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Abstract

Purpose – This paper aims to determine the potential for the spread of bacteria from raw meat and poultry during home food preparation to the surrounding kitchen environment, hands and prepared food due to unsafe handling practices, which are predicted by consumers' knowledge, behaviour and attitudes.

Design/methodology/approach – The potential for transfer of *E.coli* and *C. jejuni* was monitored in a simulated domestic kitchen environment while food preparation was filmed ($n = 60$ respondents). A survey was also administered.

Findings – The results of the study show that transfer of bacteria around the kitchen environment and onto prepared meals are predicted by a lack of thoroughly washing contaminated hands, knives and chopping boards both during and after meal preparation. A higher level of perceived importance of correct food handling behaviour is associated with higher levels of educational attainment and age and food risk perceptions are positively associated with age.

Practical implications – The results highlight the importance of promoting preventative measures and the means of employing them specifically to the young and less educated public who do not frequently cook and prepare food.

Originality/value – This paper is the first to include a verifiable audit of consumer food safety behaviour, microbiological sampling of surfaces, food and hands as well as a consumer survey of knowledge, behaviour and attitudes.

Keywords Food safety, Contamination, Individual behaviour, Consumers

Paper type Research paper

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1. Introduction

Foodborne illness causes substantial morbidity and economic loss on the island of Ireland. A population study published in 2003 estimated that there were 3.2 million episodes of acute gastroenteritis per year which corresponds to 8,080 new cases per day. With an average duration of illness of four days, this means that 35,000 people were ill each day. Despite the fact that 29 per cent of these people sought medical care, fewer than 6,000 clinical notifications of infectious gastroenteritis or foodborne diseases were translated into routine statistics (safefood, 2003).

In line with many western countries, *Campylobacter* is the most common cause of laboratory confirmed bacterial gastrointestinal disease in both the Republic of Ireland (ROI) and Northern Ireland (NI). Between 1999 and 2006 over 20,000 laboratory-confirmed cases were reported in the two jurisdictions, giving a mean incidence rate of 47 per 100,000 population per year and representing about two thirds of all acute reported gastroenteritis. It has been reported that consumption of chicken, lettuce and food from takeaways accounts for the majority of Campylobacter infections in the island of Ireland, both ROI and NI but that further efforts are needed to identify the defective points in the food chain and enable appropriate measures to reduce the overall burden of this infection in the Irish community (Danis *et al.*, 2009). The available surveillance data for *Escherichia coli* pertain only to VTEC O157. In 2002, the total number of VTEC O157 confirmed cases notified in Ireland (all-island) was 95, giving an incidence rate of 1.7 per 100,000 population (safefood, 2002). This incidence rate for VTEC O157 was higher on the island of Ireland than the corresponding rate in England or Wales but lower than the rate in Scotland. The number of VTEC O157 cases has been increasing, with 135, 80, 174, 200, 169 confirmed cases notified in the years 2003-2007, respectively (Communicable Disease Surveillance Centre – Northern Ireland, 2010).

Information from investigated food-borne outbreaks in the European Union Member States is collected based on the Directive 2003/99/EC. In 2007, 22 European Member States and two other European countries submitted information on food-borne outbreaks to the European Food Safety Authority (EFSA) in accordance with this Regulation. According to the subsequent report, the most common setting of exposure for verified outbreaks was the private household (37.0 per cent), followed by restaurants and cafés (28.6 per cent) (EFSA, 2009). General outbreaks of infectious intestinal diseases linked with private residences in England and Wales were previously investigated, the most common food hygiene faults linked to outbreaks of food poisoning in England and Wales were: inappropriate storage (39 per cent), inadequate cooking (31 per cent) and cross-contamination (20 per cent). Similar data on the domestic food preparation/cooking faults leading to foodborne illness not available for Northern Ireland or the Republic of Ireland. However, several studies have also shown that cross contamination is an important source of food borne illness in the home on the island of Ireland (Kennedy *et al.*, 2005a), in the Republic of Ireland (Gorman *et al.*, 2002) and countries (Kusumaningrum *et al.*, 2003; Fischer *et al.*, 2007). Furthermore, cross contamination has been shown to be the main contributing factor to food borne illness (32 per cent) in outbreaks investigated in the period 1999-2000 (WHO, 2003). Similarly, the US Centers for Disease Control and Prevention reported that 18 per cent of foodborne diseases caused by bacteria in the years 1993-1997 in the USA were associated with contaminated equipment (CDC, 2000).

Since the 1960s several outbreaks of gastroenteritis associated with contaminated surfaces have been described (Sanborn, 1963). Indeed, pathogens have been shown to spread by cross-contamination throughout the domestic kitchen, e.g. onto knives, cutting boards, work-tops, draining boards, sinks and dish cloths in a variety a studies since then (Kennedy *et al.*, 2005a; Kusumaningrum *et al.*, 2003; Gorman *et al.*, 2002; Hilton and Austin, 2000; Boer and Hahne, 1990). This can lead to many cases of food borne illness (Beumer *et al.*, 1999). These bacteria can also contaminate hands (Chen *et al.*, 2001) and it has been suggested that kitchen surfaces and hands may contaminate each other in a cyclical pattern (Rusin *et al.*, 1998).

However, there is a lack of information about the determinants of cross-contamination during domestic food preparation. Specifically, more data are required on the relative contributions of each of consumer attitudes, perceptions, knowledge, demographics and food preparation skills. A Eurobarometer survey found that people do not differentiate greatly between various types of food related risks (Eurobarometer, 2006). However, they were found to be mostly worried about external factors over which they have no control (such as contamination of food by bacteria and unhygienic conditions outside home) and less concerned about factors linked to their own behaviour (such as food preparation at home). Asking consumers how they prepare food is not enough. Previous research has indicated that there is a divergence between what people say about their behaviours and how they actually behave (Kennedy *et al.*, 2005b). When asked about their behaviour, study participants may have imperfect memory or selective recollection of the many occasions during which they prepared food, with occasions that presented a threat and in which the participant engaged in safe behaviour more likely to be recalled (Levy and Anderson, 2008), a phenomenon that leads to bias in self-reports (Wilson and Brekke, 1994). We argue that the psychosocial emphasis in this current study is appropriate in light of considerations of how public health interventions are designed to yield changes in people's food safety behaviours. Within public health, there has been a shift towards accessing people's psychological content in order to better understand their behaviour. Such research has produced a significant body of knowledge in how to design investigations that measure each of knowledge, attitudes and behaviours (KAB), now typical in tracking and explaining health behaviours (Layte *et al.*, 2006). We estimate that a KAB approach may thus be applied to food safety behaviours as a subset of health behaviour generally. First gaps in people's knowledge of food safety behaviours may well predict unsafe procedures as they do not know which actions to take and which not to take. Second, a comparative heedlessness in perceived risk or vulnerability is also likely to be predictive of unsafe food behaviours, as the person is logically less inclined to take precautions. In addition, their perceived utility or value of safe food behaviours is also likely to be indicative of what behaviours they regularly perform in the kitchen. Finally, the recording of a person's behaviour in real time allows one to minimise the problem of erroneous self-reporting, a common factor when asking people to describe their behaviour (Tourangeau *et al.*, 2000).

In this study, in accordance with recommendations from several researchers including Fischer *et al.* (2005), a transdisciplinary approach was taken. An audit of consumer food safety behaviours was conducted during food preparation sessions and verified by webcam footage. The audit employed in the current study is a modified version of other observational food safety behaviour studies (Maurer *et al.*, 2006; Worsfold and Griffith, 1995). Microbiological contamination on five surfaces in the kitchen environment as well as hands and final prepared meals provided evidence for the efficacy of food handling behaviours. Finally, an extensive quantitative survey was conducted which measured participants' food risk perception, food safety knowledge, and perceived importance of correct food handling behaviours in the prevention of food-borne illness was conducted.

This study aims to determine the potential for the spread of bacteria from raw meat and poultry during food preparation to the surrounding kitchen environment, hands and prepared food due to unsafe handling practices, which are predicted by consumers' food risk perceptions, food safety knowledge and their perceived importance of correct food handling behaviour in the prevention of food borne disease. No previous studies have statistically linked observed and verifiable consumer behaviour with microbiological data and quantitative survey data to provide statistical evidence of the previously suspected routes of contamination. The most comparable is a study by Fischer *et al.* (2007) where interviews (to assess food safety knowledge), observations of consumers preparing a recipe, and microbiological data from finished prepared meals were compared. This current study is only one component of a larger study with an overall objective of identifying the most appropriate campaign for the promotion of safe food handling in the home. Thus the purpose of this paper is to highlight suspected transfer routes and identify likely associated behaviours.

2. Methods

2.1 Sample recruitment

Amarach, a marketing research company recruited a quota control sample of 60 food shoppers in Ireland. The criteria employed in the quota control was age and gender. The participants were recruited in urban areas (shopping centres (in Dublin ($n = 15$), Belfast ($n = 15$)) and in rural areas (food shops in Kilkenny ($n = 15$) and Newry ($n = 15$)). These participates were invited, four at any given time, to a demonstration kitchen where they were each allocated a separate workstation. Ethical approval was granted including approval for members of the public to handle food that had been inoculated with naturally occurring *Escherichia coli* and *Camylobacter jejuni* on the basis that the following safeguards were in place: participants were instructed not to consume any of the food they handled either during or after food preparation; participants were not permitted to take away any of the food prepared and were required to present the finished dishes to the researchers; two researchers observed each participant for the duration of the trial food preparation to ensure that no food was consumed and finally, participants were required to thoroughly wash their hands with warm soapy water once swabs had been taken from their hands post-food preparation and before they left the premises. The management of the catering college requested that all study participants wore safety shoes for insurance purposes. As the sessions were to reflect the domestic food preparation process as far as possible, participants were not requested to wear white coats, hair nets and gloves.

2.2 Observations and audits

Test kitchens were located in a hospitality training and catering college. Four separate workstations were set up each for each session. Each workstation comprised a measured worktop space (100 × 50 cm) clearly marked out by the researcher using blue adhesive tape, sink area and draining board, taps and the following inventory: washing up liquid, standard bar of soap, hand towel, paper towels, one tea towel, one disposable fine-weave dish cloth (J-cloth™), one chopping board, one preparation bowl, one small mixing bowl, one colander, one fish slice/spatula, one large knife, one tablespoon, one teaspoon, one serving plate and one frying pan.

The worktop areas, chopping boards, knives, taps, sink drainers and refrigerator handles were cleaned with 90 per cent ethanol and swabbed before the participants entered the kitchens for the purpose of sterilising all kitchen surfaces prior to food preparation and cooking and to ensure that no bacteria were present on surfaces that would have the potential to distort the microbiological results of the study. Each participant was instructed to use only the utensils present in their workstation and to retrieve foods from the refrigerator designated to them.

Recipes for homemade beef burgers and a hot chicken salad were provided for participants. These recipes were chosen because they involve; handling of raw meats, require thorough cooking, require handling and preparing raw salad vegetables; combining cooked and uncooked foods as well as using various utensils, surfaces and equipment. Similar criteria for recipe selection have been employed in previous studies of food safety involving participant food preparation (Maurer *et al.*, 2006; Fischer *et al.*, 2007). All recipe ingredients were provided for participants placed in a separate refrigerator designated for each workstation. Each recipe sheet included instructions for the handling and preparation of the food. Participants were required to present the dishes to the researcher as soon as it was served.

A structured audit checklist was used by the researchers to record food safety behaviours during the food preparation session. Participants were also filmed for the duration of the session via two webcams which were positioned above each designated work station (one pointed at the sink and one pointed at the preparation area and cooker). All webcam footage ($n = 60$) was reviewed by two researchers and each completed audit check-list was verified by the footage. Blank screen savers were set to activate after three minutes in order to prevent participants from seeing the recordings during food preparation. The resulting footage was used to independently verify audit observations by two researchers. Current guidelines from *safe*food, the all-island food safety promotion agency on the island of Ireland were used to determine correct food handling behaviours (s*afe*food™).

2.3 Microbiological sampling

The chicken and minced beef portions to be used by the participants were inoculated with *C. jejuni* and *E. coli,* respectively. Both meat sample types (minced beef and chicken breast) were bulk purchased, the required portion size for each meat type was aseptically determined, and the portions placed into commercially available freezer bags. All meat portions were then stored at -20°C until required. As required the frozen meat portions were thawed at 5°C overnight, prior to inoculation on the morning of the study. Prior to inoculation, samples of skinless chicken breasts and minced beef were tested for the presence and incidence of *C. jejuni* and *E. coli.* All the skinless chicken breasts were negative for *C. jejuni. E. coli* was present in the minced beef so the *E. coli* strain used in the inoculation was marked with a fluorescent green protein. The *E. coli and C. jejuni* strains used in the inoculae were previously isolated from food.

Cells from a 24 hr broth culture of *E. coli* and a 48 hr broth culture of *C. jejuni* were harvested by centrifugation (8,000 $\times$ g for 10 min) and washed twice in sterile one quarter strength Ringers solution (Ringers; Oxoid, Basingstoke, UK). The washed cells were re-suspended in Ringers solution to form standard inoculae with O.D at 600 nm of 0.1, which equates to approximately 10^8 CFU/ml. These standard inoculae were further diluted using standard decimal dilutions to give final working concentrations of 10^7 *E. coli* CFU/ml and 10^3 *C. jejuni* CFU/ml. The concentrations of the working inoculae were confirmed using standard decimal serial dilution methods. For the chicken breasts, a

1 ml volume of 10^3 inoculum was spread over the surface of each chicken breast (weight approximately 150 g) resulting in a final concentration of approximately 10^1 CFU/g. For the minced beef, a 1 ml volume of 10^7 inoculum was added to 300 g minced beef resulting in a final concentration of approximately 10^5 CFU/g.

Sponge swabs (Cosmosbiomedical™) 10 cm^2 provided in neutralizing buffer in a sterile stomacher bag were used to aseptically take samples (using the inverted bag technique (Lasta *et al.*, 1992)) before an after food preparation from: worktops (100 cm × 50 cm), chopping boards (polypropylene approx 30 cm × 25 cm), knife blades (stainless steel), refrigerator door handles, sink drainers (50 cm × 50 cm) and sinks, taps, as well as from participants hands after food preparation, cooked chicken, cooked burger, lettuce from chicken salad and tomato from burger (25 g of each) following completion of the two dishes.

Swabs and samples were stored at 4°C until reaching the laboratory (within 12 h of testing). The swabs and food samples were diluted in a 1:10 ratio with maximum recovery diluent (MRD; Oxoid) and homogenised using a stomacher (Daigger ™) for 2 min. A 2 ml volume of the resulting suspensions were added to 18 ml of Preston selective enrichment broth (PSEB; Oxoid) and buffered peptone water (BPW; Oxoid). The enrichment broths were incubated microaerobically at 37°C for 24 h. The enriched suspensions were spread plated (100 μl) of onto either Preston agar or Chromocult® TXB (Merek; Darmstadt, Germany). Preston agar plates incubated microaerobically at 37°C for 48 h and the Chromocult® TXB was incubated for 24 h at 37°C. Growth on Preston agar plates was Gram stained, and tested for presence of *Campylobacter spp* using *Campylobacter* latex kit (Oxoid). *E. coli* were identified by typical colony colouration on Chromocult® TXB (blue). Presumptive colonies were confirmed as *E. coli* by API 32E (BioMérieux, Marcy l'Etoile, France). Swabs and food samples were enriched to detect presence (or absence) of bacteria rather than enumerated to minimise the number of false negatives (in the case of very low numbers of cells).

All batches of media passed quality control using PSEB, Agar: using wild type *Campylobacter* (CK4, University College Dublin, Ireland) and Chromocult, BPW: using *E. coli* NCTC 1093. All procedures passed quality control using *Campylobacter* (CK4); *E. coli* (NCTC 1093) applied to Cosmosbiomedical™ sterile environmental sampling swabs, retained at 4°C for 12 hr, then processed as above. *C. jejuni* and *E. coli* were both detected on selective agar plates following selective enrichment.

All data collectors were trained at the same time in: microbiological data collection involving the required swabbing and storage methods (inverted bag technique); and an audit observation and the identification of all behaviours outlined in the pre-structured check-list.

2.4 Survey of risk perception, food safety knowledge and perceived importance of correct food safety behaviours in the prevention of food borne disease

The survey was a self-administered paper survey comprising questions on food safety knowledge, perceived risk of contracting food poisoning in situational vignettes, and perceived importance of safe food behaviour in the prevention of food poisoning. A third-person form for the vignettes was used in order to reduce the likelihood of managed responding (see Schwarz and Oyserman, 2001). The third person technique allows the investigator to probe potentially sensitive issues less invasively, thus increasing the likelihood of more accurate responses.

2.5 Data analysis

Scores for cross-contamination were constructed based on the presence or absence of *E. coli* and/or *C. jejuni* in 11 areas (worktops, chopping boards, knives, refrigerator door handles, sink drainers, sinks, taps, hands cooked chicken, cooked burger, lettuce from chicken salad, lettuce from burger (25 g of each). Possible scores ranged from 0-22; 0 indicating no contamination and 22 indicating contamination of all surfaces, utensils, hands and food samples tested.

Participants' perceived risk of contracting food poisoning was measured by their response to nine situational vignettes (see Table I). For the purpose of analysis a 36 point "Risk" scale of was constructed (ranging from 9 to 45); using these nine items (Cronbach Alpha 0.89); 9 indicating an extremely low level of perceived risk and 45 indicating an extremely high level of perceived risk. Furthermore, the Cronbach alpha level of the risk perception scale (and the importance scale) indicated that all sub-scale items were highly correlated with one another thus indicating the internal consistency of the scale which measures the risk associated with everyday situations of food handling, storage, preparation, cooking and consumption.

Participants' food safety knowledge was measured by their responses to nine food safety questions on a scale of 1 to 10; 1 indicating poor food safety knowledge and 10 indicating good food safety knowledge.

The participants' perceived importance of correct food safety practices in the prevention of food poisoning was measured by their responses to nine questions about the perceived importance of various food handling practices. For the purpose of analysis a 36 point scale (ranging from 9 to 45) "Importance of correct food safety practices" was developed using these nine items (Cronbach's alpha = 0.74).

3. Results

3.1 Sample recruitment

The demographic profiles and reported cooking skills of the participants are shown in Table II.

3.2 Observations and audits

In the audit of food safety practices, a large majority of the participants (89.7 per cent) reported that the manner in which they prepared and cooked the food during the study was reflective of their food preparation and cooking behaviour when at home. The

Table I. Respondents and standard deviation (SD) of the importance of some correct food handling practices in the prevention of food borne disease

Food safety behaviour	Mean	SD
Correctly checking that beef burgers and poultry are sufficiently cooked	1.03	0.26
Washing your hands before preparing food	1.05	0.22
Storing leftover meat/poultry correctly	1.08	0.34
Making sure that bacteria are not spread from uncooked/raw food to kitchen surfaces and utensils	1.10	0.44
Using food by its use-by date	1.15	0.36
Storing raw meat on the correct shelf in the refrigerator	1.18	0.56
Making sure your refrigerator is operating at the correct temperature	1.22	0.52
Making sure that the restaurant you are going to eat in looks clean	1.22	0.5
Transporting chilled/frozen food home from the supermarket	1.25	0.5

Notes: $n = 60$; mean ranking (1 = very important, 5 = very unimportant

Participant demographics	Percentage	*n*
Gender		
Male	23.3	14
Female	76.7	46
Age		
18-24	4.1	2
25-34	24.5	12
35-44	24.5	12
45-64	36.7	18
65 and over	10.2	5
Educational attainment		
No education level completed	1.7	1
Primary level	10.0	6
Secondary level (partially completed)	15.0	9
Secondary level	35.0	21
Diploma	3.3	2
Degree	10.0	6
Postgraduate	5.0	3
Professional qualification	1.7	1
Specific/special diet followed (yes)	36.7	22
Frequency of own cooking		
Always	55.2	32
Quite often	34.5	20
Some of the time	10.3	6
Frequency of own grocery shopping		
Always	85.0	51
Quite often	13.3	8
Perceived own cooking skill		
Very good	19.0	11
Good	34.5	20
Neither good nor bad	44.8	26
Poor	1.7	1
Time typically spent on main meal preparation		
Less than 30 minutes	16.4	9
31 to 60 minutes	74.5	41
61 to 90 minutes	3.6	2
More than 90 minutes	3.6	2

Table II. Socio-demographic profile among participants of the study and their reported involvement in food shopping and preparation

percentage of participants who prepared food in the audit in a way that opposed general recommendations (*safe*food) are represented in Table III.

3.2.1 Audit during beef burger preparation. Raw beef was handled directly by 27.1 per cent of participants, 53.3 per cent of whom either did not wash their hands or rinsed them in water only after handling it. When forming the burger patties, 38.3 per cent of participants handled the raw mince, 66.7 per cent of whom did not wash their hands or rinsed them in water only, after doing so. When transferring the beef burgers to the frying pan, 67.8 per cent of participants used their hands, 70.2 per cent of whom did not wash their hands or rinsed them in water only after handling the raw beef.

Table III. Unsafe food handling/preparation practices during the audit observation

Unsafe food handling practices	Participants Beefburgers *n*	Percentage	Chicken salad *n*	Percentage
Meat preparation				
Hands not thoroughly washed before handling raw meat	14	23.3	51	85.0
Hands not thoroughly washed after handling raw meat during food preparation	40	66.7	50	83.3
Contaminated hands used on taps	50	89.3	51	94.4
Contaminated hands placed in flour	29	42.9	n/a	
Contaminated hands used to open other food packaging, e.g. olive oil	18	31.0	16	29.6
Contaminated hands came in contact with other cooking utensils, e.g. frying pan handle	27	50.9	37	66.1
Knife used in raw meat preparation not thoroughly washed prior to use with raw salad vegetables	35	57.3	38	69.1
Chopping board used for raw meat preparation no thoroughly washed prior to use with raw salad vegetables	31	54.4	29	51.8
Correct methods not employed to ensure meat was thoroughly cooked	60	100	60	100
Salad preparation				
Salad vegetables not washed	15	25.4	22	37.9
Chopped raw vegetables for salad on board contaminated with raw meat	20	34.5	31	54.4
Interim cleaning (post beef preparation and pre chicken preparation				
Chopping board not thoroughly washed	18	29.8	n/a	
Mixing bowl not thoroughly washed	21	38.2	n/a	
Knife not thoroughly washed	17	27.1	n/a	
Spatula/fish slice not thoroughly washed	25	44.6	n/a	
Kitchen surfaces not thoroughly washed	55	96.2	n/a	

Of the methods employed to determine that the beef burger was cooked thoroughly, 30 per cent of the participants employed the recommended methods of: cutting into it to check that the juices run clear, that the burger was piping hot all the way through and that there was no pink meat left (safefood, 2006). A further 6.6 per cent of participants checked the burger by either prodding it or touching it. On visual inspection of the beef burgers by the researcher, the meat was still pink in the middle in 30.4 per cent of the cases.

3.2.2 Audit during chicken salad preparation. Prior to the preparation of a hot chicken salad, a majority of participants (69.6 per cent) did not wash their hands while 16.1 per cent rinsed their hands with water only. After the preparation of the raw chicken and prior to its use in the preparation of the raw salad vegetables, 41.1 per cent of participants washed the chopping board thoroughly with warm water and washing up liquid.

After preparation of the raw chicken and prior to its use in the preparation of the raw salad vegetables, approximately only one-third of participants (29.1 per cent) washed the contaminated knife thoroughly with washing up liquid. Almost half of the participants rinsed the contaminated knife with water only and 20 per cent of participants did not wash the contaminated knife at all. A total of 37.9 per cent of participants did not wash the raw salad vegetables for the hot chicken salad, a small proportion (13.6 per cent) washed the pepper only or the tomato only (6.9 per cent).

In order to determine that the chicken for the hot chicken salad was cooked thoroughly, over one-fifth (21.8 per cent) cut the chicken with a knife and looked at the internal colour of the chicken. A small proportion of the participants prodded the chicken (3.6 per cent) or touched the surface of the chicken with their hands (5.5 per cent) (see Table III).

3.2.3 Correlations between food handling practice and microbiological results. Failure to thoroughly clean chopping boards, contaminated through contact with raw chicken, prior to their reuse in the preparation of raw salad vegetables was significantly correlated with the presence of *C. jejuni* in samples of salad, $r = 0.269$, $n = 57$, $p < 0.05$ from the hot chicken salad. Failure to thoroughly clean chopping boards, which were contaminated through contact with raw beef was associated with the presence of *E. coli* on chopping boards after food preparation, $r = 0.279$, $n = 53$, $p < 0.05$. Failure to clean knives after beef burger preparation was associated with the presence of *E. coli* on knives after chicken preparation, $r = 414$, $n = 43$, $p < 0.01$. The presence of *C. jejuni* on participants' hands after food preparation was associated with the presence of *C. jejuni* in samples of chicken salad, $r = 0.360$, $n = 60$, $p < 0.01$.

Failure to thoroughly wash hands after handling raw chicken was associated with the presence of *C. jejuni* on refrigerator handles after food preparation, r=0.332, $n = 60$, $p < 0.01$ and on the presence of *C. jejuni* on knives after food preparation, r=0.360, $n = 60$, $p < 0.01$.

Failure to thoroughly wash hands after handling raw mince when transferring the raw burgers to the pan was associated with the presence of *C. jejuni* on worktops after food preparation, $r = 0.441$, $n = 60$, $p < 0.001$, the presence of *E. coli* in samples of the chicken salad, $r = 0.312$, $n = 52$, $p < 0.05$, on knives $r = 0.499$, $n = 52$, $p < 0.001$ and on taps, $r = 0.318$, $n = 52$, $p < 0.05$.

Failure to thoroughly wash hands after handling raw beef when transferring the raw burgers to the pan was associated with higher contamination scores after food preparation, $r = 0.400$, $n = 52$, $p < 0.05$.

3.3 Microbiological sampling

Figure 1 shows the incidence of each both *C. jejuni* and *E. coli* on each surface, utensils and hands after food preparation. The incidence of *E. coli* on all areas tested was higher than that of *C. jejuni*. The highest incidence of both *C. jejuni* and *E. coli* was on sink drainers (15.0 per cent and 58.3 per cent, respectively).

After cooking, *E. coli* was found in over one third of the beef salad samples (35.0 per cent) and in almost one-third of the beef burger samples (31.7 per cent). *E. coli* was also found in 16.7 per cent of the chicken salad samples and in 6.7 per cent of the chicken samples. *C. jejuni* was found in 13.3 per cent of the chicken salad samples and 13.3 per cent of the chicken samples. There was no *C. jejuni* found in either the beef sample or the beef salad sample.

After the food preparation, *E. coli* was present on 26.7 per cent of participants' hands and *C. jejuni* was present on 5.0 per cent of hands. The mean score for cross-contamination (from 0-22) was 4 ± 9.55.

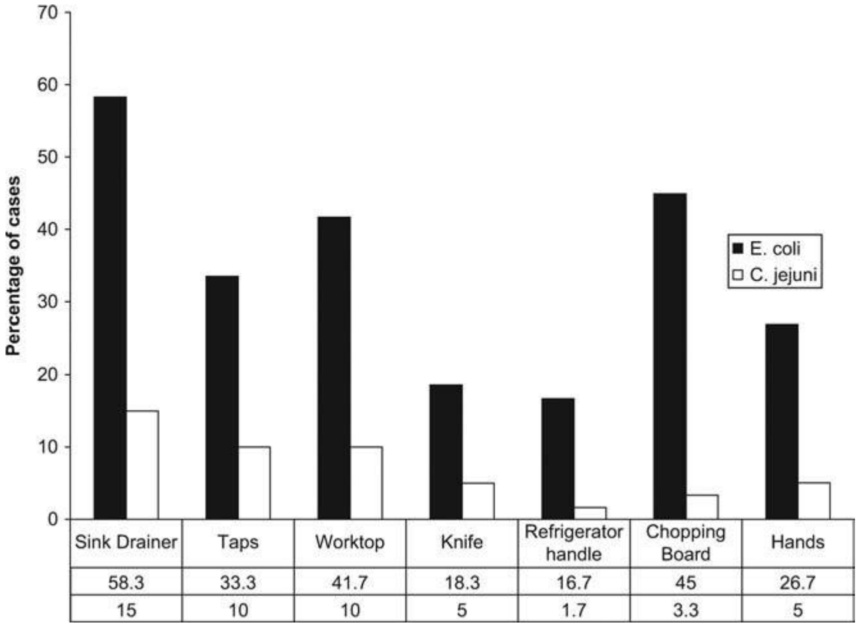

Figure 1.
Incidence (%) of *E. coli* and *C. jejuni* on kitchen surfaces and hands after food preparation and cooking

3.4 Survey of food safety knowledge, risk perception, and perceived importance of correct food safety behaviours in the prevention of food borne disease

3.4.1 Food safety knowledge. Food safety knowledge scores ranged from one to eight, the average scores was 4.03 ± 1.65 and the model score was 3 indicating that overall, participants had a poor knowledge of food safety issues. A positive significant relationship between food safety knowledge and the frequency with which one does their own cooking was observed, $r = -0.312$, $n = 58$, $p < 0.05$.

The most common cause of food borne illness on the island of Ireland is *Campylobacter*, identified by only 1.9 per cent of participants. The majority (56.6 per cent) of participants incorrectly reported *Salmonella* as the most common cause of food borne illness, followed by *E. coli* (35.8 per cent) and *Listeria* (5.7 per cent). Over half of the participants (53.8 per cent) correctly identified chicken as the food most commonly linked with *Salmonella*, followed by 44.2 per cent of participants who identified eggs, and a small minority identified pork (1.9 per cent).

The majority of participants (56.1 per cent) reported that contracting food borne illness "at home", at a "fast food outlet" and at a "restaurant" are all equally likely, followed by 19.3 per cent who identified "fast food outlet", 12.3 per cent who identified at a "restaurant", 10 per cent who identified "at home", and 1.8 per cent who reported in a "work/college canteen".

The food most commonly linked with *E. coli* is beef, which was correctly identified by the majority of participants (30.8 per cent). One-quarter (25 per cent) identified chicken followed by eggs (17.3 per cent) and dairy products (13.5 per cent) salads (7.7 per cent) and pork (5.8 per cent) were also identified by participants as the food most commonly linked with *E. coli*.

Almost one-quarter (24.1 per cent) of participants correctly identified the temperature zone of 5-63°C as the temperature "danger zone" within which food poisoning bacteria can multiply. This was followed by 22.8 per cent of participants who identified 25-40°C, 21.1 per cent who identified 63-100°C, 12.3 per cent who identified 0-100°C and 1.8 per cent who identified 0-5°C.

Almost half of the participants (49.1 per cent) correctly identified "using the same chopping board for raw meat and salad" as the food preparation/storage practice most likely to result in food borne illness. Over one-quarter of participants (28.3 per cent) identified "using the same chopping board for different types of raw meat" and 13.2 per cent of participants who identified "keeping raw meats beside each other in the refrigerator". A further 9.4 per cent of participants reported "keeping cooked meats beside raw vegetables in the refrigerator" as the food preparation/storage practice most likely to result in food poisoning.

The majority of participants (59.6 per cent) reported poultry as food which has caused the most food borne illness on the island of Ireland in the last year, followed by 40.4 per cent who reported beef burgers.

3.4.2 Risk perception. When asked to rank 9 situation vignettes in terms of the perceived risk of contracting food borne illness (1 = very likely and 5 = very unlikely), the vignettes which were reportedly the most likely to cause food borne illness was; "Jim prepares food, which is not going to be cooked, on a chopping board and prepares raw meat on the same chopping board" and "Mike is a farmer. When he comes home from work and prepares sandwiches, he often forgets to wash his hands first" both with mean scores of 4.27 (±1.24 and 1.27, respectively) (see Table IV). The overall mean score for perceived risk in the vignettes was 35.61 ± 8.12 indicating that overall, participants tended towards reporting a high level of perceived risk of contracting food borne illness. The relationship between age and perceived risk of food borne illness was investigated using Pearson product-moment correlation coefficient. A moderate,

Situational vignettes	Mean	SD
Jim prepares food, which is not going to be cooked, on a chopping board and prepares raw meat on the same chopping board	4.27	1.24
Mike is a farmer. When he comes home from work and prepares sandwiches, he often forgets to wash his hands first	4.27	1.27
When Julie is barbequing she uses tongs to lift the raw meat and vegetables onto the grill. When the food is fully cooked, she uses the same plate and tongs to bring them to the patio table, where they are eaten within 3 hours	4.20	1.24
Sam keeps raw meat anywhere there is space in the refrigerator	4.17	1.21
Lucy checks that her beef burgers and poultry are sufficient cooked by making sure they have a crisp, brown outer coating	4.02	1.28
Susan does not have a thermometer so she is never sure what temperature the refrigerator is operating at	3.78	1.2
Kate buys discounted food which is on its use-by date, stores it in the refrigerator and eats it within 2 days	3.55	1.46
Susan ate in a restaurant that she later heard had received an "improvement notice" a week previously	3.55	1.18
When Mark goes shopping it usually takes him more than 90 minutes to get the food from the supermarket to home storage	3.43	1.29

Notes: $n = 60$) mean ranking (1 = very unlikely, 5 = very likely

Table IV. Participants and standard deviation (SD) of the perceived risk of contracting food borne illness from various situational vignettes significant relationship was observed, $r = 0.354$, $n = 54$, $p < 0.05$ whereby higher perceived risk of food borne illness was associated with being older.

3.4.3 Perceived levels of importance of correct food safety practices in the prevention of food borne disease. A perceived level of importance of correct food safety practices in the prevention of food borne illness were measured by asking participants to rank the level of importance of nine everyday food handling practices in the prevention of food borne illness (see Table I). The highest level of importance was attributed to "correctly checking that beef burgers and poultry are sufficiently cooked" (mean score 1.03 ± 0.26). "Transporting chilled/frozen food home from the supermarket" was ranked lowest with a mean score of 1.25 ± 0.50. The overall mean score was 10.29 ± 2.22 indicating that overall, participants attributed an extremely high level of importance of safe food behaviours in the prevention of food borne illness.

A highly significant positive relationship was observed between the overall importance of correct food safety practices in the prevention of food borne illness and levels of educational attainment ($r = -0.584$, $n = 58$, $p < 0.001$). Similarly, a significant positive relationship was observed between the importance of food safety practices in the prevention of food borne illness and age, $r = 0.305$, $n = 58$, $p < 0.05$. A standard multiple regression using the enter method was performed in order to determine whether the importance of food safety was predicted by age and level of education completed. The model was significant ($F2, 37 = 10.341$, $p < 0.001$) with an adjusted R squared value of 0.324. Age made the largest contribution to the model, and was the only independent variable that made a significant, independent contribution beta -0.613 and $p < 0.001$.

4. Discussion

Transfer of bacteria around the kitchen environment has been shown in previous domestic-based studies (Gorman *et al.*, 2002; Hilton and Austin, 2000; Kennedy *et al.*, 2005a). However, a review of consumers domestic food safety practices in 2004 reported that there was still a lack of research which incorporated verifiable audits of consumer practices which identified the practices that contribute to this transfer of bacteria (Redmond *et al.*, 2004). The present study identified the consumer practices that were previously "suspected". Redmond *et al.* (2004) previously identified contaminated chopping boards and hands as *suspected* routes of cross-contamination based on observed incidences of cross-contamination and subsequent positive results for the presence of *C. jejuni*. These suspected routes of cross-contamination are evidenced in the present study.

The presence of *C. jejuni* in the hot chicken salad significantly correlated with the use of chopping boards which were contaminated from raw chicken and used in the preparation of raw salad vegetables. The presence of *C. jejuni* on participants' hands after food preparation was associated with the presence of campylobacter in samples of hot chicken salad. The absence of thorough washing of contaminated hands and utensils was statistically linked to the presence of both *E.coli* and *C.jejuni* on samples of prepared food. Failure to thoroughly clean knives and chopping boards which were contaminated through contact with both raw chicken and raw beef was significantly correlated with the presence of *E. coli* on chopping boards after food preparation. Furthermore, higher scores for the presence of bacteria on surfaces, hands and food samples after food preparation were correlated with failure to thoroughly wash hands after participants' final instance of handling raw meat.

In addition to verifying the previously suspected route of cross-contamination, a very strong relationship was found between contamination on taps and contamination in the prepared beef burgers. In the preparation of both chicken and beef dishes, the most commonly observed unsafe practice was the use of contaminated hands on taps followed by the failure of over half of the participants to thoroughly wash their hands after handling both raw meats. As hands are the intermediary between taps use and the prepared food, the results suggest that taps are an important source of cross-contamination. Gorman *et al.* (2002) evaluated the cross contamination events that occurred during domestic preparation of chicken naturally contaminated with *Salmonella* spp., *Campylobacter* spp., *E. coli* and *Staphylococcus* aureus. Results showed that the drain was the most frequently contaminated site. This is particularly important where raw vegetables may be washed in a contaminated area and indicates the necessity of regularly cleaning sink and drain areas.

In this present study, when handling meat more than once it was observed that there was an increase in the level of microbial contamination on hands. Similarly, in other studies failure to clean during the food preparation process has been shown to be associated with the further transfer of bacteria and, importantly, its presence after cooking in ready-to-eat food (Beumer *et al.*, 1999). Thus due to the relative ease and speed with which hands can become re-contaminated it has been suggested that the effectiveness of hygiene procedures in the home is heavily dependent on how and when these procedures are applied and suggest that they should be applied for a specific purpose rather than as part of a routine cleaning process (Beumer *et al.*, 1999).

Practice-specific risk perceptions have previously been found to be the primary cognitive antecedents of safe food behaviours (Levy *et al.*, 2008). Vignettes are being increasingly used as a way of getting participants to answer questions in an indirect way, thus lessening the likelihood of managed responding. Such managed responding results in people often reporting that they carry out the correct or desirable behaviours more frequently than they in fact do. In this study, when participants were asked about various scenarios involving potential food safety risks, they tended towards risk adversity. However in the vignette, "when Julie is barbequing she uses tongs to lift the raw meat and vegetables onto the grill. When the food is fully cooked, she uses the same plate and tongs to bring them to the patio table, where they are eaten within 3 hours", the majority of participants reported that her risk of getting food poisoning was "very unlikely". *safe*food has concentrated its summer campaigns on barbequing, stressing risks associated with inadequate cooking and cross contamination. These results would suggest that there is still a lack of understanding on the risks of cross-contamination during barbequing. Vulnerability to such hazards should be more personalised to domestic food preparers rather than population-wide (Wilcock *et al.*, 2004) as it has been suggested that where information is communicated to the general population, people will infer their own level of risk and due to the effects of optimistic bias, there is likely to be a discrepancy between peoples perceived risk and their actual risk status (Frewer *et al.*, 1994; Wilcock *et al.*, 2004).

Regarding the question on importance of various food related behaviours in the prevention of food borne illness, two behaviours were reported as being "not really important"; "storing raw meat on the correct shelf in the refrigerator" and "making sure that bacteria are not spread from uncooked/raw food to kitchen surfaces and utensils". However these behaviours relate to handling of raw meat, shown to be poorly performed during food preparation and cross-contamination, which was observed with a high frequency during food preparation. Perceived importance of correct food handling practices in the prevention of food borne illness on a Likert scale has been included in a study by Fischer *et al.* (2007), but the small sample size reportedly may have masked a possible relationship between this perceived importance and food safety behaviours.

It is assumed that consumers' knowledge of food safety is an important determinant of consumer behaviour (Fischer *et al.*, 2007). A previous study which segmented consumers based on their food safety knowledge found that those who are less knowledgeable in terms of safe cooking practices, prevention of cross-contamination and unfamiliar bacteria (such as *Staphylococcus aureus, Clostridium perfringens* and *Campylobacter*) were more likely to have higher microbiological counts in their refrigerators (Kennedy *et al.*, 2005b). Conversely, this study did not find a link between food safety knowledge and food handling practice. The specific areas of least food safety knowledge concerned correct chilled food storage temperature, which was also found in a study by Worsfold *et al.* (2004), and awareness of *Campylobacter* which was also found more than a decade ago by Fife-Shaw and Rowe (1996). Similarly to this study, other studies have shown that self-reported food safety knowledge is high, however a knowledge deficit in relation to microbiological hazards associated with food handling was also identified (Bruhn and Schutz, 1999) this latter phenomenon may be explained by the notion of self-efficacy and optimistic bias (Miles *et al.*, 1999; Wilcock *et al.*, 2004) insofar as the participants believed that they were sufficiently knowledgeable to understand the risks but less at risk from the hazards compared to others.

Observed food safety practices (as indicated by the audit scores) were not statistically linked to the perceived risk of contracting food borne illness from various food handling behaviours, the perceived importance of safe food practices in the prevention of food poisoning illness or food safety knowledge. A higher level of perceived importance of correct food handling behaviour was associated with higher levels of educational attainment and age. Food risk perceptions were positively associated with age. Previous studies, have shown that age and educational attainment are associated with levels of food safety knowledge and attitudes (Altekruse *et al.*, 1999; Kennedy *et al.*, 2005b). Unlike other studies, this study found that higher frequency of cooking was associated with higher food safety knowledge scores. These findings suggest that habitual behaviour has a role to play in safe food preparation and cooking. This has implications for future generations who, if the trend continues, will be less likely to cook and prepare meals in the home. As previously pointed out by Danis *et al.* (2009) it is essential to raise awareness in the population of the importance of good basic food-hygiene practices, using means of communication easily and readily accessible.

This study forms one component of a larger study aimed to identify transfer routes and predictors of transfer via participant behaviours. Results are not interpreted as reflective of the population but rather form the basis of the second component of the study which investigates predictors of behaviours which have now been statistically linked to the transfer of bacteria in the domestic environment.

The results should be interpreted within the context of the study design. The intensive level of data collection resulted in a sample size of 60. The 60 participants were selected based on a quota controlled sample and were not representative of the population of Ireland. Furthermore, although the researchers were unobtrusive in the kitchens, their presence and the presence of the webcams may have resulted in less habitual behaviour. However, if this study reflected the "best case scenario" for home food preparation because consumers were engaging in more cautious efforts due to reactivity, also known as the Hawthorne effect (Roethlisberger *et al.*, 1939), on the basis of being observed, then the case for food safety promotion is only strengthened.

5. Conclusion

The results of this study show that transfer of bacteria around the kitchen environment and onto prepared meals are predicted by a lack of thoroughly washing contaminated hands, knives and chopping boards both after and during the process of meal preparation. "Perceived risk of contracting food borne illness from various food handling behaviours", "perceived importance of safe food practices in the prevention of food poisoning illness", food safety knowledge, or specific sociodemographic profiles were not linked to better food safety practices. However, a higher level of perceived importance of correct food handling behaviour was associated with higher levels of educational attainment and age and food risk perceptions were positively associated with age. These results highlight the importance of promoting preventative measures and the means of employing them specifically to the young and less educated public who do not frequently cook and prepare food. In particular, because habitual behaviour is formed at an early age, it is important for such a frequent activity as food preparation that safe food practices be included in the primary school curriculum.

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