PEER-REVIEWED ARTICLE

Food Protection Trends, Vol 37, No. 4, p. 256–268

6200 Aurora Ave., Suite 200W, Des Moines, IA 50322-2864

Adrienne D. Andrew,*[1] Ian Young[2] and Andrew Papadopoulos[3]

[1]Dept. of Food Science, University of Guelph, Guelph, Ontario, Canada, N1G 2W1
[2]School of Occupational and Public Health, Ryerson University, 350 Victoria St., POD 249, Toronto, Ontario, Canada, M5B 2K3
[3]Dept. of Population Medicine, Ontario Veterinary College, University of Guelph, Guelph, Ontario, Canada, N1G 2W1

Food Safety Knowledge among Previously Certified Canadian Food Handlers

ABSTRACT

Food handlers can put the public's health at risk if they lack food safety knowledge. From March to June of 2015, 197 Canadian TrainCan Inc. food-handler certification students participated in a food safety survey to assess their knowledge at 1, 3 or 5 years post food handler certification. Multivariable logistic regression was used to identify and evaluate demographic variables associated with average knowledge scores. The survey consisted of 27 questions and had a response rate of 8.7%, with an average score of 88%. Participants showed a lack of knowledge on questions regarding reheating potentially hazardous foods, the manual dishwashing procedure and proper sanitary food storage. Multivariable logistic regression modelling identified a significant association ($P \leq 0.05$) of average food safety knowledge survey scores to education level, years lived in Canada, and years worked in the food service industry, with the relationship to gender being borderline significant. Regular food safety retraining between recertification courses is advocated for food handlers, to maintain their food safety knowledge and awareness, so as to ensure safe food for consumers.

INTRODUCTION

It is estimated that foodborne illness affects 4 million Canadians each year, and for each case of foodborne illness reported, there may be hundreds of cases that are unreported *(25)*. Norovirus, *Clostridium perfringens*, *Campylobacter* spp., and non-typhoidal *Salmonella* spp. are the most common domestically acquired foodborne illnesses in Canada *(25)*. Foodborne illness can range from mild gastrointestinal discomfort to vomiting, bloody diarrhea, paralysis, miscarriage and even death *(13)*.

Outbreaks of foodborne illness occasionally occur because of improper food handling, with significant and widespread impacts on human health and the economy. For example, a notable and high-profile outbreak of *Staphylococcus aureus* occurred in August, 2013, at the Canadian National Exhibition (CNE) in Toronto, Ontario, causing over 200

*Author for correspondence: Phone: +1 647.848.2979; E-mail: adrienneandrew@gmail.com

people to report gastrointestinal symptoms after consuming hamburgers that contained contaminated bacon jam *(22)*. It is hypothesized that temperature abuse of the bacon jam at both the bakery and the CNE led to conditions for *S. aureus* bacteria present in the jam to grow and produce a toxin that caused foodborne illness *(22)*. This and hundreds of other outbreaks of foodborne disease could be prevented through proper food handling practices *(26)*, which requires appropriate training of food handlers.

Approximately 25% of Canadians consume at least one food item prepared in a food premises each day *(5)*. In Ontario, the legal definition of a food premises is an establishment that stores, prepares, packages, serves, vends or offers food for human consumption *(6)*, such as restaurants, grocery stores and food commissaries. A 2012 report on food safety in Canada found that at least 50% of foodborne illness outbreaks with a known source originated in a food premise *(14)*. Lapses in food safety by food handlers may be a result of no training, improper training or declining food safety knowledge *(12)*. The safety of those who eat meals outside of the home is largely in the hands of food handlers, whose level of food safety knowledge is therefore important to the protection of public health.

Food handler food safety training can help increase food safety knowledge among food handlers, potentially reducing the instance of foodborne illness and lowering the burden associated with gastroenteritis *(10)*. Across Canada, each province and territory has its own guidelines recommending or requiring food safety training for food handlers *(29)*. In most provinces and territories, training can be provided by local public health units or accredited private agencies *(29)*. For example, TrainCan Inc. is a private company that provides food handler certification training across Canada, with the exception of the territories *(31)*.

Despite the recognized importance of food handler certification and training, only two provinces in Canada — Newfoundland and Labrador, and Prince Edward Island — require mandatory recertification or refresher courses *(29)*. In Ontario, it is suggested, but not required, by the Ontario Ministry of Health and Long-term Care (MOHLTC), a branch of the provincial government, that food handlers renew their food safety certifications every five years *(17)*. In a previous study focusing on food service volunteers, it was found that an increase in the display of positive food safety behaviors was evident in food handlers after a food safety training session *(23)*. Moreover, food handlers can experience a loss of food safety knowledge over time, or may develop poor food handling habits *(23)*. Retraining or recertification of food handlers could refresh their food safety skills and reinforce best practices, which could contribute to reducing the incidence of foodborne illness caused by food handlers in food premises *(23)*. It was hypothesized that food handlers in this study who more recently obtained their food handler certification would perform better on the food safety knowledge survey than those who obtained their certification longer ago so that time elapsed from initial certification may be associated with the level of food safety knowledge. This research aims to identify the food safety knowledge level of previously certified Canadian food handlers to determine key knowledge strengths and gaps post-certification, as well as the demographic variables associated with average food safety survey knowledge scores. The results can help to inform future research and governmental policies on food handler recertification and retraining.

MATERIALS AND METHODS

Research design and participants

Former food handler training students of the TrainCan Inc. "Basics.fst" program certified across Canada were surveyed to assess their level of food safety knowledge. The "Basics.fst" program is offered as a full day in-class training session followed by an exam *(28)*. To be eligible for this study, participants must have successfully completed the TrainCan Inc. "Basics.fst" course at any time on or before April 1, 2014, at least a year prior to the start of the study. A total of 2,257 potential participants were eligible and had provided a contact E-mail address to TrainCan Inc. The food safety survey was sent directly to the eligible 2,257 participants via E-mail by TrainCan Inc. on March 30, 2015. A reminder E-mail was sent out to potential participants a month after the initial E-mail, requesting completion of the survey. Once participants received the invitation E-mail from TrainCan Inc. and entered the survey hosted online by ProProfs.com, (ProProfs.com, Los Angeles, CA, USA), an Internet based survey application, participants were presented with an information page including consent information and research objectives. The online survey software collected the responses of each participant's demographic and food safety questions. After participants completed the online survey, their results were displayed by the survey software, including the correct answers to incorrectly answered questions. The survey was open for participation from March 30, 2015, to June 10, 2015, a total of 72 days; it was closed on June 10, 2015, two weeks after the last completed survey was submitted by a participant. Participants were compensated for their time with an entry into a drawing for one of three $25 CAD gift certificates to a retailer or food premises of their choice. This research was approved by the University of Guelph Research Ethics Board prior to the implementation of the project.

Instrument development

The online survey, offered in English only, consisted of multiple choice format questions divided into two sections. The first section focused on participant demographics: gender, age, years lived in Canada, highest level of school or highest degree completed, years worked in the food industry, holding a managerial or supervisory role, speaking English

as the first language, formal food preparation training, and the number of years passed since initial food handler certification. The second section of the survey consisted of 27 food safety questions to be answered within 30 minutes. The survey was accessible from a link in the invitation E-mail sent by TrainCan Inc. The food safety knowledge survey portion was created from a variety of multiple choice questions from four different Ontario MOHLTC food safety exams, which are used by local public health agencies throughout Ontario to assess food safety comprehension and to certify students after food handler training courses.

Permission from the Ontario MOHLTC was obtained to use their tests for this research. To create the food safety knowledge survey, tests and questions were selected at random until three questions from each of the 10 main topics of concern were chosen, resulting in 30 questions. *The Food Handler Training Program Requirements: Public Health Units* guideline of the Ontario MOHLTC indicates the central topics of study as the following *(15)*:

1. The role of the board of health/public health regulations and legislation
2. Food safety management principles, e.g., HACCP-based principles
3. Basic microbiology
4. Time and temperature
5. Storage
6. Preparation
7. Cross-contamination
8. Food handler hygiene
9. Food premises sanitation/pest control, design, and maintenance
10. Prevention of food allergy reactions, incidents and response.

The survey was intended to be sent only to previously certified food handlers in Ontario, but was distributed to past TrainCan Inc. food handler certification students across Canada. As a result, questions regarding Ontario food safety regulations were removed from the survey, bringing the number of questions to 28. A question asking for the definition of the HACCP (Hazard Analysis Critical Control Point) acronym was removed from the survey, as it was determined not be a reliable indicator of food handler knowledge; this removal resulted in a final total of 27 questions.

The questions appeared in random order for each participant, and the multiple choice answers were in a different order as well, to protect the integrity of the tests. Copies of the answers for the food safety tests were obtained from the Ontario MOHLTC and were used to determine the participants' scores. The food safety survey multiple choice questions were weighted equally for grading. Question 20, *"Handling food immediately after coughing and sneezing into hands is an example of:"* had two acceptable answers that could be considered correct, and both choices, *"physical contamination"* and *"cross-contamination,"* were marked correct. One common version of the definition for cross-contamination is the physical transfer of pathogens or foreign substances from a person, such as a food handler, or things, such as utensils, equipment and surfaces, to food items *(9)*. The word *"physical"* was used in defining *"cross-contamination"* which may have been misleading and as a result, both options were considered correct. The passing grade of the food safety survey was 70%, the same passing grade as on the Ontario MOHLTC's exams, which should correspond with safe food handling techniques *(17)*.

Statistical analysis

Stata 14 for Windows (StataCorp LP, College Station, Texas, USA) was used to perform statistical analysis. Survey responses were analyzed descriptively with frequency tabulations. Multivariable logistic regression modeling was conducted to test the association between demographic variables in this study and participants' food safety knowledge scores. The dependent variable was the proportion of correct answers out of 27 total questions. The model was developed using a generalized linear modelling framework with a binomial distribution and logit link. The following demographic variables were assessed as predictors: gender (female vs. male); age (60–79, 40–59, 20–39, vs. ≤ 19 years old); years lived in Canada (≤ 5, 5 to < 10, vs. ≥ 10), highest education level completed (high school or lower, some college/university, vs. completed college/university or higher degree); years worked in the food service industry (< 1, 1 to < 5, 5 to < 10, vs. ≥ 10); currently holding a managerial or supervisor position (yes vs. no); speaking English as a first language (yes vs. no); formal training in food preparation (yes vs. no); and years since obtaining most recent food handler certificate (≥ 5, 3 to < 5, vs. 1 to < 3).

Demographic variables were first assessed in univariable regression models, and those with P values ≤ 0.20 were included in multivariable model building. Multivariable models were calculated using a backward stepwise approach. This included adding all significant demographic variables from univariable models and removing them one at a time until all remaining variables were significant at $P \leq 0.05$. Pairwise interactions between all variables in the final multivariable model were assessed. Model diagnostics were evaluated, including visual examination of residuals and application of the Hosmer-Lemeshow goodness-of-fit test.

RESULTS

Of the 2,257 former TrainCan Inc. students who were sent the survey invitation E-mail, 197 or 8.7%, completed the survey. The average food safety survey score among participants was 23.6 out of 27 (88%). A total of 17 participants obtained the highest possible score, 27 out of 27 (100%), on the food safety survey, and one participant obtained the lowest score, 14 out of 27 (52%). The average

time a participant used to complete the food safety survey was 10 minutes and 3 seconds. Most participants, 190 of 197, or 96%, obtained a passing grade, which was a score of 70% or higher.

Participants' demographics are shown in *Table 1*. Of the 197 participants, 168 (85%) had successfully completed their most recent food handler certification course ≥ 1 year ago and < 3 years ago; 14 (7.1%) successfully completed their most recent food handler certification course ≥ 3 years ago and < 5 years ago, and 8 (4.1%) completed their most recent certification ≥ 5 years ago, while 7 (3.6%) did not provide an answer to this question *(Table 1)*. The food safety knowledge survey questions and the number of participants answering each question correctly can be found in *Table 2*. The questions answered correctly by the most participants concerned the transfer of bacteria to food (99%), probe thermometer use to determine internal cooking temperatures (99%), and the difference between cleaning and sanitizing

TABLE 1. Demographics and food safety knowledge survey scores of previously certified food handler participants

Questions	Responses	Participant Totals (n = 197) (%)	Average Total Correct Responses per Participant (%)	Standard Deviation of Average Percentage of Correct Responses (%)
Q.1) What is your gender?	Male	71 (36)	24.0 (89)	8.1
	Female	126 (64)	23.5 (87)	9.1
Q.2) What is your age in years?	19 years or younger	17 (8.6)	22.8 (84)	9.8
	20 years to 39 years	110 (56)	23.9 (89)	8.4
	40 years to 59 years	59 (30)	23.6 (87)	9.5
	60 years to 79 years	11 (5.6)	23.3 (86)	6.4
Q.3) How many years have you lived in Canada?	<1	7 (3.6)	24.0 (89)	4.3
	≥1 and <5	16 (8.1)	21.6 (80)	10.4
	≥5 and <10	17 (8.6)	23.3 (86)	11.2
	≥10	150 (76)	24.0 (89)	8.1
	Prefer not to answer	7 (3.6)	-	-
Q.4) What is the highest level of school you have completed or the highest degree you have received?	Some elementary school or completion of elementary school	6 (3.0)	23.8 (88)	3.6
	Some high school but no degree	7 (3.6)	24.4 (90)	6.0
	High school degree or equivalent (e.g., OSSD or GED)	31 (16)	23.3 (86)	7.9
	Some college or university but no degree	64 (32)	23.3 (86)	10.8
	College or university graduate with degree	80 (41)	24.0 (89)	8.0
	Any graduate studies beyond college or university	8 (4.1)	24.1 (89)	7.5
	Prefer not to answer	1 (0.5)	-	-
Q.5) How many years have you worked in the food service industry?	< 1	26 (13)	23.3 (86)	8.1
	≥ 1 and < 5	84 (43)	23.2 (86)	9.4
	≥ 5 and < 10	45 (23)	24.5 (91)	7.3
	≥ 10	40 (20)	24.4 (90)	6.3
	Prefer not to answer	2 (1.0)	-	-

Continued on next page.

TABLE 1. Demographics and food safety knowledge survey scores of previously certified food handler participants (cont.)

Q.6) Are you a manager / supervisor?	Yes	63 (32)	24.3 (90)	8.0
	No	113 (57)	23.5 (87)	8.0
	N/A	21 (11)	-	-
Q.7) Is English your first language?	Yes	152 (77)	22.5 (83)	7.7
	No	44 (22)	-	11.0
	N/A	1 (0.5)		-
Q.8) Have you received any formal training in food preparation (e.g., chef training or culinary school)?	Yes	57 (29)	24.0 (89)	9.1
	No	135 (69)	23.6 (87)	8.5
	N/A	5 (2.5)	-	-
Q.9) How many years have passed since obtaining your most recent food handler certification?	≥ 1 and < 3	168 (85)	23.7 (88)	8.7
	≥ 3 and < 5	14 (7.1)	24.3 (90)	7.7
	≥ 5	8 (4.1)	23.5 (87)	12.4
	Prefer not to answer	7 (3.6)	-	-

(99%). The questions with the lowest number of correct answers pertained to the time frame to reheat food to the original internal cooking temperature (57%), the correct method to manually wash dishes (62%), and sanitary food storage (62%) *(Table 2)*.

Results from univariable logistic regression models of associations between demographic variables and participants' food safety knowledge scores are shown in *Table 3*, while *Table 4* shows the results of the final multivariable model. Those who had lived in Canada for ≤ 5 years had lower knowledge scores than those who had lived in Canada for ≥ 10 years (odds ratio [OR] = 0.68; $P = 0.001$). Knowledge scores were higher among those who completed a college or university degree, or a more advanced degree (e.g., graduate school), than among those who had completed only some college or university education (OR = 1.32; $P = 0.006$); however, there was no significant difference in scores between those who had completed a bachelor's degree or higher and those who had completed high school or had less education. Those who had worked in the food service industry for ≥ 10 years had significantly higher knowledge scores than those who had worked in the industry for 1 to < 5 years (OR = 1.37; $P < 0.001$), but their scores did not significantly differ from those who had worked in the industry for < 1 year or for 5 to < 10 years. In the multivariable model, the effect of gender was found to be borderline significant (OR = 1.20; $P = 0.058$), with males tending to have higher knowledge scores than females. Gender was included in the final model as it was believed to be a confounder, and its inclusion improved model fit. No significant variable interactions were identified in the final model *(Table 4)*.

DISCUSSION

Food handlers who lack sufficient food safely knowledge may make errors while handling food, leading to possible outbreaks of foodborne illness. In a study focusing on foodborne illness outbreaks in which food handlers were found to be the cause of illness, some of the most common causes of outbreaks were temperature abuse, inadequate cleaning and sanitizing of utensils and equipment, and improper food storage *(27)*, which is similar to topics of questions participants in this study answered incorrectly. In this study, food handler participants had difficulty with questions in regard to the time to reheat a potentially hazardous food item back to its original cooking temperature, the correct method to wash dishes and utensils manually, and sanitary food storage. A lack of knowledge on these topics may show incomplete comprehension, or knowledge loss, provided these topics were covered in their initial food safety courses.

Despite being aware of proper probe thermometer use to determine internal cooking temperatures, participants scored only 57% on question 15, which asked the length of time necessary to reheat a food item to the original internal cooking temperature *(Table 2)*. Food items should not remain in the temperature "danger zone," the range between 4°C and 60°C where pathogenic microorganisms that cause foodborne illness grow the best, for more than two hours; otherwise, the food would be considered temperature abused *(4)*. It is possible that foodborne illness pathogens can multiply to levels that can cause illness if food items are reheated back to the original cooking temperature over a time frame of greater than 2 hours *(13)*. The cellular

TABLE 2. Food safety knowledge survey questions and totals of participants who answered correctly

Question and Multiple Choices (When "all of the above" is listed as a multiple choice option, it is the correct answer)	Total (n = 197) Participants Who Answered Question Correctly	Percentage of Participants Who Answered Question Correctly (%)
The role of the board of health/public health regulations and legislation		
Q.1) A major role of a public health inspector is to: • conduct compliance inspections of food premises • educate and consult with food service personnel • prevent foodborne illness from occurring in food premises • all of the above	186	94
Food safety management principles i.e., HACCP-based principles		
Q.2) The HACCP system involves: • a monitoring system to ensure control measures are in place • identifying critical control points • establishing control measures to reduce or eliminate risk • all of the above	189	96
Q.3) Which of the following is an example of a Critical Control Point (CCP) in preparing a boneless chicken breast? • Cooking the chicken until internal temperature reaches 74°C (165°F)	179	91
Basic Microbiology		
Q.4) A pathogen is a: • disease-causing microorganism	186	94
Q.5) Bacteria that cause foodborne illness: • cannot be seen, tasted or smelled	178	90
Q.6) Which of the following is a factor in bacterial growth? • Acidity • Time and temperature • Moisture • All of the above	170	86
Time and Temperature		
Q.7) What is the correct way to determine the cooking temperature of hazardous food? • Inserting a probe thermometer into the thickest part of the food	195	99
Q.8) The Danger Zone is the temperature range between: • 4°C to 60°C (40°F to 140°F)	147	75

Continued on next page.

TABLE 2. Food safety knowledge survey questions and totals of participants who answered correctly (cont.)

Q.9) What is the minimum hot holding temperature? • 60°C (140°F)	144	73
Storage		
Q.10) The safest way to store raw meats and ready to eat foods in a refrigerator is: • raw meats on the bottom shelf and ready to eat foods on the top shelf	191	97
Q.11) Potentially hazardous foods should be stored at an internal cold holding temperature of: • 4°C (40°F) or lower	159	81
Q.12) Food must be stored above the floor by at least: • 15 centimeters (6 inches)	123	62
Preparation		
Q.13) Which of the following is an acceptable cooling method? • Placing food in a shallow pan with proper air circulation • Placing a container of food in an ice bath • Portioning food into smaller batches • All of the above	154	78
Q.14) What is an acceptable way to safely defrost frozen turkey? • In a refrigerator	174	88
Q.15) How fast should you reheat food to the proper internal cooking temperature? • Within 2 hours	112	57
Cross-Contamination		
Q.16) Which of the following is an example of cross-contamination? • Using the same knife to cut raw poultry and to chop lettuce	190	96
Q.17) Which of the following statements presents the best reason for providing separate cutting boards for raw and cooked foods? • Bacteria from uncooked foods may be transferred to cooked foods by means of a cutting board	189	96
Q.18) Which of the following examples can prevent cross-contamination? • Using a separate cutting board for raw meats and ready to eat food	179	91

Continued on next page.

TABLE 2. Food safety knowledge survey questions and totals of participants who answered correctly (cont.)

Food Handler Hygiene		
Q.19) What is the best way to keep hands clean in a food premises? • Wash hands with liquid soap and warm water frequently	162	82
Q.20) Handling food immediately after coughing and sneezing into hands is an example of:* • physical contamination • cross-contamination	180	91
Q.21) Bacteria can be transmitted to food by: • working while ill • improper hand washing • sneezing or coughing on food • all of the above	196	99
Food premises sanitation (pest control, design, and maintenance)		
Q.22) What is the difference between cleaning and sanitizing? • Cleaning removes contamination and sanitizing kills pathogens	195	99
Q.23) The correct order to manually wash dishes is: • wash, rinse, sanitize	123	62
Q.24) Rodents seen in daylight in a food premises usually means: • there is a very large infestation	182	92
Prevention of food allergy reactions, incidents and response		
Q.25) A customer says they are having an allergic reaction to the food served; you should: • call for medical assistance immediately	188	95
Q.26) If a customer has a food allergy and asks for the ingredients of a pie, you should: • take the ingredient list to the customer	191	97
Q.27) Food-related allergic reactions: • are sometimes fatal • may cause difficulty breathing • are individual reactions • all of the above	193	98

*Both listed multiple choice options were considered correct for this question.

TABLE 3. Univariable logistic regression model results of demographic factors associated with participants' food safety knowledge scores (proportion of correct responses out of 27 questions)

Variable	Odds ratio	SE	95% CI	*P* value
Gender				
Female (referent)	-	-	-	-
Male	1.23	0.11	1.03, 1.46	0.020
Age				0.068
≤ 19 years old (referent)	-	-	-	-
20–39 years old	1.42	0.20	1.08, 1.88	0.012
40–59 years old	1.29	0.19	0.96, 1.73	0.089
60–79 years old	1.16	0.25	0.77, 1.76	0.479
Years lived in Canada				< 0.001
≥ 10 (referent)	-	-	-	-
5 to < 10	0.79	0.11	0.60, 1.05	0.106
≤ 5	0.60	0.07	0.48, 0.75	< 0.001
Education level				0.032
Completed college/ university or higher degree (referent)	-	-	-	-
Some college/university	0.78	0.07	0.65, 0.94	0.011
High school or lower	0.84	0.09	0.68, 1.04	0.113
Years worked in the food service industry				< 0.001
≥ 10 (referent)	-	-	-	-
5 to < 10	1.04	0.15	0.79, 1.37	0.782
1 to < 5	0.65	0.07	0.52, 0.82	< 0.001
< 1	0.68	0.10	0.51, 0.91	0.010
Currently a manager or supervisor				
No (referent)	-	-	-	-
Yes	1.30	0.13	1.07, 1.57	0.007
First language is English				
No (referent)	-	-	-	-
Yes	1.57	0.15	1.31, 1.88	< 0.001
Received formal training in food preparation				
No (referent)	-	-	-	-
Yes	1.17	0.11	0.97, 1.41	0.105

Continued on next page.

TABLE 3. Univariable logistic regression model results of demographic factors associated with participants' food safety knowledge scores (proportion of correct responses out of 27 questions) (cont.)

Years since obtaining most recent food handler certificate				0.406
1 to < 3 (referent)	-	-	-	-
3 to < 5	1.26	0.22	0.89, 1.78	0.195
≥ 5	0.94	0.20	0.63, 1.42	0.780

division rate for bacterial microorganisms under ideal conditions is every 10 to 20 minutes *(16)*. The infectious dose for a pathogen such as non-typhoidal *Salmonella* spp. is rather low, at approximately 10^3 organisms *(21)*, which could be reached within a couple of hours if cellular division occurs in an environment with favourable conditions, including a temperature within the "danger zone" (depending on the initial colony size) *(16)*, potentially causing a foodborne illness.

The question with the second lowest number of correct responses, 62%, was question 23 *(Table 2)*, which concerned the correct order of the procedure for manually washing dishes. The correct procedure is to wash the dishes in warm, clean water with an appropriate detergent, rinse with warm, clean water, and then sanitize using an approved sanitizer for the appropriate contact time *(24)*. Prior to washing, the dishes should be scraped to remove excess food, and after sanitizing, the dishes should be allowed to air dry *(13)*. This procedure is known as the wash-rinse-sanitize method *(13)*. If the sanitization step does not occur at the end of the process, the dishes may be exposed to contamination if they are handled for washing and rinsing after sanitation *(13)*. Cleaning must occur before sanitization, as cleaning with warm water and an appropriate detergent *(24)* removes accumulated food and soil, which allows the sanitizer to make full contact with the surface of the item, unobstructed by any left-behind food and soil and to destroy 99.9% of pathogens. Any food or soil remaining on the item to be sanitized can protect foodborne illness microorganisms from being destroyed by the sanitizer, potentially leading to a foodborne illness outbreak *(13)*. Tied for the question with the second lowest number of correct answers was question 12; only 62% of participants knew that food should be stored at least 15 cm above the floor *(Table 2)*. Storing food at least 15 cm above the floor will allow for adequate cleaning of the space underneath the stored food items, reducing the potential for physical or chemical contamination of the food *(4, 9)*. Elevating food storage would also allow signs of a potential pest infestation *(24)* to be observed. Rodents and insects can transmit foodborne illness-causing bacteria to food items, either from their bodies or from excrement left on food *(13)*.

Gender was a demographic variable that was found to be of marginal significance in this study, with a *P* value of 0.058, OR = 1.20 *(Table 4)*. The average score for male participants was 89%, while female participants had an average score of 87% *(Table 1)*. Gender was not found to be a significant factor regarding test scores on food safety knowledge surveys in other studies of food handlers *(3, 11, 18, 19)*. The sample of participants in this survey was comprised of almost twice the number of females, 126 (64%), as males, 71 (36%) *(Table 1)*, which is similar to the gender distribution in the food and beverage industry in Canada (60% female, and 40% male), as noted in a 2009 report carried out by the Canadian Tourism Human Resource Council *(1)*. The role of gender in food handler knowledge of food safety should be further investigated. Food handler participants in this study who had completed a college or university degree, or a postgraduate degree, had higher food safety knowledge survey scores than those who had completed only some college or university education (OR = 1.32; *P* = 0.006) *(Table 4)*. Other studies of food handlers have shown that higher education levels were a significant factor in increased food safety knowledge scores over scores of participants with lower education levels *(3, 12, 20)*. No significant differences were found in food safety knowledge scores of participants who had completed a bachelor's degree or higher as compared with participants with an educational level of high school or less *(Table 4)*. It is not known what type of bachelor's degree or higher level degree participants in this study possessed, or the region or country where participants received any level of their education; this information might give more insight into why no significant differences were seen. Participants who had lived in Canada for ≥10 years (OR = 0.68; *P* = 0.001) had higher food safety knowledge scores compared with those who had lived in Canada for ≤ 5 years *(Table 4)*. Recently emigrating from a country with a different food safety system than Canada's may be negatively associated with a participant's food safety knowledge; the difference in knowledge of recommended food safety practices could be related to differences in food safety regulations and cultural practices in other countries *(18)*. For example, a food handler from a country where unpasteurized milk can be legally offered for sale may not understand the risks connected to unpasteurized milk consumption *(2)*. Previous studies have found higher rates of food safety inspection

TABLE 4. Multivariable logistic regression model results of demographic factors associated with participants' food safety knowledge scores (proportion of correct responses out of 27 questions)

Variable[a]	Odds ratio	SE	95% CI	*P* value
Gender				
Female (referent)	-	-	-	-
Male	1.20	0.11	0.99, 1.44	0.058
Years lived in Canada				0.004
≥ 10 (referent)	-	-	-	-
5 to < 10	0.78	0.12	0.58, 1.04	0.090
≤ 5	0.68	0.08	0.53, 0.86	0.001
Education level				0.020
Completed college/ university or higher degree (referent)	-	-	-	-
Some college/university	0.76	0.08	0.62, 0.92	0.006
High school or lower	0.84	0.10	0.67, 1.05	0.132
Years worked in the food service industry				0.001
≥ 10 (referent)	-	-	-	-
5 to < 10	1.15	0.17	0.86, 1.53	0.194
1 to < 5	0.73	0.09	0.57, 0.93	< 0.001
< 1	0.84	0.14	0.61, 1.15	0.128

[a]Model details: n = 187; Goodness-of-fit (data grouped into five quantiles) = 5.58 ($P = 0.134$).

infractions among operators of ethnic restaurants than among operators of non-ethnic restaurants *(8)*, indicating that additional efforts may be needed to address food safety knowledge or training gaps in diverse immigrant and ethnic populations (e.g., ensuring proper translation of training materials). Participants who had worked for ≥ 10 years in the food service industry had significantly higher food safety knowledge scores than participants who had worked for 1 to < 5 years in the food service industry (OR = 1.37; $P < 0.001$) *(Table 4)*. Perhaps participants with ≥ 10 years of experience were able to draw from their technical food safety experience, and the practical experience they obtained over their years of service added to their food safety knowledge. This is supported by results of another study that examined the food safety knowledge of restaurant managers in Oklahoma, where scores on a food safety exam increased as the amount of time a participant had worked in the food service industry increased *(10)*. The number of years worked in the food industry was also found to be a significant factor related to increased food safety knowledge in an evaluation of food handlers in British Columbia, Canada *(12)*.

Previous studies have examined the value of certification and recertification for food handlers *(11, 12, 23)* but there seems to be a gap in the literature concerning when recertification should occur. No statistically significant relationship was found between the amount of time that had passed since the last food handler certification course and the amount of food safety knowledge possessed, at least for the time frames examined in this study *(Table 4)*. The lack of a relationship might be because the time frames examined were too short, and longer times from the last certification course should have been studied. Future research is needed to explore the optimal time for food handler recertification, examining longer time periods from initial certification than were examined in this study, which had a maximum time frame of ≥ 5 years from initial certification. Perhaps time frames of 10 years and 20 years post-initial certification should be examined to adequately observe and measure food safety knowledge attrition, with a

greater number of participants in each time frame to properly observe trends over time.

LIMITATIONS

The small sample size and low response rate in this study may be a limitation, as the sample may not have been representative of the larger population of food handlers. Therefore, the conclusions drawn in this study may not apply to the general population of food handlers in Canada. However, it is not known how many E-mails were undeliverable to participants, which would reduce the number of invited participants from 2,257, thereby increasing the response rate. There was likely underrepresentation of some demographic categories that limited the ability to test for associations with average knowledge scores. There was low representation of participants who obtained their food handler certification ≥ 3 years ago but < 5 years ago, and ≥ 5 years ago, as compared to the high representation of participants who acquired certification ≥ 1 year ago but < 3 years ago *(Table 1)*. The larger number of participants in the group who obtained their most recent food handler certification ≥ 1 year ago but < 3 years ago may have been seen because this group was eager to test their food safety knowledge, as they had more recently certified. There may have been fewer participants in the other two time frame groups because they had certified earlier and may have been facing a decline in food safety knowledge, which would make them less likely to participate in the survey.

The high turnover rate of employees in the food service industry may be another reason why there were relatively few participants who had obtained their food handler certification ≥ 3 years ago but < 5 years ago, and ≥ 5 years ago *(Table 1)*. The food service industry employs a sizeable number of young people and students, seasonal/temporary workers and part-time workers *(7)*. These workers may be employed for only a short period of time, such as a summer or holiday season, or they may be returning to school or ending their employment in the food service industry for a position in another industry *(7)*. These factors may indicate why such a large portion of participants in this study had obtained their food handler certification in the time frame of ≥ 1 year ago and < 3 years ago from the start of the study.

The survey questions used in this study were picked at random from four different Ontario MOHLTC food safety exams, to ensure that no bias was demonstrated in question selection. Questions that were randomly selected may not have been the best questions to test food safety knowledge, compared with other questions that were not selected for the survey. To eliminate this type of limitation, questions could be selected based on the food safety knowledge needed to answer them correctly, instead of by randomization.

The Government of Canada has not mandated a Canada-wide minimum passing score for food handler certification tests; the provinces and territories determine their own passing scores. As the Ontario MOHLTC's tests were used for this study, their minimum passing score of 70% was used for consistency. The only provincial or territorial government that recommends a minimum passing score for food handler certification is Ontario *(30)*. In contrast, the passing grade for TrainCan Inc.'s "Basics.fst" exam is 74% *(28)*. A disparity may be created by using the Ontario minimum score.

The food safety knowledge survey was forwarded to potential participants by TrainCan Inc., resulting in unavailability of demographic information of potential participants who did not respond to the survey invitation. The demographic information of non-responding potential participants could give insight into why they did not partake in the study, compared with the demographic information of those who participated.

As a result of the design of the study, the country of origin of participants is not known in relation to the number of years lived in Canada, which was related significantly to the amount of food safety knowledge displayed on the food safety survey. To better explain these results, information on the country of origin of these participants, other countries where these participants have previously resided, and the length of time residing in other countries would be required. Similarly, the type of bachelor's degree or postgraduate degree possessed by participants in this study was not captured. For budgetary reasons, the survey was offered only in English, possibly resulting in an underrepresented sample among those who do not speak English as their first language. English fluency levels were not assessed among participants in this study, which may affect food safety knowledge survey scores if participants were not able to understand questions because of a lack of English language comprehension skills.

The initial food handler certification results of the participants were not known, which could give statistical indication of food safety knowledge retention through analysis of scores before and after food safety training. Further research in this area should include comparison of previous and current food handler certification test scores for assessment of food safety knowledge retention and changes between tests. Incorporating behavioral observation of food handling would provide further information on the practical application of food safety knowledge among food handlers.

CONCLUSIONS

Food handlers in this study demonstrated incorrect knowledge of some food safety topics, such as adequate reheating of potentially hazardous foods, manual dishwashing, and proper sanitary food storage. Food-handling training courses should consider emphasizing these topics to reinforce the required knowledge. The demographics associated with the highest food safety knowledge scores in this study — education level, years lived in Canada, years worked in the food service industry,

and gender — are typically factors over which food handlers have little to no immediate influence. However, training agencies such as health units and private companies can attempt to address certain gaps by providing training in multiple languages and by ensuring that important cultural differences are explored and covered. Further research is needed on determining an ideal time frame for food handler recertification. To further support retraining, governments should create policies that encourage or require food handler food safety training and retraining at appropriate intervals, to reduce knowledge decline and increase food safety knowledge.

ACKNOWLEDGMENTS

The authors gratefully acknowledge Jim Kotch from TrainCan Inc. for arranging to have the survey distributed to TrainCan Inc.'s former food handler certification students. The authors would also like to thank the reviewers of this article for their helpful comments.

REFERENCES

1. Canadian Tourism Human Resources Council. Who's Working for You? A Demographic Profile of Tourism Sector Employees. Available from: http://cthrc.ca/~/media/Files/CTHRC/Home/research_publications/labour_market_information/ttse/DemoPro_Full_Report_EN.ashx. Accessed 16 November 2016.
2. Centers for Disease Control and Prevention. 2015. Raw Milk Questions and Answers. Available at: http://www.cdc.gov/foodsafety/rawmilk/raw-milk-questions-and-answers. html. Accessed 13 November 2016.
3. DeBess, E. E., E. Pippert, F. J. Angulo, and P. R. Cieslak. 2009. Food handler assessment in Oregon. *Foodborne Pathog. Dis.* 6:329–335.
4. Federal/Provincial/Territorial Food Safety Committee. 2016. Food Retail and Food Services Code. Available at: http://www.hss.gov.yk.ca/pdf/foodservicescode.pdf. Accessed 12 November 2016.
5. Garriguet, D. 2004. Overview of Canadians' Eating Habits. Available at: http://publications.gc.ca/Collection/Statcan/82-620-M/82-620-MIE2006002.pdf. Accessed 23 November 2016.
6. Government of Ontario. 1990. Health Protection and Promotion Act. Available at: https://www.ontario.ca/laws/statute/90h07. Accessed 23 November 2016.
7. Government of Canada. 2014. Food and Beverage Servers. Available at: http://www.servicecanada.gc.ca/eng/qc/job_futures/statistics/6453.shtml. Accessed 23 November 2016.
8. Harris, K. J., K. S. Murphy, R. B. DiPietro, and G. L. Rivera. 2015. Food safety inspections results: A comparison of ethnic-operated restaurants to non-ethnic-operated restaurants. *Int. J. Hosp. Manage.* 46:190–199.
9. Jenner, T., M. Elliot, C. Menyhart, and H. Kinnear. 2005. The HACCP Advantage Guidebook. Available at: http://www.ontla.on.ca/library/repository/mon/10000/251324.pdf. Accessed 23 November 2016.
10. Lynch, R. A., B. L. Elledge, C. C. Griffith, and D. T. Boatright. 2005. A comparison of food safety knowledge among restaurant managers, by source of training and experience, in Oklahoma County, Oklahoma. *J. Environ. Health* 66:9–14.
11. McIntyre, L., D. Peng, and S. B. Henderson. 2014. Retraining effectiveness in FOODSAFE trained food handlers in British Columbia, Canada. *Food Control.* 35:137–141.
12. McIntyre, L., L. Vallaster, L. Wilcott, S. B. Henderson, and T. Kosatsky. 2013. Evaluation of food safety knowledge, attitudes and self-reported hand washing practices in FOODSAFE trained and untrained food handlers in British Columbia, Canada. *Food Control.* 30:150–156.
13. McSwane, D., N. Rue, R. Linton, and D. Reeves. 2006. Essentials of Food Safety and Sanitation. Pearson Prentice Hall, Toronto, ON.
14. Munro, D., J-C Le Lallée, and J. Stuckey. 2012. Improving Food Safety in Canada: Toward a More Risk-Responsive System. The Conference Board of Canada, Canada.
15. Ontario Ministry of Health and Long-Term Care. 2013. Food Handler Training Program Requirements: Public Health Units. Ontario Ministry of Health and Long-Term Care, Toronto, ON.
16. Ontario Ministry of Health and Long-Term Care. 2013. Food Safety: A Guide for Ontario's Food Handlers. Available at: http://www.health.gov.on.ca/en/pro/programs/ publichealth/enviro/docs/training_manual.pdf. Accessed 3 December 2016.
17. Ontario Ministry of Health and Long-Term Care. 2013. Guidance Document for the Provincial Food Handler Training Plan. Available at: http://www.health.gov.on.ca/en/ pro/programs/publichealth/oph_standards/docs/guidance/gd_provincial_food_handler_training_plan.pdf. Accessed 23 November 2016.
18. Panchal, P. K., P. Bonhote, and M. S. Dworkin. 2013. Food safety knowledge among restaurant food handlers in Neuchâtel, Switzerland. *Food Prot. Trends* 33:64–72.
19. Panchal, P. K., A. Carli, and M. S. Dworkin. 2014. Identifying food safety knowledge gaps among restaurant food handlers in Bolzano, Italy. *Food Prot. Trends* 34:83–93.
20. Panchal, P. K., L. Liu, and M. S. Dworkin. 2012. Food safety knowledge is lower among Spanish-speaking than among English-speaking restaurant food handlers in Chicago. *Food Prot. Trends* 32:16–25.
21. Public Health Agency of Canada. 2011. *Salmonella enterica* spp. Available at: http://www.phac-aspc.gc.ca/lab-bio/res/psds-ftss/salmonella-ent-eng.php. Accessed 23 November 2016.
22. Rogers, K. 2013. Maple bacon jam identified as culprit in CNE Cronut burger illnesses. Available at: http://www.theglobeandmail.com/news/toronto/maple-bacon-jam-identified-as-culprit-in-cne-cronut-burger-illnesses/article13968451/. Accessed 23 November 2016.
23. Smith, L., S. A. Sirsat, and J. A. Neal. 2014. Does food safety training for non-profit food service volunteers improve food safety knowledge and behavior? *Food Prot. Trends* 34:156–165.
24. Thomas, G., M. Kayhan, and C. van den Heuvel. 2000. Basics.fst Food Safety Training in Canada. TrainCan Inc., Toronto, ON.
25. Thomas, M. K., R. Murray, L. Flockhart, K. Pintar, F. Pollari, A. Fazil, A. Nesbitt, and B. Marshall. 2013. Estimates of the burden of foodborne illness in Canada for 30 specified pathogens and unspecified agents, circa 2006. *Foodborne Pathog. Dis.* 10:639–648.
26. Todd, E. C. D., J. D. Greig, C. A. Bartleson, and B. S. Michaels. 2007. Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 2. Description of outbreaks by size, severity and settings. *J. Food Prot.* 70:1975–1993.
27. Todd, E. C. D., J. D. Greig, C. A. Bartleson, and B. S. Michaels. 2007. Outbreaks where food workers have been implicated in the spread of foodborne disease. Part 3. Factors contributing to outbreaks and description of outbreak categories. *J. Food Prot.* 70:2199–2217.
28. TrainCan Inc. Basics.fst. Available at: http://www.traincan.com/index-basics.asp. Accessed 23 November 2016.
29. TrainCan Inc. Canadian Food Safety Training Legislation by Province. Available at: http://www.traincan.com/provinciallegislation.pdf. Accessed 16 November 2016.
30. TrainCan Inc. Combined Regulations Booklet. Available at: http://www.traincan.com/CombinedRegulationsBooklet.pdf. Accessed 16 November 2016.
31. TrainCan Inc. Course Schedules. Available at: http://www.traincan.com/index-courses.asp. Accessed 16 November 2016.