Analyses of the Contributing Factors Associated With Foodborne Outbreaks in School Settings (2000–2010)

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Abstract **State-reported school foodborne outbreaks account for about 3.8% (*n* = 464) of all outbreaks and 8.2% (*n* = 20,667) of all illnesses reported to the Centers for Disease Control and Prevention's Foodborne Disease Outbreak Surveillance System. Of 464 school foodborne outbreaks, 122 (26%) outbreaks, 7,603 illnesses, and 301 reported food safety errors met the criteria for inclusion in the analyses. The purpose of the authors' study was to examine the role of contributing factors in school foodborne outbreaks. Contamination factors accounted for the greatest proportion (49.2%) of outbreaks involving some level of food handling interaction by a school food service worker, followed by proliferation (34.9%) and survival factors (15.9%). Over 56% of all illnesses were associated with norovirus and food service worker practices. The results of these analyses highlight the importance of effective food safety education programs that focus on the role of contributing factors and prevention of foodborne disease from food safety errors.**

Introduction

Contributing Factors and Foodborne Disease

The health burden posed by foodborne disease is significant. The Centers for Disease Control and Prevention (CDC) estimate that viral, bacterial, and parasitic foodborne disease strikes about 48 million individuals resulting in 128,000 hospitalizations and 3,000 deaths on an annual basis (Painter et al., 2013; Scallan et al., 2011). Foodborne disease surveillance reports highlight the significant health burden particularly among children, who are one of the most vulnerable segments of the population to the effects of foodborne disease (Centers for Disease Control and Prevention [CDC], 2012a; McCabe-Sellers & Beatte, 2004).

According to foodborne surveillance data, contributing factors play a significant role in foodborne disease in school settings (Daniels et al., 2002). Contributing factors are defined as "food safety practices and behaviors that most likely contributed to a foodborne illness outbreak (Bryan, Guzewich, & Todd, 1997)." Contributing factors associated with foodborne outbreaks fall into three broad categories with associated subcategories of food safety errors:

- contamination (C1 to C15), i.e., food safety practices that contribute to the introduction of pathogens into food (e.g., bare-hand or gloved-hand contact with food by an infected food worker);
- proliferation (P1 to P12), i.e., improper food preparation practices that allow pathogens to proliferate while food is being prepared (e.g., improper temperature control during hot or cold holding); and
- survival (S1 to S5), i.e., failure of processes intended to eliminate or inhibit the survival of a microbial contaminant (e.g., insufficient time/temperature control during cooking, reheating, or freezing) (CDC, 2012b, 2013a; Gould, Walsh et al., 2013).

Contributing factors are typically identified during the environmental health assessment phase of a foodborne outbreak investigation, which is initiated at the start of an outbreak investigation (Todd, Guzewich, & Bryan, 1997). Identification of contributing factors can be both challenging and complex. The value of an environmental health assessment relies heavily on the quality, completeness, and accuracy of epidemiological information from the outbreak investigation (CDC, 2012c; Council to Improve Foodborne Outbreak Response [CIFOR], 2009). Environmental health assessments are not conducted for all outbreaks, however, which is one major obstacle in identification of contributing factors.

The U.S. Department of Agriculture Food and Nutrition Service administers the National School Lunch Program (NSLP) and the School

TABLE **1**

Contamination Contributing Factors

Contributing Factor	Food Safety Errors # (%)
C12: Other mode of contamination (excluding cross contamination) by food handler/worker/preparer who is suspected to be infectious	62 (41.9)
C6: Contaminated raw product—food was intended to be consumed after a kill step	19 (12.8)
C10: Bare-hand contact by a food handler/worker/preparer who is suspected to be infectious	16 (10.8)
C11: Glove-hand contact by food handler/worker/preparer who is suspected to be infectious	14 (9.5)
C13: Foods contaminated by non-food handler/worker/preparer who is suspected to be infectious	11 (7.4)
C15: Other source of contamination	9 (6.1)
C7: Contaminated raw product—food was intended to be consumed raw or undercooked/underprocessed	5 (3.4)
C9: Cross contamination of ingredients (not involving ill food workers)	5 (3.4)
C14: Storage in contaminated environment	3 (2.0)
C3: Poisonous substance accidentally/incidentally added	2 (1.4)
C5: Toxic container	1 (0.7)
C8: Foods originating from sources shown to be contaminated or polluted (such as growing field or harvest area)	1 (0.7)
Total food safety errors	148 (100)

Breakfast Program (SBP) through state education, health, or agriculture agencies. As of fiscal year 2012, the NLSP and the SBP served over 101,000 (93%) schools throughout the U.S. with 32 million lunches and 12 million breakfasts daily (U.S. Department of Agriculture Food and Nutrition Service, 2013). The potential for foodborne outbreaks to occur in a closed setting such as schools and to affect a large segment of the school-aged population is significant (Daniels et al., 2002). Based on this potential, preventing foodborne disease is a major goal. The purpose of our study was to examine the role of contributing factors and the spread of foodborne disease in school foodborne outbreaks.

Methods

Data Sources and Analyses

State-reported outbreak surveillance data from the CDC's Foodborne Disease Outbreak Surveillance System spanning 2000 through 2010 (CDC, 2013b) were used in the analyses. Criteria for inclusion in the analyses were restricted to foodborne outbreaks of confirmed etiologic agent(s), reported contributing factor(s), implicated food(s) if reported, and school-associated outbreak (i.e., food either eaten or prepared in any type of school setting was defined as school associated). Food safety errors were grouped into specific categories based on similarity and genus, species, and serotypes were merged into pathogenic and nonpathogenic groups. Food safety errors and pathogenic groups associated with the largest number of illnesses per outbreak and implicated food(s) were further analyzed. Reported contributing factor(s) associated with food safety error was the unit of analysis. Descriptive statistics were calculated and analyzed using STATA v. 10.0 and Microsoft Office Excel 2007.

Results

Contributing Factors Associated With Foodborne Outbreaks

State-reported foodborne outbreaks in school settings accounted for 3.8% (n = 464) of all outbreaks and for 8.2% (n = 20,667) of all foodborne illnesses when compared to all other settings. Laboratory-confirmed foodborne outbreaks in school settings accounted for 45.3% (n = 210) of all outbreaks and for 56.6% (n = 11,698) of all illnesses when compared to other settings. Of 464 school-associated foodborne outbreaks and 20,667 associated foodborne illnesses, 122 (26%) met the criteria for inclusion. The 122 outbreaks consisted of 301 reported food safety error entries. The range of food safety errors was 1–10 (median = 2; interquartile range = 2). At least one food safety error was reported in 54 (44%) outbreaks. Reported contamination contributing factors accounted for 49.2% (n = 148) of all reported food safety errors followed by proliferation (34.9%; n = 105) and survival factors (15.9%; n = 48).

Contamination Factors

Individual analyses of contamination factors indicated that C12 accounted for 41.9% (n = 62) of reported food safety errors followed by C6 (12.8%, n = 19), C10 (10.8%, n = 16), and C11 (9.5%, n = 14) (Table 1).

Proliferation Factors

Individual analyses of the proliferation factors indicated that P1 accounted for 27.6% (n = 29) of reported food safety errors followed by P2 and P4 (19.1%, n = 20 and 19.1%, n = 20) and P6 (15.2%; n = 16) (Table 2).

Survival Factors

Individual analyses of the survival factors indicated that S1 accounted for 41.7% (n = 20) of reported food safety errors followed by S2 (35.4%; n = 17) and S5 (16.7%; n = 8) (Table 3).

Pathogenic and Nonpathogenic Groups and Associated Foodborne Illnesses

The total number of illnesses associated with all contributing factors for 122 outbreaks was 7,603 (95% confidence interval: 5,944–9,261; mean: 62; range: 2–510). Foodborne illnesses were most often associated with the pathogenic groups norovirus (56.4%; n = 4,285) followed by *Salmonella* spp. (16.2%; n = 1,234) and *Clostridium perfringens* (12.2%; n = 925). Foodborne illnesses were less often associated with pathogenic and nonpathogenic Shiga toxin–producing *E. coli* spp. (STEC) (5.1%; n = 386), *Staphylococcus aureus* (4.2%; n = 320), *Campylobacter* spp. (1.7%; n = 132), chemicals (1.5%; n = 115), *Shigella sonnei* (1.4%; n = 104), *Bacillus* spp. (1.0%; n = 79), heavy metals (0.3%; n = 21), and hepatitis A (0.03%; n = 2).

Pathogenic Groups and Associated Contributing Factors Categories

In order to determine the proportion of pathogenic groups associated with contributing factors, 11 interrelated food safety errors were further merged into one of three categories: 1) contamination due to school food worker practices (C10, C11, and C12); 2) pathogen growth due to insufficient time/temperature control (P2, P3, P4, P6, P7, and P8); and 3) pathogen survival due to insufficient time/temperature control (S1 and S2). Analyses of the resultant 199 food safety errors associated with specific bacterial and viral pathogen groups indicated that errors were most often associated with norovirus (35.7%; n = 71), *C. perfringens* (29.2%; n = 58), *Salmonella* spp. (13.1%; n = 26), and *S. aureus* (8.5%; n = 17). Food safety errors were less often associated with STEC (5.0%; n = 10), *Campylobacter* spp. (3.5%; n = 7), *Bacillus* spp. (2.5%; n = 5), *S. sonnei* (2.0%; n = 4), and *Streptococcus* spp. (0.5%; n = 1).

Further analyses of the food safety errors indicated that C10, C11, and C12 accounted for 98.6% (n = 70) of norovirus food safety errors; P2, P4, and P6 accounted for 58.6% (n = 34) and S1 and S2 accounted for 27.6% (n = 16) of *C. perfringens* food safety errors; S1 and S2 accounted for 42.3% (n = 11) of *Salmonella* spp. food safety errors; and S1 and S2 accounted for 29.5% (n = 5) of *S. aureus* food safety errors.

TABLE **2**

Proliferation Contributing Factors

Contributing Factor	Food Safety Errors # (%)
P1: Food preparation practice that supports proliferation of pathogens (during food preparation)	29 (27.6)
P2: No attempt was made to control the temperature of implicated food or the length of time food was out of temperature control (during food service or display of food)	20 (19.1)
P4: Improper cold holding due to malfunctioning refrigeration equipment	20 (19.1)
P6: Improper hot holding due to malfunctioning equipment	16 (15.2)
P3: Improper adherence of approved plan to use time as a public health control	8 (7.6)
P8: Improper/slow cooling	4 (3.8)
P7: Improper hot holding due to improper procedure or protocol	3 (2.9)
P12: Other situations that promoted or allowed microbial growth or toxic production	3 (2.9)
P9: Prolonged cold storage	2 (1.9)
Total food safety errors	105 (100)

TABLE **3**

Survival Contributing Factors

Contributing Factor	Food Safety Errors # (%)
S1: Insufficient time or temperature control during the initial cooking/heat processing	20 (41.7)
S2: Insufficient time or temperature control during reheating	17 (35.4)
S5: Other process failure that permit pathogen survival	8 (16.7)
S4: Insufficient or improper use of chemical processes designed for pathogen destruction	3 (6.3)
Total food safety errors	48 (100)

Discussion

Contributing Factors Associated With Foodborne Outbreaks

Only 26% of the outbreaks had reported contributing factors and of those reported, 56% percent of outbreaks involved multiple reported food safety errors, illustrating the challenge during outbreak investigations in identifying the root cause. Contamination contributing factors (49.2%) accounted for the greatest proportion of reported food safety errors when compared to proliferation (34.9%) and survival factors (15.9%).

Contamination Factors, Proliferation Factors, Survival Factors

The most commonly reported contamination food safety errors were C12 (other mode of contamination [excluding cross contamination] by food handler/worker/preparer who is suspected to be infectious), C6 (contaminated raw product—food was intended to be consumed after a kill step), C10 (bare-hand contact by a food handler/worker/preparer who is suspected to be infectious), and C11 (glove-hand contact by food handler/worker/preparer who is suspected to be infectious). Three of the most commonly reported contamination factors (i.e., C10, C11, and C12) involved contamination due to food safety practices by an infected school food service worker.

The most commonly reported proliferation food safety errors were P1 (food preparation practice that supports proliferation of pathogens [during food preparation]), P2 (no attempt was made to control the temperature of implicated food or the length of time food was out of temperature control [during food service or display of food]), and P4 (improper cold holding due to malfunctioning refrigeration equipment) and P6 (improper hot holding due to malfunctioning equipment), which both involved improper equipment holding temperatures. P1 and P2 involved pathogen growth due to insufficient time/temperature control during preparation or holding prior to service and P4 and P6 involved improper equipment holding temperatures or inadequate temperature control due to faulty equipment during food preparation, holding, service storage or cooling, and subsequent pathogen growth. The most commonly reported survival food safety errors were S1 and S2. S1 and S2 involved pathogen survival due to insufficient time and temperature control during cooking and reheating resulting in the production of heat-resistant spores in food.

Pathogenic Groups and Associated Foodborne Illnesses

Approximately 94% of all foodborne illnesses were associated with the pathogenic groups norovirus, *Salmonella* spp., *C. perfringens,* STEC, and *S. aureus*. Although many outbreaks involve sporadic cases and a smaller number of illnesses per outbreak, norovirus outbreaks frequently result in larger clusters of cases due to the virulent nature and high infectivity of the pathogen (Painter et al., 2013). Norovirus outbreaks involved ready-to-eat foods that had been handled by an ill food service worker (e.g., cheesecake, 329 illnesses; salad bars, 425 illnesses; deli sandwiches, 130 illnesses). *Salmonella* spp. outbreaks involved undercooked foods such as poultry (e.g., turkey and gravy, 77 illnesses) and raw produce (e.g., tomatoes, 510 illnesses). *C. perfringens* outbreaks involved cooked spore-forming foods. Spores can survive and multiply in foods that have been temperature abused (e.g., stews and chili, 100 illnesses) and roast turkey and gravy (87 illnesses). STEC outbreaks involved undercooked meats (e.g., venison, 29 illnesses) and unpasteurized dairy products (e.g., unpasteurized milk, 202 illnesses). *S. aureus* outbreaks involved prepared foods that had heat-stable toxins and had undergone extensive handling and preparation prior to consumption (e.g., turkey with stuffing, 53 illnesses; barbecued pork, 89 illnesses) (Food and Drug Administration [FDA], 2012).

Pathogenic Groups and Associated Contributing Factors Categories

Norovirus, *Salmonella* spp., *C. perfringens,* STEC, and *S. aureus* pathogenic groups were associated with about 92% of food safety errors. Norovirus was exclusively associated with contamination due to school food worker practices: C10, C11, and C12. The virus is generally transmitted by an infected food worker via bare-hand or gloved-hand contact with food or by other means of food contact. The infected food service worker acquires the infection and transmits the virus by way of the fecal-oral route (i.e., lack of or improper hand hygiene and transference of the virus to food) resulting in the contamination of food. The virus can also be transmitted by way of aerosolized vomitus or contact with a contaminated surface. *C. perfringens* was most often associated with pathogen growth due to insufficient time/temperature control: P2, P4, and P6 and pathogen survival due to insufficient time/temperature control: S1 and S2. *Salmonella* spp. was most often associated with pathogen survival due to insufficient time/temperature control: S1 and S2. *S. aureus* was most often associated with pathogen survival due to insufficient time/temperature control.

Conclusion

One challenge to identifying the root cause of foodborne outbreaks lies in the failure to identify contributing factors during the outbreak investigation. Complete and accurate environmental health assessments and epidemiological investigations must be conducted in tandem in order to identify contributing factors (CIFOR, 2009; Gould, Rosenblum et al., 2013).

School food service workers must have a thorough understanding of the role of contributing factors in the spread of foodborne disease (Gould, Walsh et al., 2013). Effective food safety education programs must focus on contributing factors, how factors cause foodborne disease, and how to prevent food safety errors. Time/temperature control is an important intervention to prevent bacterial growth or toxin production and survival in foods (FDA, 2009). Effective food safety education programs must focus on time/temperature control compliance procedures for foods and food holding equipment as well as the importance of taking corrective actions when foods or food holding equipment temperatures are not in compliance. Although school-associated outbreaks generally involve school food service workers, it is also important to recognize that other individuals not formally trained in food safety may be involved in food preparation in the school environment (e.g., teachers, parents, students, etc.). Effective food safety education programs must also target the broader school community in training all individuals involved in school food preparation (i.e., food service workers, teachers, parents, students, etc.) as well as the variety of settings and activities where food may be prepared and served to school-aged children (e.g., field trips, class parties, fund-raisers, etc.).

The results of these analyses are similar to other research studies (Gould, Rosenblum et al., 2013; Hedberg et al., 2006; Lee & Greig, 2010; Todd, Greig, Bartleson, & Michaels, 2007). Infected food service workers were involved in 65% of outbreaks and bare-hand contact was associated with 35% of outbreaks in retail settings (Hedberg, 2006). Sixty-four percent of foodborne outbreaks involved food safety errors related to food service worker health and hygiene in restaurant settings (Gould, Rosenblum et al., 2013). Food safety errors associated with school food service worker health and hand hygiene are significant factors in school-associated foodborne outbreaks and yet involve the simplest and most preventable counter measures in preventing foodborne disease.

Future research efforts should examine barriers to reporting contributing factors and explore potential corrective measures. In addition, research should focus on examining the uniqueness of the school food service environment in order to assess the conditions and circumstances in which food safety errors occur (e.g., specific contributing factors, language barriers, faulty equipment, sick leave policies, and adequate hand washing facilities) (Todd et al., 1997).

Limitations of the surveillance data include underreporting and accuracy as well as the small number of the outbreaks represented in our study and must be considered when interpreting surveillance data analyses.

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