Epidemiol. Infect. (2002), **129**, 277–285. © 2002 Cambridge University Press
DOI: 10.1017/S0950268802007331 Printed in the United Kingdom

Risk factors for salmonella food poisoning in the domestic kitchen – a case control study

S. M. PARRY[1], S. R. PALMER[1*], J. SLADER[2], T. HUMPHREY[2] AND THE SOUTH EAST WALES INFECTIOUS DISEASE LIAISON GROUP

[1] *Department of Epidemiology, Statistics and Public Health, University of Wales College of Medicine, Heath Park, Cardiff, CF14 4XN*, Tel: 029 20 742321, Fax: 029 20 742898, email: palmersr@cardiff.ac.uk
[2] *Exeter Public Health Laboratory, Church Lane, Heavitree, Exeter, EX2 5AD*

(*Accepted 2 April 2002*)

SUMMARY

Domestic kitchen food handling risk factors for sporadic salmonella food poisoning are largely unknown. We compared food consumption and food handling practices, opportunities for cross contamination and refrigerator temperature control, in 99 households in South East Wales in 1997/8 with a case of salmonella food poisoning, and control households matched for electoral ward. On univariate analyses, cases were significantly more likely than control respondents to have purchased free-range eggs in the preceding week, and more likely than control households to have handled frozen whole chicken in the previous week, and to handle raw chicken portions at least weekly. In multivariate analysis, only consumption of raw eggs and handling free-range eggs were significant risk factors, independent of the age structure of the family and of the season.

INTRODUCTION

Most cases of foodborne infections in the United Kingdom occur sporadically rather than in recognized outbreaks [1, 2]. Food prepared in the home has been considered a likely source for many of these individual cases, although it is seldom possible to identify the vehicles and sources of sporadic infection. A few case control studies of sporadic salmonella infection have been conducted in the United Kingdom, and these have demonstrated associations with eating fresh shell eggs, egg products and pre-cooked hot chicken [3, 4], but surprisingly, not with consumption of chicken generally [3–5]. However, these studies did not clearly distinguish between food prepared at home and food bought out. In a case control study of *S*. Typhimurium DT104, Wall et al. [6] found that consumption of chicken bought from a restaurant or takeaway was associated with an increased risk, but chicken cooked at home had a decreased risk. Sausages cooked at home were not associated with increased risk, but pork sausages from a restaurant or takeaway were. Investigations of outbreaks due to food prepared in domestic kitchens suggests that cross contamination has an important role [7], and the handling of food such as chicken carcasses and eggs has been shown to result in the widespread dissemination of pathogens on kitchen surfaces, utensils and dishcloths [8]. However, the role of cross contamination in the aetiology of sporadic cases is not known. Here we present a case control study of sporadic salmonella cases to identify risk factors in the domestic kitchen.

* Author for Correspondence.

METHODS

Case definition

A person with microbiologically confirmed symptomatic salmonella (any serogroup) infection who was not part of a recognized general outbreak, aged over

1 year, and who had not travelled abroad in the 7 days prior to onset, identified in the South East Wales area (population, 1·3 million) between July 1997 and December 1998.

Case selection

We calculated that 153 cases and controls would be required to detect an odds ratio of two with 95% confidence and 80% power where 30% of controls were exposed. We set a target for each Local Authority by calculating the expected number of cases based on the previous 4 years' experience. Collaborating Local Authorities were asked to provide a random sample of cases from their registers, using a supplied randomly generated list of numbers. Personal contact was made every 1–2 weeks to check on recruitment. However, occurrence of outbreaks and periods of staff shortage meant that collaborators found it difficult always to follow this regime. In order to check whether there was bias in the recruitment of cases we compared study cases with total cases of salmonella food poisoning reported to the PHLS in Wales Communicable Disease Surveillance Centre (CDSC), Cardiff, over the study period by age, sex, location and date of onset.

Data collection

Following informed signed consent, data on usual domestic food consumption and food handling, and actual practices in the 7 days prior to onset of illness, were collected from the main food handler of the household by an Environmental Health Officer (EHO) of the local authority using a standard questionnaire. 'Handling' food items in the kitchen included storage in the refrigerator, defrosting and use for cooking, but did not include putting food unwrapped from purchase in a freezer. In addition a self-administered questionnaire was completed by the main food handler in the presence of the EHO. EHOs recorded observations of the domestic kitchen on a standard proforma. The proforma was developed with EHOs before the study and a training workshop set up to standardize interview and observation techniques.

Controls

Control households, matched for electoral ward, were selected by applying random numbers to the electoral register of the appropriate ward. Only first entries for an address were included to avoid over representation of large households. Controls were approached initially by letter and non-responders were contacted by telephone or by a personal visit. Three attempts were made to contact the first control before a further control was selected. Following signed informed consent, the main food handler of the control household was questioned (as for cases) about food handling in the 7 days prior to interview and in general, and kitchens were inspected. The control sample was compared with census data for the study area for age of household members and household size.

Data analysis

Data were recorded and analysed using Epi Info version 6 (Center for Disease Control and Prevention, USA\WHO Geneva, Switzerland) and Stata (Stata Corporation (1997) Stata Statistical Software: Release 5.0 College Station, TX: Stata Corporation). We tested three hypotheses: (i) potential sources of *Salmonella* spp. were more likely to have been handled in case kitchens; (ii) there were more opportunities for cross contamination in case kitchens; (iii) refrigerator temperature control problems were more likely to be identified in case kitchens. Exposure and rates of isolation of *Salmonella* spp. in case and control kitchens were compared by matched odds ratios and 95% exact confidence intervals and McNemar's χ^2 and 2-tailed exact probabilities. Foods consumed by cases over 15 years old in the 72 h prior to onset (chicken and eggs, cooked and raw/undercooked) were compared with foods consumed by control household interviewees (all over 15 years) in the 72 h, prior to interview. Ethical approval was given by Gwent and Bro Taf Health Authorities' Ethics Committees.

RESULTS

Summary data on cases and controls

All 137 cases approached and 99 of 129 (77%) control households, agreed to participate. The matched analysis was carried out on 99 cases with their controls. Serogroups were available for 93 of the 99 cases, comprising 76 *S.* Enteritidis [phage type 4 (33), phage type 6 (15), phage type 6a (5), phage type 21b (7), untyped (10) and one each of phage types 13a, 14b, 1a, 21, 34a and 5a]. Fourteen of the 99 cases were *S.* Typhimurium DT104 (10), phage type 104b (1), 12

Table 1. *Comparison of case and control households and 1991 Census data for South East Wales*

	Case ($n = 99$)	Control ($n = 99$)	Census (%)
Child under 5 years	20 (20%)	9 (9%)	9·2
Adult over 65 years*	12 (12%)	22 (22%)	22·2
No. of persons in household*			
1	8 (8%)	20 (20%)	20·2
2	33 (33%)	37 (37%)	37·4
3	21 (21%)	19 (19%)	19·2
4	29 (29%)	14 (14%)	14·1
5+	8 (5%)	9 (8%)	9·1
Age of main foodhandler†			
15–34 years	33 (33%)	14 (14%)	N/A
35–44 years	29 (29%)	27 (27%)	N/A
45–54 years	16 (16%)	17 (17%)	N/A
55–64 years	13 (13%)	13 (13%)	N/A
65+ years	8 (8%)	28 (28%)	N/A

* χ^2_4 10·76, $P = 0·03$; † χ^2_4 18·9, $P = 0·0008$.

(1), 49 (1) and untyped (1)]. The remaining serogroups were *S*. Infantis, *S*. Oyonnax, and *S*. Virchow.

Nineteen interviewers participated in the study. The mean delay between onset and interview in cases was 19·4 days (range, 4–58 days; mode, 14 days; median, 16 days), and the period between the case and control interviews averaged 35 days (mode, 7 days; median, 27 days). Consequently, a variable for season (quarter of the year) of interview was included in logistic regression analysis.

Cases in the matched analysis were similar to all cases in South East Wales (and to the original 137 recruited cases) in age and sex distribution, but a higher proportion came from the Cardiff, Vale of Glamorgan and Monmouth areas. 53% of cases in 1997 were recruited from June to August, a period that contributed 26% of cases from the whole recruitment period. Control households were similar to all households in the area in distribution by age of occupants and household size (Table 1).

Comparison of case and control households

In case households the main foodhandler was more likely to be aged 25–34 years (29/99) than in control households (12/99; $P < 0·01$) and less likely to be aged over 65 years (8/99 *v*. 28/99, $P < 0·01$ (Table 1)). Case households were more likely to include a child under 5 years of age (20/99 *v*. 9/99, $P = 0·03$) and less likely to include a household member over 65 years (12/99 *v*. 22/99, $P = 0·0002$) (Table 1). Some kitchen hygiene practices varied by the age structure of the household. Case and control households with a child under 5 years were more likely to defrost foods in the refrigerator and less likely to keep eggs for more than 1 week. Households with a person $\geqslant 65$ were less likely to handle whole chicken weekly than other families. Consequently variables for age of main food handler and the presence of a child under 5 years of age or adult of 65 years or over were included in logistic regression analysis.

Since all controls providing food histories were adults, we compared these with the 74 cases over 15 years of age in an unmatched analysis. Cases (22/74) were significantly more likely to have eaten raw/undercooked eggs than control respondents (9/99) even after stratifying for age group and sex ($P < 0·001$). Cases were not more likely to have eaten any eggs ($P = 0·32$) or any chicken ($P = 0·17$) or undercooked chicken ($P = 0·70$).

Hypotheses 1: Potential food sources of salmonella were more likely to have been handled in case than in control households.

On univariate analyses case households were significantly ($P < 0·05$) more likely to have handled frozen whole chicken in the previous 7 days but not fresh whole chicken, and more likely to usually handle raw chicken portions but not whole chicken weekly (Table 2). Case households were significantly less likely to have handled free-range eggs and more likely to have handled non free-range eggs in the previous 7 days. Twenty-six of 80 (33%) case households that had eggs in the kitchen said they used free-range eggs, compared to 48 of 88 (55%) control households. Just over a third of case and control households who handle free range eggs obtained them from local stores, as opposed to farms (7%), and supermarkets (56%). Of the 80 case households where eggs were present, 56 (70%) had kept them in the fridge, and 9 (11%) had kept them for 3 weeks or longer, compared to 67 (76%) and 8 (11%) control households respectively.

Similar results were obtained when the analysis was restricted to (i) only *S*. Enteritidis cases; (ii) only cases reported in Cardiff, Monmouthshire and the Vale of Glamorgan; (iii) the 35 cases who ate all of their meals in the domestic kitchen in the 72 h prior to onset, and matched controls.

Multivariate analyses was conducted by specifying a conditional logistic regression model including food exposure variables significant in univariate analysis together with the four confounding factors (season, age group of foodhandler, child under 5 years in

Table 2. *Frequency of exposure to potential sources of salmonella in domestic kitchens in paired cases and controls*

	Cases	Controls	Matched odds ratio 95% CI	*P* value
Exposure (7 days prior to onset in cases and interview in controls)				
Handled any raw chicken	52/93	9/99	1·1 (0·75–2·2)	0·40
Handled fresh whole chicken	13/84	14/88	1·3 (0·5–3·5)	0·62
Handled frozen whole chicken	11/83	4/88	5·0 (1·1–22·8)	0·03
Handled any eggs	80/99	88/99	0·6 (0·3–1·2)	0·13
Handled free-range eggs	26/80	48/88	0·4 (0·2–0·8)	0·006
Handled non free-range eggs	48/80	36/88	2·3 (1·27–4·32)	0·002
Handling beef	26/98	35/98	0·7 (0·3–1·3)	0·26
Handling pork	23/98	35/98	0·6 (0·3–1·2)	0·14
Handling lamb	15/98	22/98	0·6 (0·2–1·4)	0·25
Pets in kitchen (observational proforma)	44/99	35/99	1·1 (0·8–2·8)	0·15
Presence of raw milk	4/99	4/99	1·0 (0·3–3·7)	1·0
Usual practice				
Keeping eggs for more than 3 weeks	9/80	8/88	1·1 (0·4–3·4)	0·81
Handled raw whole chicken weekly or more	20/99	15/99	1·6 (0·7–3·8)	0·30
Handled raw chicken portions weekly or more	42/99	23/99	2·5 (1·3–4·7)	0·005

household, person over 65 in household) (Table 3). Raw egg consumption and having a child under 5 years were positively and independently associated with case households, and handling free-range eggs was negatively and independently associated with case households. Handling chicken was not independently associated with case households.

Hypotheses 2: There are more opportunities for cross contamination in case households kitchens.

Only one of the factors listed in Table 4, defined as usual practice, was statistically significant at the 5% level, and only one was significant at the 10% level (more than one person preparing food at one time). Cases were less likely to use eggs in a blender (15/97 *v*. 38/96) even after adjusting for confounders in a logistic regression model, with an adjusted odds ratio of 0·3 (0·2–0·8).

Hypotheses 3: Temperature control was poorer in case than in control kitchens.

None of the observations listed in Table 5 were significant at the 10% level. The mean temperature of domestic refrigerators in case households (7·3 °C; range 1·2–18·0 °C) did not differ significantly from that in control households (7·5 °C; range 0–15·9 °C) (Kruskal–Wallis, $P = 0{\cdot}63$). Methods of defrosting food (room temperature, refrigerator, hot or cold water and microwave) were similar in case and control kitchens.

DISCUSSION

The source of infection in most cases of sporadic salmonellosis is never determined. Food samples are rarely available and the history of exposure in just one individual is usually impossible to interpret. It is generally believed that a significant proportion of these cases are acquired from food prepared in the domestic kitchen [9], but risk factors have not been identified. Previous studies have focussed on recording the knowledge of food hygiene amongst the general public [10, 11] and some have made measurements such as recording the internal temperature of the domestic fridge [12] and microbiological surveys of domestic kitchens [13], but they have not compared the kitchens of case and control households. In our study, features of food preparation and hygiene in the domestic kitchen of cases were compared with randomly selected control households. The data

Table 3. *Conditional multiple logistic regression analysis of risk factors.**

	Odds ratio (95% CI)	*Z* scores	*P* value
Raw egg consumption in previous week	15·16 (2·16–105·93)	2·741	0·006
Handling free-range eggs in previous week	0·22 (0·06–0·85)	−2·190	0·029
Handling frozen whole chicken in previous week	1·00 (0·95–1·05)	0·012	0·99
Handling chicken pieces weekly or more	1·02 (0·99–1·05)	1·749	0·08
Age group food handler	0·99 (0·56–1·72)	−0·049	0·96
Season	1·47 (0·53–4·07)	0·742	0·46
> 65 years person in household	0·25 (0·04–1·46)	−1·542	0·12
Under 5 years person in household	13·68 (1·23–151·50)	2·133	0·03

* Log likelihood = −23·36.

recorded were compared with randomly selected control households. The data recorded were determined in consultation with EHOs who are responsible for foodborne infection control in South East Wales, and covered food histories in the week before onset, frequency of handling of known high risk foods in the kitchen, usual practices for handling and storing eggs, cooked foods, equipment in the kitchen, and hygiene practices such as frequency of cleaning and use of disinfection, as well as selected observation about the kitchen suggested to be important by EHOs.

Our study cases were broadly representative of all other cases in the area in terms of age and sex, but cases with onset in the summer of 1997 and cases from three of the participating local authorities were over-represented. Nevertheless, adjusting for these factors did not alter the results. Control households were representative of all households in South East Wales. Case households were significantly younger, a higher proportion had a young child, and a lower proportion had a person 65 years or over. Interestingly, the younger families tended to be less likely to defrost food outside the refrigerator and to keep eggs over 1 week. We used people's recall of exposures and, as in all case control studies, recall bias is a threat to validity. Cases will ruminate on possible exposures and have more detailed recall than controls. We attempted to reduce this by asking controls to recall the 7 days prior to interview rather than the exposure period of their matched cases. Cases were on average seeking to recall events 3 weeks before the interview.

Data from outbreaks confirm that poultry and eggs have been the major vehicles of salmonellosis in the past 20 years [14, 15] up until 1998, but this has not been so easily demonstrated in sporadic cases. A small case control study in Wales in 1988 showed an association with consumption of raw eggs [3] and a larger study in England the following year [4] found that consumption of raw eggs, shop bought sandwiches containing mayonnaise or eggs, and pre-cooked hot chicken, but not other forms of chicken, were risk factors. In 1993 a study of 111 cases and controls in North East Thames [16] found that consumption of foods containing raw shell eggs were significantly associated with *S*. Enteritidis infection but not with *S*. Typhimurium infection, although raw egg consumption was reported by only 7% of cases. No information was reported on risk for undercooked eggs. In France, a study of 105 cases and controls in children aged 1–5 years in 1995 [17] found that *S*. Enteritidis infection was significantly associated with consumption of raw or undercooked eggs. Interestingly, the authors reported that storing eggs more than 2 weeks after purchase was associated with a fourfold increase in risk of infection. A study of 64 cases and controls by Hayes et al. in North and West Wales in 1997 [18] found that consumption of raw or undercooked egg was associated with a fivefold increase in risk of being a case of *S*. Enteritidis. Bought sandwiches containing mayonnaise were associated with a seven fold increased risk. The participants were not able to say if the mayonnaise had been made with raw egg. Within the national Intestinal Infectious Diseases Study [19] between 1993–6 there was a small nested case control study of 51 cases of *S*. Enteritidis PT4 and controls which did not find statistically significant associations between increased risk of *S*. Enteritidis PT4 infection and consumption of any particular food. However, although not reaching

Table 4. *Comparison of factors potentially related to cross contamination in domestic kitchens in cases and controls*

Exposure (usual practice)	Cases	Controls	Matched odds ratio	*P* value
Washing meat prior to cooking	61/98	63/98	0·9 (0·5–1·8)	0·44
Storing eggs out of the box	48/96	54/95	0·7 (0·4–1·4)	0·19
Blending/mixing eggs	14/97	39/96	0·3 (0·1–0·6)	0·0002
Storing raw meat other than on the bottom shelf of fridge	43/99	52/99	0·7 (0·4–1·3)	0·13
Storing unwrapped food in the fridge	18/97	25/97	0·7 (0·3–1·5)	0·20
Overcrowded fridge	15/98	20/98	0·7 (0·3–1·5)	0·17
Visible dirt in fridge	28/98	35/98	0·7 (0·4–1·3)	0·15
No hand washing soap in kitchen	53/99	45/98	1·4 (0·8–2·6)	0·16
More than one person preparing food at one time	57/9·9	45/99	1·6 (0·9–3·1)	0·06
No chopping board	15/99	13/98	1·2 (0·5–3·1)	0·41
Less than two chopping boards	37/90	36/86	1·0 (0·5–2·1)	0·57
Same chopping board for raw and cooked foods	35/88	32/89	1·1 (0·6–2·3)	0·43
Raw and cooked foods not separated in freezer	48/92	47/96	1·1 (0·6–2·1)	0·44
Same knife for raw and cooked food	33/96	33/97	1·1 (0·5–2·0)	0·50
Bleaching of dishcloth	27/96	28/93	1·0 (0·5–2·0)	0·57
Never using a brush to clean the chopping board	39/99	40/99	1·0 (0·5–1·8)	0·50
Using antibacterial to clean food preparation areas	62/99	53/99	1·6 (0·8–3·3)	0·15
Frequency of cleaning food preparation area	18/85	21/87		
After use				
⩾ 2 daily	6/85	8/87		
Daily	41/85	42/87		
4/5 times weekly	4/85	3/87		0·94
2/3 times weekly	7/85	7/87		
Weekly	9/85	6/87		
Using antibacterial to clean fridge	29/99	20/99	1·8 (0·9–3·7)	0·12
Frequency of cleaning fridge				
Daily	1/88	0/80		
Twice weekly	4/88	3/80		
Weekly	30/88	36/80		
Fortnightly	24/88	14/80		
3 weeks/monthly	24/88	15/80		
2/3 months	4/88	6/80		0·1
4/5 months	0/88	5/80		
Annually	0/88	1/80		
Never	1/88	0/80		
Wiping dishes dry	80/99	72/98	1·6 (0·7–3·4)	0·15
Not owning a dishwasher	72/99	70/98	1·1 (0·5–2·3)	0·50
Not washing hands after raw meat	2/99	2/95	1·0 (0·1–13·8)	0·69
Not using soap to wash hands	5/97	6/96	1·0 (0·2–5·4)	0·64
Equipment breakdown	3/99	3/99	1·0 (0·1–7·5)	0·66
Unusual food handling	5/99	2/99	4·00 (0·4–197·0)	0·99
Work surface space				
< 5 units	43/98	49/99		
5–9 units	51/98	47/99		0·62
10+ units	4/99	2/99		

Table 4. (Contd)

Exposure (usual practice)	Cases	Controls	Matched odds ratio	*P* value
Frequency of changing dishcloth				
Daily	9/86	7/77		
Every other day	0/86	2/77		
Twice weekly	10/86	7/77		
Weekly	25/86	19/77		0·34
Fortnightly	15/86	9/77		
Monthly	24/86	24/77		
Every 2 months	3/86	8/77		
more	0/86	1/77		

Table 5. *Comparison of temperature control in case and control domestic kitchens*

Exposure	Cases	Controls	Matched odds ratio	*P* value
Storing eggs at room temperature	29/96	24/97	1·3 (0·7–2·5)	0·27
Using a meat thermometer to judge if meat is cooked	98/98	96/98	OR undefined	0·15
Fridge door unable to close properly	4/98	5/98	0·8 (0·2–3·7)	0·50
Fridge door seal damaged	9/98	7/98	1·1 (0·4–3·7)	0·50
Overcrowded fridge	15/98	20/98	0·7 (0·3–1·5)	0·17
No fridge thermometer	28/98	35/98	1·1 (0·5–2·3)	0·50
Re-heating food in microwave	39/65	41/66	1·0 (0·3–3·1)	0·60
Cooked meats with meat at room temperature for over 1 h	47/62	41/64	1·7 (0·6–5·6)	0·23
Fridge needs defrosting	6/98	6/98	1·0 (0·3–3·7)	0·61
Frequent cooling of food for later/leftovers	27/98	33/99	0·8 (0·4–1·5)	0·27

statistical significance, *S*. Enteritidis PT4 cases did eat more runny or raw eggs.

In these case control studies failure to show an association with consumption of chicken other than bought pre-cooked hot chicken is perhaps surprising given carcase contamination rates of > 20% [20], but it suggests that cross contamination from foods such as raw chicken may be more important in domestic salmonellosis than consumption of chicken itself. The risks from incomplete defrosting and undercooking chicken may now be better known by the public. Consumption of undercooked chicken was reported by only four cases and two controls in our study.

We looked for associations with likely sources of cross contamination. Several microbiological studies have confirmed the potential for cross contamination of other foods during the preparation of chicken [7, 8]. Frozen chicken is defrosted before cooking and therefore present in the kitchen for longer periods than fresh poultry. Furthermore, the defrosting process frequently produces a lot of liquid which can easily contaminate other foods. However, although most case households who had handled raw chicken had defrosted it at room temperature rather than in the refrigerator, and most had washed out the chicken over a wide area, we found no evidence to support the hypotheses that case households have more opportunities for cross contamination or poorer temperature control. Generally, the methods of food preparation (including work surface space, age and condition of refrigerator) and hygienic practices (frequency of changing/bleaching dishcloth, presence of visible dirt in fridge and use of antibacterials on work surfaces) were similar in case and control households. Handling whole frozen chicken in the preceding week, and handling chicken portions in the kitchen weekly, were associated with case households in univariate analysis, but not in multivariate analysis when exposures to eggs and age structure of the family were taken into account.

In our case control study, as in previous case control studies [3, 4, 16–18] we did show an association with consumption of undercooked eggs, but not with eating chicken. Consumption of raw eggs was the most prominent risk factor but it would explain only 20% of the cases. Case households were not more likely than controls to handle eggs in the kitchen in the preceding week, but they were significantly less likely to have free range eggs. Published microbiological surveys of eggs are limited, but as far as can be ascertained, free-range eggs were just as likely to have been contaminated during the study period as other eggs [21]. One possible explanation is that the "protective" effect of free-range eggs is because families who purchase free-range eggs differ from other families in other life style factors which are related to risk of salmonellosis. This is supported by the observation that case households were less likely to use eggs in a blender, an activity which has been shown to cause dissemination of salmonellas in kitchen surfaces [8], and therefore would be expected to increase risk.

We looked in detail at the extensive range of food hygiene practices but we were unable to find any other significant differences between case and control households. Once purchase of free-range eggs and consumption of raw eggs were taken into account, the significant association with chicken variables disappeared. It is possible that the negative results of this study arise because we did not ask about the relevant kitchen factors which predispose to salmonella infection, but the factors we did ask about were generally believed by EHOs to be the main markers of risk, and they do appear to have had predictive value in other studies. For example, in a case control study of sporadic *E. coli* O157 infection in the United States not consistently washing hands after handling ground beef, and not washing work surfaces that had been in contact with raw ground beef, were associated with odds ratios of 8·5 and 10 respectively [22].

Our results caution against assuming that the main causes of sporadic salmonellosis lie within the domestic kitchen. Other sources such as contamination of purchased ready to eat foods, or eating out, may be more important [23]. Furthermore, it is possible that many apparently sporadic cases are part of unrecognized community-wide outbreaks. Paradoxically, it is easier to recognize these outbreaks when the infecting organism is rare [24]. When the level of contamination is low and the organism is common, such as *S.* Enteritidis PT4, then widespread unrecognized outbreaks are likely to go undetected and will appear in routine statistics as apparently sporadic cases.

ACKNOWLEDGEMENTS

We acknowledge the assistance of the numerous colleagues in the Public Health Laboratory Service and local authorities in South East Wales, and the assistance of Dr Robert Newcombe in statistical analysis. This study was supported by a grant from the National Assembly for Wales.

REFERENCES

1. The Committee on the Microbiological Safety of Food. The Microbiological Safety of Food Part I: Report of the Richmond Committee on the Microbiological Safety of Food to the Secretary of State for Health, the Minister of Agriculture, Fisheries and Food and the Secretaries of State for Wales, Scotland, Northern Ireland. London: HMSO, 1990.
2. The Committee on the Microbiological Safety of Food. The Microbiological Safety of Food Part II: Report of the Richmond Committee on the Microbiological Safety of Food to the Secretary of State for Health, the Minister of Agriculture, Fisheries and Food and the Secretaries of State for Wales, Scotland, Northern Ireland. London: HMSO, 1991.
3. Coyle EF, Palmer SR, Ribeiro CD, et al. *Salmonella enteritidis* phage type 4 infection associated with hens' eggs. Lancet 1988; ii: 1295–6.
4. Cowden JM, Lynch D, Joseph CA, et al. Case control study of infections with *Salmonella enteritidis* phage type 4 in England. Br Med J 1989; **299**: 771–3.
5. Ryan MJ, Wall PG, Gilbert RJ, Griffin M, Rowe B. Risk factors for outbreaks of infectious intestinal disease linked to domestic catering. Comm Dis Rev 1996; **13**: R179–83.
6. Wall PG, Morgan D, Lamden K, et al. A case control study of infection with an epidemic strain of multiresistant *Salmonella typhimuirium* DT104 in England and Wales. Comm Dis Rev 1994; **4**: R130–5.
7. De Wit JC, Broekhuizen G, Kampelmacher EH. Cross contamination during the preparation of frozen chickens in the kitchen. J Hyg 1979; **83**: 27–32.
8. Humphrey TJ, Martin KW, Whitehead A. Contamination of hands and work surfaces with *Salmonella enteritidis* PT4 during the preparation of egg dishes. Epidemiol Infect 1994; **113**: 403–9.
9. Border P, Norton M. Safer eating, microbiological food poisoning and its prevention. Parliamentary Office of Science and Technology, 1997.

10. Williamson DM, Gravani RB, Lawless HT. Correlating food safety knowledge with home food preparation practices. Food Tech, May 1992: 94–100.
11. Ministry of Agriculture, Fisheries and Food. A report on a consumer survey. London: HMSO, 1988.
12. Johnson AE, Donkin AJ, Morgan K, et al. Food safety knowledge and practice among elderly people living at home. J Epidemiol Comm Hlth 1998; **52**: 745–8.
13. Scott E, Bloomfield SF, Barlow CG. An investigation of microbial contamination in the home. J Hyg 1982; **89**: 279–93.
14. Advisory Committee on the Microbiological Safety of Food. Report on poultry meat. London: HMSO, 1996.
15. Palmer SR, Parry S, Perry D, et al. The role of outbreaks in developing food safety policy: population based surveillance of salmonella outbreaks in Wales 1986–1988. Epidemiol Infect 2000; **125**: 467–72.
16. Banatvala N, Cramp A, Jones IR, Feldman RA. Salmonellosis in North Thames (East), UK: associated risk factors. Epidemiol Infect 1999; **122**: 201–7.
17. Delarocque-Astageneau E, Desenclos J-C, Bowet P, Grimont PAD. Risk factors for the occurrence of sporadic *Salmonella enterica* serotype *enteritidis* infections. Epidemiol Infect; **121**: 561–7.
18. Hayes S, Nylen G, Smith R, Salmon RL, Palmer SR. Undercooked hen's eggs remain a risk factor for sporadic *Salmonella enteritidis* infection. Comm Dis Pub Hlth 1999; **2**: 66–7.
19. Food Standards Agency. A Report on the Study of Infectious Intestinal Disease in England. London: HMSO, 2000.
20. Advisory Committee on the Microbiological Safety of Food. Second Report. Salmonella in eggs. Foods Standards Agency. London: HMSO, 2001.
21. Advisory Committee on the Microbiological Safety of Food. Report on poultry meat. London: HMSO, 1996.
22. Mead PS, Firelli L, Lambert-Fair MA, et al. Risk factors for sporadic infection with *Escherichia coli* 0157:H7. Arch Intern Med 1997; **157**: 204–8.
23. Palmer SR, Houston H, Lervy B, Ribeiro D, Thomas P. Problems in the diagnosis of foodborne infection in general practice. Epidemiol Infect 1996; **117**: 479–84.
24. Thornton L, Gray S, Bingham P, et al. The problems of tracing a geographically widespread outbreak of salmonellosis from a commonly eaten food. *Salmonella typhimurium* DT193 in North West England and North Wales in 1991. Epidemiol Infect 1993; **111**: 465–71.