

RESEARCH ARTICLE

Food Safety Education Needs of High-School Students: Leftovers, Lunches, and Microwaves

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ABSTRACT

BACKGROUND: We explored priority areas of food safety education needed by high-school students within Ontario, Canada.

METHODS: We analyzed transcripts from semistructured interviews with 20 experts in food safety, food safety education in youth, and high-school education in Ontario. Inductive thematic analysis was used to identify priority food safety education needs.

RESULTS: We identified 4 priority action areas for food safety education targeting students: how to safely do the things they typically do with food; how to keep themselves and their kitchens clean and safe; how microorganisms grow and how they can result in foodborne disease; and how to keep food out of the “danger zone” 4°C to 60°C (40°F to 140°F). The results indicate that students need specific education around the use of microwaves, consumption of convenience meals, preparing and handling foods at school events, and safe transportation of food for lunches, school trips, and sporting events.

CONCLUSIONS: High-school students need food safety education specific to their usual interactions with food, including the foods, tools, and settings students regularly encounter. Delivery of food safety education should emphasize sequences of safe food-handling behaviors for specific food interactions, such as reheating a meal in the microwave, rather than traditional food safety concepts, such as temperature abuse.

Keywords: public Health; food safety; adolescent; secondary schools.

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In Canada, 4 million cases of domestically acquired foodborne disease occur each year,¹ resulting in over 11,000 hospitalizations and 200 deaths.² A

significant proportion can be attributed to mistakes during food preparation, either at home or in commercial kitchens,^{3,4} emphasizing the importance

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of food safety education for consumers and food service workers. In Canada, spikes in foodborne disease cases among young adults have been reported for campylobacteriosis,⁵ and general gastrointestinal illness.⁶⁻⁹ The increase in foodborne disease in young adulthood, combined with youths' increasing food-handling responsibilities, suggests that high school may represent an important opportunity for food safety education to prevent future foodborne disease.

In Canada, the most common method of food safety education is food handler training predominantly targeted at commercial food handlers.^{10,11} Consumer-oriented education is less common, and includes messages at point-of-sale,¹² and government and nongovernment websites such as the Canadian Public Health Association, food safety in the home.¹³

Canadian consumers' food safety practices are generally lacking and include poor hygiene, poor prevention of cross contamination, inadequate temperature control of food, not using a thermometer to check cooking temperatures and consumption of risky foods.^{14,15} A recent study of Ontario high-school students found low safe food-handling knowledge, and poor self-reported behaviors around hand hygiene, food thermometer use, and temperature control of lunches and snacks outside of the home.¹⁶ Because high-school students in Ontario are increasingly responsible for food-handling and preparation within and outside the home, and are often employed or volunteer in environments where they regularly handle and prepare food for the public,¹⁶ it is important that this demographic receives good food safety education. Although food safety is included within Food and Nutrition courses in the current Ontario high-school curriculum,¹⁷ these elective courses do not reach all students and are often geared toward students with career interests in the commercial realm. The overall goal of this study was to generate data to provide evidence-based guidance for the development of high-school student food safety education. The specific objective of this study was to explore food safety and youth educators' perceptions of priority content areas of food safety education for high-school students, hereafter referred to as "students," within the Ontario, Canada context.

METHODS

A series of 19 in-depth, semistructured, interviews were conducted between May and June 2014, with 20 experts in food safety in Ontario, food safety education in youth, and high-school education in Ontario (2 people from one organization requested that they do an interview together). Individuals with these backgrounds were considered "information rich cases" as they deliver food safety education to youth either through food and nutrition courses in high school

or via workplace food safety education programs. Participants were identified from the peer-reviewed literature, from education, food safety, and public health organizations, and using snowball sampling. Participants were educators (high school, college, or private industry), food safety experts (researcher, food, food safety and nutrition policy, or home economist) or public health professionals (certified Public Health Inspectors, public health managers, public health specialists, or health promoter), all with at least 10 years' experience in their identified areas of expertise. Sampling continued until data saturation, that is, until no new ideas or information emerged from the interviews.¹⁸ Interviews took approximately 45 minutes each.

These audio-recorded telephone interviews were transcribed verbatim to explore nuanced food safety needs among students and priority content areas for education. Questions pertaining to the present study's objectives included: of all the things high-school students could be taught about food safety, what are the key things they need to learn? and what do you think should be offered in high-school curriculum? Prior to the interview, participants were given the Ontario Ministry of Health and Long-Term Care's (MOHLTC) food safety training manual,¹⁹ as a guide to stimulate discussion about student-oriented food safety education needs. At the start of the interview, participants provided verbal informed consent, and participant confidentiality was maintained in the final anonymized transcripts using coding such as [P3, P15] instead of names.

To identify and interpret concepts related to priority content areas for student-oriented food safety education, inductive thematic analysis²⁰ was used to analyze the transcripts. Analysis was facilitated by qualitative research software ATLAS.ti, version 7.5.6 (Cincom Systems, Inc. Berlin, Germany, © 2015). Codes were iteratively derived using the process outlined by Fereday & Muir-Cochrane,²¹ as follows. Three researchers independently reviewed 5 transcripts, purposively selected to capture a breadth of interview content, and separately developed preliminary codes. These transcripts and preliminary codes were discussed among the 3 researchers, and final codes decided. These were then collated into a codebook, containing codes, working definitions, and explanatory quotes. The codebook was revised until it accurately captured the content of the 5 selected interviews. Codes were then grouped under researcher-identified food safety themes. The codebook was then used to code all transcripts (including the 5 used to develop the preliminary codes), and was refined as needed, resulting in a final codebook that contained the most important areas to cover when teaching food safety to high-school students. Additional details on study methods are reported elsewhere.²²

Table 1. Codes and Exemplar Quotes Underpinning the Theme, “students need to be taught how to safely do the things they typically do with food”, Derived from Key Informant Interviews of 20 Food Safety and Youth Education Experts (May - June, 2014)

| Code | Code Description | Primary Example of Code used |
|----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| How to pack a safe lunch and travel with food? | Use an ice pack in your lunch bag to keep foods cold, and select foods that are safe to travel (ie, can be in the danger zone for longer periods). | “Well, a lot of them carry lunch bags, right, so having lunches and the importance of keeping it cold and they never really thought about and the types of foods they would put in . . . that is part of the food safety discussion.” [P18] |
| How to deal with leftovers? | Do not leave foods out overnight (eg, pizza), refrigerate leftovers within 2 hours, and reheat leftovers to 74°C before eating. | “The other thing, too, is definitely refrigerating those leftovers, because in the homes that we visited, and the kids that we talked to, you know food gets left out on the counter overnight and they just have it for breakfast in the morning, and that is not such a good idea, but they do.” [P14] |
| What to do at school fund raisers and for parties? | Be aware of and follow safe food-handling practices - particularly, around under-cooked foods, cross contamination, temperature abuse, and sharing of foods (ie, transfer of saliva)—at charity events (eg, bar-b-ques, bake sales, pizza sales) and during other youth social gatherings (eg, dances, parties). | “And, we had an incident . . . groups were fund-raising and they were selling hamburgers, and one of the teachers just happened to take a look at the hamburgers, and they were quite pink inside, which raised the whole issue, okay, so what about when kids are doing fund raisers, be it hamburgers, hot dogs, pizza? Those kinds of things.” [P16] |
| How to use a microwave for food preparation? | Understand when and how to safely use the microwave to thaw, reheat, and cook foods, as well as safety considerations when using the microwave to avoid injury (eg, letting foods cool down, not testing heat with finger). | “So I would think having a microwave and microwave safety—what is thawing and heating and reheating foods in the microwave, what does it mean, what is cooking in the microwave.” [P15] |

RESULTS

Participants discussed 4 priority areas in which high-school students need food safety education, specifically that they need to be taught: how to safely do the things they typically do with food (Table 1); how to keep themselves and their kitchens clean and safe (Table 2); about microorganisms and how they can result in foodborne disease (Table 3); and 4 specific things to do to keep food out of the “danger zone” (Table 4). These concepts and several other noteworthy findings are further described below. We did not identify significant differences in the priority content areas between the different expert perspectives (eg, public health and education). Overall, participants agreed; any points of dissentation are noted below.

Students need to be taught how to safely do the things they typically do with food. Participants discussed specific food interactions that were common to high-school students, such as traveling with food for school trips or sporting events, school fundraisers, or that students were potentially exposed to more frequently than other food handlers, such as using a microwave to cook or reheat food (Table 1). For example, participants identified that students need to be taught how to safely handle foods outside of the home, particularly, how to pack and store a safe lunch, and how to prepare and handle food safely during school events, such as bake sales, fundraisers, or sporting events. One expert stated,

I have a really close friend who works a lot with sports teams and one of the big problems that these kids have is buying food ahead of time to eat on the bus, to get to where they are going, and it is not refrigerated, and they're

buying . . . cold cuts and that kind of thing. So there is a real opportunity there for kids to see a big improvement, I think, in their ability to keep themselves safe when it comes to those kinds of foods [P14].

Participants also noted the need to teach students how to properly use a microwave to cook and reheat food, the importance of avoiding sharing food and drink, and how to prevent contamination with allergens, because “allergens would probably be of interest to that group as well . . . probably as one of the top items, because . . . in their class there is probably somebody has an allergy” [P15].

Students need to be taught how to keep themselves and their kitchen spaces clean and safe. Participants identified that students need to be taught how to keep themselves and their food preparation areas clean and safe, and conceptualized ‘safety’ as preventing both injuries and foodborne disease (Table 2). Teaching personal hygiene, including why and how to wash hands properly, and why and how to keep the things food can touch, such as counters and utensils, clean, were identified as key for foodborne disease prevention.

I would say that personal hygiene would be on the top 5 list for sure, for this group, especially around hand washing and understanding the importance of disease transmission through hands [P6].

Teaching knife safety, and how to prevent slips, falls, and burns were also identified as key in teaching students how to prevent food related injuries (eg, “. . .burning themselves, when they heat in the microwave. Heating up a [microwavable pizza

Table 2. Codes and Exemplar Quotes Underpinning the Theme, “students need to be taught how to keep themselves and their kitchens clean and safe,” Derived from Key Informant Interviews of 20 Food Safety and Youth Education Experts (May - June, 2014)

| Code | Code Description | Primary Example of Code used |
|-------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Why and how to wash hands properly? | Students need to know the importance of handwashing and specifically when and how to properly wash their hands using soap and water. | “They have to wash their hands many times, before, during, and after . . . and not just run them under the water, they need to use soap, they need to spend that time washing their hands.” [P18] |
| Use good personal hygiene to prevent contamination | Students need good personal hygiene habits—beyond hand washing—to help protect food from contamination and keep the food handler clean and safe (eg, wearing clean clothing, coughing into their sleeves, and not smoking while preparing food). | “Like, why they should have clean clothing. Why they should not be eating or smoking in their food area.” [P18] |
| Why and how to keep the things your food could touch clean? | Students need to know the importance of keeping kitchen areas clean and organized, and specifically how to properly clean utensils (knives, mixing bowls, plates, etc.), equipment (ovens, mixers), and surfaces (cutting boards, counters, and floors). | “You know, if you can somehow drill that in about cleaning the counters, before and after food preparation, minimizing the clutter off the counter that can become contaminated with, heaven knows what . . . I just think about the kinds of things that we saw in these kitchens, . . . gerbil cages . . . on top of the refrigerator, and near the food preparation areas.” [P14] |
| How to prevent injury? | Students need to know how to work safely around food and in a kitchen to prevent injury, including: prevention of burns from hot food; organization, and storage of utensils (eg, knives); proper cleaning and use of equipment (eg, mix master); and prevention of slips, trips, and falls (eg, mopping spills immediately). | “The ‘kitchen safety’ would deal with accidents . . . and the prevention of accidents and using equipment properly, knives as an example.” [P16] |

sandwich] and then biting into it and burning themselves” [P15]).

Students need to be taught about microorganisms and how they can result in foodborne disease. Participants stressed that students need to be taught about microorganisms, including which ones cause disease, ideal microbial growth conditions in foods, how microorganisms can contaminate the food, what happens when you get a foodborne disease, and what you should do as a sick food handler (Table 3).

I really think we need to emphasize how serious the outcomes from foodborne illness can be, and get it beyond the ‘it’s a day or 2 of diarrhea’, which is frequently true, but tragically not always true [P7].

One participant highlighted the importance of understanding microbiology in order to understand other food safety measures, “help[ing] them understand basic microbiology [is] key, because then you can transfer it to all those other intervention steps, if you understand microbiology, you’ll understand hand washing, cross-contamination, temperature; so, that’s critical” [P4]. Participants stressed the importance of understanding how foods become contaminated, and how to prevent contamination of food, particularly when grocery shopping and storing food in the refrigerator.

What do you put on top, in the middle, and then on the bottom [grocery carts and bags]? Stacking of things, but also bringing stuff home from the grocery store [P8].

Don’t put the dripping (raw) hamburger above the vegetables in the fridge, just because it’s a flat surface that can hold more . . . [P7].

Students need to be taught 4 specific things to do to keep food out of the “danger zone”. Participants identified 4 specific actions that students need to learn to keep potentially hazardous foods out of the “danger zone” of 4°C to 60°C (40°F to 140°F), namely (1) not leaving food at room temperature, (2) not thawing foods on the counter, (3) properly reheating leftovers, and (4) using a food thermometer (Table 4). In essence, students need to learn how to keep hot foods hot and cold foods cold to prevent the growth and survival of potentially hazardous microorganisms. Paramount among these actions was using a food thermometer to determine when food is properly cooked or reheated: “it’s important that all Canadians . . . know how to use a food thermometer, and that it becomes a, as much a part of their life as a toothbrush” [P5]. Participants also discussed the need for students to learn about the “danger zone” in school, because they may not be learning about it at home or elsewhere: “I’m not sure that kids do have a clear understanding of . . . the ‘danger zone’ . . . and how perishable food [is], like cooked foods and so on . . . because when do they have that exposure otherwise?” [P16]. Additionally, students may be learning poor food-handling habits at home, increasing their risk of foodborne disease, for example: “. . . like thawing food, you know on the counter, taking it out in the morning, practices that their parents have done . . .” [P18].

Table 3. Codes and Exemplar Quotes under the Theme, “students need to be taught about microorganisms and how they can result in foodborne disease”, Derived from Key Informant Interviews of 20 Food Safety and Youth Education Experts (May - June, 2014)

| Code | Code Description | Primary Example of Code used |
|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Basic microbiology: what are pathogens, how do they grow, and how do they spread? | Students need a general understanding of microbiology; they need to know what a “pathogen” is and understand how they replicate, multiply and can contaminate their foods. This general understanding of microbiology provides the context for safe food-handling practices (cooking, cleaning, hand washing, etc.). | “They need to know how these types of pathogens, well first, what is a pathogen, and then, second, how do they grow, how do they reproduce, how are they spread?” [P2] |
| What foods can make me sick and how do I avoid getting sick? | Students want to know what foods can make them sick (ie, potentially hazardous foods), and what safe food-handling practices they can use to avoid getting sick from the foods they eat. | “So they really wanted to know what foods would make them sick, and/or could make them sick” [P14], and, “How to, “make sure that they do not get sick.” [P16] |
| Who is susceptible to foodborne disease, and what are consequences? | Students need to understand and care about the potential impacts of foodborne illnesses, why different people are more or less susceptible to illness (eg, dose, immune status, immunization, past exposure, general health status), and that they are at risk of foodborne illnesses. | “I really think we, we need to emphasize how serious the outcomes from foodborne illness can be and get it beyond the ‘it’s a day or 2 of diarrhea’ . . . which is frequently true, but tragically not always true.” [P7] |
| How can I prevent the spread of pathogens and allergens? | Students need to learn how to control the spread of pathogens and allergens by first identifying opportunities for contamination (eg, move from food, hands, utensils, and surfaces to food), and then using safe food-handling practices to stop the spread (eg, handwashing, washing fruits and vegetables, storing raw meats separate from ready-to-eat foods). | “Demonstrate the use of safe food handling practices required to prevent cross contamination by pathogens, parasites and allergens.” [P16] |
| What should I do as a sick food handler? | Students working in the food industry need to understand not to handle food when they are sick (diarrhea or vomiting), to report their illness to their employer, stay off work until fully healthy, and where they can go for information and help (eg, doctor, public health). | “The whole idea of not passing on germs, because you know, there is this stigma about calling in sick, and there is a lot of pressure from managers about . . . “you need to be here”, but the bottom line is, people who are sick should not be working in food services.” [P12] |

Experts also indicated that students often are seeking answers for “how long” foods can stay in the fridge, freezer, cupboard, and even on the counter before they have to be eaten, moved, or thrown away, for example: “[h]ow long is something good in the fridge?” [P2]. Of particular concern was proper cooling of foods and the handling of leftovers. For example:

...they need to put their pizza in the fridge. And the leftovers in the fridge. Don't leave them out all night [P9].

Participants also identified the need for students to understand cooking instructions, to use caution when using a microwave to cook foods, and to monitor cooking temperatures with a probe thermometer:

My daughter cooked a chicken-based, frozen dinner, and didn't cook it properly, and I'm pretty sure she had Salmonella poisoning, so, I think things like proper cooking, following instructions, and maybe not using microwaves for certain types of, you know, for proper cooking of food, and also the use of thermometers is important to make sure that you know the food's been cooked to a proper temperature [P11].

Priority Food Safety Messages for Students

Several participants volunteered their top-priority student-oriented food safety messages, including:

Wash your hands, wash your hands, wash your hands [P2];

I'm thinking cross-contamination being, I think, probably one of the bigger ones [P3].

...in order I would say, hand washing for teenagers, bacteria growth, or microbial growth second, and then third cooking and cooling temperatures, and then food storage [P7].

In aggregate, the top 5 food safety education messages needed by high-school students ranked as: (1) wash your hands; (2) avoid cross contaminating your food; (3) avoid “temperature abuse of foods” (where temperature abuse is term used by food safety experts to describe improper cold holding, cooking, and hot holding foods that permit the spread and growth of pathogens in food) and focus on reheating, handling leftovers, lunches, and snacks); (4) keep yourself and food preparation areas clean; and (5) understand how microbes can make you sick.

Table 4. Codes and Exemplar Quotes under the Theme, “students need to be taught 4 key things to do to keep food out of the ‘danger zone,’” Derived from Key Informant Interviews of 20 Food Safety and Youth Education Experts (May - June, 2014)

| Code | Code Description | Primary Example of Code used |
|-------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Do not leave cooked or perishable foods at room temperature? | Cooked foods that are not going to be eaten right away (eg, leftovers) and perishable foods (eg, cheese and yogurt) need to be put in the refrigerator as quickly as possible to keep them safe. | “Understanding that perishable food needs to be refrigerated, within a certain short time frame . . .” [P5] |
| Do not thaw food on the counter? | Do not thaw potentially hazardous foods (ie, foods that microorganisms can grow in), such as roasts and chicken, on the counter or in the sink; thaw them in the refrigerator instead. | “Thawing seems to be, and I think it’s because we have all, kind of, learned from our grandmothers, and then they teach their parents and they have learned the same bad habits, but, thawing things seems to always be an ‘ah-ha’ moment, when they realize, ‘oh, you mean, I cannot take the steak out or the chicken and leave it on the counter when I go to school, and cook it at home later?’” [P2] |
| Properly reheat food before eating | Students need to know which foods needed to be reheated and the difference between reheating to make food safe (temperature above 74°C) and warming food up so it tastes better. | “Understanding ‘does the product need to be reheated?’, ‘does it need to be cooked?’” [P11] “I think that’s the reheating, that people forget about the importance of reheating to 74 [degrees Celsius], right?” [P9] |
| Use a probe thermometer to determine when food is properly cooked or reheated | Use a food thermometer—the only method to check that food is actually cooked—to verify foods are properly cooked or reheated. Get an accurate temperature by placing the thermometer into either the thickest part of the meat, or the middle of the food (eg, soup, chili), and avoid touching anything else (eg, the cooking surface, equipment, or bones in meat). | “It’s really important that all Canadians, including high school students . . . when they start to cook, know how to use a food thermometer, and that it becomes a, as much a part of their life as a toothbrush” [P5]. |

Low-Priority Food Safety Topics for Students

In addition to identifying the most major areas students need to be taught, participants also identified several topics within the provided MOHLTC manual that they felt were not necessary for student-oriented food safety education, specifically pest control, receiving and storage of food within commercial settings, hazard analysis and critical control points, and food safety legislation.

DISCUSSION

Participants noted that students need to be taught safe food-handling behaviors specific to students’ common food-handling experiences, including reliance on microwaves for reheating and cooking, consumption of convenience meals, fund raisers and social gatherings, storage and transportation of food for lunches, school trips and sporting events, and preventing food allergen exposure and contamination.

The focus on how to handle food safely during specific food interactions, versus a focus on learning food safety concepts, such as cross contamination, time and temperature abuse, is a nuanced but important distinction separating our findings from traditional food safety education formats,^{11,23} which focus on increasing food safety knowledge under the assumption that improved knowledge will lead to improved behaviors.²⁴ Here, emphasis on imparting knowledge was limited to why personal hygiene is important, and understanding basic microbiology, particularly

how pathogens grow and spread, with the idea that such knowledge will help students understand the importance of hand washing, avoiding cross contamination, and temperature control of food. Our experts emphasized that food safety education should prioritize teaching students appropriate sequences of actions and decisions within specific food interactions they commonly encounter, including packing a safe lunch, properly washing hands, and using a food thermometer, and what to do as a sick food handler. Being explicit about sequences of safe food-handling behaviors has been previously noted by Levine et al²⁵ who examined recipes for the presence of safe food-handling directions and found that the majority failed to include these steps, particularly around the use of food thermometers, appropriate cooking temperatures, and avoiding washing raw meats. How recipe modification and other mechanisms can support behavior change and the development of safe habits bears further investigation. Nevertheless, engaging students in age-specific food safety activities and experiences should reinforce these behaviors and highlight the importance of food safety in their daily lives.²⁶

As expected, the education needs identified by our participants align with Ontario’s Social Sciences and Humanities grade 9 to 12 curriculum,¹⁷ where safe food-handling is explicit in elective Food and Nutrition courses; indeed, food and nutrition courses have been identified as key mechanisms to teaching these skills to students.^{27,28} However, opportunities

to teach and enforce safe food-handling behaviors exist any time that food, food preparation, healthy eating, or microorganisms are discussed across the high-school curriculum, and many of the education needs identified here fit within curriculum beyond elective foods courses. For example, food and foodborne pathogens can be used to explain chemical and biological processes to meet Ontario's Science curriculum objectives, such as the current grade 10 applied chemistry curriculum question, "what types of chemical reactions do chefs need to be aware of when they process or store food?"²⁹ Additional microbiological principles, including which organisms cause disease, microbial growth factors, how microbes contaminate food, and the potential severity of diseases, align with the biological sciences curriculum, as does food allergen information.

Other opportunities to embed food safety education within high schools, as discussed by our participants, included addressing student needs around extra-curricular activities such as sports teams, fundraisers, and student events. Students regularly participate in such activities, which require them to transport food for significant amounts of time, or prepare or distribute food to others, presenting a food safety risk. Therefore, these events offer opportunities for intervention, for example, providing school teams, coaches, and student athletes with coolers, cooler bags, ice packs, and directions for packing and transporting food safely. These extra-curricular avenues for potential intervention and education have not been previously identified, and may offer new mechanisms for supporting food safety education in high schools.

Many food safety education materials targeting commercial^{10,11,19} and consumer¹³ food handlers exist, and certain content areas and behaviors are consistent across materials, namely, practice good personal hygiene, particularly hand washing; keep foods at safe temperatures; ensure foods are cooked or reheated to proper temperatures; separate raw and ready-to-eat foods; and ensure cooking spaces, utensils, and equipment are clean. These concepts, particularly the emphasis on how to handle and prepare foods safely, align with the student-oriented food safety themes identified in our study, suggesting existing resources, may be useful references for schools, with 4 important additions.

First, the knife safety and burn prevention needs identified by our participants are not routinely contained in food safety education material, and for students with limited food-handling experience, explicitly adding such skills to food safety education is needed. Second, participants indicated students want to know how to safely store foods and for how long, particularly leftovers. Storage and use of leftovers has implications beyond food safety; in a study of undergraduate students at a Canadian

university, the majority thought leftovers need to be thrown out after 1-2 days (versus the recommended 3-4 days),³⁰ potentially contributing to food waste and security issues. Third, the use of microwaves as an important target for food safety education for high-school students as identified here is a concept that is not explicit in most food handler training materials. For example, within the MOHLTC material,¹⁹ safe microwave use is restricted to the thawing of small amounts of food. However, because microwaves are a convenient, easy method to prepare a large variety of foods, being able to use a microwave safely (eg, following directions, warming versus cooking foods) is an important domestic skill for students to acquire, particularly given that this is an age group that appears to reheat foods using microwaves at least multiple times a week.³¹ Finally, students need specific education on safe preparation and consumption of "convenience meals," which are perceived to have few or no preparation steps. Our participants indicated that students handle, prepare, and eat a large amount of "convenience meals," at home and away. Consumption of convenience meals, combined with students' low food safety knowledge, poor food-handling behaviors, and risky food-handling habits, puts them at increased risk for foodborne disease if these products are prepared incorrectly.¹⁶ There is a need to balance teaching kids to cook full meals from scratch - to develop life-long food safety habits,²⁷ and improve healthy eating²⁸ - with a "harm reduction" approach of teaching students how make less healthy foods such as convenience meals in safe ways.

Limitations

This study is subject to several limitations. Most importantly, we used expert perspectives to determine the food safety education needs of students, and did not include student or parent views, which may be different than those reported here. Future studies should seek to determine student and parent perspectives, particularly as such views may overlap or contrast with expert perspectives. Nevertheless, these findings from youth and food safety education perspectives suggest important ways that current food safety education efforts can be reframed or revised, to target food safety education to meet the needs of high-school students.

Conclusions

High-school students have food safety education needs that centered on needing to be taught how to safely do the things they typically do with food, as well as some basic knowledge of microbiology and the importance of personal hygiene. Subsumed within this, students need to be taught to practice good personal hygiene, keep foods at safe temperatures, use a food thermometer, separate raw and ready-to-eat

foods, and ensure cooking spaces, utensils, and equipment are clean. Food safety education should focus on students' own current food-handling experiences, including: the use of microwaves for reheating and cooking; consumption of convenience meals; school events; transportation of food for lunches, school trips and sporting events; and food allergen awareness. Our results suggest that education should focus on sequences of safe food-handling behaviors relevant within specific student food interactions, such as packing a lunch, or microwaving or reheating a convenience meal, rather than traditional food safety concepts, such as cross contamination, time and temperature abuse.

IMPLICATIONS FOR SCHOOL HEALTH

In addition to the curricular and extra-curricular mechanisms identified above, there are numerous opportunities and resources for schools that can enhance students' safe food-handling behaviors and potentially reduce the burden of foodborne disease, with little-to-no budgetary impacts. Specifically, schools can use existing food safety resources including the MOHLTC's food handler guide¹⁹ and the US Food and Drug Administration's supplementary curriculum for high-school classrooms³² to deliver food safety education where needed. Furthermore, high-school food and nutrition teachers can connect with local, state, or provincial public health professionals to get update to material, pamphlets, secure guest speakers, and obtain practical real-world examples of food safety risks and scenarios. For example, in Ontario, York Region Public Health provides food safety resources for schools, including food handler certification workshops, speakers, pamphlets, and recommended websites.³³ Purposely, teachers can enhance food safety education for high-school students by:

- Connecting with public health, such as York Region Public Health,³³ and other food safety experts, such as the Partnership for Food Safety Education,³⁴ who can provide existing food safety education materials to support classroom curriculum, help maintain and enhance high-school teachers' food safety knowledge, and provide on-site instructional supports.²⁶
- Modifying existing food safety education material, akin to that of MOHLTC¹⁹, to address high-school students' education needs by omitting commercially oriented content, such as shipping and receiving, and adding student-specific messages including food allergen awareness, proper use of microwaves for reheating and cooking, safe consumption of convenience meals, and safe transportation of food for lunches, school trips and sporting events.

- Using existing school kitchens for teaching so students can practice safe food-handling; given that, in Ontario, the physical set up of school teaching kitchen classrooms supports safe food-handling with food and nutrition courses.³⁵
- Advocating for student refrigeration units or other methods, such as coolers and ice packs, to allow students to store lunches and leftovers at safe temperatures.
- Reinforcing safe food-handling practices such as hand washing, safe food temperature control, and preventing cross contamination of foods with pathogens and allergens during school events, including sporting events, bake sales, and parties.
- Using foodborne pathogens to teach cellular biology and biological and chemical pathways in science courses.
- Incorporating safe food-handling practices, including how to pack a safe lunch, how to reheat foods properly, and embedding safe food-handling steps in all recipes, into health and physical education classes, supporting existing healthy eating and food insecurity learning objectives.²⁴
- Linking safe food-handling actions to existing school policies, particularly school allergy policies, by explaining the importance of avoiding cross contamination by discussing the potential spread of a food allergen in a classroom.

Human Subjects Approval Statement

The study was approved through a University of Waterloo Research Ethics Committee.

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