-analysis of the effect of introducing a food safety intervention on microbial counts detected in samples collected from foodservices, by food establishment type

A final subgroup analysis was conducted by time period elapsed between the latest follow-up sample collection and the intervention date. As shown in Table 6, relative reductions in microbial counts were highest for samples collected ≤ 1 month following the food safety program implementation (-48.1%; 95% CI: -55.7% to -40.5%) and lowest for samples collected more than one year after the introduction of this intervention (-12.2%; 95% CI: -15.4% to -9.0%).

[Table 6 around here] - Table 6. Meta-analysis of the effect of introducing a food safety intervention on microbial counts detected in samples collected from foodservices, by latest sample collection time (post-intervention)

3.7. Risk of bias across studies

As shown in the funnel plot for publication bias in the Appendix Figure 4, the spread of the standard errors suggests a moderate presence of publication bias. Specifically, the funnel plot suggests that studies are missing in the lower left side of the plot, making it appear asymmetric. The heterogeneity found in the main and subgroup analyses could be one of the reasons for this between-study variability. Additionally, due to the relatively low number of articles included, visual interpretation of the funnel plot should be taken with caution.

3.8. Sensitivity analyses

Sensitivity analyses were performed removing two studies with particularly large weights (Pivarnik et al., 2013; Soares et al., 2013). With the removal of Pivarnik et al., there was still a statistically significant average relative percent change reduction (-34.0%; 95% CI: -37.1% to -30.9%; $p = 0.000$) in microbial counts after food safety training program implementation (Table 7). A similar result was observed following the removal of Soares et al. (Appendix Table 7).

In another sensitivity analysis, repeating the baseline meta-analysis using a random effects model led to a pooled effect estimate (-32.8%; 95% CI: -48.2 to -17.5; I-squared = 99%, $p = 0.000$) very similar to that reported using the fixed effects model (-28.6%, 95% CI: -30.6% to -26.7%; I-squared = 99%, $p = 0.000$), both in terms of direction and statistical significance. Similar trends in terms of direction and significance of overall effect estimates were also found when using a random effects model for subgroup meta-analyses (see Appendix Table 8).

4. Discussion

4.1. Summary of evidence

This systematic literature review and meta-analysis investigating the impact of food safety interventions found these policies to be effective in reducing microbial counts, a marker for food contamination (National Research Council, 1985). Despite cross-study heterogeneity, all studies consistently pointed towards a microbial count reduction following the implementation of interventions.

Overall, interventions based on training food handlers in hazard analysis, critical control point identification, handwashing and other essentials of food safety theory were successful at decreasing microbial proliferation during food preparation. The effects of these interventions were found to be time-dependent as microbial counts were higher as time of sample collection post-intervention

implementation was longer. The highest reductions in microbial counts were measured for samples collected within one month of the intervention being implemented. This would suggest that to maintain the impact of food safety trainings, knowledge and practice follow-ups may need to be introduced.

Findings from this study are consistent with other systematic reviews in this field evaluating the effectiveness of education and training in improving food handlers' self-reported knowledge, attitudes, and practices (KAP) (Young et al., 2019, 2020). Past reviews have shown that educational interventions for food safety produce large positive effects on KAP outcomes and that substantial heterogeneity across categories can be detected.

This review complements previous analyses by showing that improvements in food handler's KAP directly translate in a food contamination reduction assessed as a relative percent change in foodservice inspection scores based on microbial counts. Our findings also indicate that *Enterobacterales* stand out in terms of effect size. This is a positive outcome as this family of bacteria include many important virulent foodborne pathogens such as *Salmonella*, *Escherichia coli* and *Shigella*, which are among the most common causes of foodborne diseases.

4.2. Strengths and limitations

This study addresses some of the gaps highlighted in previous systematic reviews and meta-analyses published in this field by evaluating the effectiveness of food safety interventions using microbial indicators of contamination (Lim et al., 2013; Seaman & Eves, 2008; Soon et al., 2012). Nonetheless, results from this review should be interpreted with caution due to a number of limitations.

As a first strong point of this study, a comprehensive number of databases were searched and a systematic and exhaustive data compilation was performed. Additionally, substantial efforts were made to avoid language bias by including non-English written studies with the assistance of native speakers.

With respect to study quality and risk of bias, eligible articles were assessed using the ROBINS-I tool, a standard instrument recommended by Cochrane for systematic reviews of non-randomized trials. While the risk of bias was considered low for the vast majority of study-domain combinations, all the studies received a poor rating on their design, which was neither randomized nor controlled. To a large extent, this should be considered as inevitable, given the type of intervention tested which makes it difficult to use randomized controlled trials. Conversely, our review confirmed that included studies used robust methods to screen for microbial presence and hence food contamination. For example, sampling of food extracts and swabs of food-related working environment, such as food handler's hands or chopping boards, were collected to include all the representative sources of potential contamination.

Consistent with previous reviews of the literature in this field, our study identified some heterogeneity across studies, which warrants caution in the interpretation of the results. To minimize potential between-study heterogeneity attributed to country-specific differences in food systems, food policies and basic hygiene practices, the geographic scope for inclusion was limited to OECD member countries, which are more homogeneous in terms of implemented policies as well as of income per capita (Nyarugwe, Linnemann, Hofstede, Fogliano, & Luning, 2016). In addition, only studies assessing comparable outcomes and using equivalent metrics were selected, although this has led to the exclusion of studies reporting findings in terms of MPN. Despite this, between-study variability was detected, which persisted in the subgroup analyses. This variability could be explained by, for example, methodological variation across studies, the conservative assumptions explained below used to maximize the number of estimates included in the meta-analysis as well as other unmeasured factors.

To maximize the number of studies contributing to the pooled estimates, missing summary statistics and unreported values were estimated using standard procedures recommended in the CHSRI (Higgins & Green, 2011). This approach introduces some uncertainty, compared to using the original

data, as the used approach produces estimates that tend to be more conservative. Similarly, the assumptions needed to deal with the categorical values in Cenci-Goga et al. (2005) may have also reduced the values of the true effect. If anything, this means that our findings may underestimate the true effectiveness of interventions.

A comprehensive set of sensitivity analyses was conducted to explore the impact of using different meta-analysis models as well as to explore the impact of excluding studies with large weights. As results from these additional analyses remained consistent throughout, this adds confidence that the meta-analysis findings can be considered robust (Higgins & Green, 2011).

Finally, UBA studies are sensitive to the Hawthorne effect, a phenomenon whereby cases in an experiment modify their behaviour as a result of being observed (Grimshaw, 2000). While findings provide support for the implementation of food safety policies, it would be important to strengthen the quality of existing evidence using more robust research methods, such as randomized controlled trials and controlled before and after studies.

4.3. Implications for current practice and recommendations for future research

Findings from this systematic review suggest that implementation of food safety policies in the form of HACCP-based theoretical and practical trainings are effective in reducing the overall microbial prevalence in foodservice premises. Despite these promising findings, evidence gaps remain for what concerns the lack of expertise in HACCP, the cost of regular trainings, and how to further improve food handlers' compliance to the framework. Recommendations for future research include exploring issues associated with the evidence gaps just mentioned as well as exploring the drivers behind high levels of heterogeneity across included studies. Additionally, future studies could also focus on evaluating the effectiveness of different training programs' features on KAP. Finally, it would be important to consider the potential role of food safety policies in slowing down the unfolding antimicrobial resistance crisis. In practice, this would entail screening food samples for antibiotic resistance in any identified bacterium.

5. Conclusions

This systematic review and meta-analysis found that food safety measures introduced in food establishments targeting food handlers at the end of the food supply chain reduced the presence of microorganisms. Notably, the meta-analysis found that *Enterobacterales* counts, which are indicators of food contamination, could be more than halved after implementation of HACCP-based training programs. The underlying studies had a risk of bias, which was addressed through sub-group and sensitivity analyses, but further investigations using gold-standard research designs should be encouraged in this field. This in turn would provide greater confidence in the policy implications of future studies.

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Declarations of interest

None.

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Research International, 100(1), 53-62. <https://doi.org/10.1016/j.foodres.2017.07.042>

Table 1. Baseline characteristics of studies included in the qualitative analysis

Author(s), publication year	Study location	Study design	Population	Intervention	Comparison	Outcome	Follow-up period after intervention	Method of outcome collection	Micro-organisms reported
Cenci-Goga et al, 2005	Italy	UBA	Mix of food handlers	HACCP pre-requisite and HACCP system training programs	Baseline (=before intervention)	Microbial count	6-9 months & 15-19 months	Samples grown on PCA (TPC), BAB (BCC), BPAB (SAC), CCA (TCC)	Total bacteria, <i>B. cereus</i> , coliforms, fecal coliforms, <i>S. aureus</i>
Garayoa et al, 2016	Spain	UBA	Mix of food handlers (n=46)	Handwashing of gloves or bare-hands while performing kitchen activities	Baseline (=before intervention; HACCP already in practice)	Microbial count	Immediately after (minutes after handwashing)	Swab-rinse technique; samples grown on PCA (TPC), MSA (SAC), VRBG (EC)	Total bacteria, <i>S. aureus</i> , <i>Enterobacteriales</i>
Hart, 1997	United States	UBA	Foodservice managers (n=8)	Theoretical HACCP training prior to HACCP implementation	Baseline (=before intervention)	Microbial count	3 weeks – 1 month	Samples plated on nutrient pad kits inserted in petri dish for TPC	Total bacteria
Lim et al, 2013	South Korea	UBA	Mix of food handlers (n=8)	Theoretical HACCP training prior to HACCP implementation	Baseline (=before intervention)	Microbial count	1 month & 2 months	Swab-rinse technique; plating of samples on petri-film (3M)	Total bacteria, <i>Enterobacteriales</i> , coliforms
Pivarnik et al, 2013	United States	UBA	RCCI managers and staff (n=50-82)	HACCP-based food safety curriculum and activities	Baseline (=before intervention)	Microbial count	2-3 months	Plating on Simplate for TPC detection	Mould/ yeast
Roy et al, 2016	United States	UBA	Mix of food handlers	Minimal-text posters with handwashing, GMPs, hygiene practices	Baseline (=before intervention)	Microbial count	1 month & 3-4 months	Plating of samples on coliform & aerobic count plate petri-film (3M)	Total bacteria, fecal coliforms, coliforms
Soares et al, 2013	Portugal	UBA	Foodservice employees, mix of food handlers (n=60)	Hand disinfection and HACCP-based food safety training program (theoretical, practical)	Baseline (=before intervention; HACCP already in practice)	Microbial count	2 weeks	Swab-rinse technique; samples grown on PCA (TPC), VRBLA (TCC), VRBG (EC), CGA (MYC)	Total bacteria, mould/ yeast, coliforms, <i>Enterobacteriaceae</i>
Soriano et al, 2002	Spain	UBA	Mix of food handlers	HACCP pre-requisite and HACCP system	Baseline (=before	Microbial count	1 year	APC found by spreading sample on PCA	Total bacteria

training programs	intervention)
<p>UBA, uncontrolled before-and-after; PCA, plate count agar; TPC, total plate count; BAB, Bacillus cereus Agar Base; BCC, Bacillus cereus count; BPAB, baird-parker agar base; SAC, staphylococcus aureus count; CCA, chromogenic coliform agar; TCC, total coliform count; MSA, mannitol salt agar; VRBG, violet red bile glucose; EC, Enterobacterales count; APC, aerobic plate count; VRBLA, violet red bile lactose agar; CGA, chloramphenicol glucose agar; MYC, mould and yeast count</p>	

Table 2. Summary results of the eight included studies in the meta-analysis

Author(s), publication year	Data type	Outcome unit	No. of samples taken	No. of estimates	Overall before count	Overall after count	Average variance
Cenci-Goga et al, 2005	Continuous	Log CFU/g	894	15	3.64	3.19	0.017
Garayoa et al, 2016	Continuous	Log CFU/cm ²	184	6	1.20	0.74	0.037
Hart, 1997	Continuous	CFU/g	42	1	4.50	3.78	0.332
Lim et al, 2013	Continuous	Log CFU/g	295	111	3.37	2.41	0.213
Pivarnik et al, 2013	Continuous	Log CFU/cm ²	280	6	1.81	1.32	0.007
Roy et al, 2016	Continuous	CFU/mL	144	6	1.16	0.91	0.116
Soares et al, 2013	Continuous	Log CFU/cm ²	480	19	0.79	0.34	0.020
Soriano et al, 2002	Continuous	Log CFU/g	190	2	3.31	1.91	0.120

CFU, colony forming units

Table 3. Meta-analysis of the effect of introducing a food safety intervention on microbial counts detected in samples collected from food establishments, by microorganism type

Micro-organism type	No. of studies pooled ^a	Average relative change (%)	95% CI	Heterogeneity statistic	DF	p-value	I ² * (%)
<i>Coliforms</i>	4	-17.45	(-22.88, -12.02)	2.3e+05	3	0.000	100
<i>Fecal coliforms</i>	2	-41.16	(-41.82, -40.49)	1887.29	1	0.000	99.9
<i>S. aureus</i>	2	-5.09	(-9.10, -1.09)	13.95	1	0.000	92.8
<i>Enterobacteriales</i>	3	-71.68	(-81.58, -61.79)	37297.18	2	0.000	100
Total bacteria	7	-35.62	(-44.31, -26.94)	67.23	6	0.000	91.1
Moulds & yeasts	2	-22.14	(-24.14, -20.14)	88.03	1	0.000	98.9
Overall	20	-36.13	(-37.31, -34.95)	1.3e+05	19	0.000	100

^a Includes duplicates of studies whenever these contribute to the analysis with multiple estimates

* statistic describing the percentage of total variation across studies that is due to heterogeneity rather than chance. CI, confidence interval; DF, degrees of freedom

Table 4. Meta-analysis of the effect of introducing a food safety intervention on microbial counts detected in samples collected from food establishments, by sample origin

Sample origin	No. of studies pooled ^a	Average relative change (%)	95% CI	Heterogeneity statistic	DF	p-value	I ² * (%)
Food	5	-44.69	(-45.84, -43.54)	694.19	4	0.000	99.4
Hands	3	-48.89	(-59.26, -38.51)	39.55	2	0.000	94.9
Food-contact surfaces	3	-22.57	(-25.15, -19.98)	9.03	2	0.011	77.8
Overall	11	-41.25	(-42.42, -40.09)	1668.18	10	0.000	99.4

^a Includes duplicates of studies whenever these contribute to the analysis with multiple estimates

* statistic describing the percentage of total variation across studies that is due to heterogeneity rather than chance. CI, confidence interval; DF, degrees of freedom

Table 5. Meta-analysis of the effect of introducing a food safety intervention on microbial counts detected in samples collected from foodservices, by food establishment type

Food establishment type	No. of studies pooled ^a	Average relative change (%)	95% CI	Heterogeneity statistic	DF	p-value	I²* (%)
University	4	-18.45	(-24.67, -12.23)	1109.69	3	0.000	99.7
Food catering facilities	2	-33.27	(-44.44, -22.09)	4.67	1	0.031	78.6
Care facilities	2	-22.14	(-24.14, -20.14)	3680.83	1	0.000	100
Overall	8	-26.79	(-32.45, -21.12)	2020.70	7	0.000	99.7

^a Includes duplicates of studies whenever these contribute to the analysis with multiple estimates

* statistic describing the percentage of total variation across studies that is due to heterogeneity rather than chance. CI, confidence interval; DF, degrees of freedom

Table 6. Meta-analysis of the effect of introducing a food safety intervention on microbial counts detected in samples collected from foodservices, by latest sample collection time (post-intervention)

Post-intervention collection time period	No. of studies pooled ^a	Average relative change (%)	95% CI	Heterogeneity statistic	DF	p-value	I ² * (%)
≤ 1 month	2	-48.09	(-55.74, -40.45)	51.09	4	0.000	98.0
2-9 months	3	-27.88	(-32.11, -23.65)	33.19	2	0.000	94.0
1+ year	2	-12.19	(-15.43, -8.95)	233.83	2	0.000	99.6
Overall	7	-25.59	(-28.97, -22.21)	790.71	10	0.000	99.2

^a Includes duplicates of studies whenever these contribute to the analysis with multiple estimates

* statistic describing the percentage of total variation across studies that is due to heterogeneity rather than chance. CI, confidence interval; DF, degrees of freedom

Appendix

Food Safety Policies and their Effectiveness to Prevent Foodborne Diseases in Catering Establishments: a Systematic Review and Meta-analysis

Appendix Table 1. PRISMA Checklist

Appendix Table 2. PICO table for research question, eligibility criteria and search strategy formulation

Appendix Table 3. Full Search Strategy: Detailed search algorithms for each bibliographic database

Appendix Table 4. ROBINS-I Quality Assessment Form

Appendix Table 5. Template of Raw Data Extraction Table

Appendix Table 6. ROBINS-I Table with Reasons for Risk of Bias Judgement

Appendix Figure 1. Forest plot of subgroup analysis, by microorganism type

Appendix Figure 2. Forest plot of subgroup analysis, by sample origin

Appendix Figure 3. Forest plot of subgroup analysis, by food establishment type

Appendix Figure 4. Funnel Plot of Studies with 95% Confidence Limits

Appendix Table 7. Sensitivity analysis excluding studies with larger weights

Appendix Table 8. Sensitivity analysis using the random effects model

Appendix Table 1. PRISMA Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	2,3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	4
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	4,5
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5,6
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	6
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	6
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	6,7
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	7
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	7,8,9

Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	9
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	10
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	10,11
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	11,12
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	12
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	12,13
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	14,15
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	13,14,15,16
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	16
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	17,18
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	19,20,21
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	21

Appendix Table 2. PICO table for research question, eligibility criteria and search strategy formulation

Topic	Preventing food contamination or FBDs from occurring in food premises located at the final stage of the food supply chain
Population	Food handlers, foodservice staff, food establishment employees
Intervention	Introduction of food safety policies, measures, activities or training programs
Comparison	No food safety intervention, baseline situation
Outcome	Microbiological analyses measuring colony forming units in food-related samples

Appendix Table 3. Full Search Strategy: Detailed search algorithms for each bibliographic database

Date	March 25, 2020
Platform/Interface	Scopus
Databases	Scopus (1823-Current)
Institution	OECD
Search string:	<p>((<i>"food safety"</i> or <i>"food-borne"</i> or <i>foodbourne</i> or <i>foodborne</i> or <i>"food-bourne"</i> or <i>"food handl*"</i> or <i>"food preparation"</i> or <i>"food poison*"</i> or <i>"food contamination*"</i> or <i>"food hygiene"</i> or <i>"safe food"</i> or <i>"food quality"</i>) AND (<i>HACCP</i> or <i>"hazard analysis and critical control point*"</i> or <i>"hazard control"</i> or <i>"critical control point*"</i> or <i>"good hygiene practice*"</i> or <i>"hygiene training*"</i> or <i>"food safety training*"</i> or <i>campaign*</i> or <i>strateg*</i> or <i>program*</i> or <i>measure*</i> or <i>polic*</i> or <i>workshop*</i> or <i>initiative*</i> or <i>educat*</i> or <i>media</i> or <i>training*</i> or <i>poster*</i>) AND (<i>"aerobic plate count*"</i> or <i>APC</i> or <i>"coliform count*"</i> or <i>"microbial analys*"</i> or <i>"microbiological count*"</i> or <i>"microbiological analys*"</i>))</p> <p>in Article title OR Abstract OR Keywords</p>
Hits	551
Limits	None

Date	March 25, 2020
Platform/Interface	PubMed/MEDLINE
Databases	PubMed (1950-2020)
Institution	OECD
Search string:	<p>((<i>"food safety"</i> or <i>"food-borne"</i> or <i>foodbourne</i> or <i>foodborne</i> or <i>"food-bourne"</i> or <i>"food handl*"</i> or <i>"food preparation"</i> or <i>"food poison*"</i> or <i>"food contamination*"</i> or <i>"food hygiene"</i> or <i>"safe food"</i> or <i>"food quality"</i>) AND (<i>HACCP</i> or <i>"hazard analysis and critical control point*"</i> or <i>"hazard control"</i> or <i>"critical control point*"</i> or <i>"good hygiene practice*"</i> or <i>"hygiene training*"</i> or <i>"food safety training*"</i> or <i>campaign*</i> or <i>strateg*</i> or <i>program*</i> or <i>measure*</i> or <i>polic*</i> or <i>workshop*</i> or <i>initiative*</i> or <i>educat*</i> or <i>media</i> or <i>training*</i> or <i>poster*</i>) AND (<i>"aerobic plate count*"</i> or <i>APC*</i> or <i>"coliform count*"</i> or <i>"microbial analys*"</i> or <i>"microbiological count*"</i> or <i>"microbiological analys*"</i>))</p> <p>in Title/Abstract</p>
Hits	139
Limits	None

Date	March 26, 2020
Platform/Interface	The Cochrane Central Register of Controlled Trials (CENTRAL)
Databases	Cochrane Library (1996 - Current)
Institution	OECD
Search string:	<p>((<i>"food safety"</i> or <i>"food-borne"</i> or <i>foodbourne</i> or <i>foodborne</i> or <i>"food-bourne"</i> or <i>"food handl*"</i> or <i>"food preparation"</i> or <i>"food poison*"</i> or <i>"food contamination*"</i> or <i>"food hygiene"</i> or <i>"safe food"</i> or <i>"food quality"</i>) AND (<i>HACCP</i> or <i>"hazard analysis and critical control point*"</i> or <i>"hazard control"</i> or <i>"critical control point*"</i> or <i>"good hygiene practice*"</i> or <i>"hygiene training*"</i> or <i>"food safety training*"</i> or <i>campaign*</i> or <i>strateg*</i> or <i>program*</i> or <i>measure*</i> or <i>polic*</i> or <i>workshop*</i> or <i>initiative*</i> or <i>educat*</i> or <i>media</i> or <i>training*</i> or <i>poster*</i>) AND (<i>"aerobic plate count*"</i> or <i>APC</i> or <i>"coliform count*"</i> or <i>"microbial analys*"</i> or <i>"microbiological count*"</i> or <i>"microbiological analys*"</i>))</p> <p>in Title Abstract Keyword</p>

Hits	537
Limits	None

Date	March 27, 2020
Platform/Interface	ProQuest
Databases	Australian Education Index (1977 - Current) SciTech Premium Collection (1947 – Current) Sports Medicine & Education Index (1970 – Current)
Institution	OECD
Search string:	((<i>"food safety"</i> or <i>"food-borne"</i> or <i>foodbourne</i> or <i>foodborne</i> or <i>"food-bourne"</i> or <i>"food handl*"</i> or <i>"food preparation"</i> or <i>"food poison*"</i> or <i>"food contamination*"</i> or <i>"food hygiene"</i> or <i>"safe food"</i> or <i>"food quality"</i>) AND (<i>HACCP</i> or <i>"hazard analysis and critical control point*"</i> or <i>"hazard control"</i> or <i>"critical control point*"</i> or <i>"good hygiene practice*"</i> or <i>"hygiene training*"</i> or <i>"food safety training*"</i> or <i>campaign*</i> or <i>strateg*</i> or <i>program*</i> or <i>measure*</i> or <i>polic*</i> or <i>workshop*</i> or <i>initiative*</i> or <i>educat*</i> or <i>media</i> or <i>training*</i> or <i>poster*</i>) AND (<i>"aerobic plate count*"</i> or <i>APC</i> or <i>"coliform count*"</i> or <i>"microbial analys*"</i> or <i>"microbiological count*"</i> or <i>"microbiological analys*"</i>)) in Document title OR in Abstract
Hits	349
Limits	None

Date	March 27, 2020
Platform/Interface	EBSCOHost
Databases	CINAHL Plus with Full Text (1937-2014) ERIC (1966-2014)
Institution	OECD
Search string:	((<i>"food safety"</i> or <i>"food-borne"</i> or <i>foodbourne</i> or <i>foodborne</i> or <i>"food-bourne"</i> or <i>"food handl*"</i> or <i>"food preparation"</i> or <i>"food poison*"</i> or <i>"food contamination*"</i> or <i>"food hygiene"</i> or <i>"safe food"</i> or <i>"food quality"</i>) AND (<i>HACCP</i> or <i>"hazard analysis and critical control point*"</i> or <i>"hazard control"</i> or <i>"critical control point*"</i> or <i>"good hygiene practice*"</i> or <i>"hygiene training*"</i> or <i>"food safety training*"</i> or <i>campaign*</i> or <i>strateg*</i> or <i>program*</i> or <i>measure*</i> or <i>polic*</i> or <i>workshop*</i> or <i>initiative*</i> or <i>educat*</i> or <i>media</i> or <i>training*</i> or <i>poster*</i>) AND (<i>"aerobic plate count*"</i> or <i>APC</i> or <i>"coliform count*"</i> or <i>"microbial analys*"</i> or <i>"microbiological count*"</i> or <i>"microbiological analys*"</i>)) in All Text
Hits	26
Limits	None

Citation list of the eight snowballed articles from Young et al (2019 & 2020) and Reynolds and Dolasinski (2019)

1. Ababio, P. F., Taylor, K. D., Swainson, M. & Daramola, B. A., 2016. Effect of good hygiene practices intervention on food safety in senior secondary schools in Ghana. Food Control, 12, Volume 60, pp. 18-24.
2. Charalambous, M., 2011. Implementation of Food Safety Management Systems in Small Enterprises in Cyprus, s.l.: s.n.
3. Han Acikel, C. et al., 2008. The hygiene training of food handlers at a teaching hospital. Food Control.
4. Hart, C., 1997. Impact Analysis of Training Food Service Personnel Relative to Food Safety,

s.l.: s.n.

5. Lim, T. H., Choi, J. H., Kang, Y. J. & Kwak, T. K., 2013. The implementation of a HACCP system through u-HACCP® application and the verification of microbial quality improvement in a small size restaurant. *Journal of the Korean Society of Food Science and Nutrition*, 42(3), pp. 464-477.
6. Maung, N. S. et al., 2017. Raising Food Safety by Food Safety Training Program to Street-Food Vendors in an Urban Area of Yangon. s.l.:s.n.
7. Pivarnik, L. F. et al., 2013. Development and pilot testing of a food safety curriculum for managers and staff of residential childcare institutions (RCCIs). *Journal of Food Science Education*, 19, 12(4), pp. 67-74.
8. Young, I., Greig, J., Wilhelm, B. J. & Waddell, L. A., 2019. Effectiveness of food handler training and education interventions: A systematic review and meta-analysis. s.l.:International Association for Food Protection.

Appendix Table 4. ROBINS-I Quality Assessment Form

Responses underlined in green are potential markers for low risk of bias, and responses in red are potential markers for a risk of bias. Where questions relate only to sign posts to other questions, no formatting is used.

Signalling questions	Description	Response options
Bias due to confounding		
1.1 Is there potential for confounding of the effect of intervention in this study? If <u>N/PN</u> to 1.1: the study can be considered to be at low risk of bias due to confounding and no further signalling questions need be considered If <u>Y/PY</u> to 1.1: determine whether there is a need to assess time-varying confounding:		Y / PY / <u>PN / N</u>
1.2. Was the analysis based on splitting participants' follow up time according to intervention received? If <u>N/PN</u>, answer questions relating to baseline confounding (1.4 to 1.6) If <u>Y/PY</u>, go to question 1.3.		NA / Y / PY / PN / N / NI
1.3. Were intervention discontinuations or switches likely to be related to factors that are prognostic for the outcome? If <u>N/PN</u>, answer questions relating to baseline confounding (1.4 to 1.6) If <u>Y/PY</u>, answer questions relating to both baseline and time-varying confounding (1.7 and 1.8)		NA / Y / PY / PN / N / NI
Questions relating to baseline confounding only		
1.4. Did the authors use an appropriate analysis method that controlled for all the important confounding domains?		NA / <u>Y / PY</u> / PN / N / NI
1.5. If <u>Y/PY</u> to 1.4: Were confounding domains that were controlled for measured validly and reliably by the variables available in this study?		NA / <u>Y / PY</u> / PN / N / NI
1.6. Did the authors control for any post-intervention variables that could have been affected by the intervention?		NA / Y / PY / <u>PN / N</u> / NI
Questions relating to baseline and time-varying confounding		
1.7. Did the authors use an appropriate analysis method that controlled for all the important confounding domains and for time-varying confounding?		NA / <u>Y / PY</u> / PN / N / NI
1.8. If <u>Y/PY</u> to 1.7: Were confounding domains that were controlled for measured validly and reliably by the variables available in this study?		NA / <u>Y / PY</u> / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to confounding?		Favours experimental / Favours comparator / Unpredictable

Bias in selection of participants into the study

2.1. Was selection of participants into the study (or into the analysis) based on participant characteristics observed after the start of intervention? If N/PN to 2.1: go to 2.4		Y / PY / <u>PN / N</u> / NI
2.2. If Y/PY to 2.1: Were the post-intervention variables that influenced selection likely to be associated with intervention?		NA / Y / PY / <u>PN / N</u> / NI
2.3 If Y/PY to 2.2: Were the post-intervention variables that influenced selection likely to be influenced by the outcome or a cause of the outcome?		NA / Y / PY / <u>PN / N</u> / NI
2.4. Do start of follow-up and start of intervention coincide for most participants?		<u>Y / PY</u> / PN / N / NI
2.5. If Y/PY to 2.2 and 2.3, or N/PN to 2.4: Were adjustment techniques used that are likely to correct for the presence of selection biases?		NA / <u>Y / PY</u> / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to selection of participants into the study?		Favours experimental / Favours comparator / Towards null / Away from null / Unpredictable

Bias in classification of interventions		
3.1 Were intervention groups clearly defined?		<u>Y / PY</u> / PN / N / NI
3.2 Was the information used to define intervention groups recorded at the start of the intervention?		<u>Y / PY</u> / PN / N / NI
3.3 Could classification of intervention status have been affected by knowledge of the outcome or risk of the outcome?		Y / PY / <u>PN / N</u> / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to classification of interventions?		Favours experimental / Favours comparator / Towards null / Away from null / Unpredictable

Bias due to deviations from intended interventions		
If your aim for this study is to assess the effect of assignment to intervention, answer questions 4.1 and 4.2		
4.1. Were there deviations from the intended intervention beyond what would be expected in usual practice?		Y / PY / <u>PN / N</u> / NI
4.2. If Y/PY to 4.1: Were these deviations from intended intervention unbalanced between groups <i>and</i> likely to have affected the outcome?		NA / Y / PY / <u>PN / N</u> / NI
If your aim for this study is to assess the effect of starting and adhering to intervention, answer questions 4.3 to 4.6		
4.3. Were important co-interventions balanced across intervention groups?		<u>Y / PY</u> / PN / N / NI
4.4. Was the intervention implemented successfully for most participants?		<u>Y / PY</u> / PN / N / NI
4.5. Did study participants adhere to the assigned intervention regimen?		<u>Y / PY</u> / PN / N / NI
4.6. If N/PN to 4.3, 4.4 or 4.5: Was an appropriate analysis used to estimate the effect of starting and adhering to the intervention?		NA / <u>Y / PY</u> / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI

Optional: What is the predicted direction of bias due to deviations from the intended interventions?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable
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Bias due to missing data		
5.1 Were outcome data available for all, or nearly all, participants?		<u>Y / PY</u> / PN / N / NI
5.2 Were participants excluded due to missing data on intervention status?		Y / PY / <u>PN / N</u> / NI
5.3 Were participants excluded due to missing data on other variables needed for the analysis?		Y / PY / <u>PN / N</u> / NI
5.4 If PN/N to 5.1, or Y/PY to 5.2 or 5.3: Are the proportion of participants and reasons for missing data similar across interventions?		NA / <u>Y / PY</u> / PN / N / NI
5.5 If PN/N to 5.1, or Y/PY to 5.2 or 5.3: Is there evidence that results were robust to the presence of missing data?		NA / <u>Y / PY</u> / PN / N / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to missing data?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in measurement of outcomes		
6.1 Could the outcome measure have been influenced by knowledge of the intervention received?		Y / PY / <u>PN / N</u> / NI
6.2 Were outcome assessors aware of the intervention received by study participants?		Y / PY / <u>PN / N</u> / NI
6.3 Were the methods of outcome assessment comparable across intervention groups?		<u>Y / PY</u> / PN / N / NI
6.4 Were any systematic errors in measurement of the outcome related to intervention received?		Y / PY / <u>PN / N</u> / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to measurement of outcomes?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Bias in selection of the reported result		
Is the reported effect estimate likely to be selected, on the basis of the results, from...		
7.1. ... multiple outcome <i>measurements</i> within the outcome domain?		Y / PY / <u>PN / N</u> / NI
7.2 ... multiple <i>analyses</i> of the intervention-outcome relationship?		Y / PY / <u>PN / N</u> / NI
7.3 ... different <i>subgroups</i> ?		Y / PY / <u>PN / N</u> / NI
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the predicted direction of bias due to selection of the reported result?		Favours experimental / Favours comparator / Towards null /Away from null / Unpredictable

Overall bias		
Risk of bias judgement		Low / Moderate / Serious / Critical / NI
Optional: What is the overall predicted direction of bias for this outcome?		zFavours experimental / Favours comparator / Towards null / Away from null / Unpredictable

Appendix Table 5. Template of Raw Data Extraction Table: featuring three out of eight eligible studies for meta-analysis

Study ID	Study sampling year	Intervention	Outcome being extracted (units)	Micro-organisms	Sample origin	Food type	Food stage	Surface type	Food establishment type	Latest post intervention collection time
Cenci-Goga et al., 2005	1996-2002	HACCP-based training program for food handlers	log10 CFU	Total bacteria	Food	Animal product	Cooked		University (restaurant, canteen, café)	1+ year
Cenci-Goga et al., 2005	1996-2002	HACCP-based training program for food handlers	log10 CFU	Total bacteria	Food	Mix	Cooked		University (restaurant, canteen, café)	1+ year
Cenci-Goga et al., 2005	1996-2002	HACCP-based training program for food handlers	log10 CFU	Total bacteria	Food	Salad	Raw		University (restaurant, canteen, café)	1+ year
Cenci-Goga et al., 2005	1996-2002	HACCP-based training program for food handlers	log10 CFU	B.cereus	Food	Animal product	Cooked		University (restaurant, canteen, café)	1+ year
Cenci-Goga et al., 2005	1996-2002	HACCP-based training program for food handlers	log10 CFU	B.cereus	Food	Mix	Cooked		University (restaurant, canteen, café)	1+ year
Cenci-Goga et al., 2005	1996-2002	HACCP-based training program for food handlers	log10 CFU	B.cereus	Food	Salad	Raw		University (restaurant, canteen, café)	1+ year
Cenci-Goga et al., 2005	1996-2002	HACCP-based training program for food handlers	log10 CFU	Coliforms	Food	Animal product	Cooked		University (restaurant, canteen, café)	1+ year
Cenci-Goga et al., 2005	1996-2002	HACCP-based training program for food handlers	log10 CFU	Coliforms	Food	Mix	Cooked		University (restaurant, canteen, café)	1+ year
Cenci-Goga et al., 2005	1996-2002	HACCP-based training program for food handlers	log10 CFU	Coliforms	Food	Salad	Raw		University (restaurant, canteen, café)	1+ year
Cenci-Goga et al., 2005	1996-2002	HACCP-based training program for food handlers	log10 CFU	Fecal coliforms	Food	Animal product	Cooked		University (restaurant, canteen, café)	1+ year
Cenci-Goga et al., 2005	1996-2002	HACCP-based training program for food handlers	log10 CFU	Fecal coliforms	Food	Mix	Cooked		University (restaurant, canteen, café)	1+ year
Cenci-Goga et al., 2005	1996-2002	HACCP-based training program for food handlers	log10 CFU	Fecal coliforms	Food	Salad	Raw		University (restaurant, canteen, café)	1+ year
Cenci-Goga et al., 2005	1996-2002	HACCP-based training program for food handlers	log10 CFU	S.aureus	Food	Animal product	Cooked		University (restaurant, canteen, café)	1+ year
Cenci-Goga et	1996-	HACCP-based training	log10 CFU	S.aureus	Food	Mix	Cooke		University (restaurant,	1+ year

al., 2005	2002	program for food handlers					d		canteen, café)	
Cenci-Goga et al., 2005	1996-2002	HACCP-based training program for food handlers	log10 CFU	S.aureus	Food	Salad	Raw		University (restaurant, canteen, café)	1+ year
Garayoa et al., 2016	2010-2015	Other (handwashing , preventative messaging, hand disinfection)	log10 CFU	Total bacteria	Hands			Gloves	Food catering facilities (restaurants, food establishments)	Not reported
Garayoa et al., 2016	2010-2015	Other (handwashing , preventative messaging, hand disinfection)	log10 CFU	Total bacteria	Hands			Skin	Food catering facilities (restaurants, food establishments)	Not reported
Garayoa et al., 2016	2010-2015	Other (handwashing , preventative messaging, hand disinfection)	log10 CFU	Enterobacterales	Hands			Gloves	Food catering facilities (restaurants, food establishments)	Not reported
Garayoa et al., 2016	2010-2015	Other (handwashing , preventative messaging, hand disinfection)	log10 CFU	Enterobacterales	Hands			Skin	Food catering facilities (restaurants, food establishments)	Not reported
Garayoa et al., 2016	2010-2015	Other (handwashing , preventative messaging, hand disinfection)	log10 CFU	S.aureus	Hands			Gloves	Food catering facilities (restaurants, food establishments)	Not reported
Garayoa et al., 2016	2010-2015	Other (handwashing , preventative messaging, hand disinfection)	log10 CFU	S.aureus	Hands			Skin	Food catering facilities (restaurants, food establishments)	Not reported
Hart, 1997	1996-2002	HACCP-based training program for food handlers	log10 CFU	Total bacteria	Food	Animal product	Cooked		Stores (grocery, convenience, highway)	≤1 month

Appendix Table 5. Template of Raw Data Extraction Table: featuring three out of eight eligible studies for meta-analysis (*Continued*)

Study ID	Variance	Inverse variance	Before mean count	After mean count	p-value	Change score	Relative percent change (%)	SE	SE (%)	SEx1.96 (%)	Lower CI	Upper CI
Cenci-Goga et al., 2005	0.031	32.423	5.03	3.85	0.05	-1.18	-23.46	0.026	2.630	5.155	-28.61	-18.30
Cenci-Goga et al., 2005	0.043	23.168	4.30	3.21	0.05	-1.09	-25.35	0.027	2.722	5.336	-30.68	-20.01
Cenci-Goga et al., 2005	0.018	55.055	7.36	5.13	0.05	-2.23	-30.30	0.021	2.086	4.089	-34.39	-26.21
Cenci-Goga et al., 2005	0.018	55.043	3.47	3.47	0.05	0	0	0.020	2.019	3.957	-3.96	3.96
Cenci-Goga et al., 2005	0.014	71.902	3.47	3.47	0.05	0	0	0.015	1.545	3.029	-3.03	3.03
Cenci-Goga et al., 2005	0.019	51.530	3.47	3.47	0.05	0	0	0.022	2.156	4.226	-4.23	4.23
Cenci-Goga et al., 2005	0.011	87.337	2.78	2.47	0.05	-0.31	-11.15	0.016	1.603	3.141	-14.29	-8.01
Cenci-Goga et al., 2005	0.006	161.780	2.47	2.47	0.05	0	0	0.010	1.030	2.019	-2.02	2.02
Cenci-Goga et al., 2005	0.015	67.447	4.48	2.47	0.05	-2.01	-44.87	0.019	1.885	3.694	-48.56	-41.17
Cenci-Goga et al., 2005	0.008	123.846	2.47	2.47	0.05	0	0	0.013	1.346	2.638	-2.64	2.64

Cenci-Goga et al., 2005	0.006	161.780	2.47	2.47	0.05	0	0	0.010	1.030	2.019	-2.02	2.02
Cenci-Goga et al., 2005	0.009	115.942	2.47	2.47	0.05	0	0	0.014	1.438	2.818	-2.82	2.82
Cenci-Goga et al., 2005	0.018	55.043	3.47	3.47	0.05	0	0	0.020	2.019	3.957	-3.96	3.96
Cenci-Goga et al., 2005	0.014	71.902	3.47	3.47	0.05	0	0	0.015	1.545	3.029	-3.03	3.03
Cenci-Goga et al., 2005	0.019	51.530	3.47	3.47	0.05	0	0	0.022	2.156	4.226	-4.23	4.23
Garayoa et al., 2016	0.063	15.867	1.93	0.68	0.001	-1.25	-64.77	0.080	8.030	15.739	-80.51	49.03
Garayoa et al., 2016	0.032	31.346	2.35	1.75	0.001	-0.60	-25.53	0.112	11.186	21.925	-47.46	-3.61
Garayoa et al., 2016	0.016	62.500	0.36	0.07	0.001	-0.29	-80.56	0.004	0.354	0.693	-81.25	79.86
Garayoa et al., 2016	0.011	90.250	0.33	0.09	0.001	-0.24	-72.73	0.086	8.599	16.854	-89.58	55.87
Garayoa et al., 2016	0.055	18.170	0.59	0.43	0.001	-0.16	-27.12	0.004	0.354	0.693	-27.81	26.43
Garayoa et al., 2016	0.046	21.664	1.63	1.41	0.001	-0.22	-13.50	0.113	11.308	22.163	-35.66	8.67
Hart, 1997	0.332	3.013	4.5	3.78		-0.72	-16.00	0.178	17.779	34.847	-50.85	18.85

Appendix Table 6. ROBINS-I Table with Reasons for Risk of Bias Judgement

Author(s), publication year		1.1 Is there potential for confounding of the effect of intervention in this study?	1.2 Was the analysis based on splitting participants' follow up time according to intervention received? If N/PN (No/Probably no), answer questions relating to baseline confounding (1.4 to 1.6)	1.4 Did the authors use an appropriate analysis method that controlled for all the important confounding domains? If Y/PY to 1.4: Were confounding domains that were controlled for measured validly and reliably by the variables available in this study?	1.6 Did the authors control for any post-intervention variables that could have been affected by the intervention?	1.7 Did the authors use an appropriate analysis method that controlled for all the important confounding domains and for time-varying confounding?	Risk of bias judgement
Cenci-Goga et al., 2005	1. Bias due to confounding	Yes	No	No	No	No	Critical
Garayoa et al., 2016		Yes	No	Probably no	No	No	Critical
Christopher Eric Hart, 1997		Yes	No	No	No	No	Critical
Lim et al., 2013		Yes	No	No	No	No	Critical
Pivarnik et al., 2013		Yes	No	No	No	No	Critical
Roy et al, 2016		Yes	No	No	No	No	Critical
Soares et al, 2013		Yes	No	No	No	No	Critical
Soriano et al, 2002		Yes	No	No	No	No	Critical

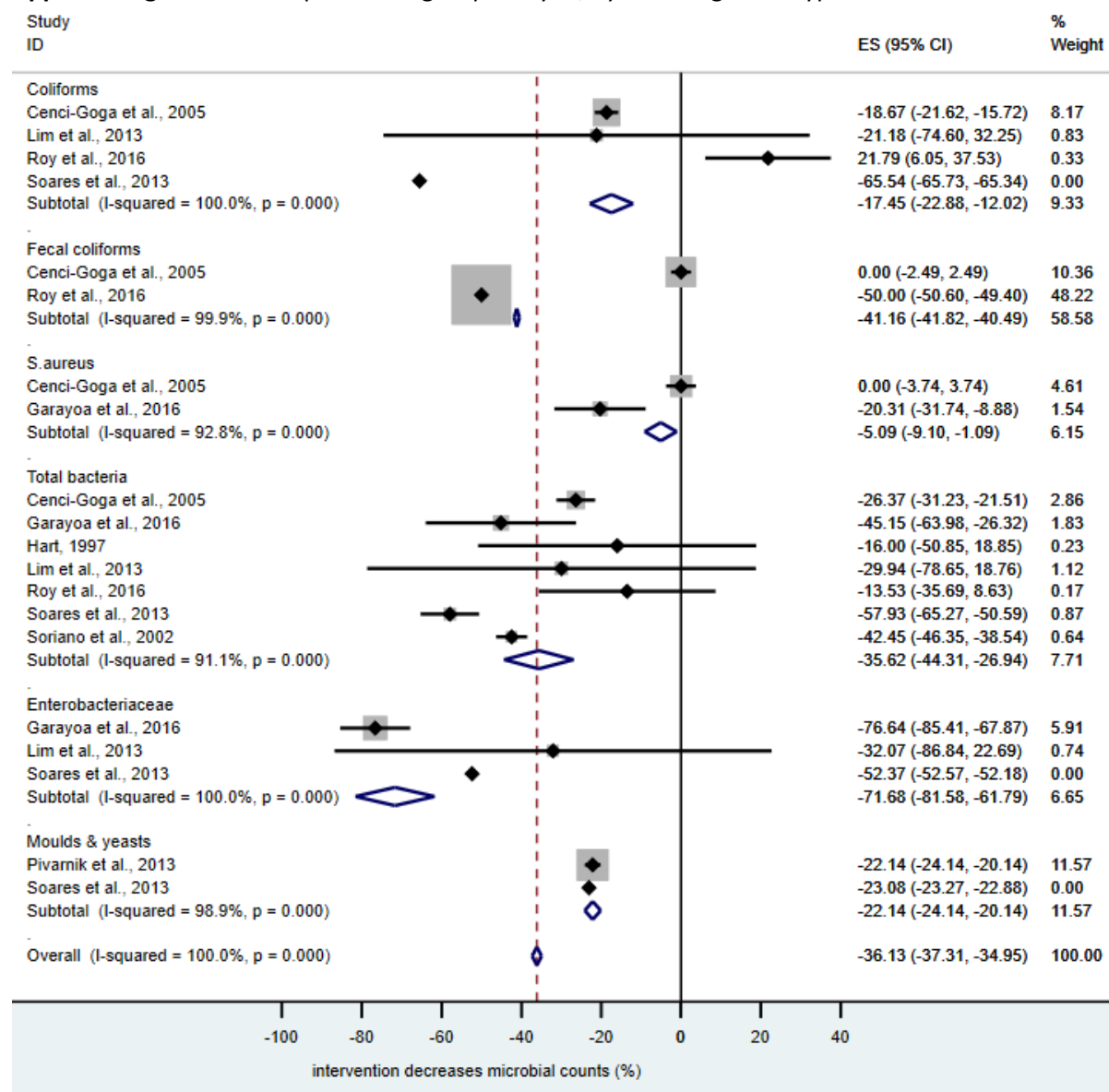
Author(s), publication year		2.1 Was selection of participants into the study (or into the analysis) based on participant characteristics observed after the start of intervention? If N/PN to 2.1: go to 2.4	2.4 Do start of follow-up and start of intervention coincide for most participants?	Risk of bias judgement		3.1 Were intervention groups clearly defined?	3.2 Was the information used to define intervention groups recorded at the start of the intervention?	3.3 Could classification of intervention status have been affected by knowledge of the outcome or risk of the outcome?	Risk of bias judgement
Cenci-Goga et al., 2005	2. Bias in selection of participants into the study	No	Yes	Low	3. Bias in classification of interventions	Yes	Yes	Probably no	Low
Garayoa et al., 2016		No	Yes	Low		Yes	Yes	Probably no	Low
Christopher Eric Hart, 1997		No	Yes	Low		Yes	Yes	Probably no	Low
Lim et al., 2013		No	Yes	Low		Yes	Yes	Probably no	Low
Pivarnik et al., 2013		No	Yes	Low		Yes	Yes	Probably no	Low
Roy et al., 2016		No	Yes	Low		Yes	Yes	Probably no	Low
Soares et al., 2013		No	Yes	Low		Yes	Yes	Probably no	Low
Soriano et al., 2002		No	Yes	Low		Yes	Yes	Probably no	Low

Author(s), publication year		4.1 Were there deviations from the intended intervention beyond what would be expected in usual practice?	Risk of bias judgement		5.1 Were outcome data available for all, or nearly all, participants?	5.2 Were participants excluded due to missing data on intervention status?	5.2 - Comments	5.3 Were participants excluded due to missing data on other variables needed for the analysis?	Risk of bias judgement
Cenci-Goga et al., 2005	4. Bias due to deviations from intended interventions	No	Low	5. Bias due to missing data	Probably yes	No		No	Low
Garayoa et al., 2016		No	Low		Probably yes	No		Probably no	Low
Christopher Eric Hart, 1997		Probably no	Low		Yes	No		No	Low
Lim et al., 2013		No	Low		Yes	No information	Information on possible missing data is lacking	No	Moderate
Pivarnik et al., 2013		No	Low		Probably yes	No information		No	Moderate
Roy et al, 2016		No	Low		Yes	No		No	Low
Soares et al, 2013		No	Low		Probably yes	No information	Information on possible missing data is lacking	No	Moderate
Soriano et al, 2002		No	Low		Yes	No		No	Low

Author(s), publication year		6.1 Could the outcome measure have been influenced by knowledge of the intervention received?	6.2 Were outcome assessors aware of the intervention received by study participants?	6.2 - Comments	6.3 Were the methods of outcome assessment comparable across intervention groups?	6.4 Were any systematic errors in measurement of the outcome related to intervention received?	Risk of bias judgement
Cenci-Goga et al., 2005	6. Bias in measurement of outcomes	Probably no	No information		Yes	No	Low
Garayoa et al., 2016		Probably no	No information		Yes	No	Low
Christopher Eric Hart, 1997		Probably no	No information		Yes	No	Low
Lim et al., 2013		Probably no	No information		Yes	No	Low
Pivarnik et al., 2013		Probably no	No information		Yes	No	Low
Roy et al, 2016		No	No	Blinded study due to samples coded prior to study start	Yes	No	Low
Soares et al, 2013		Probably no	No information		Yes	No	Low
Soriano et al, 2002		Probably no	No information		Yes	No	Low

Author(s), publication year		7.1 Is the reported effect estimate likely to be selected, on the basis of the results, from multiple outcome measurements within the outcome domain?	7.2 Is the reported effect estimate likely to be selected, on the basis of the results, from multiple analyses of the intervention-outcome relationship?	7.3 Is the reported effect estimate likely to be selected, on the basis of the results, from different subgroups?	Risk of bias judgement	Risk of bias judgement - Comment	Overall risk of bias judgement
Cenci-Goga et al., 2005	7. Bias in the selection of the reported results	No	No	No	Low		Critical
Garayoa et al., 2016		No	No	Probably yes	Moderate	Before and after data missing for surface samples; data for Escherichia coli, Salmonella spp, Listeria monocytogenes not reported	Critical
Christopher Eric Hart, 1997		No	No	No	Low		Critical
Lim et al., 2013		No	No	No	Low		Critical
Pivarnik et al., 2013		Yes	No	No	Moderate	Microbial outcomes for Listeria spp. and Salmonella spp. not reported; FLASH tests (data not shown)	Critical
Roy et al., 2016		Yes	No	No	Moderate	Microbial outcomes for indirect food contact surfaces not reported	Critical
Soares et al., 2013		Yes	No	No	Moderate	No microbiological counts reported for samples of surfaces, food tools and food equipment	Critical
Soriano et al., 2002		Yes	No	No	Moderate	Staphylococcus aureus, Escherichia coli, E. coli O157:H7, Listeria monocytogenes, Salmonella spp. and Clostridium perfringens counts in CFU not reported; APC data reported as ranges instead of means	Critical

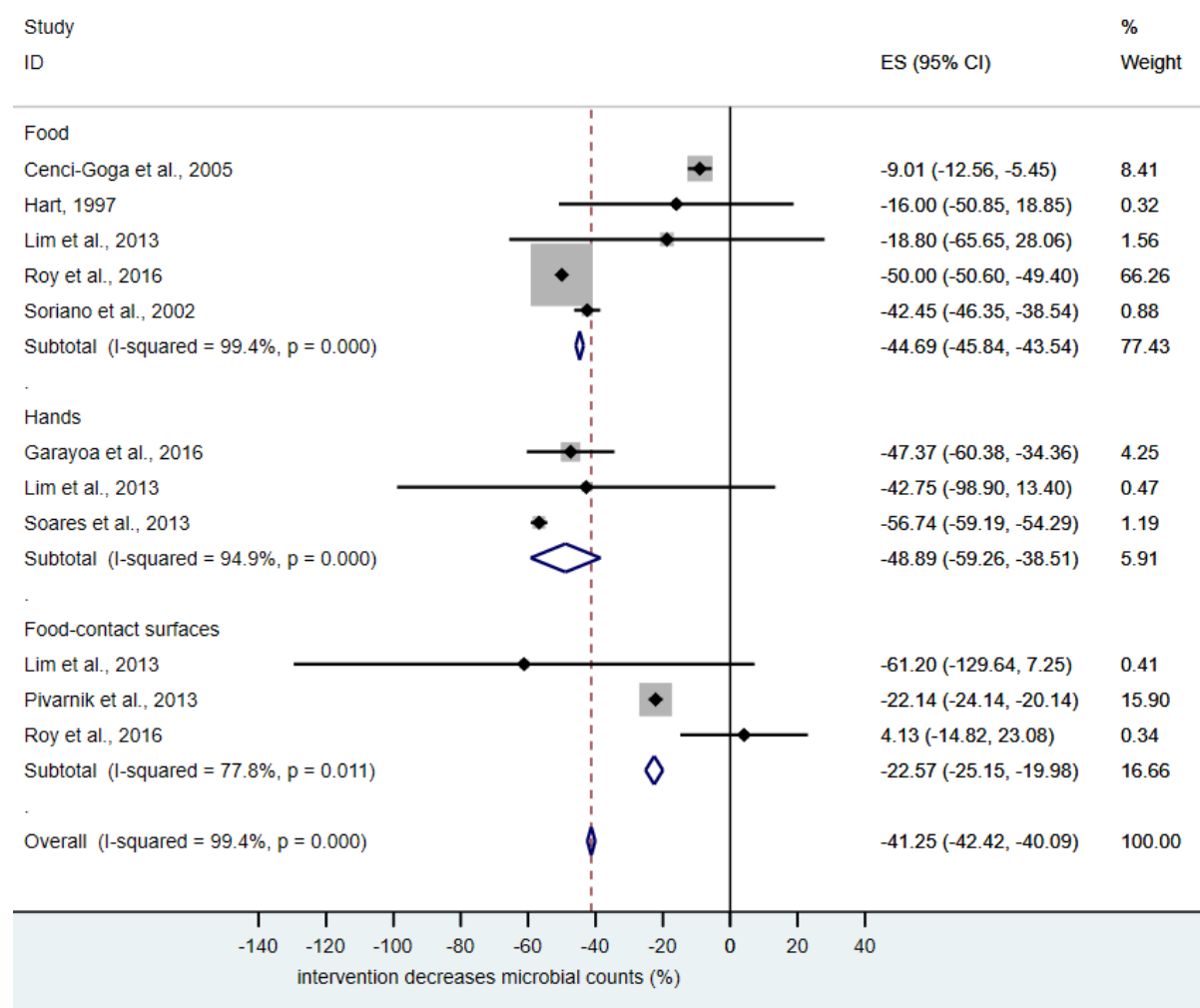
Appendix Figure 1. Forest plot of subgroup analysis, by microorganism type



Forest plot displaying an inverse variance weighted fixed-effect meta-analysis of the effect of introducing a food safety intervention on microbial counts detected in samples collected from food establishments, by microorganism types

ES, effect size; CI, confidence interval

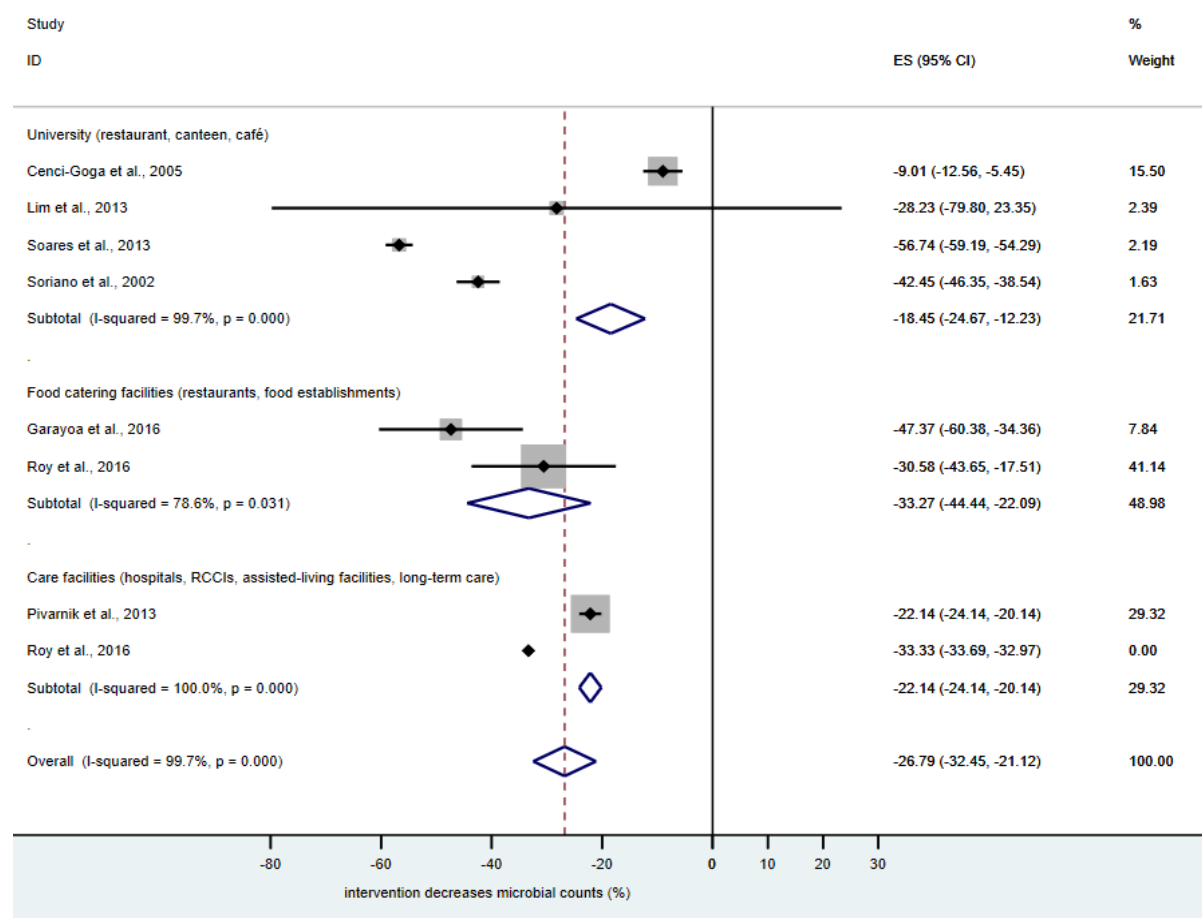
Appendix Figure 2. Forest plot of subgroup analysis, by sample origin



Forest plot displaying an inverse variance weighted fixed-effect meta-analysis of the effect of introducing a food safety intervention on microbial counts detected in samples collected from food establishments, by sample origin

ES, effect size; CI, confidence interval

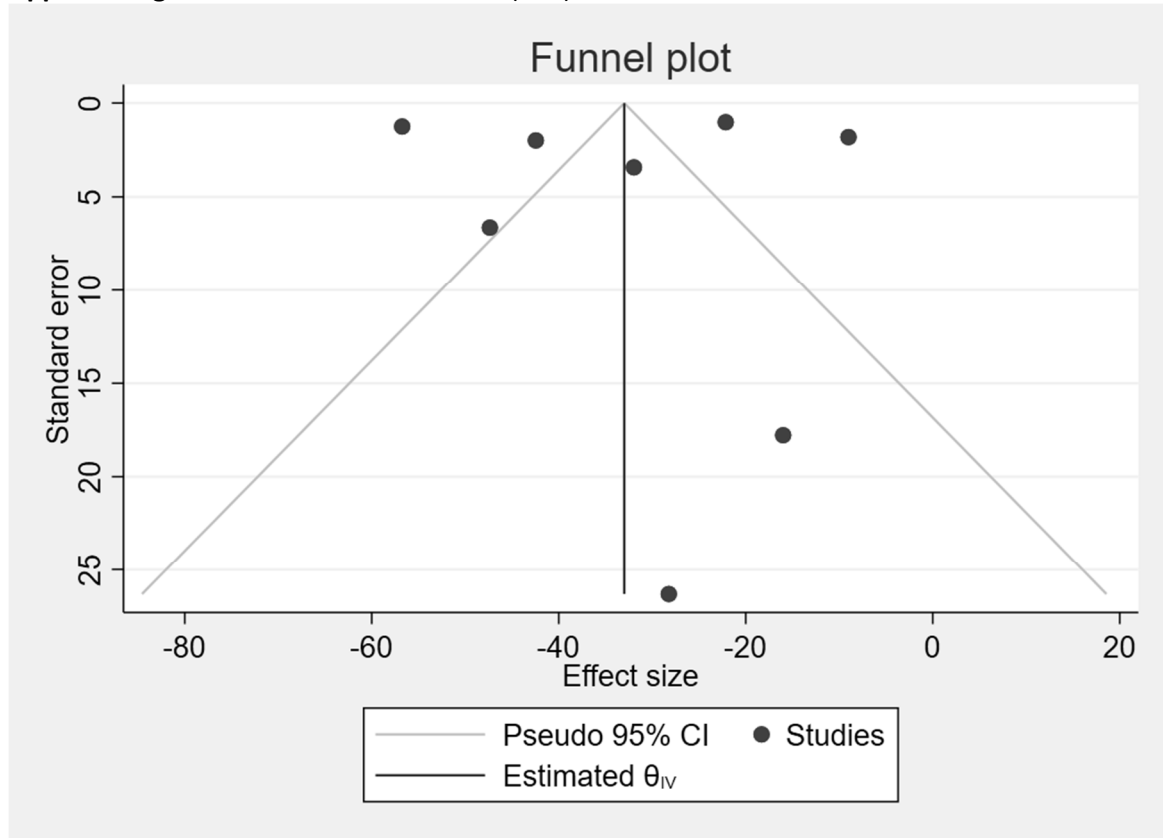
Appendix Figure 3. Forest plot of subgroup analysis, by food establishment type



Forest plot displaying an inverse variance weighted fixed-effect meta-analysis of the effect of introducing a food safety intervention on microbial counts detected in samples collected from foodservices, by food establishment type

ES, effect size; CI, confidence interval

Appendix Figure 4. Funnel Plot of Studies (n=8) with 95% Confidence Limits



Funnel plot assessing the risk of publication bias of the 8 studies included in the meta-analyses

Appendix Table 7. Overall results of the main meta-analysis of the effect of introducing a food safety intervention on microbial counts detected in samples collected from food establishments, excluding

Sensitivity test	Average relative change (%)	95% CI	P-value	I² * (%)
Removal of studies with large weights				
Overall (Pivarnik et al. excluded)	-34.00	(-37.12, -30.88)	0.000	98.9
Overall (Soares et al. excluded)	-22.77	(-25.01, -20.53)	0.000	97.1

studies with larger weights

* statistic describing the percentage of total variation across studies that is due to heterogeneity rather than chance.
CI, confidence interval; DF, degrees of freedom

Appendix Table 8. Results of the subgroup analyses of the effect of introducing a food safety intervention on microbial counts detected in samples collected from food establishments, using the random effects model

Sensitivity test	Average relative change (%)	95% CI	P-value	I² * (%)
Main meta-analysis (studies = 8)				
Overall	-32.84	(-48.17, -17.50)	0.000	99
Microorganism subgroup analysis (studies = 8)				
Coliforms	-21.49	(-57.26, -14.28)	0.000	99.7
Fecal coliforms	-25.02	(-74.01, -23.98)	0.000	99.9
S. aureus	-9.41	(-29.25, 10.44)	0.001	90.9
Total bacteria	-36.41	(-48.35, -24.48)	0.000	90.3
Enterobacterales	-60.29	(-82.17, -38.42)	0.000	93.3
Moulds & yeasts	-23.07	(-23.26, -22.87)	0.359	0
Overall	-30.43	(-40.49, -20.37)	0.000	100
Sample origin subgroup analysis (studies = 8)				
Food	-29.52	(-50.68, -8.36)	0.000	99.2
Hands	-55.79	(-59.92, -51.67)	0.341	7.2
Food- contact surfaces	-15.77	(-39.65, 8.10)	0.014	76.7
Overall	-32.29	(-44.57, -20.01)	0.000	99.2
Type of food establishment subgroup analysis (studies = 7)				
University	-34.99	(-61.70, -8.28)	0.000	99.4
Food catering facilities	-38.99	(-55.44, -22.53)	0.074	68.6
Care facilities	-27.78	(-38.75, -16.81)	0.000	99.1
Overall	-34.08	(-43.64, -24.52)	0.000	99
Post-intervention latest sample collection time subgroup analysis (studies = 7)				
≤ 1 month	-40.23	(-79.44, -1.03)	0.000	80.9
2-9 months	-26.46	(-35.19, -17.74)	0.000	73.6
1+ year	-25.72	(-58.49, 7.05)	0.000	99.4
Overall	-30.60	(-47.17, -14.03)	0.000	99.1

* statistic describing the percentage of total variation across studies that is due to heterogeneity rather than chance. CI, confidence interval; DF, degrees of freedom

Identification

Records identified through
database searching
(n = 1602)

Additional records identified
through snowballing
(n = 8)

Screening

Records after duplicates removed
(n = 1138)

Records screened
(n = 1138)

Records excluded based on
abstract and titles
(n = 1028)

Eligibility

Full-text articles assessed
for eligibility
(n = 110)

Full-text articles excluded,
with reasons
(n = 102)

Unsuitable setting: 40
Missing outcome measure: 29
Missing intervention: 19
Unsuitable food supply stage: 7
Unclear/missing intervention and
outcome: 3
Unsuitable design: 3
Unclear intervention timeframe: 1

Included

Studies included in
qualitative synthesis
(n = 8)

Studies included in
quantitative synthesis
(meta-analysis)
(n = 8)

	Risk of bias domains							Overall
	D1	D2	D3	D4	D5	D6	D7	
Cenci-Goga et al., 2005	!	+	+	+	+	+	+	!
Garayoa et al., 2016	!	+	+	+	+	+	-	!
Hart, 1997	!	+	+	+	+	+	+	!
Lim et al., 2013	!	+	+	+	-	+	+	!
Pivarnik et al., 2013	!	+	+	+	-	+	-	!
Roy et al., 2016	!	+	+	+	+	+	-	!
Soares et al., 2013	!	+	+	+	-	+	-	!
Soriano et al., 2002	!	+	+	+	+	+	-	!

Domains:

D1: Bias due to confounding.

D2: Bias due to selection of participants.

D3: Bias in classification of interventions.

D4: Bias due to deviations from intended interventions.

D5: Bias due to missing data.

D6: Bias in measurement of outcomes.

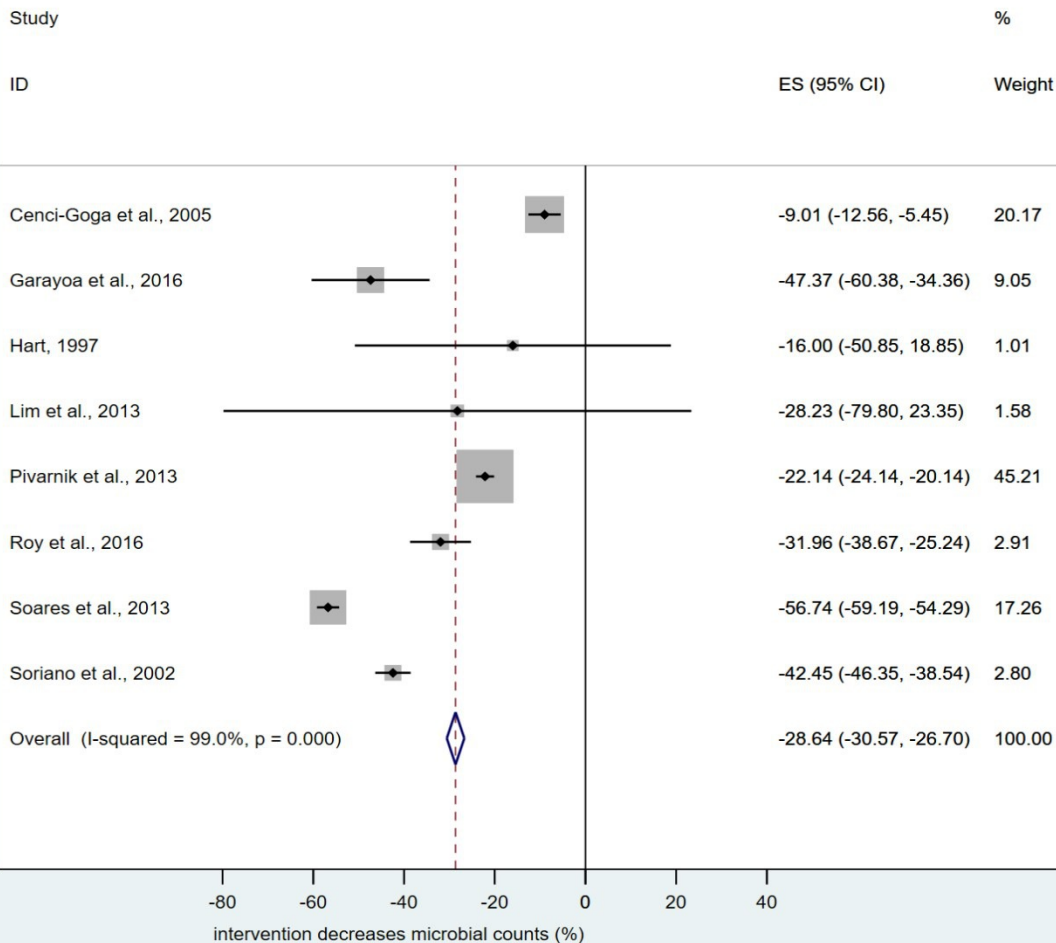
D7: Bias in selection of the reported result.

Judgement

! Critical

- Moderate

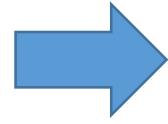
+ Low





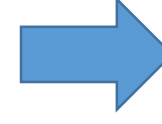
Research question

What's the impact of food safety policies in catering establishments in preventing foodborne diseases?



Enquired databases:

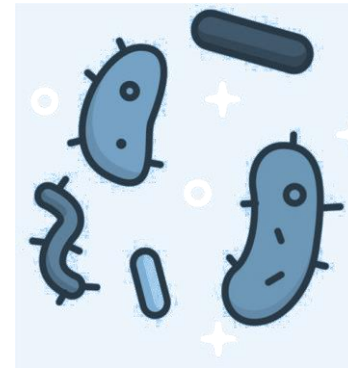
PubMed, Scopus, CENTRAL, ProQuest, CINAHL and ERIC



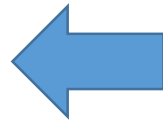
Quality assessment, using ROBINS-I tool



8 Studies contributing 166 estimates



Food safety interventions reduce microbial contamination by 28.6% (95% CI: -30.6% to -26.7%)



Consistent results in subgroup analyses by:

- type of microorganism screened,
- sample origin,
- type of food establishment, and
- sample collection time post-intervention