



## Direct Observational Study of the Risk of Cross-contamination during Raw Poultry Handling: Practices in Private Homes

### ABSTRACT

A substantial proportion of foodborne illnesses are associated with foods prepared in home kitchens. To determine risk factors that can contribute to the spread of pathogens in domestic kitchen environments, a combination study of raw poultry handling by individuals, using direct observational and questionnaire-based methods, was conducted. Fifty-six individual households were included in the study. Notational analysis was used to transcribe video recorded food handling behaviors into quantifiable risk factors. Additionally, questionnaires were administered to ascertain individuals' knowledge of safe raw poultry handling. Questionnaire responses suggested that although participating individuals were knowledgeable about recommended poultry handling practices, observed poultry handling was frequently inconsistent with recommended practices. All of the individuals reported on the questionnaires that they wash their hands before and after handling raw poultry, but hands were actually washed properly after handling raw poultry only 12% of the time. Food handling practices leading to direct and/or indirect

cross-contamination of hands, kitchen utensils, the kitchen environment, product containers (e.g., seasoning bottles) and devices (e.g., cell phones) were observed for 100% of the participating subjects. The results indicate that cross-contamination events are common during poultry handling in home kitchens, and that people's knowledge of proper food handling was not fully translated into practice. Intervention efforts should strive to align food safety knowledge with behaviors, focusing particularly on ways to minimize the risk of cross-contamination during poultry handling in homes.

### INTRODUCTION

Foodborne illnesses continue to be a major public health burden in the United States (2, 13) and the rest of the world (16, 43). In the United States, infection with non-typhoidal *Salmonella* spp. and *Campylobacter* spp. result in the majority of hospitalizations and deaths associated with foodborne bacterial pathogens (35). Despite efforts in the past fifteen years, the level of salmonellosis reported in the United States population has not declined, compared with

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illnesses caused by other major pathogens of concern (2, 4). Reports have estimated that 10% to 50% of foodborne outbreaks are associated with foods prepared or consumed in homes (27, 33). A more recent CDC report states that 7% of overall foodborne illness outbreaks and 20% of salmonellosis outbreaks are associated with food prepared in the home (6).

Nineteen percent of outbreaks with an identified food vehicle implicated poultry products (6). Further, *Salmonella* and poultry was the second most implicated pathogen-commodity pair (6). Market prevalence studies have consistently found significantly higher rates of *Salmonella* and *Campylobacter* contamination in poultry products than in other foods of animal origin, despite considerable efforts by processors to control contamination rates in their products (17, 26, 39). As a result, relying solely on processors' efforts to reduce the contamination rates of raw poultry products may not adequately mitigate the risk of infection (40). The recent multistate foodborne outbreaks due to *Salmonella* Heidelberg from raw poultry, resulting in more than 134 illnesses and 33 hospitalizations, underscores the importance of proper poultry handling practices (5).

Improper food handling practices of raw poultry or other types of meats have been identified as risk factors for foodborne illnesses in homes (21, 31, 34). When raw poultry products are improperly handled, cross-contamination of food and non-food contact surfaces can readily occur within domestic kitchens (9, 11, 45). Laboratory studies have evaluated the rates of bacterial transfers between different surfaces, including from raw chicken to hands (7, 28), from chicken to cutting boards (7, 22, 42), from contaminated hands to ready-to-eat foods (7, 28) from hand to tap and vice versa (7), and from cutting board to salad (7, 32). These and other studies have found bacteria are transferred between surfaces in food preparation environments (7, 10, 11, 22, 24, 28) and are able to persist in various environments (19), on hands (7), and on cutting boards (9, 10). Implementation of safe food handling practices in private homes is critical to reduce the spread of these pathogens.

Although roughly three quarters of meals are prepared and consumed at home in the United States, our understanding of how raw poultry products are handled in private homes is scanty (1). Our primary understanding of how foods are handled in private homes comes mostly from questionnaire-based studies and a handful of observational studies (31, 33, 34, 36, 37, 44). Questionnaire-based studies, which rely on what study subjects report, may suffer from individual reporting bias. In contrast, reporting bias is minimized in observational studies, since trained food safety professionals can observe food safety activities directly and evaluate risk factors. However, previous observational studies have commonly utilized mock/commercial kitchens

or contrived scenarios (e.g., preparation of a single pre-determined dish), rather than providing observations of actual kitchen behaviors, which limits the observations of the diverse ways whole meals are prepared (8, 18, 36). Further, previous observational studies have had little ability to record certain critical food handling practices (e.g., storage and thawing of food products) (8, 31). Another limitation of previous studies is that they have confined observations to individual participants in isolation, ignoring potential interactions of others that live within the house (e.g., roommates).

The objectives of this study were to evaluate raw poultry handling practices and quantify the various risk factors contributing to intrameal (within the same meal) and intermeal (between different meals) cross-contamination, using a study design that was both observational and questionnaire-based. Observations were made in the subjects' private kitchens, providing subjects with a familiar setting to perform their typical food handling activities (e.g., sanitizing contaminated surfaces, using dishcloths or paper towels), as well as allowing us to observe non-food handling practices during meal preparation (e.g., taking out the garbage, answering phones). Additionally, subjects were not limited to a single recipe, but rather were encouraged to prepare any meal (including side dishes), as long as it included handling of raw poultry. Furthermore, the current study design allowed specific observations of how raw poultry products were stored and thawed, as well as any interactions of the subject with other individuals in the kitchen.

## MATERIALS AND METHODS

The research protocol and the administered questionnaires (*Attachment A*) were approved by the Institutional Review Board at the University of Washington.

### Subject recruiting

A convenience sample of participants from different households was recruited for the study. Inclusion criteria for participants included being 18 years old or older and self-identification as a person who regularly prepares meals beginning with raw poultry for themselves and/or others. Recruitment was accomplished through the posting of fliers at the University of Washington and through e-mails sent to students and university employees. Additional subjects were recruited by word of mouth from the researchers' circle of friends within and outside the university, and family members. A written description of the study was presented to potential participants, and researchers were available to answer questions. Participants in the study were told that they were participating in a food safety research study evaluating their raw poultry handling practices. Subjects who were interested and agreed to participate were required to sign the consent form before they were formally

**Attachment A: Food-handling questionnaires.**

**Food-handling Behavior Survey Questionnaires**

**Demographic**

	<b>Gender</b>	<b>Male</b>	<b>Female</b>				
	<b>Age Group</b>						
	<b>Educational Level</b>	<b>&lt; HS</b>	<b>HS</b>	<b>Some college</b>	<b>BS or greater</b>		

**Frequency of raw chicken contact**

1	On average, how many packages of fresh chicken do you buy per month? (Note: the answer will be used in subsequent questions). Referred to "P"						
2	On average, how many packages of fresh ground turkey do you buy per month?						
3	Out of a total of "P" fresh raw chickens you purchase in a month, how many are ground?						
4	Where do you normally buy your raw chicken from?						
5	How much chicken (lb.) do you buy each time you purchase fresh chicken? If both, what proportion of each?	Small/medium Pack (1 lb-2 lbs)	Family pack (>2 lbs)				
6	What part(s) of chicken do you buy the most? (If multiple parts, out of "P" purchases per month, how many of each type do you buy?)	Breast	Thighs	Drums	Wings	Split breast	Whole/combination set
7	How many times per month do you prepare meals using raw chicken? (This value "M" is used in subsequent questions). Referred to "M"						
8	Out of the "P" chicken packages you purchase per month, how many of them do you prepare?						

**Transportation**

9	What is the average travel time from the retail store where you buy the chicken from to your home?	<15 min	30 min	60 min	90 min	120 min	Write ____
10	On average, how long after you arrive at home do you put away the purchased fresh chicken?	<15 min	30 min	60 min	90 min	120 min	Write ____

**Raw chicken room temperature storage**

11	How soon after purchase do you use the raw chicken to prepare meals? Break down total purchases into each category.	Same day	within two days	within three days	four days	Write ____	
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## Food-handling Behavior Survey Questionnaires (cont.)

### Demographic

	Gender	Male	Female				
	Age Group						
	Educational Level	< HS	HS	Some college	BS or greater		
12	For chickens to be used the same day, do you store the chicken anywhere else other than in the refrigerator or freezer? If yes, where and how long?	Yes	No	If Yes, where and how long? _____			
13	If the fresh chicken is not used the same day it was purchased, how do you store the chicken for later use? If multiple answers, you can break down the "P" purchases into each method.	Room temp. storage		Refrigerator		Freezer	
14	If chicken is stored in the refrigerator, on average how long do you store it before use? (in days)						
15	If fresh chickens are stored in the refrigerator, where in the refrigerator do you store the chicken? (If multiple answers, pick the one that is most common.)	Top	Middle	Bottom			
16	Do you have an operating thermometer in the refrigerator? (yes or no)	Yes	No				
17	If chickens are stored in the freezer for later use, what procedure do you use to thaw the frozen chicken? If multiple methods are used, mark all those that apply.	Room temp. storage	Transfer to refrigerator	Run under hot/cold water	Microwave	Do not thaw	
18	If the fresh chicken is thawed at room temperature, how long do you leave the chicken at that temperature?						

### Preparation

19	Do you normally wash fresh chicken pieces prior to using them to prepare meals?	Yes	No				
20	Do you have separate cutting boards for cutting raw chickens versus non meat products?	Yes	No				
21	If you have separate cutting boards, do you ever reuse the same cutting board without washing to prepare other foods such as fruit, salad, bread? How many times in the last month?	Yes	No	If yes, how many times in the last month?			

## Food-handling Behavior Survey Questionnaires (cont.)

### Demographic

	Gender	Male	Female				
	Age Group						
	Educational Level	< HS	HS	Some college	BS or greater		
22	If you do not have separate cutting boards, do you ever reuse the same cutting board without washing to prepare other foods such as fruit, salad, bread? How many times in the last month?	Yes	No	If yes, how many times in the last month?			
23	With how many of the "M" chicken meals (total number of chicken meals in a month time) did you also have side dishes (e.g., fruit, salad, bread)?						
24	Of those meals for which you had a side dish with your chicken (e.g., fruit, bread, green salad), when did you most often prepare the side dish(es)? (If multiple answers, choose the one most often followed.)	Before preparing chicken	At the same time I prepare chicken	After I prepare chicken	Do not prepare side dishes		
25	After you use cutting boards to prepare fresh chicken, how do you wash the cutting board before it is used again? If multiple methods are used, pick one that you follow the most.	Rinse with cold water	Rinse with hot water	Wash with hot water and soap	Wash with hot water, soap and brush	Wash in the dishwasher	Other:
26	In the last "M" times you prepared chicken meals, how many times did you reuse the knife to prepare cooked foods or other ready to eat foods (such as bread, fruit, green salad)?						
27	Do you use wash rags or sponges to clean kitchen counters and other kitchen surfaces?	Yes	No				
28	If you use wash rags, out of the "M" times you prepared meals with fresh chicken in the last month, how many times did you clean the counter tops using wash rags?						
29	How often do you wash the rag?						
30	How often do you replace wash rags?						
31	Do you use disinfectants to clean counter surfaces?	Yes	No				
32	After "M" times you prepared meals with fresh chicken in the last month, how many times were the counter tops cleaned using disinfectants?						
33	What type (s) of disinfectant is used to clean counter tops?						Don't know

## Food-handling Behavior Survey Questionnaires (cont.)

### Demographic

	<b>Gender</b>	<b>Male</b>	<b>Female</b>				
	<b>Age Group</b>						
	<b>Educational Level</b>	<b>&lt; HS</b>	<b>HS</b>	<b>Some college</b>	<b>BS or greater</b>		

### Hand washing

34	Do you wash your hands before preparing meals?	Yes	No				
35	Prior to how many of the "M" chicken meals you prepared in the last month, did you wash your hands?						
36	How do you normally wash your hands before preparing meals?	With cold water	With hot water	With cold water and soap	With hot water and soap	Use sanitizer	Don't wash hands
37	Do you wash your hands with hot water and soap after touching fresh chicken/turkey, prior to handling anything else?	Yes	No				
38	During the preparation of the "M" meals in the last month, how many times did you wash your hands with hot water and soap after handling raw chicken?						
39	Do you wash hands with hot water and soap prior to preparing side dish(es)?	Yes	No				
40	Do you wash your hands with hot water and soap after you are done preparing chicken meals?	Yes	No				

### Final cook

41	How do you determine when the chicken is cooked?	Look	Touch	Taste	Take final cook temp.	Measure time	
42	Do you sometimes check final meat temperature using a thermometer?	Yes	No				
43	Do you handle the cooked chicken with your bare hands when serving?	Yes	No				
44	What temperature should a fresh chicken be cooked to?		Don't know				
45	Do you reuse any of the utensils (cutting board, knives, spoons, plates) that were used to handle fresh chicken for the cooked chicken?	Yes	No				
46	In the last month, how many times did you wash your kitchen sink?						

enrolled in the study. Data collection from participants was scheduled at their convenience.

Both the knowledge of the purpose of the study and the presence of researchers during food handlings might have influenced participant's overall food handling behavior. However, it might be expected that prior knowledge of study purpose or the presence of researchers would bias subjects to heightened awareness and thus to improved behaviors. As a result, the findings of this study might be viewed as a conservative estimate of compliance with food safety behaviors in the home.

**Video recording**

Video recording was used to capture food handling practices and a notational analysis, as described by Lubran et al. (*Attachment B*) (25), was utilized for the purpose of

enumerating and analyzing the observations. Recording of a subject's food handling procedures was performed in the subjects' home kitchens, using a handheld digital video camera (Cisco, Flip Video). All activities related to the preparation of the meal, including preparation of side dishes and utensil washing activities, were recorded. Video recording commenced when a subject indicated he or she was ready to begin meal preparation. In the event that a subject had placed the poultry in the oven for cooking and was not doing anything related to the preparation of the final meal, video recording was paused and then recommenced when the poultry product was removed from the oven and food preparation activities resumed. The video recordings were concluded when subjects had completed all food preparation steps and were ready to serve or consume the prepared meals. All video recordings were transferred

**Attachment B: Notational analysis forms.**

Date	Analyst	Subject ID	Age	Gender	Duration	# of actions	Product type?	Partners?	Cooking duration	Name of meal:						
										Hand Washing	Cross-contamination			Cleaning of food contact surfaces	Other	
Action sequence	Required	Adequate	Attempted? Soap used?	Length (sec.)	Cutting board/ Counter/towels	Utensil	Wash rags	Side dish	Final cooked product	Hands contaminated	Touched the faucet	Other (touching self, cabinets, knob, other surfaces)	Adequate	Attempted	Sanitizer used or not?	Other major observation (e.g., ingested potential contamination)

to external hard drives for viewing on a computer monitor. For ease of tracking, the video recordings were labeled with the name of the researcher recording the meal preparation, followed by the subject ID, which is a numerical number assigned to the subject (e.g., Eyob\_01).

### Administering questionnaires

The written questionnaires (Attachment A) were administered after the video recordings were completed, to minimize the impact of the questionnaires on the observed behaviors. The questionnaires consisted of 51 questions in six distinct sections: (1) consumption/preparation frequencies, (2) product transportation, (3) storage/handling temperatures, (4) poultry handling/sanitation, (5) hand washing and (6) final cook temperatures. Each questionnaire was labeled with the same codes used for the video recordings.

### Notational analysis

To prepare the records of food handling activities for data analysis, a modified version of a notational analysis form (*Attachment B*) was used to annotate subject videos (25). In brief, notational forms were used to keep a detailed track of each activity a subject preparing a meal performed from the beginning to the end of the recording. The information recorded included the type of activity (e.g., hands washed), how the activity was done (e.g., soap, hot water, and paper towel used), how long the activity lasted (e.g., 15 seconds), and how hands were dried (e.g., cloth towel). Each step of the food handling procedure was written in the first column of the notational form. In addition, the notational form had columns for tracking specific cross-contamination activities (e.g., cloth towels contaminated), activities related to sanitation of food contact surfaces (e.g., cutting board washed, rinsed and sanitized before re-use), and activities that could compromise the final cooked product (e.g., tasted food with unwashed hands) or contamination activities that could potentially compromise future food handling (e.g., salt shaker contaminated). For each recorded step, a determination of whether or not an activity was a proper food handling practice (e.g., whether or not hand washing was required before or after the step, or if and what kind of cross contaminations occurred) was made, based on pre-determined criteria adapted from the United States Food and Drug Administration, Retail Food Code, 2009 (*Table 1*) (38).

Each video recording was reviewed by two researchers and their observations recorded on separate notational analysis forms. To ensure consistency in coding between researchers (i.e., using FDA guidelines), a margin of 10% was set as the allowable maximum divergence in measured activities (e.g., total number of required hand washes). For example, if after watching the video of subject "01", one of the two researchers documents 20 separate occasions the

subject failed to wash his/her hands, the second researcher would also have to identify between 18 to 22 failures. If divergence in excess of 10% between reviewers' recorded observations was found, the recorded videos were reviewed jointly and differences harmonized.

### Data analysis

Microsoft Excel (Microsoft Corporation, Redmond, Washington) was used to compile data, summarize data points, and calculate basic descriptive statistics (e.g., mean, standard deviation, percentages of responses and observations). Fisher exact tests were used to evaluate significant differences between reported and observed food handling practices (GraphPad Calculator, GraphPad Software, Inc., San Diego, CA). *T*-tests were performed to evaluate the differences in cross-contamination episodes relative to side dish preparation (GraphPad Calculator, GraphPad Software, Inc., San Diego, CA).

## RESULTS

### Questionnaire results

#### Demographics

Between November 01, 2011 and December 15, 2012, 56 subjects were recruited. None of the study subjects were students, faculty, or staff from the academic department of the researchers, and more than half of the subjects had no affiliation with the university. The racial distribution of subjects in the study was 7% (4) African American; 36% (20) Asian; 54% (30) Caucasian; and 3% (2) others. The ages of subjects in the study ranged from 18 to 65 years old, with a median age of 21 years. Fifty-three percent of subjects were female. Thirty-five percent (17/48) of the participants possessed a bachelor's degree; 62 percent (30/48) reported some college education, while one subject reported only a high school education. Some participants left a few questions unanswered so that the total number of respondents per question was less than 56. Because of the sampling method used (i.e., convenience sampling), the participants may not represent the general public. The educational level of the study subjects is higher than that of the general public, and the average age is less than that of the general public; therefore, our data might be more reflective of the food handling practices of the younger generation than of the general population.

### Poultry consumption

All study subjects reported that they regularly buy chicken, with 14% reporting also buying ground turkey products. Chicken breasts were the most commonly reported items, with 86 percent of subjects reporting buying them. Study participants reported that they consumed meals with poultry from once a month to daily. On average, participants reported preparing meals

**TABLE 1. Criteria used to score lack of proper food-handling practices**

Activities or risk factors	Expected proper food-handling practices
Before beginning food handling	*Proper hand washing prior to starting food handling.
Bare hand contact with raw poultry (e.g., unpacking or processing)	Proper hand washing prior to handling anything that will continue to be used during the course of cooking (e.g., utensils) or will not be discarded right away (e.g., packaging materials).
Washing dishes or cleaning counter tops contaminated with raw poultry	Food utensils should be washed, rinsed and sanitized before reuse. Contaminated food contact surfaces should be cleaned and properly sanitized. Proper hand washing after thoroughly cleaning or sanitizing dishes or contaminated surfaces.
Activities contributing to cross-contaminations	If hands or utensils (e.g., spoons) have been used to handle raw poultry, they should be thoroughly washed.
Handling of reusable food containers (e.g., seasoning bottles)	Prior to handling re-usable food containers, hands should be properly washed or in an event the food containers are cross-contaminated, they should be thoroughly washed.
Cleaning contaminated food contact surfaces	All contact surfaces that are contaminated (e.g., sink contaminated with chicken juice or counter surfaces), should be thoroughly cleaned (e.g., using sanitizer) right after contamination or at the completion of cooking session.
Contamination of cloth towels	Cloth towels should not be used to dry hands that are not properly washed or to dry contaminated surfaces. Single use paper towels recommended.
Proper storage of foods	Raw poultry products should be stored on the lowest shelf in the cooler.
Thawing of frozen poultry	Frozen raw poultry should be thawed using one of the following methods: refrigerator, microwave, thawed under cold running water.
Checking chicken doneness	Use a thermometer
Serving/eating	Proper hand washing after completing meal preparation, before handling items that will be eaten (e.g., salad) or used (e.g., serving spoons).

\*Proper hand washing: 20 seconds of hand washing with soap and hot water with 15 seconds of active rubbing.

with poultry five times per month (SD = 4). Study subjects reported that they prepared most or all of the meals they consume in their homes.

#### Transportation and storage

Subjects were asked what the average transport time was from store to their home, and how soon after arriving home they stored poultry products in the refrigerator or freezer. Ninety-nine percent reported arriving home within less than thirty minutes, and 98 percent of them reported storing poultry either in the refrigerator or freezer within fifteen minutes after arriving. Sixty-one percent (n = 27) of subjects reported storing poultry products in the refrigerator on the bottom shelf, whereas the remainder reported storing products on either the top or middle shelf. "Bottom shelf" refers to either the last bottom shelf or the bottom drawer

that is not used for storing fresh produce. Subjects reported storing raw poultry products in the refrigerator for one to seven days before use (Avg. 2.7 days, SD = 1.4 days).

#### Raw poultry handling

The questionnaires ascertained several aspects of food preparation and handling of raw poultry (Table 2). Four different methods of thawing frozen poultry products were reported, with 72% (n = 34) reporting that they thawed in the refrigerator or used a microwave oven; 45 percent (n = 21) reporting that they washed raw poultry under running water; 45 percent (n = 21) reporting that they did not have separate cutting boards for handling raw poultry and other (non-poultry) food items. Of those that do not have separate cutting boards, 95 percent of the subjects (n = 20/21) reported that they washed the cutting board before

**TABLE 2. Summary of questionnaire results**

Questions (# of responses)	Responses	% Responses
Where do you store raw poultry? (47)	Refrigerator	58
	Freezer	40
	Use the same day purchased	2
Where is poultry stored in the refrigerator? (44)	Bottom	61
	Middle	34
	Top	5
# Days raw poultry is stored in the refrigerator? (39)	< 2 days	49
	3 days	31
	4 days	10
	>5 days	10
Do you have thermometer? (47)	Yes	42.5
	No	57.5
How often do you wash hands?(47)	Wash hands before food prep.	100
	Wash hands after touching raw poultry	98
	Wash hands when done making meals	92
How do you thaw? (47)	Refrigerator	48
	Running water	14
	Microwave	24
	Room Temp.	14
Do you wash raw chicken? (47)	Yes	45
	No	55
Cutting board usage (47)	Don't have separate cutting board	45 (21/47)
	Don't reuse without properly washing	95 (20/21)
Use of wash rags (43)	Use wash rags	79
	Wash daily	40 (17/43)
	Replace wash rags > monthly	34 (14/41)
Do you use sanitizers? (47)	Yes	77
	No	23

*Table 2 continued on next page*

**TABLE 2. Summary of questionnaire results (cont.)**

Questions (# of responses)	Responses	% Responses
Final cook temperature (48)	Don't check	75 (35/47)
	Final temp. not known	37.5
	Think final cook temp is < 165°F	10
	Think final cook temp is >165°F	17
When side dishes prepared (47)	Before	23
	During	45
	After	19
	No side dishes	13

using it to handle other food items. Sixty-four percent (n = 30) of subjects reported preparing side dishes either during or after handling raw poultry.

**Hand washing**

All of the subjects reported washing their hands with hot water and soap before food preparation begins. Subjects also reported washing their hands 92% to 100% of the time before, during, and after handling poultry. Additionally, 90% (n = 42) reported washing their hands before preparing side dishes (e.g., salad).

**Final cook temperatures**

Seventy-five percent (n = 35) of respondents reported not taking final cook temperature of cooked poultry. However, all subjects reported relying on look and feel to determine adequacy of cooking. Furthermore, 38 percent (n = 18) reported not knowing the appropriate final cook temperature (165°F) for poultry, with one subject reporting 100°F as the final cook temperature for poultry.

**RESULTS OF VIDEO OBSERVATIONS**

A total of 1880 minutes (31.3 hrs.) of direct observations of raw poultry handling was recorded and analyzed. The average length of video observation per household was 33.6 minutes (SD = 20.0 minutes). A total of 9,166 activities during the observational study were recorded on notational forms for analysis. The mean number of activities per meal preparation was 164 (SD = 92.0 activities). However, the number of activities per household (per meal prepared) ranged from a low of 54 to a high of 473 activities.

**Poultry storage**

In contrast to survey results, only 42 percent (16/38) of households were observed storing raw poultry either on the top shelf (n = 13) or middle shelf (n = 3).

**Thawing procedure**

Seventy-three percent of subjects (41/56) prepared meals starting from fresh raw poultry; therefore, thawing procedures were not observed for the majority of the households. However, among those that started with frozen raw poultry, 53 percent of them (8/15) thawed in the microwave oven, 27 percent under running water (4/15), and 20 percent (3/15) in the refrigerator overnight.

**Hand washing**

There were a total of 463 hand washes required throughout the study, making up about 5% of the total activities. *Table 1* lists the criteria used to score compliance with hand washing and other food handling practices. Eighty percent (44/56) of subjects did not wash their hands with soap and water at all prior to starting to prepare the meal. Overall, 55% (253/463) of the observed activities that should have been followed by a hand wash were not. The mean duration of hand washing with soap and water, when hand washing was required, was 13 seconds (SD = 7 seconds).

Among the 463 activities after which subjects were expected to wash their hands, 182 (39%) involved bare hand contact with raw poultry or utensils soiled with raw poultry (e.g., washing plates that were used to handle raw poultry). Following these 182 activities, 58% (106/182) of subjects did not wash their hands.

**Cross-contamination**

Of the total 9,166 activities annotated in the observational study, 2,281 (25%) resulted in cross-contamination events. Contamination events were defined as direct or indirect contact of a contaminated surface (e.g., hand, towel, utensil, or other item that had been in contact with raw poultry) with an uncontaminated surface or item. Numerous kitchen surfaces were contaminated, such as counter tops, utensils, appliances, cabinet handles, knobs, reusable

food containers (e.g., salt shakers, oil bottle), wash rags, and cloth hand towels. Twenty-nine percent (16/56) of subjects started meal preparation by first washing the raw poultry in the sink. Each of these washes resulted in contamination of hands, sinks and the surrounding counter top surfaces.

**Figure 1** summarizes the frequency and items cross-contaminated during raw poultry handling. Items that were most frequently cross contaminated by hands were handles (e.g., of cabinets, drawers, or appliances), making up 35% (806/2281) of total cross-contamination events. The next four most frequently contaminated items were hands (15%), reusable food containers (12%), faucet handles (11%) and utensils (7.6%). Lack of proper hand washing contributed to 85% of total cross-contamination events (1947/2281).

While cutting boards are often suspected of contributing to cross-contamination events, none of the subjects were observed to reuse a cutting board that was previously used to prepare raw poultry for handling ready-to-eat foods, without first washing them. Nevertheless, mishandling of contaminated cutting boards (e.g., turning a board over to use the “clean” side) can result in cross contaminating hands and counter top surfaces.

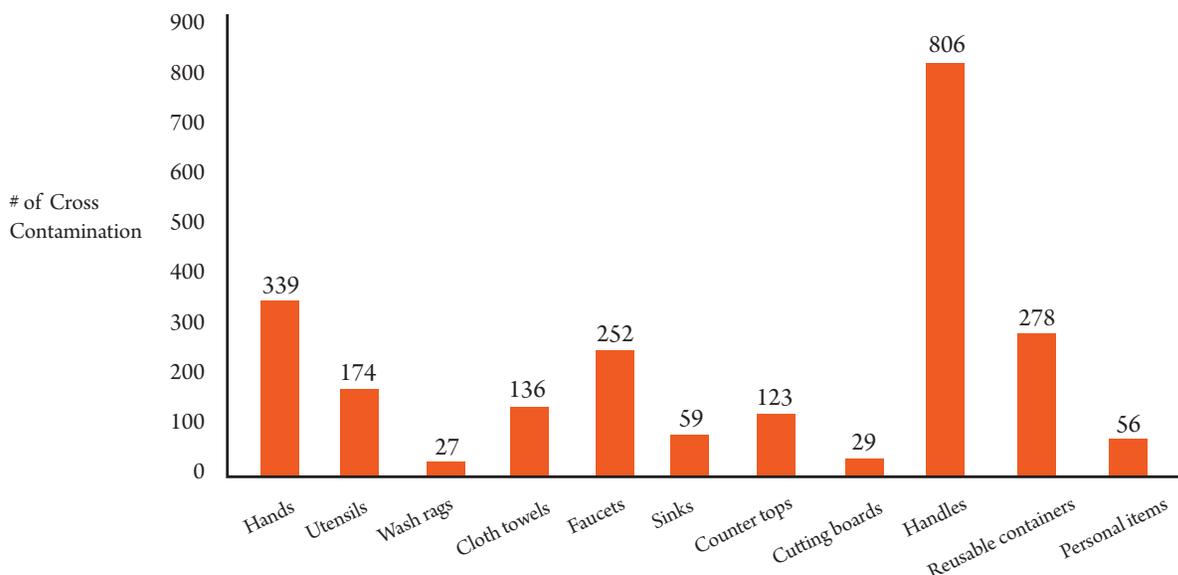
During the course of meal preparations, there were 355 instances where subjects were observed touching their hair, mouth, face or other body parts. Seventy-one percent of participants were observed touching bare body parts during the course of meal preparation (40/56), with frequency of touching ranging from 1 to 47 times (Avg. 17, SD = 12).

### Final meal and cook temperature monitoring

Five percent (3/56) of subjects took final cook temperature of cooked meals, and all the meals had achieved the recommended temperature of 165°F. On the other hand, 43% of the households reported owning a thermometer and 25% (12/46) reported checking final cook temperatures. However, all subjects checked the inside of the meat for color and consistency before eating or serving.

Overall, 82% (46/56) of the meals were directly or indirectly handled with contaminated hands or utensils. In addition, during the course of preparing meals, 43% of subjects (24/56) were observed eating or drinking foods (e.g., chips), while preparing meals without first properly washing their hands or after touching contaminated surfaces.

Among those households that prepared side dishes (n = 26), 58% prepared their side dishes during the same time the main dish was being prepared, and 35% (9/26) prepared side dishes after the dish was prepared. The mean number of cross-contamination events for those that did not prepare side dishes at all (n = 30), and those that prepared them before (n = 2), during (n = 15) and after (n = 9), were 35, 30, 53 and 70, respectively. There is a statistically significant difference in the frequency of cross-contamination events between those that did not prepare side dishes at all (n = 30) and those that prepare side dishes during or after the main meals (*t*-test, *P* = 0.026). There was no significant difference in the frequency of cross contaminations observed between those who prepared side dishes during and after the main meals (*t*-test, *P* = 0.438).



**FIGURE 1.** Frequencies of observed cross-contamination events for contact surfaces

Note: Handles include drawers, cabinets and appliances

### Cleaning/sanitizing

During the recorded meal preparations, 62.5% (35/56) of subjects cross contaminated their counter tops, whereas only 7% (4/56) of subjects were observed properly cleaning or sanitizing the contaminated counter top surfaces. Twenty-five percent of subjects (14/56) used dish wash rags to wipe counter surfaces and other contact surfaces.

### Reported vs. observed food handling practices

Subjects showed more safe food handling knowledge than was observed in practice. The most striking differences were found with respect to hand washing prior to meal preparation (Fisher exact,  $P < 0.0001$ ) and the use of sanitizer to disinfect contact surfaces (Fisher exact,  $P < 0.0001$ ). *Table 3* summarizes some of the food handling practices differences, reported vs. observed.

### DISCUSSION

Our study identified and quantified a number of risk factors that potentially increased the risk of infection with *Salmonella* or *Campylobacter* during raw poultry handling. However, illness was neither tracked nor reported following the study.

This study used a combination approach involving both video recorded observations of food handling activities and questionnaires to assess food safety knowledge and declared practices. Our observed inconsistencies between questionnaire results and observed behavior is consistent with several results of studies that have reported differences in what consumers say they do and what they actually practice when observed (20, 31, 33, 36). Video recording (onsite or closed circuit) of food handling activities is the most common method employed in observational studies (31, 33, 34, 36). Video recording provides the researcher with a permanent record by which to evaluate actual food

handling activities that direct in-person observations fail to do. Thus, direct observational studies utilizing video recordings are better able to accurately evaluate food handling behaviors than other methods (31, 34, 36).

Only a handful of published studies have utilized observational methods for evaluation of safe food handling (8, 18, 31, 34, 36). The major risk factors identified in these studies include improper refrigeration storage temperature (21), lack of proper hand washing practices before or after handling raw products (15, 25, 34, 36), poor temperature control of food products (e.g., during thawing) (31), activities leading to cross contaminations of contact surfaces (12, 31, 34), and failure to monitor final cook temperatures of products (31). However, these studies typically did not focus on general poultry handling practices during meal preparation in the home setting; rather, they focused on other specific scenarios or other food commodities. The use of notational analysis (i.e., process documentation) in food safety was first introduced by Clayton and Griffith (8). Similar, formalized approaches to document step-by-step food handling activities have been used in subsequent observational studies to evaluate food handling behaviors systematically (18, 25, 36).

### Transportation and storage

According to the survey results, 99% of raw poultry products are put away in the refrigerator or freezer within 60 minutes after purchase. Extended room temperature storage after purchase does not appear to be a significant risk factor among households in the study. However, a large proportion of households (42%) were observed to store raw poultry products either on the top or middle shelf of the refrigerator, potentially increasing the risk of contamination of food products stored below these shelves.

**TABLE 3. Reported vs. observed food-handling practices**

Safe Food-handling Practices	Reported % (n)	Observed % (n)
Poultry storage (bottom shelf)	61 (27)	42 (23)
Raw poultry not washed	55 (26)	71 (40)
Use sanitizer to disinfect contact surfaces*	77 (36)	12.5 (7)
Wash hands before beginning of meal preparation*.	100 (47)	20 (11)
Take final cook temperature*	23 (47)	5 (56)

\*indicates  $P < 0.5$

Fifty-one percent of the subjects in the study reported storing raw poultry in the refrigerator for three or more days, with 10 percent of them keeping raw poultry in the refrigerator for more than five days. The recommended storage time for raw poultry products in home refrigerators is less than two days (41). Extended refrigeration storage of raw poultry in poorly cooled refrigerators can increase the risk of re-growth of pathogenic organisms, resulting in an increased risk of cross-contamination. An observational study of domestic refrigeration temperatures found 59% of refrigerators holding foods at temperatures above the recommended cold holding temperature of 41°F (5°C) (21).

### **Poultry handling**

Almost half of the households reported regularly washing raw poultry (45%) before preparing it, which is higher than the data from the current observational study (29%). Either way, a substantial proportion of households continue to wash raw poultry, thereby contaminating their hands, the sink, and the counter top around the sink. For this reason, washing of meats is not recommended (41).

Proper thawing of frozen raw poultry can minimize the growth of bacterial pathogens and reduce the risk of cross-contamination. Seventy-two percent of households reported that they thawed frozen raw poultry either in the microwave oven or in the refrigerator. Fourteen percent of them reported that they thawed at room temperature, and another 14% reported that they thawed under warm running water. Neither of the latter methods is recommended for thawing poultry, since both can increase the risk of *Salmonella* regrowth and of cross-contamination. Of the 15 participants in the study who were observed thawing poultry, microwave thawing was performed 53% of the time, and thawing under running water 27% of the time. A similar result was reported in an observational study, in which 16% of households thawed frozen burgers at room temperature on the counter, while 56% of households thawed in the refrigerator (31).

### **Hand washing**

While 100% of subjects reported washing their hands before preparation of meals, only 5% of the observed subjects actually washed their hands. While 98% of subjects reported that they washed their hands with soap and hot water after handling raw poultry, our observations found that hands were properly washed only 12% of the time after being directly contaminated with raw poultry.

Previous observational studies have reported lack of proper hand washing practices among food handlers (18, 20, 31, 34, 36). An observational study evaluating the frequency of hand washing before, during and after poultry meal preparation found that in only 5% of households were hands washed before beginning meal preparation,

35% after contact with raw poultry, and 5% after completing meal preparation (18). Our study found compliance with proper hand washing at only about one-third the rate reported previously.

In addition to lack of hand washing, the recommended duration of twenty seconds of hand washing with soap and water is frequently not met. In the current study, the duration of hand washing with soap and hot water varied from as short as two seconds to as long as 33 seconds, with an overall average of 13 seconds (SD = 7 seconds). Other observational studies evaluating raw burger handling reported a lack of compliance for the recommendation that hand washing include 20 seconds of active rubbing (31, 36).

An observational study by Redmond et al. reported 100% of participants failed to carry out adequate and immediate hand washing and drying after handling raw chicken on at least one occasion (34). The risk posed by lack of proper hand washing can increase if contaminated bare hands are used to hold snacks during the course of food handling. In our study, 46% (26/56) of subjects were observed snacking or tasting cooked meals with potentially contaminated hands.

### **Cross-contamination events**

Between undercooking and the risk of cross-contamination, cross-contamination events are believed to be the most dominant pathway for becoming infected with *Salmonella* (23, 29, 30). An observational study coupled with microbiological sampling of contact surfaces found that 80–86% of all unsafe food-handling behaviors were associated with cross-contamination (34). Similar studies have reported the ease with which pathogens can be transferred from contaminated raw poultry to various surfaces, including ready-to-eat foods (11, 24, 32).

Unwashed hands contributed to 85% of all of the cross-contamination episodes observed in the current study, underscoring the importance of proper hand washing. Numerous parts of the kitchen environment were directly or indirectly contaminated. By far the most frequently contaminated non-food contact surfaces were handles (e.g., of cabinets and appliances). In addition, food containers such as salt shakers, oil bottles and other reusable food containers are also commonly contaminated objects. Subjects were observed directly handling these items without first washing their hands after handling raw poultry. This finding is consistent with previous observational studies (31, 34).

In our study, a substantial proportion of households reported not having separate cutting boards (45%), and almost all reported never reusing cutting boards without first adequately cleaning them. When observed, none of the participants reused contaminated cutting boards to process ready-to-eat foods. This finding might be a reflection of the fact that only 21% of households used cutting boards

during recorded meal preparations. However, in a survey done by the U.S. Food and Drug Administration more than two decades ago, 26% of consumers did not clean a cutting board after using it to cut raw meat or chicken (3). If this is an actual shift in food-handling practices, it is encouraging, since cross-contamination events due to improper use or cleaning of cutting boards have been implicated in foodborne illness outbreaks (9).

Use of hand towels was frequently observed for cleaning contaminated unwashed hands, cleaning counter tops, and drying clean utensils. Contamination of hand towels made up 6% of the contamination episodes. *Campylobacter* isolation from hand towels that were suspected of being used to dry inadequately washed hands and wipe kitchen work surfaces has reported (34).

### Final cook temperature

The only certain way to monitor final cook temperature is to use a thermometer, but in the current study, only a small proportion of the households reported or were observed using thermometers. Twenty-five percent of households reported regularly using a thermometer to check final cook temperatures of cooked poultry, but only three percent of the households were observed using a thermometer to monitor final cook temperatures. In addition, almost half of the households reported either not knowing the final cook temperature (37%) or thinking that the final cook temperature was less than 165°F (10%). This number is lower than that reported by Phang et al., in whose study 65% of subjects responded they did not know the final cook temperature for burgers (31). Despite the unreliability of checking the inside of chicken, all of the households were observed checking this for adequacy of cooking. Lack of thermometer use to check the final cook temperature has similarly been reported in other studies (18, 21).

The order of when different types of foods are prepared can have an impact on the overall risk of cross-contamination. Among those in the study who prepared side dishes, 93% percent prepared side dishes either while

or after handling raw poultry. Another observational study reported 100% of individuals in the study were observed touching side dishes (i.e., ready-to-eat foods) after handling raw poultry (31). As can be expected, individuals who prepared side dishes before handling raw poultry or not at all had significantly fewer cross-contaminations compared with those preparing during or after. Therefore, encouraging consumers to prepare side dishes before handling raw poultry products could significantly reduce the risk of acquiring foodborne illnesses.

### Cleaning/Sanitizing

During the course of meal preparations, 62.5% (35/56) of subjects cross-contaminated their counter tops, whereas only 7% (4/56) of subjects were observed partially cleaning or sanitizing contaminated counter top surfaces using disposable wipes. None of them were observed properly washing, rinsing and sanitizing food contact surfaces. In contrast, 77% percent of households reported using sanitizers on a regular basis. The following detergents and sanitizers were reported in use: Lysol, Clorox wipes (frequent response), All Purpose, Simple Green, Pine Sol, and regular dish soaps. Some bacterial pathogens such as *Salmonella* are known to attach and survive on various kitchen surfaces (19, 32, 45). Therefore, sanitizing or cleaning of food and non-food contact surfaces with appropriate types of sanitizers is important in preventing cross-contamination. Twenty-five percent of the households were observed using wash rags to wipe surfaces contaminated with raw poultry. In some instances, the same wash rags were also used to clean counter tops.

Consumers should be educated to treat each package of raw poultry product as potentially contaminated with pathogens and to handle each package with caution to minimize cross-contaminations. Identifying the barriers as to why consumers' food safety knowledge is not translated into actual practices can result in successful intervention efforts (14, 15).

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