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A longitudinal evaluation of food safety knowledge and attitudes among Ontario high school students following a food handler training program

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## 26 ABSTRACT

27 Youth are a unique audience for food safety education, in part due to low food safety knowledge.  
28 Although the effectiveness of such education has been explored for primary school and college  
29 students, no studies have assessed effectiveness among high school students specifically. We  
30 conducted a longitudinal intervention study in Ontario, Canada, between February and May  
31 2015, to measure the baseline food safety knowledge and attitudes of high school students  
32 (n=119; from 8 classes in 4 high schools), and determine whether these factors improved  
33 following in-class delivery of a provincial standardized food handler training program. Linear  
34 mixed effects regression models were used to model within-student changes in knowledge scores  
35 and attitudes over time (i.e., circa 2 and 12 weeks post-intervention), and to investigate  
36 associations with student characteristics. At baseline, knowledge and attitudes were poor.  
37 Following training, overall knowledge was significantly greater than at baseline, although at  
38 three months post-intervention only knowledge of safe times and temperatures for cooking and  
39 storing food remained significantly higher than baseline. Following training, students were  
40 significantly less interested in learning about how to avoid foodborne disease. Other attitudes, as  
41 well as knowledge of cross-contamination prevention and disinfection procedures, remained  
42 unchanged. These findings suggest that delivering existing food handler training programs  
43 within high schools may be a feasible mechanism for food safety educators to improve students'  
44 food safety knowledge, both overall and specific to safe times and temperatures, albeit  
45 potentially for short timeframes. Whether knowledge continues to decline beyond three months  
46 after training bears further investigation. As well, future research to investigate how students'  
47 actual food safety practices may change following such training, and whether improvements in  
48 knowledge translate into reduced foodborne disease risk, is warranted.

49

50 **KEYWORDS:** food safety; foodborne disease; food handler training

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## 51 HIGHLIGHTS

- 52 • High school students have poor food safety knowledge
- 53 • 2 weeks post-food handler training knowledge improved, but attenuated 3 months later
- 54 • Before training, students were interested in learning about food safety
- 55 • Interest in learning about food safety declined post-training
- 56 • High school students do not see foodborne disease as a personal threat

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## 57 1. INTRODUCTION

58 Youth represent a unique audience for food safety education. They make risky food  
59 consumption choices (Nesbitt et al., 2009), have low food safety knowledge (Burke and  
60 Dworkin, 2015; Majowicz et al., 2015; Mullan et al., 2015), and are the age prior to young  
61 adults, who also consume risky foods and exhibit unsafe food handling behaviours (Morrone and  
62 Rathbun, 2003; Byrd-Bredbenner C, Maurer J, Wheatley V, Schaffner D et al., 2007; Byrd-  
63 Bredbenner C, Maurer J, Wheatley V, Cottone E, Clancy M, 2007; Stein et al., 2010; Abbot et  
64 al., 2012). Beyond their own risk, youth also handle food for the public. In Ontario, Canada,  
65 20% of high school students handle food for the public via work or volunteer activities  
66 (Majowicz et al., 2015), and the accommodations/food industry is the second largest  
67 employment sector for those aged 15-24 (Service Canada, 2014).

68 The effectiveness of food safety education has been evaluated among food handlers and  
69 within food service settings. For example, training can increase knowledge and improve  
70 attitudes towards hand hygiene (Soon et al, 2012); however, whether improved understanding  
71 translates into improved behavior is unclear. In their 2015 systematic review, Viator et al.  
72 concluded that improved reporting of intervention studies is needed before wider conclusions  
73 about education effectiveness, including in changing behaviours, can be drawn. Similarly,  
74 consumer food safety education programs appear effective in some contexts, but study  
75 heterogeneity impedes clear conclusions about effectiveness (Young et al., 2015). Specific to  
76 younger populations, food safety education has improved various combinations of knowledge,  
77 attitudes, and behaviours in primary school-aged children (Kim et al., 2012; Losasso et al., 2014;  
78 Shen et al., 2015) and college students (Yarrow et al., 2009; Stein et al., 2010; Abbot et al.,

79 2012). However, effectiveness in high school students, including the potential effectiveness of  
80 existing food handler training programs, has not been specifically explored.

81 The high school environment can promote or inhibit healthier lifestyles among youth; for  
82 example, curriculum and built classroom characteristics influence students' physical activity  
83 levels (Hobin et al., 2012), and the number of student smokers per school is driven in part by  
84 whether schools have, and enforce, tobacco control policies (Kaai et al., 2014). Schools have  
85 also been identified as an important intervention point for food safety education (Young et al.,  
86 2015). Therefore, given the importance of youth as a target audience for improved food safety,  
87 the need to determine the effectiveness of food handler training in youth, and the potential  
88 importance of the school environment for food safety education delivery, our objectives were to:  
89 measure the baseline food safety knowledge and attitudes of high school students in Ontario; and  
90 determine whether knowledge and attitudes improved following in-class delivery of the Ontario  
91 Ministry of Health and Long-term Care's (MOHLTC's) standardized food handler training  
92 program. We hypothesized that students' overall food safety knowledge (including knowledge  
93 about cross-contamination, safe times and temperatures for cooking and storing foods, and risky  
94 foods) would improve directly following the intervention, but would attenuate by the end of the  
95 school term. We also hypothesized that students' food safety attitudes (specifically their interest  
96 in learning how to avoid foodborne disease, their belief that they are personally susceptible to  
97 foodborne disease, and their belief that foodborne disease is a personal threat) would also  
98 improve then attenuate.

99

## 100 2. MATERIALS AND METHODS

### 101 2.1 Design

102 We conducted an intervention study using a repeated measures design, collecting  
103 longitudinal data circa 1 week before ( $T_1$ ), and circa 2 ( $T_2$ ) and 12 weeks ( $T_3$ ) after the  
104 intervention, from 119 high school students attending 8 food and nutrition classes at 4 Ontario  
105 high schools. Our original design included random allocation of classes to the intervention or  
106 control group; however, during class recruitment all teachers indicated that participation was  
107 conditional on their students receiving food safety training between  $T_1$  and  $T_2$ . Thus, we  
108 provided the intervention to all eight classes, with no comparison control group. Further details  
109 about sample size, recruitment (including blinding, debriefing, and remuneration), and study  
110 sequence are given in Appendix A. This study was reviewed and received ethics clearance  
111 through a University of Waterloo Research Ethics Committee.

112

## 113 *2.2 Intervention*

114 The intervention was a modified version of the Ontario MOHLTC's standardized  
115 provincial food handler training program, a commercially-oriented program that consists of a  
116 manual (Ontario Ministry of Health and Long-term Care, 2013) and a set of PowerPoint slides  
117 (T. Amalfa, MOHLTC, personal communication) available for use by local public health  
118 authorities when teaching food safety to food handlers. To fit intervention delivery into the 2-3  
119 hours of total in-class time allotted, and to focus on elements common across commercial and  
120 consumer settings, we omitted food safety legislation, shipment receiving and storage, kitchen  
121 layouts and plans, pest control, and Hazard Analysis and Critical Control Point concepts from  
122 our delivery. The intervention was delivered in the eight food and nutrition classrooms, to the  
123 whole class during class time, via interactive presentation of the Ontario MOHTLC's PowerPoint  
124 slides; slide material was presented and discussed, and interspersed with classroom activities

125 (i.e., handwashing practice using an ultraviolet fluorescent glow light; thermometer calibration  
126 using an ice water bath; identifying key food safety steps when preparing chili for a large number  
127 of people; and using pictures to illustrate how to wash dishes and how to store foods in the  
128 refrigerator) and example stories of professional and personal food safety experiences, making  
129 the delivery of the intervention concurrent with delivery in professional practice. Intervention  
130 delivery, and all measurements, were done during class time on dates requested by the teachers.  
131 Further delivery details are given in Appendix A.

132

### 133 *2.3 Knowledge and Attitude Measurements*

134 We measured students' food safety knowledge and attitudes via a paper survey, designed  
135 to take approximately 15 minutes for students to complete, and developed using questions from  
136 existing, validated questionnaires. Our survey (Appendix B) contained 76 food safety  
137 knowledge questions, 17 food safety attitude questions, and 8 demographic and food handling  
138 experience questions. For partial participant blinding purposes, we also included 26 attitude  
139 questions on other food-health topics (e.g., food allergies) and 18 food behaviour questions, not  
140 analysed here.

141 Most (70/76) knowledge questions were taken from the food safety knowledge  
142 instrument developed by Byrd-Bredbenner et al (2007a), specifically these three scales: (i)  
143 'cross-contamination prevention and disinfection procedures' (29 questions), that assessed items  
144 such as washing of fruits, vegetables, and counters, as well as hand hygiene and sanitizing; (ii)  
145 'safe times/temperatures for cooking/storing food' (14 questions), that assessed items like  
146 internal cooking temperatures, and reheating and cooling methods; and (iii) 'foods that increase  
147 the risk of foodborne disease' (27 questions; modified from the original 28 questions), that

148 assessed items such as whether foods like rare hamburger or commercially canned vegetables  
149 increase a person's risk of foodborne disease. To these 70 questions we added: 4 questions about  
150 specific microorganisms that may be found in particular foods (e.g., *Salmonella* in raw chicken)  
151 and 1 question on the definition of microorganisms, from the instrument developed by Lynch et  
152 al (2008); and 1 question on leftover storage times as per Yarrow et al (2009). All 76 questions  
153 had a single correct answer and were multiple choice format.

154 Most (14/17) food safety attitude questions came from the food safety psychosocial  
155 questionnaire developed by Byrd-Bredbenner et al (2007b); specifically, three 5-point Likert  
156 scales measuring the following food safety beliefs: (i) 'interest in learning about avoiding food  
157 poisoning' (measured using a set of 5 statements); (ii) 'food poisoning susceptibility' (3  
158 statements); and (iii) 'food poisoning is a personal threat' (6 statements). We also included 3  
159 additional attitude statements, each as a 5-point Likert-type scale, that explored aspects of  
160 perceived behavioural control. All Likert scales used 1 – 'strongly agree' to 5 – 'strongly  
161 disagree' for the analysis and reporting of results.

162

#### 163 2.4 Analysis

164 The 76 knowledge questions were scored as correct or incorrect; overall and scale-  
165 specific knowledge scores were calculated and treated as continuous outcomes. For the three  
166 attitude scales, statements within scales were averaged and the average scale value was treated as  
167 a continuous outcome. The three questions related to perceived behavioural control were  
168 analysed descriptively. Means were calculated for the overall and the three scale knowledge  
169 scores, and the three attitude scales. Differences between means, unadjusted for other measured  
170 factors, were tested using paired t-tests. Pairwise correlations were calculated to support future

171 meta-analyses (Appendix C). Internal consistency of the knowledge and attitude scales was  
172 assessed per time point using Cronbach's alpha. Descriptive analyses were conducted in Stata  
173 SE 14.1 and SAS 9.4. All analyses were conducted at the individual level.

174 Student characteristics and baseline knowledge and attitudes were assessed for all  
175 students present at  $T_1$  ( $n=106$ ). Changes in knowledge and attitudes were assessed at the student  
176 level (i.e., we examined within-student changes in outcomes across time points), using all  
177 available data from all students participating in the study ( $n=119$ ), via linear mixed effects  
178 regression models to model the trends in the overall and scale knowledge scores, and the three  
179 attitude scales, fitting separate models for each outcome. In all models, the following fixed  
180 effects were included: two slopes, the change in knowledge or attitude between  $T_1$  to  $T_2$  (i.e.,  $T_1-$   
181  $T_2$ ), and the change from  $T_2$  to  $T_3$  (i.e.,  $T_2-T_3$ ); school; and all eight student characteristics. All  
182 regression analyses were conducted using PROC MIXED in SAS 9.4; the significance of the  
183 change in knowledge or attitude between  $T_1$  to  $T_3$  was tested using an approximate t-test (via  
184 PROC MIXED with ESTIMATE option). Further details about the regression analysis,  
185 including random terms, correlation structures, and missing data, are given in Appendix A.

186

### 187 3. RESULTS

#### 188 3.1 Participation

189 Of the 140 students invited to participate, 122 agreed, 5 refused, and 13 dropped the class  
190 at the start of the term. Of the 122 agreeing students, 119 participated at one or more time  
191 points, 1 dropped the class prior to  $T_1$ , and 2 were absent at all three time points. Of the 119  
192 participants, 106 participated at  $T_1$ , 110 at  $T_2$ , and 92 at  $T_3$ , with 77 participating at all three time  
193 points; reasons for non-participation were absence on the data collection day for sports, illness,

194 vacation, or other personal reasons (n=38), dropping the class (n=2), and withdrawing from the  
195 study (n=2).

196

### 197 *3.2 Baseline Knowledge and Attitudes*

198 At baseline, students (n=106) averaged 49.1% (37.3/76; SD 6.6) correct answers to the  
199 knowledge questions, were interested in learning about how to avoid foodborne disease (1.9; SD  
200 0.7), were neutral as to whether foodborne disease was a personal threat (3.1; SD 0.8), and  
201 indicated some perceived personal susceptibility to foodborne disease (2.3; SD 0.8; Table 1).  
202 Overall, the knowledge and attitude scales had acceptable internal consistency, with Cronbach's  
203 alpha >0.7 at all time points, with the exception of the 'safe times/temperatures for  
204 cooking/storing food' scale at T<sub>1</sub> (Appendix D). Students agreed that they were able to do things  
205 to change their food preparation habits (2.5; SD 1.0) and that they have control over the food  
206 they eat (2.2; SD 1.0), and were confident they could cook safe, healthy meals for themselves  
207 and their family (2.2; SD 1.0); because these three items had low internal consistency  
208 (Cronbach's alpha: 0.50) they were not combined into an overall measure.

209 At baseline, students' knowledge of specific food safety elements varied. Although most  
210 knew to wash hands after touching their face (78.3%) or a pimple (83.0%), the majority did not  
211 know to wash hands after touching fresh fruit (82.1%), and only 45.3% knew the best way to  
212 wash hands. Only 1 in 4 students knew the best procedure for cleaning kitchen counters  
213 (25.5%), and the best way to wash dishes (25.5%). Regarding safe times and temperatures,  
214 62.3% of students correctly selected keeping foods refrigerated until they are cooked or served as  
215 the most important way to prevent illness, and 67.0% knew that an open box of raisins did not  
216 need to be refrigerated. However, only 17% of students knew the safe internal temperature for

217 cooking foods, only 13.2% knew that leftovers need to be reheated until boiling hot, and only  
218 10.4% knew the safest method for cooling a large pot of hot soup.

219 Knowledge of risky foods varied by food product. Only rare hamburgers (65.1%), raw  
220 oysters, clams, or mussels (65.1%), soft food (e.g., jelly) after scraping off mold (65.1%), and  
221 raw homemade cookie dough/cake batter (64.2%) were correctly identified as risky by more than  
222 half the students. Greater than 4 out of 5 students did not recognize that soft scrambled eggs  
223 (82.1%), unpasteurized fruit juice (84.0%), leftover soup reheated until warm but not boiling  
224 (84.9%), raw sprouts (89.6%), and sliced melon (94.3%) were risky foods. Additionally, greater  
225 than 3 out of 5 students incorrectly identified a box of rice that does not show an inspection  
226 stamp (61.3%), food stored in a cabinet beside an oven (85.6%), and meat cooked medium well  
227 (86.8%) as being risky.

228

### 229 *3.3 Changes in Knowledge*

230 Mean unadjusted scores by knowledge scale and time point are shown in Table 2 for all  
231 students (n=119). The average overall food safety knowledge of students within schools is  
232 shown over time (Figure 1), for students present at all three time points (n=77). When assessed  
233 at the student level, from T<sub>1</sub> to T<sub>2</sub>, overall knowledge increased significantly, by 5.88 points out  
234 of 76, and then decreased significantly by 1.95 points from T<sub>2</sub> to T<sub>3</sub> (Table 3), for an overall  
235 increase from T<sub>1</sub> to T<sub>3</sub> of 3.93 points (SE: 0.83, p<0.0001). Student characteristics were not  
236 significant predictors of overall knowledge (Table 3).

237 From T<sub>1</sub> to T<sub>2</sub>, knowledge of safe times and temperatures increased significantly, by 2.96  
238 points out of 14, and then decreased significantly by 0.84 points from T<sub>2</sub> to T<sub>3</sub> (Table 4), for an  
239 overall increase from T<sub>1</sub> to T<sub>3</sub> of 2.12 points (SE: 0.29, p<0.0001). From T<sub>1</sub> to T<sub>2</sub>, knowledge of

240 foods that increase the risk of foodborne disease increased significantly, by 1.81 points out of 28,  
241 but was not significantly different between T<sub>2</sub> and T<sub>3</sub> (Table 5), for an overall increase from T<sub>1</sub> to  
242 T<sub>3</sub> of 0.98 points (SE: 0.41, p=0.0177). Student characteristics were not significant predictors of  
243 knowledge of safe times and temperatures, nor foods that increase foodborne disease risk (Tables  
244 4 and 5).

245 Knowledge of cross-contamination did not change after the intervention (regression  
246 results not shown) and was not different between T<sub>1</sub> and T<sub>3</sub> (p= 0.3867). Self-described cooking  
247 ability was the only fixed effect significantly associated with cross-contamination knowledge,  
248 such that for each level increase in students' self-described cooking ability, they were more  
249 knowledgeable about cross-contamination prevention and disinfection procedures (by 0.23 points  
250 out of 29; p=0.0206), adjusting for all other factors in the model.

251

### 252 *3.4 Changes in Attitudes*

253 Mean unadjusted scores by attitude scale and time point are shown in Table 2 for all  
254 students (n=119). From T<sub>1</sub> to T<sub>2</sub>, students' interest in learning about how to avoid foodborne  
255 disease declined significantly, by 0.26 points out of 5, but was not significantly different between  
256 T<sub>2</sub> and T<sub>3</sub> (Table 6), for an overall decrease in interest from T<sub>1</sub> to T<sub>3</sub> of 0.28 points (SE: 0.08,  
257 p=0.0004). The average interest in learning about how to avoid foodborne disease of students  
258 within schools is shown by time (Figure 2) for students present at all three time points (n=77).  
259 Age and working or volunteering in a food service premises were both significantly associated  
260 with interest; for each year increase in age, students were significantly less interested in learning  
261 about how to avoid foodborne disease, and those who worked or volunteered in food service

262 premises were significantly more interested than those who did not, adjusting for all other factors  
263 in the model (Table 6).

264 Students' moderate belief about personal susceptibility to foodborne disease did not  
265 change after the intervention (regression results not shown) and was not different between T<sub>1</sub> and  
266 T<sub>3</sub> (p= 0.4704). Working or volunteering in a food service premises was the only fixed effect  
267 significantly associated with this belief, such that students who worked or volunteered in food  
268 service premises had slightly stronger beliefs of personal susceptibility (by 0.37 points out of 5;  
269 p=0.0491) than those who did not, adjusting for all other factors in the model.

270 Students' neutrality to foodborne disease being a personal threat did not change after the  
271 intervention (regression results not shown) and was not different between T<sub>1</sub> and T<sub>3</sub> (p= 0.9851).  
272 Handling food for the public in a work or volunteer capacity was the only fixed effect  
273 significantly associated with this belief, such that students who handled food for the public had  
274 slightly stronger beliefs that foodborne disease is a personal threat (by 0.29 points out of 5;  
275 p=0.0386) than those who did not, adjusting for all other factors in the model.

276

#### 277 4. DISCUSSION

278 We investigated high school students' food safety knowledge and attitudes before and  
279 after in-class delivery of an adapted version of the Ontario MOHLTCs standardized food handler  
280 training program. Before the intervention, students' knowledge was poor, students were  
281 interested in learning about how to avoid foodborne disease, and were neutral as to whether  
282 foodborne disease was a personal threat. As hypothesized, students' overall knowledge  
283 improved following program delivery, and although it attenuated over the school term, it still  
284 remained higher than baseline. Some knowledge aspects improved more than others, and at the

285 end of the term only knowledge of safe times and temperatures remained higher than baseline.  
286 Reasons for such differential knowledge retention are unclear, as there is a paucity of literature  
287 on food safety knowledge retention over time, both overall and specific to particular knowledge  
288 elements. A 2013 study of food handlers from the Canadian province of British Columbia found  
289 a gradual but significant loss of knowledge over a 15 year time frame, with “much of the  
290 knowledge decline occur[ing] within a few months to a year after the initial training” (McIntyre  
291 et al., 2013); however, because most of the knowledge questions used by McIntyre et al.  
292 pertained to safe times and temperatures (11/13, with 2/13 pertaining to cleaning practices), it is  
293 difficult to interpret our observed results in the context of their findings. Future studies  
294 examining retention of various aspects of food safety knowledge at multiple time points are  
295 needed, to uncover characteristics common to more- or less-easily retained information.

296 Contrary to our expectations, we observed that students’ interest in learning about how to  
297 avoid foodborne disease declined following the intervention, and their beliefs about personal  
298 susceptibility to, and personal threat of, foodborne disease remained unchanged over the study.  
299 The decline in interest following education has not been previously reported, and may relate to  
300 the developmental stage of our high school study population; teens across cultures demonstrate  
301 increased novelty seeking (Johnson SB et al., 2009), and it may be possible that the observed  
302 decline in interest reflects that learning about food safety following education is no longer novel.  
303 Reasons for unchanged attitudes related to perceived susceptibility to, and personal threat from,  
304 foodborne disease are unclear. It is possible that changes in these attitudes occurred here, but  
305 were too nuanced to detect given our sample size. In comparison, a U.S. study that examined the  
306 impact of a food safety educational video game on attitudes among 1,268 middle school students  
307 found that students felt more susceptible to foodborne illness following the game (Quick et al.,

308 2013); whether this discrepancy in findings relates to differences in student ages (i.e., middle  
309 school versus high school), the interventions used, or other factors is unknown. It is also  
310 unknown whether working to influence these attitudes when targeting food safety education to  
311 high school students would prove effective in impacting actual food safety behaviours and  
312 foodborne disease risk.

313 Interestingly, in our the linear mixed effects models, we identified two different random  
314 effect structures for the two different types of outcomes (i.e., random intercept, random time  
315 effect for knowledge, but only random intercept for attitudes). This indicates a greater  
316 inconsistency between students' knowledge trajectory over time than for their attitudes,  
317 suggesting that there may be more mutability in knowledge than attitudes over time, at least over  
318 short time periods like the one in this study. Given that food safety education effectiveness has  
319 typically been assessed by measuring changes in knowledge, attitudes, and often self-reported  
320 behaviours (e.g., Yarrow et al., 2009; Losasso et al., 2014), it is possible that knowledge  
321 measurements offer educators a sensitive, short-term indicator of effectiveness. However, given  
322 a recent qualitative review of barriers and facilitators to safe food handling, that identified that  
323 consumers' food safety behavior is a function of practice and habituation, and that consumers are  
324 generally not motivated to change behavior based on new knowledge, but rather as a result of  
325 social pressures (Young and Waddell, 2016), improvements in knowledge - although potentially  
326 easy and sensitive to measure - should not be taken as indicating reduced foodborne disease risk  
327 without further substantiating evidence.

328 Our findings from Ontario high school students are consistent with those from Chicago  
329 high school students, who also appear to have poor food safety knowledge (Burke and Dworkin,  
330 2015). Our findings are also consistent with those from primary school children in China, where

331 food safety education improved knowledge but did not change attitudes (Shen et al., 2015), and  
332 for middle school students in Korea and Italy (Kim et al, 2012; Losasso et al., 2014) and college  
333 students from the United States (Yarrow et al., 2009; Stein et al., 2010; Abbott et al., 2012),  
334 where knowledge was higher post-education. The overall knowledge attenuation observed here  
335 was expected and is consistent with findings from US college students (Yarrow et al., 2009),  
336 where knowledge attenuated five weeks post-education, remaining elevated only for health  
337 majors (who indicated that the education information was important for their future professions).  
338 Further understanding of factors associated with attenuation may help in framing food safety  
339 messages for maximum retention by groups with different interests.

340 Our survey comprised questions that had been used previously in other consumer food  
341 safety studies, predominantly in young adult populations. Although differences in study  
342 populations and time frames preclude precise comparisons of individual questions, it is worth  
343 noting that high school students in this study had generally as poor, or worse, knowledge than  
344 other, older student groups. For example, the percent of respondents correctly knowing the best  
345 way to clean kitchen counters ranges from roughly 1 in 4 students, as observed here and in two  
346 North American university undergraduate studies (Green and Knechtges, 2015; Courtney,  
347 Majowicz, and Dubin, 2016), to roughly 1 in 3 students at two universities in Jordan (Osaili et  
348 al., 2011) and Greece (Lazou et al., 2012), to over 3 in 4 students at a university in Lebanon  
349 (Hassan et al., 2014). Another example is that half our students knew that chilling or freezing  
350 does not eliminate harmful germs (data not shown), which is comparable to the students from  
351 Jordan (Osaili et al., 2011), but lower than the circa 60% - 80% of university students from  
352 Canada, the United States, Lebanon, and Greece (Lazou et al., 2012; Hassan et al., 2014; Green  
353 and Knechtges, 2015; Courtney, Majowicz, and Dubin, 2016). Given the growing number of

354 food safety knowledge surveys that use the same or very similar questions, future knowledge  
355 syntheses that rigorously summarize estimates across study populations would be a valuable  
356 contribution to the literature.

357 Here, student characteristics were not significantly associated with food safety  
358 knowledge, with the exception of students' self-described cooking ability, which was associated  
359 with greater knowledge about cross-contamination prevention and disinfection procedures.  
360 Burke and Dworkin (2015) found that experience cooking meat and experience cooking on one's  
361 own were both significantly associated with greater overall food safety knowledge among high  
362 school students at a Chicago school, which is in line with our observation.

363 Among our participants, one-third had taken a previous food handling or preparation  
364 course, such that some may have been previously exposed to material similar to our intervention  
365 (particularly since the MOHLTC standardized program was in use for food handler certification  
366 during the study period). Regardless, our observation that baseline knowledge was not  
367 associated with prior training, coupled with our observation that knowledge attenuated over the  
368 three-month post-intervention period, strongly suggests that food handler training and food  
369 safety education may require ongoing "booster" sessions in youth audiences, as has been  
370 observed for provincial food handlers in another Canadian province (McIntyre et al., 2013). We  
371 observed that students' interest in learning about how to avoid foodborne disease declined with  
372 age, suggesting that perhaps targeting intensive food safety education in early high school, with a  
373 "booster" in later grades, may be a strategy to investigate.

374 We observed that students' knowledge and attitudes were independently associated with  
375 school, in addition to time point, suggesting that there may be school characteristics that either  
376 inhibit or promote food safety. General food safety knowledge of the whole student body varied

377 across our study schools (Majowicz et al., 2015), and the four Food and Nutrition classrooms in  
378 which this study was conducted had different physical set-ups (although all met the minimum  
379 provincial requirements for food service premises; Brown et al., 2016). How the variation by  
380 school observed here relates to underlying student differences, teacher influences, or  
381 characteristics of the school environments is unknown. Regardless, school appears to be an  
382 important factor related to food safety knowledge and attitudes, and warrants further  
383 consideration, particularly to inform the tailoring and targeting of both future food safety  
384 education and future intervention efforts.

385         This study is subject to several limitations, most notably the lack of a control group.  
386 While our original design included a control group of four classes, no teachers were willing to  
387 participate in this capacity. This provides an accurate reflection of the methodological  
388 challenges faced when working in applied research settings, especially schools. Another  
389 important consideration when interpreting our study results is that we assessed knowledge and  
390 attitude changes solely based on statistical significance; whether the changes observed here  
391 translate into changes in the foodborne disease risk faced by these students, either in theory or in  
392 practice, must still be determined.

393

## 394 5. CONCLUSIONS

395         This study provides evidence that food safety knowledge and attitudes among high school  
396 students are generally poor, and that in-class delivery of existing programs, like the Ontario  
397 MOHLTC's standardized food handler training program, may be a feasible mechanism for food  
398 safety educators to improve students' food safety knowledge, both overall and specific to safe  
399 times and temperatures, albeit likely in the short term. This study also raises several questions

400 that bear further investigation, namely: whether food safety knowledge continues to decline  
401 beyond three months post-training, whether knowledge changes relate to changes in students'  
402 foodborne disease risk, why students' interest in learning about food safety might decline post-  
403 training, and whether this decline impacts students' retention of education messages. In addition,  
404 assessments that use observational data to investigate the impact that food safety education has  
405 on students' actual food safety behaviours are needed, to accurately determine how training and  
406 education may ultimately translate into reductions in foodborne disease risk.

407

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416

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## 431 FIGURE TITLES

432 **Figure 1.** Mean overall food safety knowledge scores (out of 76) for those high school  
433 students (n=77) present at baseline and at the two time points after the  
434 intervention, by school and calendar date of data collection, in Ontario, Canada,  
435 February 2015; timing of the intervention is marked with a hollow marker

436  
437 **Figure 2.** Mean interest in learning about how to avoid foodborne disease (5-point Likert  
438 scale, 1-strongly agree to 5-strongly disagree) among those high school students  
439 (n=77) present at baseline and at two time points after the intervention, by school  
440 and calendar date of data collection, in Ontario, Canada, February 2015; timing of  
441 the intervention is marked with a hollow marker

442

443

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**Table 1.** Demographic characteristics and baseline (T<sub>1</sub>) food safety knowledge and attitudes of participating high school students in Ontario, Canada, February 2015, for all students (n=119) and those present at baseline (n=106)

<b>Factor measured</b>	<b>All students (n=119)</b>	<b>Students present at T<sub>1</sub> (n=106)</b>
<i>Demographic and food handling experience characteristics</i>		
Mean age (SD)	15.8 (1.2)	15.7 (1.2)
% female	63.4	70.0
% handling food for the public in a work or volunteer capacity	29.5	26.4
% working or volunteering at a food service premises	25.2	21.7
% who had ever taken a food preparation/handling course*	34.2	32.1
Frequency of cooking from basic ingredients		
% “never”	10.1	11.3
% “a few times a year”	7.2	6.6
% “a few times a month”	22.5	23.6
% “a few times a week”	40.9	35.9
% “at least once a day”	19.3	22.6
Self-described cooking ability		
% “don’t know how to cook”	3.0	3.9
% “can only cook when the instructions are on the box”	9.3	10.7
% “can do the basics from scratch (like boil an egg... ) but nothing more complicated”	9.6	12.6
% “can prepare simple meals if I have a recipe to follow”	55.5	50.5

% “can cook almost anything”	22.6	22.3
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***Mean (SE) food safety knowledge and attitude scores***

Overall knowledge score, out of 76	-	37.3 (0.64)
Cross-contamination score, out of 29	-	17.6 (0.30)
Safe times/temperatures score, out of 14	-	5.1 (0.21)
Foods that increase foodborne disease risk score, out of 27	-	11.7 (0.31)
Interest in learning about avoiding foodborne disease, out of 5**	-	1.9 (0.07)
Foodborne disease susceptibility, out of 5**	-	2.3 (0.08)
Foodborne disease is a personal threat, out of 5**	-	3.1 (0.08)

\* Prior to the current food and nutrition course during the study; includes courses such as cooking classes, previous food and nutrition courses, and food handler certification

\*\* Measured on a 5-point Likert scale (1-strongly agree, 5-strongly disagree)

**Table 2.** Mean food safety knowledge and attitudes of high school students (n=119), before (T<sub>1</sub>) and after (T<sub>2</sub>, T<sub>3</sub>) the intervention, in Ontario, Canada, February-May 2015, with results of the paired t-tests (p-values <0.05 are shown in bold)

Factor measured	Mean			T <sub>1</sub> to T <sub>2</sub>		T <sub>2</sub> to T <sub>3</sub>		T <sub>1</sub> to T <sub>3</sub>	
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	Diff.*	p-value	Diff.*	p-value	Diff.*	p-value
Overall knowledge score (out of 76)	37.3	43.1	40.9	<b>5.8</b>	<b>&lt;0.001</b>	-2.2	0.070	<b>3.6</b>	<b>0.004</b>
Cross-contamination score (out of 29)	17.5	18.0	17.8	0.5	0.343	-0.2	0.629	0.2	0.669
Safe times/temperatures score (out of 14)	5.1	8.1	7.2	<b>3.0</b>	<b>&lt;0.001</b>	<b>-0.9</b>	<b>&lt;0.001</b>	<b>2.1</b>	<b>0.026</b>
Foods that increase disease risk score (out of 27)	11.7	13.4	12.5	<b>1.8</b>	<b>&lt;0.001</b>	-0.9	0.083	0.9	0.094
Interest in learning about how to avoid	1.9	2.2	2.2	<b>0.3</b>	<b>0.006</b>	-0.02	0.877	<b>0.3</b>	<b>0.014</b>

foodborne

disease\*\*

Foodborne	2.3	2.2	2.2	-0.1	0.256	0.0	0.981	-0.1	0.294
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disease

susceptibility\*\*

Foodborne	3.1	3.1	3.0	0.0	0.857	0.0	0.737	-0.1	0.609
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disease is a

personal threat\*\*

\* Difference between scores

\*\* Measured on a 5-point Likert scale (1-strongly agree, 5-strongly disagree)

**Table 3.** Results of the linear mixed effects regression model, showing the change in overall food safety knowledge (scored out of 76) of Ontario high school students (n=119) after the intervention (T<sub>1</sub>-T<sub>2</sub>) and at the end of the school term (T<sub>2</sub>-T<sub>3</sub>); p-values <0.05 are shown in bold

Fixed Effects Parameters		Co-efficient	SE	p-value
Intercept		52.84	10.60	<.0001
Slope: T <sub>1</sub> – T <sub>2</sub>		<b>5.88</b>	<b>0.81</b>	<b>&lt;.0001</b>
Slope: T <sub>2</sub> – T <sub>3</sub>		<b>-1.95</b>	<b>0.88</b>	<b>0.0278</b>
School (1: referent)	2	-1.75	2.26	0.4422
	3	<b>-4.47</b>	<b>1.55</b>	<b>0.0047</b>
	4	<b>-5.09</b>	<b>1.95</b>	<b>0.0102</b>
Age (in years)		-0.91	0.64	0.1538
Sex (female: referent)		-2.08	1.31	0.2536
Works or volunteers at a food service premises		-0.32	1.66	0.8499
Handles food for the public		1.13	1.41	0.4288
Has ever taken a food preparation/handling course		-0.19	1.16	0.8695
Frequency of cooking from basic ingredients		0.18	0.46	0.6958
Self-described cooking ability		0.29	0.49	0.5544

**Table 4.** Results of the linear mixed effects regression model, showing the change in safe times and temperatures knowledge (scored out of 14) of Ontario high school students (n=119) after the intervention (T<sub>1</sub>-T<sub>2</sub>) and at the end of the school term (T<sub>2</sub>-T<sub>3</sub>); p-values <0.05 are shown in bold

Fixed Effects Parameters		Co-efficient	SE	p-value
Intercept		5.52	3.40	0.1067
Slope: T <sub>1</sub> – T <sub>2</sub>		<b>2.96</b>	<b>0.26</b>	<b>&lt;.0001</b>
Slope: T <sub>2</sub> – T <sub>3</sub>		<b>-0.84</b>	<b>0.29</b>	<b>0.004</b>
School (1: referent)	2	-1.18	0.71	0.0997
	3	<b>-1.36</b>	<b>0.49</b>	<b>0.0062</b>
	4	-1.05	0.61	0.0872
Age (in years)		0.01	0.20	0.9788
Sex (female: referent)		-0.39	0.41	0.4481
Works or volunteers at a food service premises		-0.27	0.54	0.6284
Handles food for the public		0.33	0.46	0.4848
Has ever taken a food preparation/handling course		-0.23	0.38	0.5518
Frequency of cooking from basic ingredients		-0.08	0.15	0.5702
Self-described cooking ability		0.14	0.16	0.3972

**Table 5.** Results of the linear mixed effects regression model, showing the change in knowledge of foods that increase foodborne disease risk (scored out of 27) of Ontario high school students (n=119) after the intervention (T<sub>1</sub>-T<sub>2</sub>) and at the end of the school term (T<sub>2</sub>-T<sub>3</sub>); p-values<0.05 are shown in bold

Fixed Effects Parameters		Co-efficient	SE	p-value
Intercept		20.20	4.75	<.0001
Slope: T <sub>1</sub> – T <sub>2</sub>		<b>1.81</b>	<b>0.41</b>	<b>&lt;.0001</b>
Slope: T <sub>2</sub> – T <sub>3</sub>		-0.83	0.44	0.0609
School (1: referent)	2	-1.28	0.96	0.1849
	3	-1.29	0.67	0.0556
	4	-1.50	0.83	0.0755
Age (in years)		-0.46	0.28	0.1087
Sex (female: referent)		-0.33	0.57	0.6151
Works or volunteers at a food service premises		1.61	0.79	0.0576
Handles food for the public		-0.56	0.67	0.4154
Has ever taken a food preparation/handling course		0.73	0.54	0.1952
Frequency of cooking from basic ingredients		-0.26	0.24	0.2847
Self-described cooking ability		0.01	0.22	0.9513

**Table 6.** Results of the linear mixed effects regression model, showing the change in Ontario high school students' (n=119) interest in learning about how to avoid foodborne disease (5-point Likert scale, 1-strongly agree to 5-strongly disagree), after the intervention (T<sub>1</sub>-T<sub>2</sub>) and at the end of the school term (T<sub>2</sub>-T<sub>3</sub>); p-values<0.05 are shown in bold

Fixed Effects Parameters		Co-efficient	SE	p-value
Intercept		-0.53	0.99	0.5935
Slope: T <sub>1</sub> – T <sub>2</sub>		<b>0.26</b>	<b>0.07</b>	<b>0.0003</b>
Slope: T <sub>2</sub> – T <sub>3</sub>		0.02	0.08	0.8027
School (1: referent)	2	0.23	0.22	0.2961
	3	<b>0.33</b>	<b>0.15</b>	<b>0.0286</b>
	4	0.34	0.18	0.0646
Age (in years)		<b>0.15</b>	<b>0.06</b>	<b>0.0122</b>
Sex (female: referent)		0.00	0.12	0.9881
Works or volunteers at a food service premises		<b>-0.45</b>	<b>0.15</b>	<b>0.0106</b>
Handles food for the public		0.04	0.13	0.779
Has ever taken a food preparation/handling course		-0.02	0.11	0.8395
Frequency of cooking from basic ingredients		0.09	0.04	0.0518
Self-described cooking ability		-0.05	0.05	0.2806



