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Research Paper

Observation of High School Students' Food Handling Behaviors: Do They Improve following a Food Safety Education Intervention?

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ABSTRACT

Youth are a key audience for food safety education. They often engage in risky food handling behaviors, prepare food for others, and have limited experience and knowledge of safe food handling practices. Our goal was to investigate the effectiveness of an existing food handler training program for improving safe food handling behaviors among high school students in Ontario, Canada. However, because no schools agreed to provide control groups, we evaluated whether behaviors changed following delivery of the intervention program and whether changes were sustained over the school term. We measured 32 food safety behaviors, before the intervention and at 2-week and 3-month follow-up evaluations by in-person observations of students ($n = 119$) enrolled in grade 10 and 12 Food and Nutrition classes ($n = 8$) and who individually prepared recipes. We examined within-student changes in behaviors across the three time points, using mixed effects regression models to model trends in the total food handling score (of a possible 32 behaviors) and subscores for "clean" (17 behaviors), "separate" (14 behaviors), and "cook" (1 behavior), adjusting for student characteristics. At baseline, students ($n = 108$) averaged 49.1% (15.7 of 32 behaviors; standard deviation = 5.8) correct food handling behaviors, and only 5.5% (6) of the 108 students used a food thermometer to check the doneness of the chicken (the "cook" behavior). All four behavior score types increased significantly ~2 weeks postintervention and remained unchanged ~3 months later. Student characteristics (e.g., having taken a prior food handling course) were not significant predictors of the total number of correctly performed food handling behaviors or of the "clean" or "separate" behaviors, and frequency of cooking and self-described cooking ability were the only characteristics significantly associated with food thermometer use (i.e., "cook"). Despite the significant increase in correct behaviors, students continued to use risky practices postintervention, suggesting that the risk of foodborne disease remained.

Key words: Food handling behaviors; Food safety education; High school students

Food safety education aims to encourage safe food handling behaviors and increase food safety knowledge to help prevent foodborne disease *(3)*. Although such education can improve knowledge, attitudes, and food handling behaviors under certain circumstances, significant behavior gaps often remain postintervention *(15, 24, 37, 47)*. Because many studies have used self-reported behaviors *(7, 15, 18, 19, 29, 33, 42),* which overrepresent safe food handling behaviors compared with direct observations *(1, 4, 32),* ascertaining the true impacts of education on behaviors can be difficult.

Consumers are an important target audience for food safety education (*24, 47*), yet studies that measure safe food handling behaviors using direct observation have been infrequent *(1, 4, 12, 16, 32)*. The sole consumer study to date that used directly observed behaviors to assess the effectiveness of food safety education was conducted in South Wales, United Kingdom, and found that behaviors improved immediately after intervention but then waned by 4 to 6 weeks later *(31)*.

Among consumers, youth are a key target demographic; they are assuming responsibility for their own food handling *(42),* often engage in risky food handling behaviors *(2),* prepare food for others *(21),* and have limited experience and knowledge of safe food handling practices *(2, 21, 42)*. For these reasons, food safety, including food preparation and hygiene, have been identified as important life skills that should be taught to youth through home economics, food, and nutrition courses *(14, 35, 38)*. Although youth are an important demographic of consumers and extensive assessment of baseline food safety behaviors has been conducted with middle school *(10, 17, 20, 28, 30, 33)* and college-age individuals *(2, 11, 12, 25, 27, 39, 44),* little research has been conducted on food safety behaviors among high school–age youth *(6, 21, 34, 42*). Studies of cooking classes *(7),* food safety and hygiene lessons *(19),* and food safety music parodies *(43)* have revealed improved self-reported behaviors in youth; however, no research has been done on

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the effectiveness of high school–based food safety education for implementing changes in behaviors over time.

Our goal was to investigate the effectiveness of existing food safety education for improving safe food handling behaviors among high school youth in Ontario, Canada. Our specific objectives were to observe whether food handling behaviors of high school students improved following an intervention using a modified version of the standardized food handler training program from the Ontario Ministry of Health and Long Term Care (MOHLTC) *(26)* and whether those changes were sustained over the school term (~3 months). We predicted that safe food handling behaviors would be poor at baseline and would improve directly following the intervention *(1, 12)* and that safe behaviors would be sustained from after the intervention to the end of the term.

MATERIALS AND METHODS

Overall study design and intervention. We conducted a repeated measures study with students ($n = 119$) enrolled in grade 10 and 12 Food and Nutrition classes ($n = 8$) in four high schools located in southern Ontario, Canada. The schools and kitchen classrooms have been described elsewhere *(8, 21),* as have the details about school and student recruitment, consent and debriefing, remuneration, and creation and delivery of the intervention *(22)*. At enrollment in the study, students were told that this was a food skills study (with the food safety focus only disclosed during poststudy debriefing) and that researchers from the University of Waterloo (Waterloo, Ontario, Canada) would observe the students preparing meals. We visited each classroom during class time at four times during the February to June 2015 school term: (i) the first week to collect baseline data (February 2015; T_1), (ii) within 2 weeks after T_1 to deliver the intervention, (iii) within 2 weeks after the intervention to collect follow-up data (February to March 2015; T_2), and (iv) ca. 11 to 13 weeks after T_2 to collect final data (May to June 2015; T_3). Dates of school visits were published previously *(22)*.

Although our original design included a control group of four classes of students who would not receive the intervention, no teachers were willing to participate in the study unless their students received food safety education; hence, all eight classes received the intervention. Prior to T_1, students explicitly did not receive any food safety instruction from either their teachers or the research team, except for instructions on how to prevent slips, falls, and knife injuries. Following T_1, one researcher (K.J.D., a public health inspector with experience delivering the intervention) went into each classroom and delivered the intervention, which was the MOHLTC program modified to fit classroom time constraints (i.e., 3 h of instruction time) and to omit topics relevant solely to commercial settings (e.g., receiving and shipping of food). K.J.D. delivered the intervention in the same manner used by public health inspectors across Ontario. No additional formal food handler training was provided. However, between T_2 and T_3, teachers were instructed to teach their classes as usual, meaning that they likely reminded students about various food safety practices during food preparation sessions occurring within this time frame. Although teachers were not provided specific prompts or food safety messages to use following the intervention, they were present during intervention delivery and may have made reference to the intervention or reinforced specific intervention messages between T_2 and T_3. Before T_1, as part of their remuneration participating classrooms were equipped with all kitchen supplies needed for the safe food handling behaviors we measured (e.g., digital food thermometers). The study was approved by a University of Waterloo Research Ethics Committee.

Food safety behavior measurement. We measured food safety behaviors at T_1, T_2, and T_3 via in-person observations of students who individually prepared recipes. We measured 32 food safety behaviors (Table 1) across three categories, "clean" (17 behaviors), "separate" (14 behaviors), and "cook" (1 behavior), using a modified version of the food safety observation checklist (available upon request) created by Byrd-Bredbenner et al. *(12),* which was modified to be relevant to our recipes, to omit storage, thawing, and glove use behaviors, and to assess hand washing after cell phone use.

We designed three recipes, one for each observation time, that followed an identical sequence of food handling steps using the same types of foods and preparation methods (Table 1). Recipes were reviewed by participating teachers to ensure they complied with school policies and that no modifications were required due to allergies or dietary restrictions. Each student was given a copy of the recipe at their classroom cooking station. Recipes included the following instructions: "Make this recipe on your own. Different people like to follow recipes in different ways, so make this recipe the way you would do it"; and "Do not help your classmates. If you need help, ask one of the researchers."

Six observers conducted the food handling observations, with each responsible for observing one to four students (all at the same cooking station). Prior to data collection, observers were trained by reviewing the expected safe food handling behaviors, observing three mock recipe preparations, and establishing agreements on how potential situations and observations would be recorded *(16)*. Mock recipe observations were done in both a home kitchen (to mimic our participating noncommercial style teaching kitchens) and a culinary teaching kitchen (to mimic our participating commercial style teaching kitchens). For each, all observers recorded the behaviors of a set of individuals 9 to 25 years of age, each preparing the T_1 recipe. This group of recipe preparers was selected to reflect the widest possible range of kitchen skills we expected of the high school participants. Following each mock recipe observation, the observers and two researchers (K.J.D. and S.E.M.) collectively reviewed the training session, discussed any questions or challenges, and established agreements about recording specific behaviors. After each session, interobserver agreement was calculated, using percent agreement between observations of the same participants; practice sessions continued until all pairwise agreements between observers were $\geq$90%. During data collection, observers positioned themselves to allow maximal view of food preparation areas while not interfering with student movement. Observers did not communicate with students during meal preparation and referred any student questions to one of the researchers not involved in observations.

Data entry and coding. Checklist observations were entered into an Excel spreadsheet (2016; Microsoft, Redmond, WA). Double entry of data for 44 randomly selected checklists confirmed a very low data entry error rate (0.09%; 7 of 7,700 entries), so on the remaining checklists the data were entered only once. Checklist observations were combined into food safety behaviors; for example, checklist items "hands washed before beginning any food preparation" (yes) were combined with "using soap" (yes) and "running water" (yes) to yield the behavior "hands washed with soap and water before beginning any food preparation." Each of the 32 food safety behaviors was scored as performed correctly (score = 1) or incorrectly (score = 0). For each student, behavior

TABLE 1. *Recipes used for the observation of safe food handling behaviors by high school students at baseline (T_1) and after the intervention (T_2 and T_3) in Ontario, Canada, February to May 2015*

BBQ chicken ranch sliders (T_1)	Open-faced chicken bruschetta (T_2)	Butter chicken (T_3)
	Ingredient lists	
1 boneless, skinless chicken breast, cut into two pieces	1 boneless, skinless chicken breast, cut into thirds	1 boneless, skinless chicken breast, cut into strips
BBQ sauce, to taste, about ¼ cup	¼ cup Italian marinade	¼ cup of butter chicken sauce
Monterey jack cheese, sliced	Shredded Mozzarella cheese, about ¼ cup	Paneer cheese, about ⅓ cup
Iceberg lettuce, torn into bite-sized pieces	½ cup chopped plum tomatoes	3–4 spinach leaves, torn into bite-sized pieces
Tomato slices	Minced fresh basil, to taste	1–2 green onions, thinly sliced
4 mini slider buns, toasted	3 slices of baguette, toasted	1 pita
Ranch dressing, to taste	Italian dressing, to taste	2–3 tbsp heavy cream
	Recipe steps	
1. Gather all ingredients to your work station before beginning.	1. Gather all ingredients to your work station before beginning.	1. Gather all ingredients to your work station before beginning.
2. Preheat oven to 350°C.	2. Preheat oven to 350°C.	2. Preheat oven to 350°C.
3. Cover chicken with BBQ sauce and bake 20–25 min or until chicken is cooked.	3. Cover chicken with marinade and bake 20–25 min or until chicken is cooked.	3. Cover chicken with butter chicken sauce and bake 15–20 min or until chicken is cooked.
4. Spread buns with ranch dressing and place chicken on buns. Top with cheese, lettuce, and tomato.	4. Place chicken on toasted baguette slice. Top with cheese, tomatoes and basil. Add additional Italian dressing, if desired.	4. Assemble the pita pocket: layer in the spinach, green onion, cheese, and chicken. Drizzle the pocket contents with heavy cream, if desired.
5. Plate the sliders and take the final plated food to the specified area.	5. Plate the bruschetta and take the final plated food to the specified area.	5. Plate the butter chicken and take final plated food to the specified area.
6. Clean up your cooking station.	6. Clean up your cooking station.	6. Clean up your cooking station.

scores for total (32 behaviors), "clean" (17 behaviors), "separate" (14 behaviors), and "cook" (1 behavior) were tallied. The student's unique identifier was used to link (i) observations across the three time points and (ii) student demographic and food skills characteristics (Table 2) that had been collected at baseline using a self-reported paper survey *(21)*.

Analysis. Data were analyzed using Excel (2016) and SAS software version 9.4 (SAS System for Windows, 2013, SAS Institute, Cary, NC). Scores for total observed food handling, "clean," and "separate" behaviors were treated as continuous outcomes, and the single "cook" behavior (i.e., use of a thermometer) was a binary outcome. Baseline student characteristics and food handling behaviors were assessed for all students present at T_1. Crude differences (i.e., unadjusted for other measured factors) between mean total, "clean," and "separate" behavior scores across time points were tested using paired *t* tests, and differences in the use of a food thermometer were tested using McNemar's chi-square test.

Changes in observed food handling behaviors were then determined at the student level (i.e., we examined within-student changes in outcomes across time points) using all available data from all 119 students participating in the study. Linear mixed effects regression models *(36)* were used to model the trends in the total food handling, "clean," and "separate" scores, and logistic mixed effect regression models were used for "cook" scores, with separate models fitted for each outcome. We considered missing data as missing at random, given that students missed observation periods for a variety of reasons and there was no indication that students missed class to avoid the observation period. All models included the following fixed effects: two slopes (the change in observed behaviors from T_1 to T_2 and from T_2 to T_3), school, and all seven student characteristics. Regression analyses were conducted using PROC MIXED for total, "clean," and "separate" scores and using PROC GLIMMIX for "cook" scores. In all linear mixed effects regression models, random intercept and slopes were included as student-level random effects to account for repeated measurements within students, whereas in the logistic mixed effects regression model only random intercepts were included. Model fit was determined based on minimizing the Akaike information criterion.

RESULTS

Of the 119 total high school participants, 108 participated at T_1, 102 at T_2, and 92 at T_3; 71 participated at all three time points. Reasons for nonparticipation were absences for sports, illness, vacation, or other personal reasons ($n = 38$); absence due to injury ($n = 1$) or academic reasons ($n = 12$); dropping the class ($n = 2$); and withdrawing from the study ($n = 2$).

Baseline food handling behaviors. At baseline, students ($n = 108$) used a mean of 49.1% (15.7 of 32 behaviors; standard deviation [SD] = 5.8) correct total food handling behaviors, 47.6% (8.1 of 17; SD = 2.2) of correct "clean" behaviors, and 53.6% (7.5 of 14; SD = 4.6) of correct "separate" behaviors, and 5.5% (6) of the 108 students used a food thermometer to check the doneness of the chicken (the "cook" behavior) (Table 2). The total, "clean," and "separate" food handling scores all had acceptable internal consistency, with Cronbach's alpha values of 0.85, 0.83, and 0.80, respectively *(41)*.

Changes in observed food handling behaviors. Mean unadjusted scores for the total, "clean," and "separate" behaviors are shown by time point in Table 3 for all students

TABLE 2. *Demographic characteristics and baseline (T_1) observed food handling behaviors of all participating high school students and students present at all three observation time points in Ontario, Canada, February 2015*

Factor measured	Students at T_1 ($n = 108$)	Students at all three time points ($n = 71$)
Mean (SD) age (yr)	15.6 (1.2)	16.5 (1.4)
% female	64.8	64.8
% works or volunteers at food a service premise	39.8	45.1
% handling food for the public in a work or volunteer capacity	26.7	26.8
% who had ever taken a food preparation or handling course[a]	31.0	30.1
Frequency of cooking from basic ingredients		
% "never"	22.2	15.5
% "a few times a year"	34.3	40.8
% "a few times a month"	24.1	23.9
% "a few times a week"	6.5	8.5
% "at least once a day"	11.1	11.3
Self-described cooking ability		
% "don't know how to cook"	3.7	1.4
% "can only cook when the instructions are on the box"	9.3	9.9
% "can do the basics from scratch (like boil an egg . . .) but nothing more complicated"	12.0	8.5
% "can prepare simple meals if I have a recipe to follow"	49.1	52.1
% "can cook almost anything"	21.2	21.1
Mean (SD) total number of correctly performed safe food handling behaviors (perfect score = 32)	15.7 (0.35)	15.3 (0.32)
Mean (SD) total number of correctly performed "clean" safe food handling behaviors (perfect score = 17)	8.8 (0.15)	8.0 (0.14)
Mean (SD) total number of correctly performed "separate" safe food handling behaviors (perfect score = 14)	9.7 (0.27)	7.3 (0.25)
% students who used a food thermometer to check chicken doneness ("cook")	5.6	5.6
Specific "clean" safe food handling behaviors		
% "Hands were washed with soap and running water before beginning any food preparation."	75.9	76.1
% "Hands were washed with soap and running water after handling produce."	8.3	7.0
% "Hands were washed with soap and running water after getting raw chicken."	26.9	28.2
% "Hands were washed with soap and running water after slicing raw chicken."	24.1	19.7
% "Leafy greens were washed with running water (soap and/or wipes may or may not have been used) before use."	13.9	8.5
% "Vegetable (e.g., tomato, green onion) was washed with running water (soap and/or wipes may or may not have been used) before use."	10.2	5.6
% "Food items and sauces left on dishes were scraped off before washing the dishes."	25.9	26.7
% "Dirty dishes/equipment were washed with soap and water after use."	80.6	81.7
% "When dishes were washed, a clean cloth (i.e., towel, rag, sponge, paper towel, or wipe) was used."	80.6	83.0
% "When dishes were washed, they were dried using a clean cloth (i.e., towel, rag, sponge, paper towel, or wipe) or allowed to air dry after washing."	80.6	83.0
% "Kitchen counters were adequately cleaned after all food preparation activities were complete."	30.6	29.6
% "Kitchen counters were adequately cleaned if they became dirty (i.e., contaminated) during food preparation."	2.8	2.8
% "When counters were washed, a clean cloth (i.e., towel, rag, sponge, paper towel, or wipe) was used."	30.6	31.0
% "When counters were washed, they were dried using a clean cloth (i.e., towel, rag, sponge, paper towel, or wipe) or allowed to air dry after washing."	33.3	33.8
% "Student wore clothes that appeared to be clean at the start of class."	100.0	100.0
% "Student wore an apron during food preparation."	88.0	88.7
% "Student's hair was suitably confined (e.g., pulled back, hair net, hat) during food preparation."	90.7	84.5
Specific "separate" food handling behaviors		
% "Leafy greens were placed on a clean surface at student's work station."	52.8	49.3
% "Vegetable (e.g., tomato, green onion) was placed on a clean surface at student's work station."	53.7	50.7

TABLE 2. *Continued*

Factor measured	Students at T_1 ($n = 108$)	Students at all three time points ($n = 71$)
% "Cheese was placed on a clean surface at student's work station."	55.6	53.5
% "Bread was placed on a clean surface at student's work station."	50.0	47.9
% "Leafy greens were prepared (e.g., sliced, torn) on a clean surface."	57.4	54.9
% "Vegetable (e.g., tomato, green onion) was sliced/chopped on a clean surface."	53.7	50.7
% "Cheese was sliced, shredded, or crumbled on a clean surface."	53.7	50.7
% "Bread was sliced on a clean surface."	53.7	54.9
% "Finished food item was assembled on a clean surface."	73.1	71.8
% "Raw chicken was carried from the supply station to work station in a manner that prevented dripping of raw chicken juices (by either placing it in the middle of a plate, bowl, or cutting board or using a plastic food storage bag with no visible leaks)."	85.2	84.5
% "Ready-to-eat foods were kept from contacting raw chicken or raw chicken juices."	36.1	31.0
% "Dishes (e.g., plate, bowl, cutting board) and/or utensils (e.g., knife, spoon) that touched raw chicken were kept separate from clean ones during use and storage."	61.1	64.8
% "Ready-to-eat foods were protected from contamination while using the cutting board (by either properly washing the cutting board using soap and running water after use with raw chicken and before use with ready-to-eat food or by using a different cutting board for raw chicken and ready-to-eat food or cooked food)."	28.7	26.8
% "Ready-to-eat foods were protected from contamination while using knives (by either properly washing knives using soap and running water after slicing raw chicken or by using a separate knife for raw chicken and ready-to-eat or cooked food)."	31.4	29.6

[a] Prior to the current Food and Nutrition course in which the student was enrolled during the study; includes courses such as cooking classes, previous food and nutrition courses, and food handler certification.

($n = 119$). For thermometer use, the unadjusted percentage of students ($n = 119$) using a thermometer was 5% at T_1, increased significantly to 36% ($P < 0.0001$) at T_2, but then decreased significantly to 30% at T_3 ($P = 0.0072$).

Results from the regression models indicated food safety behaviors increased postintervention. From T_1 to T_2, the total number of correctly performed food handling behaviors increased significantly, by 4.4 points of 32 possible (standard error [SE] = 0.55, $P < 0.0001$) and then did not change significantly from T_2 to T_3 (Table 4). Student characteristics were not significant predictors of the total number of correctly performed food handling behaviors (Table 4). Scores for both the "clean" (Table 5) and "separate" (Table 6) behaviors followed the same pattern: they increased significantly between T_1 and T_2 and did not change significantly from T_2 to T_3, and student characteristics were not significant predictors of the numbers of correctly performed behaviors. From T_1 to T_2, use of a food thermometer increased significantly by an additional 31% (SE = 0.05, $P < 0.0001$) and then did not change significantly from T_2 to T_3. Working or volunteering in a food service establishment was the only student characteristic significantly associated with the use of a food thermometer to check chicken doneness (Table 7).

DISCUSSION

Our goal was to evaluate the effectiveness of an existing food handler training program for improving safe food handling behaviors among high school students. However, because no schools agreed to be control groups, we were able to investigate only whether high school students' safe food handling behaviors were different before versus after in-class delivery of a modified version of the Ontario MOHLTC standardized food handler training program *(26)*. Before the intervention, the vast majority of students exhibited poor safe food handling behaviors in areas including general cleaning, hand hygiene, cross-contamination prevention, and use of food thermometers. Our baseline

TABLE 3. *Number of correctly performed food safety behaviors, unadjusted for student characteristics and repeated measures, for high school students in Ontario, Canada, before (T_1) and after (T_2, T_3) food safety education intervention*[a]

	Mean no. of correctly performed behaviors								
	Mean			T_1 to T_2		T_2 to T_3		T_1 to T_3	
Behavior types	T_1	T_2	T_3	Diff	P	Diff	P	Diff	P
Food safety ($n = 32$)	15.7	19.9	20.2	4.2	<0.0001	0.3	0.61	4.5	<0.0001
Clean ($n = 17$)	8.1	9.1	9.0	1.1	<0.0001	0.15	0.64	0.9	0.0076
Separate ($n = 14$)	7.5	10.4	10.9	2.8	<0.0001	0.53	0.26	3.4	<0.0001

[a] Students ($n = 119$) were observed February to May 2015. Values are results of paired t tests Diff, mean difference in total number of correctly performed food handling behaviors between each pair of time points.

TABLE 4. *Change in the total number of correctly performed food safety behaviors of Ontario, Canada, high school students after the intervention (T_1 to T_2) and at the end of the school term (T_2 to T_3)*[a]

Fixed effects parameter	Coefficient	SE	*P*
Intercept	15.92	2.02	<0.0001
Slope: T_1 to T_2	4.40	0.55	<0.0001
Slope: T_2 to T_3	0.56	0.53	0.296
School (referent: 1)			
2	−0.50	1.03	0.631
3	−2.7	0.66	<0.0001
4	−4.05	0.88	<0.0001
Age (yr)	−0.04	0.04	0.3278
Gender (referent: female)	−0.19	0.60	0.7716
Works or volunteers at a food service premises	0.30	0.89	0.7406
Handles food for the public	0.89	0.82	0.2891
Has ever taken a food preparation/handling course	−0.27	0.61	0.6663
Frequency of cooking from basic ingredients	−0.25	0.28	0.3809
Self-described cooking ability	0.58	0.35	0.0984

[a] Results of the linear mixed effects regression model for 119 students and 32 possible behaviors. SE, standard error.

TABLE 6. *Change in the number of correctly performed behaviors related to the concept "separate" of Ontario, Canada, high school students after the intervention (T_1 to T_2) and at the end of the school term (T_2 to T_3)*[a]

Fixed effects parameter	Coefficient	SE	*P*
Intercept	8.12	1.55	<0.0001
Slope: T_1 to T_2	2.95	0.44	<0.0001
Slope: T_2 to T_3	0.69	0.42	0.1015
School (referent: 1)			
2	−0.96	0.76	0.2113
3	−1.86	0.49	0.0002
4	−2.75	0.66	<0.0001
Age (yr)	−0.04	0.03	0.1499
Gender (referent: female)	0.34	0.45	0.5002
Works or volunteers at a food service premises	−0.07	0.67	0.9156
Handles food for the public	0.52	0.61	0.4008
Has ever taken a food preparation/handling course	−0.11	0.46	0.8144
Frequency of cooking from basic ingredients	−0.19	0.21	0.3729
Self-described cooking ability	0.34	0.27	0.1981

[a] Results of the linear mixed effects regression model for 119 students and 14 possible behaviors. SE, standard error.

findings are consistent with previous observation studies of consumers, which revealed poor hand washing, inadequate cleaning of kitchen surfaces, and failure to use a thermometer to check cooking temperatures *(1, 4, 12, 16, 32)*. Our hypothesis was guided by results reported by Redmond and Griffith *(31)* who found in their observation study that safe food handling behaviors among consumers improved following an intervention. We also found that students' overall safe food handling behaviors improved following the intervention. Studies examining self-reported behaviors have also revealed similar improvements post-intervention *(7, 15, 19, 23, 43)*. We observed no change in behaviors between T_2 and T_3, which is not consistent with the findings of Redmond and Griffith, who observed waning

TABLE 5. *Change in the number of correctly performed behaviors related to the concept "clean" of Ontario, Canada, high school students after the intervention (T_1 to T_2) and at the end of the school term (T_2 to T_3)*[a]

Fixed effects parameter	Coefficient	SE	*P*
Intercept	8.76	0.93	<0.0001
Slope: T_1 to T_2	1.22	0.27	<0.0001
Slope: T_2 to T_3	−0.06	0.28	0.8391
School (referent: 1)			
2	−0.27	0.45	0.5557
3	−0.79	0.29	0.0078
4	−1.70	0.37	<0.0001
Age (yr)	0.01	0.03	0.7364
Gender (referent: female)	−0.42	0.27	0.214
Works or volunteers at a food service premises	0.40	0.41	0.3434
Handles food for the public	0.28	0.37	0.4709
Has ever taken a food preparation/handling course	−0.39	0.27	0.161
Frequency of cooking from basic ingredients	−0.11	0.12	0.356
Self-described cooking ability	−0.01	0.15	0.9733

[a] Results of the linear mixed effects regression model for 119 students and 17 possible behaviors. SE, standard error.

TABLE 7. *Change in the use of a food thermometer to check chicken doneness ("cook" behavior) of Ontario, Canada, high school students after the intervention (T_1 to T_2) and at the end of the school term (T_2 to T_3)*[a]

Fixed effects parameter	Coefficient	SE	*P*
Intercept	0.04	0.12	0.7172
Slope: T_1 to T_2	0.30	0.05	<0.0001
Slope: T_2 to T_3	−0.06	0.06	0.2649
School (referent: 1)			
2	0.53	0.06	<0.0001
3	0.00	0.03	0.9626
4	0.07	0.05	0.1165
Age (yr)	−0.01	0.00	0.1272
Gender (referent: female)	−0.03	0.03	0.4277
Works or volunteers at a food service premises	0.12	0.05	0.0260
Handles food for the public	−0.03	0.05	0.4803
Has ever taken a food preparation/handling course	−0.01	0.03	0.7936
Frequency of cooking from basic ingredients	0.01	0.01	0.5893
Self-described cooking ability	0.01	0.02	0.5801

[a] Results of the logistic mixed effects regression model for 119 students. SE, standard error.

behaviors at 4 to 6 weeks postintervention. This discrepancy raises interesting points, namely the role played by regular food handling practice and safe food handling prompts in the maintenance of safe food handling behaviors. In our study, between T_2 and T_3, students continued to handle food within their Food and Nutrition class under their teacher's instruction, suggesting that an investigation of how other factors influence changes in food safety behaviors over time (e.g., psychosocial and social norms) *(45)* is warranted. Because results in our study and that by Redmond and Griffith were obtained with different interventions, the findings are not directly comparable.

In our study, student characteristics were not significantly associated with safe food handling behaviors; the one exception was working or volunteering in a food service establishment, which was associated with more food thermometer use. Even though one-third of our participants had taken a previous food handling or preparation course prior to the study *(22),* this previous training was not associated with better behaviors. This finding is alarming and highlights again the need to examine factors associated with safe food handling behaviors, including how they change over time. In previous studies, researchers have identified gender as related to behavior, with males having lower food safety behavior scores than females *(12, 42),* and this difference has been suggested as related to females' greater involvement in meal preparation and cooking *(42).* We did not identify a gender difference when accounting for other factors including experience, previous training, and weekly involvement in food handling. This finding appears to confirm what others have previously indicated *(42),* that gender is a proxy for experience and involvement in meal preparation.

Because of the small number of schools in our study, we included school as a fixed effect only. However, we observed that school was significantly associated with students' total, "clean," "separate," and "cook" behaviors, suggesting that school characteristics may either inhibit or promote safe food handling behaviors. Because all Food and Nutrition classes within a given school were taught by the same teacher, it is possible that school is a proxy for teacher. Teachers' limited backgrounds and interest in the material and lack of resources have been identified as potential barriers to safe food handling education *(33).* However, these barriers represent an opportunity for Ontario-based food safety experts to support food and nutrition courses through the provision of resources and teacher training, as has been done elsewhere *(19, 20, 28, 30, 33, 35, 43).*

In the present study, although the use of food thermometers improved significantly after delivery of food handler training, the percentage of students using a thermometer remained below 50%. These findings are consistent with those of Takeuchi et al. *(40),* who found that self-reported thermometer use by consumers increased significantly to 52% following an intervention. The infrequent use of food thermometers observed in our study at baseline was expected and is consistent across consumer studies *(1, 4, 9, 12, 16).* However, infrequent use of thermometers in this study persisted even though thermometers were readily available in each classroom and their use was explicitly encouraged as part of the intervention.

We used mixed effects regression models to analyze behavior changes at the individual student level and account for potential confounders such as work experience and previous training. In contrast, in the majority of studies that have included examinations of behaviors, mean food behavior scores have been compared at different time points (i.e., assessed changes at the group level) to assess the impact of food safety education *(7, 15, 17, 32, 33, 43).* The advantages of mixed effects regression models are the ability to describe how an individual student's food handling behaviors change over time while also exploring whether the trajectory of the changes differs among predictors (e.g., previous food handling training or handling food for the public) *(36).* We recommend that future studies use similar regression models to describe within-individual changes over time and to relate predictors to interindividual differences in change *(36),* providing a clearer insight into what drives food handling behaviors.

Despite significant improvements in safe food handling behaviors, students in our study continued to perform numerous risky behaviors that could result in contaminated food and subsequently foodborne disease. Students routinely failed to wash hands after handling raw chicken or vegetables, carried raw and ready-to-eat foods on the same plate, and used the same knife and/or cutting board to prepare raw chicken and then ready-to-eat products. These food handling lapses are consistent with other consumer observation studies, in which inconsistent hand washing between meal preparation steps *(16)* and cross-contaminated ready-to-eat foods *(4, 32)* have been reported.

Food safety behaviors can be considered a function of practice and habits. Given that these students are early in the process of developing habits *(5),* high school may be an ideal time to teach food safety education. Family and friends also may play a role in propagating unsafe practices *(47),* particularly because young adults report first learning about food safety from their mothers, followed by fathers, school, and television *(13),* and because social pressures *(46)* and other psychosocial factors *(45)* appear to drive changes in food safety behaviors. Although we did not address these social and psychosocial factors, the high school environment may represent an opportunity to avoid development of unsafe food handling habits, combat potential negative influences of family and peers, and establish new social norms for safe food handling behaviors.

This study had several limitations, most notably the lack of a control group. As described, our original design included a control group, but teachers were unwilling to have their classes participate unless all students received food safety education. Although this attitude may reflect the importance of this topic to the teachers we approached to recruit, it also illustrates a major methodological challenge of applied research, especially in schools. Another important consideration when interpreting our study results is that we assessed behavior changes solely based on statistical significance; whether the changes observed here translate into changes in the foodborne disease risk faced by these students must still be determined. Our total food handling

behavior score was a tally of the individual behaviors measured, giving each measured behavior equal weight; thus, the score did not account for the different degrees of risk associated with individual behaviors. Finally, because of in-class time constraints, we did not observe behaviors related to the concept "chill," in particular how high school students deal with leftovers, which may be a food handling step of particular importance to this demographic group.

This study provides evidence that food safety behaviors among high school students are generally poor but can improve significantly after in-class delivery of food handler training, specifically behaviors around cleaning activities, including hand hygiene, avoiding cross-contamination of foods, and the use of food thermometers. Our findings suggest that existing programs such as the Ontario MOHLTC standardized food hander training program, which was originally designed for commercial food handlers, can be effective with high school students and that delivering such education within existing food and nutrition courses and high school kitchen classrooms is feasible. However, despite improved behaviors, students continued to perform risky practices postintervention, indicating that there may be other factors that impact students' safe food handling behaviors. Future studies should include examination of how psychosocial factors influence behavior norms and how changes in food handling behaviors translate to actual risk of foodborne disease.

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