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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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ABSTRACT

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

Youth represent a unique audience for food safety education. They make risky food consumption choices (Nesbitt et al., 2009), have low food safety knowledge (Burke & Dworkin, 2015; Majowicz et al., 2015; Mullan, Wong, Todd, Davis, & Kothe, 2015), and are the age prior to young adults, who also consume risky foods and exhibit unsafe food handling behaviours (Abbot, Policastro, Bruhn, Schaffner, & Byrd-Bredbenner, 2012; Byrd-Bredbenner et al., 2007; Byrd-Bredbenner, Maurer, Wheatley, Cottone, & Clancy, 2007; Morrone & Rathbun, 2003; Stein, Dirks, & Quinlan, 2010). Beyond their own risk, youth also handle food for the public. In Ontario, Canada, 20% of high school students handle food for the public via work or volunteer activities (Majowicz et al., 2015), and the accommodations/food industry is the second largest employment sector for those aged 15–24 (Service Canada, 2014).

The effectiveness of food safety education has been evaluated

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among food handlers and within food service settings. For example, training can increase knowledge and improve attitudes towards hand hygiene (Soon, Baines, & Seaman, 2012); however, whether improved understanding translates into improved behavior is unclear. In their 2015 systematic review, Viator et al. concluded that improved reporting of intervention studies is needed before wider conclusions about education effectiveness, including in changing behaviours, can be drawn. Similarly, consumer food safety education programs appear effective in some contexts, but study heterogeneity impedes clear conclusions about effectiveness (Young et al., 2015). Specific to younger populations, food safety education has improved various combinations of knowledge, attitudes, and behaviours in primary school-aged children (Kim et al., 2012; Losasso et al., 2014; Shen, Hu, & Sun, 2015) and college students (Abbot et al., 2012; Stein et al., 2010; Yarrow, Remig, & Higgins, 2009). However, effectiveness in high school students, including the potential effectiveness of existing food handler training programs, has not been specifically explored.

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

2. Materials and methods

2.1. Design

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

2.2. Intervention

The intervention was a modified version of the Ontario MOHLTC's standardized provincial food handler training program, a commercially-oriented program that consists of a manual (Ontario Ministry of Health and Long-term Care, 2013) and a set of PowerPoint slides (T. Amalfa, MOHLTC, personal communication) available for use by local public health authorities when teaching food safety to food handlers. To fit intervention delivery into the 2–3 h of total in-class time allotted, and to focus on elements common across commercial and consumer settings, we omitted food safety legislation, shipment receiving and storage, kitchen layouts and plans, pest control, and Hazard Analysis and Critical Control Point concepts from our delivery. The intervention was delivered in the eight food and nutrition classrooms, to the whole class during class time, via interactive presentation of the Ontario MOHTLC's PowerPoint slides; slide material was presented and discussed, and interspersed with classroom activities (i.e., handwashing practice using an ultraviolet fluorescent glow light; thermometer calibration using an ice water bath; identifying key food safety steps when preparing chili for a large number of people; and using pictures to illustrate how to wash dishes and how to store foods in the refrigerator) and example stories of professional and personal food safety experiences, making the delivery of the intervention concurrent with delivery in professional practice. Intervention delivery, and all measurements, were done during class time on dates requested by the teachers. Further delivery details are given in Appendix A.

2.3. Knowledge and attitude measurements

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

Most (70/76) knowledge questions were taken from the food safety knowledge instrument developed by Byrd-Bredbenner et al. (2007a), specifically these three scales: (i) 'cross-contamination prevention and disinfection procedures' (29 questions), that assessed items such as washing of fruits, vegetables, and counters, as well as hand hygiene and sanitizing; (ii) 'safe times/temperatures for cooking/storing food' (14 questions), that assessed items like internal cooking temperatures, and reheating and cooling methods; and (iii) 'foods that increase the risk of foodborne disease' (27 questions; modified from the original 28 questions), that assessed items such as whether foods like rare hamburger or commercially canned vegetables increase a person's risk of foodborne disease. To these 70 questions we added: 4 questions about specific microorganisms that may be found in particular foods (e.g., *Salmonella* in raw chicken) and 1 question on the definition of microorganisms, from the instrument developed by Lynch, Steen, Pritchard, Buzzell, and Pintauro (2008); and 1 question on leftover storage times as per Yarrow et al. (2009). All 76 questions had a single correct answer and were multiple choice format.

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

2.4. Analysis

The 76 knowledge questions were scored as correct or incorrect; overall and scale-specific knowledge scores were calculated and treated as continuous outcomes. For the three attitude scales, statements within scales were averaged and the average scale value was treated as a continuous outcome. The three questions related to perceived behavioural control were analysed descriptively. Means were calculated for the overall and the three scale knowledge scores, and the three attitude scales. Differences between means, unadjusted for other measured factors, were tested using paired t-tests. Pairwise correlations were calculated to support future meta-analyses (Appendix C). Internal consistency of the knowledge and attitude scales was assessed per time point using Cronbach's alpha. Descriptive analyses were conducted in Stata SE 14.1 and SAS 9.4. All analyses were conducted at the individual level.

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

3. Results

3.1. Participation

Of the 140 students invited to participate, 122 agreed, 5 refused, and 13 dropped the class at the start of the term. Of the 122 agreeing students, 119 participated at one or more time points, 1 dropped the class prior to T_1, and 2 were absent at all three time points. Of the 119 participants, 106 participated at T_1, 110 at T_2, and 92 at T_3, with 77 participating at all three time points; reasons for non-participation were absence on the data collection day for sports, illness, vacation, or other personal reasons ($n = 38$), dropping the class ($n = 2$), and withdrawing from the study ($n = 2$).

3.2. Baseline knowledge and attitudes

At baseline, students ($n = 106$) averaged 49.1% (37.3/76; SD 6.6) correct answers to the knowledge questions, were interested in learning about how to avoid foodborne disease (1.9; SD 0.7), were neutral as to whether foodborne disease was a personal threat (3.1; SD 0.8), and indicated some perceived personal susceptibility to foodborne disease (2.3; SD 0.8; Table 1). Overall, the knowledge and attitude scales had acceptable internal consistency, with Cronbach's alpha >0.7 at all time points, with the exception of the 'safe times/temperatures for cooking/storing food' scale at T_1 (Appendix

Table 1
Demographic characteristics and baseline (T_1) 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 ($n = 106$).

Factor measured		All students (n = 119)	Students present at T_1 (n = 106)
Demographic and food handling experience characteristics			
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[a]		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
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[b]		–	1.9 (0.07)
Foodborne disease susceptibility, out of 5[b]		–	2.3 (0.08)
Foodborne disease is a personal threat, out of 5[b]		–	3.1 (0.08)

[a] 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.
[b] Measured on a 5-point Likert scale (1-strongly agree, 5-strongly disagree).

D). Students agreed that they were able to do things to change their food preparation habits (2.5; SD 1.0) and that they have control over the food they eat (2.2; SD 1.0), and were confident they could cook safe, healthy meals for themselves and their family (2.2; SD 1.0); because these three items had low internal consistency (Cronbach's alpha: 0.50) they were not combined into an overall measure.

At baseline, students' knowledge of specific food safety elements varied. Although most knew to wash hands after touching their face (78.3%) or a pimple (83.0%), the majority did not know to wash hands after touching fresh fruit (82.1%), and only 45.3% knew the best way to wash hands. Only 1 in 4 students knew the best procedure for cleaning kitchen counters (25.5%), and the best way to wash dishes (25.5%). Regarding safe times and temperatures, 62.3% of students correctly selected keeping foods refrigerated until they are cooked or served as the most important way to prevent illness, and 67.0% knew that an open box of raisins did not need to be refrigerated. However, only 17% of students knew the safe internal temperature for cooking foods, only 13.2% knew that leftovers need to be reheated until boiling hot, and only 10.4% knew the safest method for cooling a large pot of hot soup.

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

3.3. Changes in knowledge

Mean unadjusted scores by knowledge scale and time point are shown in Table 2 for all students (n = 119). The average overall food safety knowledge of students within schools is shown over time

Table 2
Mean food safety knowledge and attitudes of high school students (n = 119), before (T_1) and after (T_2, T_3) 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_1 to T_2		T_2 to T_3		T_1 to T_3	
	T_1	T_2	T_3	Diff.[a]	p-value	Diff.[a]	p-value	Diff.[a]	p-value
Overall knowledge score (out of 76)	37.3	43.1	40.9	**5.8**	**<0.001**	−2.2	0.070	**3.6**	**0.004**
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	**3.0**	**<0.001**	**−0.9**	**<0.001**	**2.1**	**0.026**
Foods that increase disease risk score (out of 27)	11.7	13.4	12.5	**1.8**	**<0.001**	−0.9	0.083	0.9	0.094
Interest in learning about how to avoid foodborne disease[b]	1.9	2.2	2.2	**0.3**	**0.006**	−0.02	0.877	**0.3**	**0.014**
Foodborne disease susceptibility[b]	2.3	2.2	2.2	−0.1	0.256	0.0	0.981	−0.1	0.294
Foodborne disease is a personal threat[b]	3.1	3.1	3.0	0.0	0.857	0.0	0.737	−0.1	0.609

[a] Difference between scores.
[b] Measured on a 5-point Likert scale (1-strongly agree, 5-strongly disagree).

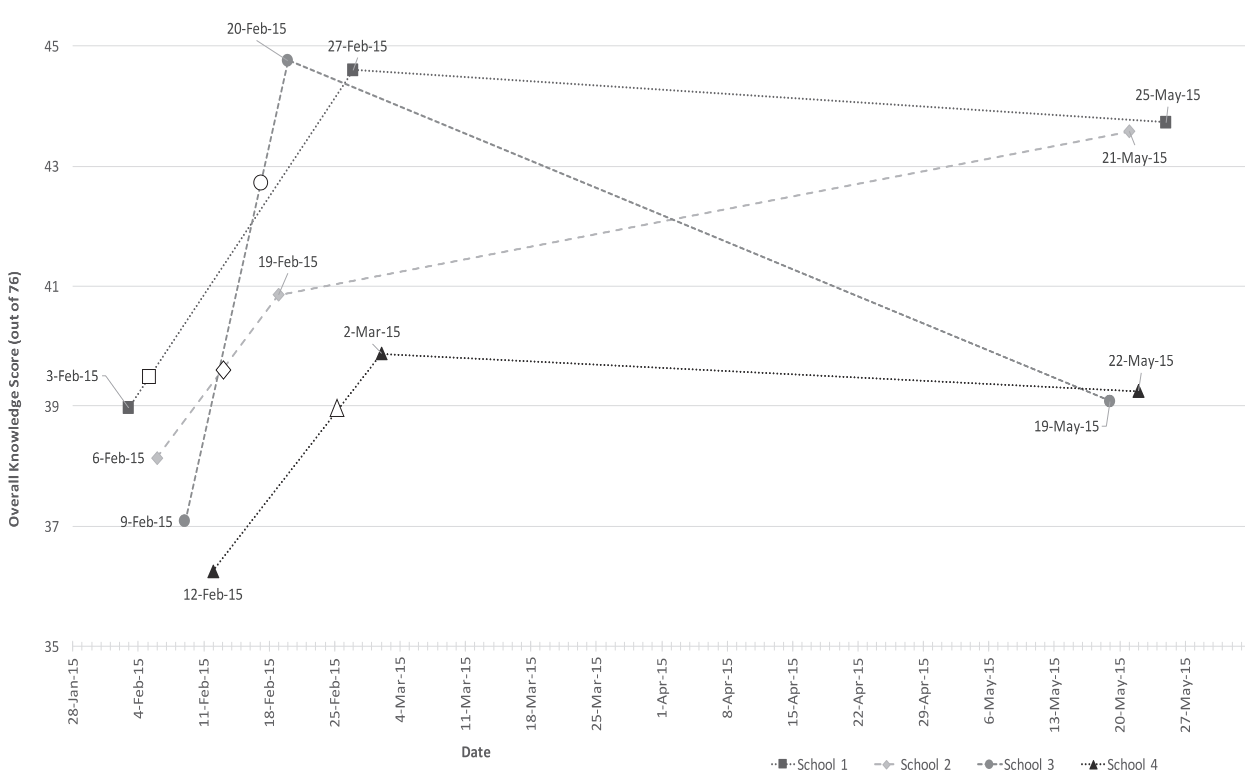

Fig. 1. Mean overall food safety knowledge scores (out of 76) for those high school students (n = 77) present at baseline and at the two time points after the intervention, by school and calendar date of data collection, in Ontario, Canada, February 2015; timing of the intervention is marked with a hollow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

(Fig. 1), for students present at all three time points ($n = 77$). When assessed at the student level, from T_1 to T_2, overall knowledge increased significantly, by 5.88 points out of 76, and then decreased significantly by 1.95 points from T_2 to T_3 (Table 3), for an overall increase from T_1 to T_3 of 3.93 points (SE: 0.83, $p < 0.0001$). Student characteristics were not significant predictors of overall knowledge (Table 3).

From T_1 to T_2, knowledge of safe times and temperatures increased significantly, by 2.96 points out of 14, and then decreased significantly by 0.84 points from T_2 to T_3 (Table 4), for an overall increase from T_1 to T_3 of 2.12 points (SE: 0.29, $p < 0.0001$). From T_1 to T_2, knowledge of foods that increase the risk of foodborne disease increased significantly, by 1.81 points out of 28, but was not significantly different between T_2 and T_3 (Table 5), for an overall increase from T_1 to T_3 of 0.98 points (SE: 0.41, $p = 0.0177$). Student characteristics were not significant predictors of knowledge of safe times and temperatures, nor foods that increase foodborne disease risk (Tables 4 and 5).

Knowledge of cross-contamination did not change after the intervention (regression results not shown) and was not different between T_1 and T_3 ($p = 0.3867$). Self-described cooking ability was the only fixed effect significantly associated with cross-contamination knowledge, such that for each level increase in students' self-described cooking ability, they were more knowledgeable about cross-contamination prevention and disinfection procedures (by 0.23 points out of 29; $p = 0.0206$), adjusting for all other factors in the model.

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_1-T_2) and at the end of the school term (T_2-T_3); p-values <0.05 are shown in bold.

Fixed Effects parameters		Co-efficient	SE	p-value
Intercept		52.84	10.60	<0.0001
Slope: $T_1 - T_2$		5.88	0.81	<0.0001
Slope: $T_2 - T_3$		−1.95	0.88	0.0278
School (1: referent)	2	−1.75	2.26	0.4422
	3	**−4.47**	**1.55**	**0.0047**
	4	**−5.09**	**1.95**	**0.0102**
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_1-T_2) and at the end of the school term (T_2-T_3); p-values <0.05 are shown in bold.

Fixed effects parameters		Co-efficient	SE	p-value
Intercept		5.52	3.40	0.1067
Slope: $T_1 - T_2$		2.96	0.26	<0.0001
Slope: $T_2 - T_3$		−0.84	0.29	0.004
School (1: referent)	2	−1.18	0.71	0.0997
	3	**−1.36**	**0.49**	**0.0062**
	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_1-T_2) and at the end of the school term (T_2-T_3); p-values<0.05 are shown in bold.

Fixed effects parameters		Co-efficient	SE	p-value
Intercept		20.20	4.75	<0.0001
Slope: $T_1 - T_2$		1.81	0.41	<0.0001
Slope: $T_2 - T_3$		−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

3.4. Changes in attitudes

Mean unadjusted scores by attitude scale and time point are shown in Table 2 for all students ($n = 119$). From T_1 to T_2, students' interest in learning about how to avoid foodborne disease declined significantly, by 0.26 points out of 5, but was not significantly different between T_2 and T_3 (Table 6), for an overall decrease in interest from T_1 to T_3 of 0.28 points (SE: 0.08, $p = 0.0004$). The average interest in learning about how to avoid foodborne disease of students within schools is shown by time (Fig. 2) for students present at all three time points ($n = 77$). Age and working or volunteering in a food service premises were both significantly associated with interest; for each year increase in age, students were significantly less interested in learning about how to avoid foodborne disease, and those who worked or volunteered in food

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_1-T_2) and at the end of the school term (T_2-T_3); p-values<0.05 are shown in bold.

Fixed effects parameters		Co-efficient	SE	p-value
Intercept		−0.53	0.99	0.5935
Slope: $T_1 - T_2$		0.26	0.07	0.0003
Slope: $T_2 - T_3$		0.02	0.08	0.8027
School (1: referent)	2	0.23	0.22	0.2961
	3	**0.33**	**0.15**	**0.0286**
	4	0.34	0.18	0.0646
Age (in years)		**0.15**	**0.06**	**0.0122**
Sex (female: referent)		0.00	0.12	0.9881
Works or volunteers at a food service premises		**−0.45**	**0.15**	**0.0106**
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

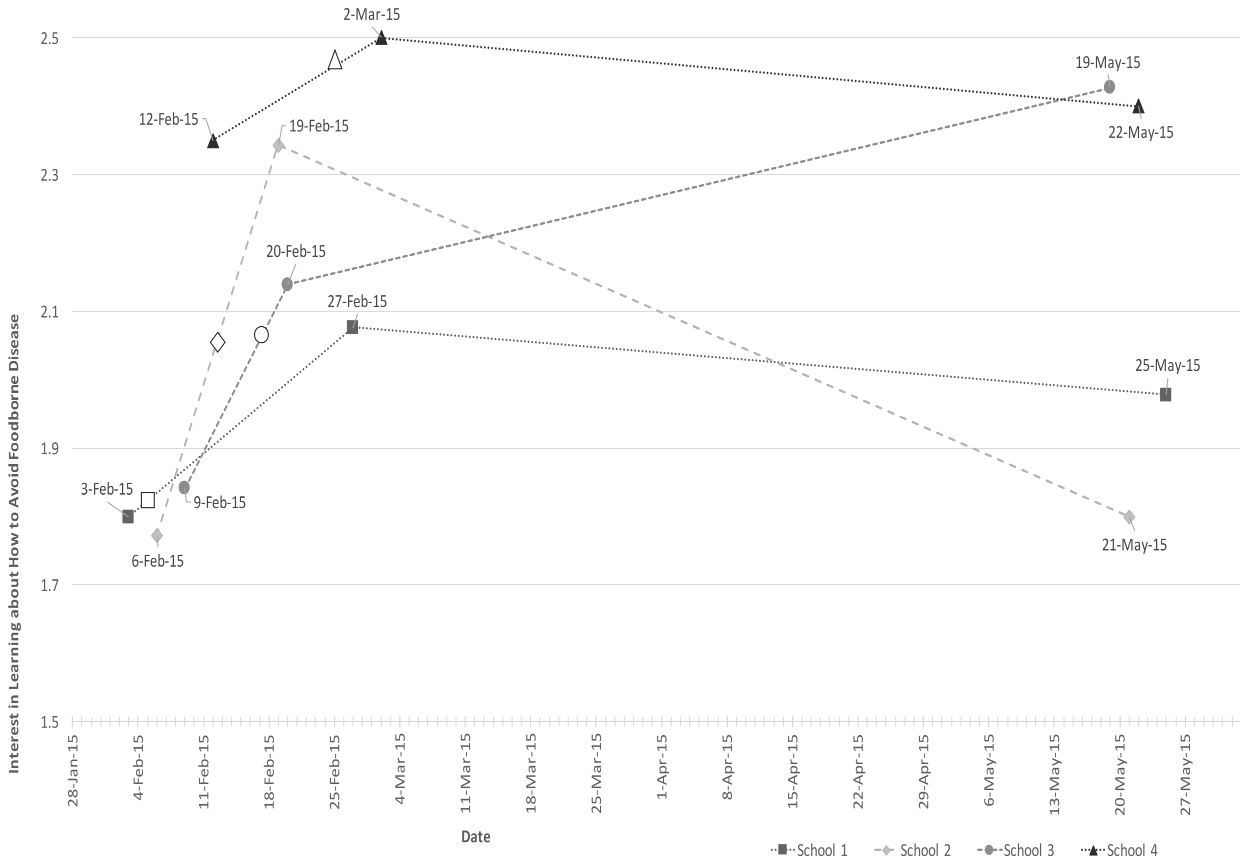

Fig. 2. Mean interest in learning about how to avoid foodborne disease (5-point Likert scale, 1-strongly agree to 5-strongly disagree) among those high school students ($n = 77$) present at baseline and at two time points after the intervention, by school and calendar date of data collection, in Ontario,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

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

Students' moderate belief about personal susceptibility to foodborne disease did not change after the intervention (regression results not shown) and was not different between T_1 and T_3 ($p = 0.4704$). Working or volunteering in a food service premises was the only fixed effect significantly associated with this belief, such that students who worked or volunteered in food service premises had slightly stronger beliefs of personal susceptibility (by 0.37 points out of 5; $p = 0.0491$) than those who did not, adjusting for all other factors in the model.

Students' neutrality to foodborne disease being a personal threat did not change after the intervention (regression results not shown) and was not different between T_1 and T_3 ($p = 0.9851$). Handling food for the public in a work or volunteer capacity was the only fixed effect significantly associated with this belief, such that students who handled food for the public had slightly stronger beliefs that foodborne disease is a personal threat (by 0.29 points out of 5; $p = 0.0386$) than those who did not, adjusting for all other factors in the model.

4. Discussion

We investigated high school students' food safety knowledge and attitudes before and after in-class delivery of an adapted version of the Ontario MOHLTCs standardized food handler training program. Before the intervention, students' knowledge was poor, students were interested in learning about how to avoid foodborne disease, and were neutral as to whether foodborne disease was a personal threat. As hypothesized, students' overall knowledge improved following program delivery, and although it attenuated over the school term, it still remained higher than baseline. Some knowledge aspects improved more than others, and at the end of the term only knowledge of safe times and temperatures remained higher than baseline. Reasons for such differential knowledge retention are unclear, as there is a paucity of literature on food safety knowledge retention over time, both overall and specific to particular knowledge elements. A 2013 study of food handlers from the Canadian province of British Columbia found a gradual but significant loss of knowledge over a 15 year time frame, with “much of the knowledge decline occur[ing] within a few months to a year after the initial training” (McIntyre, Vallaster, Wilcott, Henderson, & Kosatsky, 2013); however, because most of the knowledge questions used by McIntyre et al. pertained to safe times and temperatures (11/13, with 2/13 pertaining to cleaning practices), it is difficult to interpret our observed results in the context of their findings. Future studies examining retention of various aspects of food safety knowledge at multiple time points are needed, to uncover characteristics common to more- or less-easily retained information.

Contrary to our expectations, we observed that students' interest in learning about how to avoid foodborne disease declined following the intervention, and their beliefs about personal susceptibility to, and personal threat of, foodborne disease remained unchanged over the study. The decline in interest following education has not been previously reported, and may relate to the developmental stage of our high school study population; teens across cultures demonstrate increased novelty seeking (Johnson, Blum, & Geidd, 2009), and it may be possible that the observed decline in interest reflects that learning about food safety following education is no longer novel. Reasons for unchanged attitudes related to perceived susceptibility to, and personal threat from, foodborne disease are unclear. It is possible that changes in these attitudes occurred here, but were too nuanced to detect given our sample size. In comparison, a U.S. study that examined the impact of a food safety educational video game on attitudes among 1268 middle school students found that students felt more susceptible to foodborne illness following the game (Quick, Corda, Chamberlin, Schaffner, & Byrd-Bredbenner, 2013); whether this discrepancy in findings relates to differences in student ages (i.e., middle school versus high school), the interventions used, or other factors is unknown. It is also unknown whether working to influence these attitudes when targeting food safety education to high school students would prove effective in impacting actual food safety behaviours and foodborne disease risk.

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

Our findings from Ontario high school students are consistent with those from Chicago high school students, who also appear to have poor food safety knowledge (Burke & Dworkin, 2015). Our findings are also consistent with those from primary school children in China, where food safety education improved knowledge but did not change attitudes (Shen et al., 2015), and for middle school students in Korea and Italy (Kim et al., 2012; Losasso et al., 2014) and college students from the United States (Abbot et al., 2012; Stein et al., 2010; Yarrow et al., 2009), where knowledge was higher post-education. The overall knowledge attenuation observed here was expected and is consistent with findings from US college students (Yarrow et al., 2009), where knowledge attenuated five weeks post-education, remaining elevated only for health majors (who indicated that the education information was important for their future professions). Further understanding of factors associated with attenuation may help in framing food safety messages for maximum retention by groups with different interests.

Our survey comprised questions that had been used previously in other consumer food safety studies, predominantly in young adult populations. Although differences in study populations and time frames preclude precise comparisons of individual questions, it is worth noting that high school students in this study had generally as poor, or worse, knowledge than other, older student groups. For example, the percent of respondents correctly knowing the best way to clean kitchen counters ranges from roughly 1 in 4 students, as observed here and in two North American university undergraduate studies (Courtney, Majowicz, & Dubin, 2016; Green & Knechtges, 2015), to roughly 1 in 3 students at two universities in Jordan (Osaili, Obeidat, Abu Jamous, & Bawadi, 2011) and Greece (Lazou, Georgiadis, Pentieva, McKevitt, & Iossifidou, 2012), to over 3 in 4 students at a university in Lebanon (Hassan & Dimassi, 2014). Another example is that half our students knew that chilling or freezing does not eliminate harmful germs (data not shown), which is comparable to the students from Jordan (Osaili et al., 2011), but lower than the circa 60%–80% of university students from Canada, the United States, Lebanon, and Greece (Courtney et al., 2016; Green & Knechtges, 2015; Hassan & Dimassi, 2014; Lazou et al., 2012). Given the growing number of food safety knowledge surveys that use the same or very similar questions, future knowledge syntheses that rigorously summarize estimates across study populations would be a valuable contribution to the literature.

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

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

We observed that students' knowledge and attitudes were independently associated with school, in addition to time point, suggesting that there may be school characteristics that either inhibit or promote food safety. General food safety knowledge of the whole student body varied across our study schools (Majowicz et al., 2015), and the four Food and Nutrition classrooms in which this study was conducted had different physical set-ups (although all met the minimum provincial requirements for food service premises; Brown et al., 2016). How the variation by school observed here relates to underlying student differences, teacher influences, or characteristics of the school environments is unknown. Regardless, school appears to be an important factor related to food safety knowledge and attitudes, and warrants further consideration, particularly to inform the tailoring and targeting of both future food safety education and future intervention efforts.

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

5. Conclusions

This study provides evidence that food safety knowledge and attitudes among high school students are generally poor, and that in-class delivery of existing programs, like the Ontario MOHLTC's standardized food hander training program, may be a feasible mechanism for food safety educators to improve students' food safety knowledge, both overall and specific to safe times and temperatures, albeit likely in the short term. This study also raises several questions that bear further investigation, namely: whether food safety knowledge continues to decline beyond three months post-training, whether knowledge changes relate to changes in students' foodborne disease risk, why students' interest in learning about food safety might decline post-training, and whether this decline impacts students' retention of education messages. In addition, assessments that use observational data to investigate the impact that food safety education has on students' actual food safety behaviours are needed, to accurately determine how training and education may ultimately translate into reductions in foodborne disease risk.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.foodcont.2017.01.011.

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