Epidemiol. Infect. (2004), **132**, 601–606. © 2004 Cambridge University Press
DOI: 10.1017/S0950268804002365 Printed in the United Kingdom

Dietary intake and domestic food preparation and handling as risk factors for gastroenteritis: a case-control study

T. Z. MITAKAKIS, R. WOLFE, M. I. SINCLAIR*, C. K. FAIRLEY, K. LEDER AND M. E. HELLARD

Cooperative Research Centre for Water Quality and Treatment, Department of Epidemiology and Preventive Medicine, Monash University, Alfred Hospital, Melbourne 3004, Australia

(*Accepted 27 February 2004*)

SUMMARY

Cases of gastroenteritis were examined to identify if dietary intake prior to an episode and food-handling and storage practices in the home were risk factors for illness. Cases and controls completed a dietary questionnaire after an event or when well, and questionnaires concerning food-handling, storage and general food-hygiene practices. Comparing cases to themselves when well, subjects were more likely to have eaten cold sliced salami, fried rice and foods cooked elsewhere, and to have had a baby in nappies in the house (OR 1·52–6·24, $P \leqslant 0{\cdot}01$). Cases compared to non-cases were more likely to have bought frozen poultry, have eaten foods cooked elsewhere and to have had a baby in nappies in the house (OR 1·44–2·05, $P \leqslant 0{\cdot}01$). Although food-handling and storage practices are considered important, we were unable to detect an association in this study.

INTRODUCTION

Foodborne gastroenteritis is a substantial cause of illness. Foods that are most commonly associated with foodborne illness are raw foods of animal origin, rice, fruit and vegetables [1–6]. While foods can carry pathogens, illness can result from the process of mishandling the foods, both in commercial settings and in the home. A survey of families in Melbourne, Australia, showed that a wide range of poor food-handling practices were common [7]. This is a recurrent issue throughout the world [8]. Recommended practices have been developed by food safety authorities and public-health departments based on simple hygienic principles and known causes of foodborne outbreaks. While there are numerous studies detailing the nature and frequency of how food is prepared in the home and the cleanliness of kitchens [8], there is little research evidence on whether failing particular recommendations in the domestic kitchen leads to an increased risk of gastroenteritis.

A number of foods prepared or eaten at home have been identified as risky. These include the handling of frozen chicken and cage eggs with *Salmonella* infections [9], eating pork with *Yersinia* infections [10] and undercooked meats with *Escherichia coli* infections [11]. However, these studies were unable to show any increased risk of infection from the most basic recommended food-handling and storage practices such as those involving placement of foods in the refrigerator, thawing, use of chopping boards, knives and dishcloths, and the frequency of cleaning preparation areas and hand washing [9–11].

* Author for correspondence: Dr M. Sinclair, CRC for Water Quality and Treatment, Department of Epidemiology and Preventive Medicine, Central and Eastern Clinical School, Monash University, Alfred Hospital, Commercial Road, Melbourne 3004, Australia.

In this study, we examined the type of foods eaten and food-handling practices as risk factors for gastroenteritis in an Australian population.

METHODS

Subjects

Data collected from 600 families ($n=2811$ subjects) in a controlled trial of drinking-water quality conducted in Melbourne, Australia [12] were used in this study. For families to be eligible, they had to reside in Melbourne, have at least four members that included two children aged between 1 and 15 years (as of 1 July 1997) and to own their home. Individuals were excluded if they were immunocompromised, had a chronic diarrhoeal illness or were on long-term antibiotic therapy. The study was approved by the Monash University Standing Committee on Ethics in Research Involving Humans. Written informed consent was obtained from all adult participants.

Data collection

Dietary intake prior to gastroenteritis

Data collection and case definitions have been detailed previously [12]. Briefly, all family members recorded episodes of highly credible gastroenteritis (HCG) over 15 months between September 1997 and February 1999. A total of 2669 episodes were recorded by 1407 subjects. Within a week following an episode, cases or their parents were asked to complete a phone questionnaire concerning the consumption and preparation of food in the previous week. The subjects answered 'yes' or 'no' to whether they had consumed particular foods or performed certain food-handling practices. Of the total episodes, questionnaires were completed for 2003 of the cases, by 842 subjects. Of these subjects, 553 had a single HCG event during the study period; 182 had 2 events; 69 had 3 events; 22 had 4 events; 9 had 5 events; 5 had 6 events; 1 had 7 events and the last had 14 events.

At random time-points throughout the trial, nearly all families were asked to complete a control questionnaire at a time when the individual had been well for a period of at least 2 weeks. At the completion of the study, 687 subjects had paired case (episode) and control data, i.e. case cross-over data.

A second set of control data was generated from those study subjects who had not reported gastroenteritis at all during the study period ($n=1134$ subjects, nine of whom completed the questionnaire twice, $\approx$1143 completed control questionnaires).

Food-handling and storage practices

Food-handling and food-storage questionnaires were mailed to all families at a single time-point in February 1999, before the study was concluded, and returned over the next 2 months. The reporting participant in each family, typically the main person to prepare meals, completed the questionnaire. Responses were taken to represent the food-handling practices of all family members. The questions posed related to surface preparation, hand washing, handling of cooked foods, thawing of poultry and placement of foods in the refrigerator. The detailed questions and interpretation of 'hygienic' practices have been presented elsewhere [7]. In this study, the practices of subjects who had at least one episode of gastroenteritis were compared against the second set of controls, i.e. those subjects that did not have gastroenteritis during the study.

Statistical analyses

The case cross-over data was analysed using conditional logistic regression models. Robust standard errors were calculated to account for repeat case or control observations made within case cross-over sets, i.e. individuals, and to account for the clustering of individuals within family groups. For each model, the robust standard errors were calculated using an information-sandwich formula [13] with the 'filling' in the sandwich being constructed with family as the level of clustering and using efficient score residuals from a Cox proportional hazards regression model that was equivalent to the conditional logistic regression model. Cases without a cross-over control observation were included in the analysis by use of the missing-indicator method [14] in which virtual cross-over controls are created for the incomplete case cross-overs. Adjustment was made in multivariate regression models for indicators of season (winter/summer) and of virtual controls (virtual/observed).

The comparison of cases to the unmatched control group was performed with logistic regression models. Robust standard errors were calculated to allow for familial clustering and repeated observations on individuals. Adjustment was made in multivariate regression models for age ($<$10 years/$\geqslant$10 years), sex (male/female), education (attending/not attending an

https://doi.org/10.1017/S0950268804002365 Published online by Cambridge University Press

educational institution), and an interaction between age and sex.

Stata statistical software was used for all analyses [13]. No explicit attempt was made to control the overall Type I error that arises from the comparison of case and control information on many variables questions; a P value of less than 0·05 was considered statistically significant [15].

RESULTS

Dietary intake preceding gastroenteritis episodes

The case cross-over analysis (the case was their own control) found that participants were more likely to have eaten cold sliced salami, fried rice, fast food or take-away foods, eaten at a reception or restaurant and to have had a baby in nappies (diapers) in the house for at least 4 h in the week prior to having gastroenteritis compared to times when they were well (Table, left-hand side). The participants were less likely to have eaten chicken that was bought cooked, cold sliced ham or sliced chicken, salad of any description (including home prepared), soft cheeses, eggs either raw or well cooked or home-cooked chicken or red meat that had been bought raw but frozen at home before cooking in the week prior to an episode of gastroenteritis.

The standard case-control analysis (participants who had an episode of gastroenteritis were compared to participants who never had an episode of gastroenteritis) found that cases were more likely to have eaten cooked chicken that had been frozen, take-away or fast food, restaurant or reception food and had a baby in the house for more than 4 h in the week prior to having gastroenteritis compared to controls. They were less likely to have eaten fresh rice, home-made salad, cooked chicken that had not been frozen and yoghurt in the week prior to having gastroenteritis compared to controls (Table, right-hand side).

Food-handling and storage practices of people who had gastroenteritis

Defrosting chicken

When examining the combinations of frequency (never, rarely, sometimes, usually, always) and means of defrosting chicken (in the microwave, on the bench or in the refrigerator), the only significant combination was having frequently defrosted chicken in the microwave (OR 2·47, 95% CI 1·54–3·95, $P<0·001$).

Locating food in the refrigerator

There were no significant odds ratios associated with where cooked and raw meat and cooked and raw other foods were placed in the refrigerator (top-middle/bottom shelf, door or salad drawer).

General food- and work-surface handling

Handling of cutting boards in relation to raw and cooked foods, including not washing the cutting board with soap and water each time after raw meat had been prepared, did not have a significant bearing on episodes of gastroenteritis. How long or how often foods were left unrefrigerated was also not significant, nor when cross-contamination by dishcloths was likely (from being used to clean kitchen surfaces, including cutting boards and floors).

The two significant combinations were 'always' having placed cooked chicken and meat where raw chicken/meat had been (OR 0·31, 95% CI 0·13–0·76, $P=0·01$), and 'always' leaving food outside the refrigerator for more than 2 h (OR 0·47, 95% CI 0·23–0·96, $P=0·04$).

Hand washing after touching raw meat products

There were no significant differences between the cases and controls in the frequency of hand washing after handling raw meats ($P>0·18$).

DISCUSSION

Certain practices and foods prepared and eaten in the home were associated with an increased risk of gastroenteritis amongst this Melbourne family population. No relation was found between gastroenteritis and recommended food-handling, storage or kitchen hygiene practices.

In this study, we compared cases to themselves when they were well and also to an illness-free group of controls. The first comparison suggests that when subjects were ill, week-to-week variation in their diet, or certain foods (frozen chicken, salami, fried rice and meals from commercial outlets), may have led to gastroenteritis. The comparison between cases and those who did not have an episode suggests that there may be overall ongoing differences in diet between the two groups. The factors found here that were associated with a decreased odds of gastroenteritis may not necessarily individually confer protection *per se*. They could be markers for behavioural factors reflecting a healthy lifestyle that were not directly

https://doi.org/10.1017/S0950268804002365 Published online by Cambridge University Press

Table. *Risk of gastroenteritis from dietary intake and food shopping and handling practices in the home*

Food exposure category	% episodes exposed	Cases of gasteroenteritis compared to: Themselves when well OR	Themselves when well 95% CI	Those who did not get ill OR	Those who did not get ill 95% CI
Eaten poultry	84·5	0·74	0·53–1·04	0·79	0·56–1·13
Bought poultry raw fresh, cooked at home	37·8	0·58***	0·45–0·75	0·59***	0·45–0·77
Bought poultry raw fresh, frozen and cooked at home	42·7	0·75*	0·59–0·96	0·83	0·63–1·08
Bought poultry frozen, cooked at home	8·1	1·49	0·88–2·50	1·81**	1·14–2·89
Bought poultry pre-cooked	30·4	0·63***	0·48–0·84	1·06	0·81–1·41
Bought poultry elsewhere/other	21·6	0·83	0·65–1·06	1·23	0·91–1·65
Eaten red meat	90·3	0·90	0·59–1·38	1·14	0·75–1·72
Bought raw red meat, cooked at home	41·7	0·83	0·64–1·07	0·94	0·74–1·20
Bought raw red meat, frozen and cooked at home	61·6	0·69**	0·53–0·90	1·06	0·81–1·39
Bought red meat frozen, cooked at home	5·6	1·52	0·90–2·57	1·36	0·80–2·32
Bought red meat elsewhere/other	32·0	0·84	0·66–1·06	1·18	0·93–1·51
Eaten cold sliced ham	50·3	0·68**	0·53–0·87	1·10	0·87–1·39
Eaten cold sliced chicken	17·4	0·73*	0·53–1·00	0·78	0·57–1·06
Eaten cold sliced salami	13·0	1·65**	1·13–2·42	1·05	0·70–1·57
Eaten cold sliced other	27·2	1·22	0·93–1·59	0·98	0·75–1·28
Eaten pâté or liver chicken	4·3	0·89	0·57–1·38	0·82	0·46–1·44
Eaten shellfish – mussels/oysters	3·3	1·34	0·62–2·86	1·47	0·83–2·58
Eaten fish or seafood (non-shellfish)	46·8	0·91	0·72–1·14	0·80	0·64–1·01
Eaten salad	64·3	0·56***	0·41–0·77	0·67***	0·51–0·87
Salad prepared at home	58·7	0·70**	0·53–0·92	0·70**	0·54–0·92
Salad bought from shop – served	7·8	1·37	0·84–2·23	0·91	0·58–1·43
Salad bought from shop – self served	1·5	2·04	0·64–6·54	0·88	0·36–2·16
Salad obtained elsewhere/other	17·3	0·73*	0·54–0·98	0·97	0·72–1·29
Eaten rice	62·9	0·92	0·71–1·18	0·67***	0·51–0·88
Boiled rice eaten immediately	53·2	0·81	0·62–1·06	0·62***	0·48–0·80
Boiled rice re-heated	12·3	0·81	0·58–1·12	0·84	0·61–1·16
Fried rice	15·4	1·52**	1·12–2·06	1·05	0·76–1·45
Eaten home-made ice cream	1·0	1·26	0·35–4·90	0·80	0·20–3·20
Eaten ice cream bought at a shop	71·2	0·91	0·71–1·17	1·10	0·84–1·45
Eaten yoghurt	50·5	0·78	0·59–1·01	0·62***	0·49–0·80
Eaten soft cheese	12·7	0·72*	0·54–0·96	0·86	0·62–1·20
Eaten hard cheese	84·6	0·81	0·59–1·13	1·07	0·80–1·44
Eaten eggs	65·7	0·73*	0·55–0·96	1·04	0·81–1·35
Runny egg	21·5	0·81	0·59–1·11	0·89	0·67–1·19
Well-cooked egg	48·3	0·78*	0·64–0·99	1·07	0·84–1·36
Raw egg	3·1	0·48**	0·28–0·84	1·66	0·78–3·51
Eaten fast food/take-away	77·3	1·60***	1·24–2·05	1·71***	1·32–2·22
Eat at a restaurant/reception place	21·8	1·25	0·95–1·66	1·44**	1·10–1·87
Eat at a sandwich bar/canteen	23·8	1·10	0·87–1·40	0·96	0·75–1·24
Baby in nappies in house (>4 h per week)	45·3	6·24***	2·69–14·4	2·05***	1·45–2·90

* $P \leqslant 0{\cdot}05$, ** $P \leqslant 0{\cdot}01$, *** $P \leqslant 0{\cdot}001$.

measured in this study or due to an unadjusted confounding of another food variable. Immunity from prior exposure to pathogens is another possibility.

It is interesting to note that numerous foods typically associated with foodborne illness and outbreaks, such as raw eggs, fish and raw vegetables [2, 3, 16] were not significantly associated with illness in this population. That cold sliced salami was associated with disease more so than cold sliced chicken or ham may reflect that salamis are not usually cooked and are often air dried, whilst chicken and ham are cooked. Salami and mettwurst (typically a spreadable cured

https://doi.org/10.1017/S0950268804002365 Published online by Cambridge University Press

sausage meat) have been the cause of food-poisoning outbreaks in the past [3, 17].

Sourcing food for the home as raw products, as opposed to consuming pre-cooked foods or eating food away from the home, appears to reduce the overall risk of food poisoning. This trend was shown in both comparisons in this study and confirms earlier findings. Palmer and colleagues found that patients with a history of acute abdominal pain and diarrhoea who had recently eaten out were more likely to have *Campylobacter* and *Salmonella* infections [18]. A greater risk of food poisoning from *Salmonella* was also shown to relate to eating chicken or sausages that had been cooked commercially rather than cooked at home [19].

Person-to-person and cross-contamination are considered two of the major routes of exposure to pathogens. Person-to-person contamination is the likely explanation for the increased risk associated with having a baby in nappies in the house which was the highest odds ratio detected. That is, baby faecal matter contaminates co-inhabitants, for example by poor hand washing after changing nappies. The risks associated with frozen chicken have also been proposed to relate to the increased chance of cross-contamination resulting from the excess fluids produced during defrosting and by requiring longer 'contact' time with the kitchen [9]. Sporadic *E. coli* infections have also been attributed to cross-contamination from food preparers not washing their hands and preparation areas properly after handling raw ground beef [11]. Interestingly, there was no significance attached to where foods were located in the refrigerator, for which recommendations concern the possible cross-contamination from raw to ready-to-eat foods. The lack of association of where foods were stored in refrigerators and disease was also observed in a South East Wales population [9].

The lack of association found between the preparation and handling of food and gastroenteritis in this study does not mean that these practices are not important. There are a number of factors that may have prevented any true association from being found. In Australia, food as a vehicle of pathogens is considered to only comprise 32% (95% CI 24–40%) of the causes of gastroenteritis (Kirk, M., personal communication), and only some of these cases would relate to practices in the home. The absence of association may also relate to study design issues such as the difference in timing between when subjects were asked about handling practices and when they had gastroenteritis or filled in a control dietary questionnaire. The food-handling questionnaires asked people about their 'usual' practices. Recall bias was likely as practices can fluctuate over time. Furthermore, the perception of practices at the time when the food-handling questionnaires were completed at the end of the study may have been different to when subjects had episodes or provided control dietary information. Studies on *Yersinia* and *Salmonella* cases of gastroenteritis were also unable to demonstrate an association with food-handling or kitchen hygiene practices [9, 10]. These factors combine to reduce the likelihood of detecting associations.

Ideally, the pathogens causing the cases would have been identified, particularly to examine risk factors associated with different pathogens given their propensity to associate with specific foods. A number of participants in this study did collect faecal samples, and pathogens were identified in some samples [12]. Unfortunately, too few were identified to be analysed in relation to foods and handling.

The cases investigated here were not selected on the basis of food being the suspected vehicle, therefore, it is unlikely that all cases of gastroenteritis were caused by food. While drinking water was not found to be a source of gastroenteritis in this population [12], alternative sources of infection include pets, swimming pools and person-to-person contact.

In conclusion, the source and type of food eaten were the most strongly associated risk factors for gastroenteritis.

ACKNOWLEDGEMENTS

We thank Andrew Forbes, Colin Fee, Geoff Aldred, Richard Hayes, Pamela Lightbody, Geoff Simmons, Hana Kadza, Anne Browning and Judy Hankin for their valuable assistance. We also thank the participants of the study as well as the Cooperative Research Centre for Water Quality and Treatment, Department of Human Services, Victoria, Melbourne Water Corporation, Water Services Association of Australia, South East Water, Yarra Valley Water and City West Water for their funding support.

REFERENCES

1. Banatvala N, Cramp A, Jones IR, Feldman RA. Salmonellosis in North Thames (East), UK: associated risk factors. Epidemiol Infect 1999; **122**: 201–207.

2. Bean NH, Goulding JS, Daniels MT, Angulo FJ. Surveillance for foodborne disease outbreaks – United States, 1988–1992. J Food Prot 1997; **60**: 1265–1286.
3. Davey GR. Food poisoning in New South Wales: 1977–84. Food Technol Aust 1985; **37**: 453–456.
4. Molbak K, Neimann J. Risk factors for sporadic infection with Salmonella enteritidis, Denmark, 1997–1999. Am J Epidemiol 2002; **156**: 654–661.
5. Shiferaw B, Yang S, Cieslak P, et al. Prevalence of high-risk food consumption and food-handling practices among adults: a multistate survey, 1996 to 1997. J Food Prot 2000; **63**: 1538–1543.
6. Socket PN, Cowden JM, Le Baigue S, Ross D, Adak GK, Evans H. Foodborne disease surveillance in England and Wales 1989–1991. CDR Review 1993; **3**: R159–R174.
7. Mitakakis TZ, Sinclair MI, Fairley CK, Lightbody PK, Leder K, Hellard ME. Food safety in homes of Melbourne families. J Food Prot (in press).
8. Redmond EC, Griffith CJ. Consumer food handling in the home: a review of food safety studies. J Food Prot 2003; **66**: 130–161.
9. Parry SM, Palmer SR, Slader J, Humphrey T, Group TSEWIDL. Risk factors for salmonella food poisoning in the domestic kitchen – a case control study. Epidemiol Infect 2002; **129**: 277–285.
10. Satterthwaite P, Pritchard K, Floyd D, Law B. A case-control study of *Yersinia enterocolitica* infections in Auckland. Aust NZ J Publ Health 1999; **23**: 482–485.
11. Mead PS, Finelli L, Lambert-Fair MA, et al. Risk factors for sporadic infection with *Escherichia coli* O157:H7. Arch Intern Med 1997; **157**: 204–208.
12. Hellard ME, Sinclair MI, Forbes AB, Fairley CK. A randomized, blinded, controlled trial investigating the gastrointestinal health effects of drinking water quality. Environ Health Perspect 2001; **109**: 773–778.
13. StataCorp. Stata Corporation, College Station, TX, 2001.
14. Huberman M, Langholz B. Application of the missing-indicator method in matched case-control studies with incomplete data. Am J Epidemiol 1999; **150**: 1340–1345.
15. Savitz DA, Olshan AF. Multiple comparisons and related issues in the interpretation of epidemiological data. Am J Epidemiol 1995; **142**: 904–908.
16. Hayes S, Nylen G, Smith R, Salmon RL, Palmer SR. Undercooked hens eggs remain a risk factor for sporadic Salmonella enteritidis infection. Comm Dis Pub Health 1999; **2**: 66–67.
17. Cameron S, Walker C, Beers M, Rose N, Anear E. Enterohaemorrhagic *Escherichia coli* outbreak in South Australia associated with the consumption of mett-wurst. Commun Dis Intell 1995; **19**: 70–71.
18. Palmer SR, Houston H, Lervy B, Ribeiro D, Thomas P. Problems in the diagnosis of foodborne infection in general practice. Epidemiol Infect 1996; **117**: 479–484.
19. Wall PG, Morgan D, Lamden K, et al. A case control study of infection with an epidemic strain of multi-resistant Salmonella typhimurium DT104 in England and Wales. CDR Review 1994; **4**: R130–R135.