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Frozen chicken nuggets and strips and eggs are leading risk factors for *Salmonella* Heidelberg infections in Canada

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SUMMARY

A case-control study was conducted from 1 January to 31 May 2003 to identify risk factors for *S.* Heidelberg infection in Canada. Controls were pair-matched by age group and telephone exchange to 95 cases. Exposures in the 7 days before illness/interview were assessed using multivariate conditional logistic regression. Consumption of home-prepared chicken nuggets and/or strips [matched odds ratio (mOR) 4·0, 95% confidence interval (CI) 1·4–13·8], and undercooked eggs (mOR 7·5, 95% CI 1·5–75·5) increased the risk of illness. Exposure to a farm setting lowered the risk (mOR 0·22, 95% CI 0·03–1·00). The population-attributable fraction associated with chicken nuggets/strips was 34% and with undercooked eggs was 16%. One-third of study participants did not perceive, handle or prepare chicken nuggets and strips as high-risk products, although the majority of the products on the Canadian market are raw. These findings have prompted changes in product-labelling policy and consumer education.

INTRODUCTION

While the total number of *Salmonella* isolates reported in Canada declined from 1995 to 2003, the annual number of *Salmonella enterica* serovar Heidelberg isolates in 2002 and 2003 were the highest recorded since 1990 [1–3]. *S.* Heidelberg is currently the second most frequently isolated *Salmonella* serovar from human sources accounting for 19% of nationally reported *Salmonella* infections from 2002 to 2003 [2]. While most infections result in mild to moderate self-limited diarrhoeal illness, severe invasive infections occur in ~11% of cases and may lead to complications including meningitis, reactive arthritis, and myocarditis, and in rare cases, death [4–9]. In addition to the distress and lost productivity of infected individuals, the burden of epidemic and sporadic *S.* Heidelberg infections on medical and public health systems is substantial [9–14]. Increasing rates of *S.* Heidelberg isolations despite declining rates of *Salmonella* infections in general urged more focused examination of risk factors for infections of this serotype in Canada.

S. Heidelberg is primarily a foodborne pathogen. Outbreaks have often been associated with foods of animal origin including chicken, turkey and ham

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(Health Canada, 1998, unpublished data), eggs and cheddar cheese, with few reports of person-to-person or animal-to-person transmission [15–21]. A case-control study conducted from 1996 to 1997 in the United States examined risk factors for sporadic *S*. Heidelberg infections [22]. The researchers concluded that eggs eaten outside the home were the leading risk factor, responsible for an estimated 37% of the population's infections.

The provinces of Québec and British Columbia recently conducted provincial investigations to identify sources of *S*. Heidelberg infection. A case-series investigation in 2002 (C. Gaulin, unpublished data) demonstrated that the proportion of Québec cases reporting consumption of chicken nuggets (26%), was higher ($P=0{\cdot}07$) than would be expected among the general population based on an American food consumption survey (18·2%) [23]. In March 2003, investigation into a family cluster of *S*. Heidelberg phage type (PT) 26 infections in British Columbia lead to the isolation of the pathogen from chicken nuggets recovered from the family's home and triggered a provincial case-control study. Results indicated a statistically significant association ($P<0{\cdot}05$) between consumption of frozen chicken nuggets and/or strips prepared at home and *S*. Heidelberg infections of various phage types diagnosed between 1 January and 1 April 2003 [24].

The Foodborne, Waterborne and Zoonotic Infections Division of Health Canada (FWZID) initiated a national case-control study in April 2003 to identify risk factors for *S*. Heidelberg infections in Canada. Investigators were particularly interested in the potential association between infection and consumption of frozen chicken nuggets and strips because of the earlier findings in Québec and British Columbia. This report summarizes the study implicating consumption of undercooked eggs and home-prepared frozen chicken nuggets and strips as leading risk factors for *S*. Heidelberg infections in Canada.

METHODS

In April 2003, all provinces and territories were invited to participate in a national case-control study. Cases were defined as Canadian residents with laboratory-confirmed *S*. Heidelberg infections diagnosed since 1 January 2003 and prospectively to 31 May 2003. Cases were excluded if they had travelled outside of Canada in the week prior to becoming ill, were unable to communicate in English or French, or if they had been eligible for the British Columbia case-control study conducted from 1 January to 1 April 2003 [24]. One control was selected for each case using forward/backward digit dialling from the case's home telephone number. Controls were matched to cases by age group (0–6, 7–17, $\geqslant$18 years). Controls were excluded if they had been ill with diarrhoea in the month prior to interview or were unable to communicate in English or French.

The case and control questionnaires created for the British Columbia study were augmented and translated into French [24]. The questionnaire addressed demographic information, case illness, 25 food exposures in the week prior to symptom onset (cases) or interview (controls), brand, date, location of purchase and cooked state (fully cooked or not) of food items consumed, information about how processed chicken products were perceived (raw *vs*. pre-cooked), handled, stored and prepared, and exposure to other potential risk factors including pets, pet foods, farms, petting zoos and day-care settings. Food exposures considered included eggs, processed chicken products, various other forms of chicken and beef, turkey, pork, deli meats, nuts, cheese, milk and juice. Interviews were conducted by telephone. Parents/guardians were used as proxies for cases/controls under 18 years of age, except where cases/controls were 16 or 17 years of age and the parent/guardian requested that the case/control respond on their own behalf.

Data were managed using Epi-Info version 6.04d (CDC, Atlanta, GA, USA) and analysed using Statistical Analysis System version 8.02 (SAS Institute Inc., Cary, NC, USA). Matched case-control data were analysed by conditional logistic regression using the SAS procedure 'Logistic'. Exposures demonstrating P values $<0{\cdot}25$ in univariate analyses were further analysed by multivariate modelling using a manual stepwise approach. P values and likelihood ratio tests were used to confirm the significance of variables and potential interactions between variables. Exact methods were employed wherever cell counts were less than 5 and estimates were adjusted for gender where inclusion of gender in a model altered parameter estimates by more than 10%. To explore the potential effect of recall bias, the final model was also fitted excluding matched pairs where cases reported symptom onset more than 2 weeks prior to the study start date. Population attributable fractions were calculated using matched odds ratios (mORs) derived from multivariate conditional logistic regression and the prevalence of exposure among all cases interviewed [25].

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Table 1. *Provincial/territorial participation in the* Salmonella *Heidelberg national case-control study, Canada, 1 January to 31 May 2003*

Province/territory	No. of case-control pairs interviewed	*S.* Heidelberg isolates identified from 1 January to 31 May 2003*	
		Total	% Enrolled in study
Québec	66 (plus 16 unmatched cases)	141	58
Alberta†	14	53	26
British Columbia‡	8	39	21
New Brunswick	3	16	19
Saskatchewan	2	10	20
Newfoundland	1	4	25
Northwest Territories	1	1	100
All other provinces§	—	186	—
Canada	95 (plus 16 unmatched cases)	450	25

* Source: National Enteric Surveillance Program, Health Canada.
† Alberta enrolled cases with phage type 26 infections only from 1 January to 31 March.
‡ British Columbia participated from 1 April to 31 May. The province reported 15 cases to the National Enteric Surveillance Program from 1 April to 31 May.
§ Four other provinces identified 186 isolates but did not participate in the study: Ontario (162 isolates), Manitoba (15 isolates), Nova Scotia (8 isolates) and Prince Edward Island (1 isolate).

To assess whether study cases were representative of all cases identified nationally over the study period, enrolled cases were compared to those reported to the Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS) pilot project. Laboratory and basic demographic data were available from CIPARS for *S.* Heidelberg cases identified in Ontario, Québec, British Columbia and Alberta in the first 15 days of each month and for all other cases in Canada over the study period (CIPARS, Canadian Public Health Laboratory Network and Health Canada, 2004, unpublished data). Comparisons were based on age, gender and severity of infection (using the type of clinical specimen obtained as a marker).

Local and provincial public health laboratories confirmed cases by routine culture methods and serotyping [26]. Phage-typing analysis was performed on case isolates forwarded to the National Laboratory for Enteric Pathogens, Health Canada [27].

RESULTS

Six provinces and one territory participated in the study (Table 1). A total of 95 matched pairs were interviewed, as well as 16 unmatched cases from Québec. The dates of symptom onset among 95% of interviewed cases ranged from 1 January to 28 May 2003. The remaining 5% of cases reported symptom onset between 15 October and 31 December 2002. The median age of cases was 14 years (range 0–95 years) and 31% of cases were <6 years old. Fifty-six per cent of cases were male. The median length of illness was 10 days (range 1–90 days) and 47% of cases were admitted to a hospital as a result of the infection for a median stay of 5 days (range 1–60 days). Symptoms included diarrhoea (88%), fever (80%), abdominal cramps (65%), nausea (42%), vomiting (35%) and headache (29%). Thirty-three per cent of cases experienced bloody diarrhoea. Phage typing information was provided for 72% of case isolates. The most common types were PT19 (29 cases), PT26 (16 cases), PT29 (9 cases), PT4 (7 cases) and PT35 (4 cases). There was no significant clustering of phage types over time or by province.

Cases accounted for 25% of the 450 isolates identified through routine national laboratory surveillance over the study period (National Enteric Surveillance Program, Health Canada, 2003, unpublished data). Enrolled cases did not differ significantly by age or gender from cases reported nationally through

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Table 2. *Potential risk factors for* Salmonella *Heidelberg infection among participants of a national case-control study, Canada, 1 January to 31 May, 2003* (*only exposure variables with univariate P values <0·05 are listed*)

	Exposure in the week before onset/interview						
	Cases		Controls				
Exposure	No.	%	No.	%	OR*	95% CI	*P* value
Chicken nuggets	51	49·5	22	24·4	3·2	1·5–6·8	0·0009
Chicken nuggets prepared at home	40	38·8	13	14·4	3·5	1·6–7·7	0·0006
Chicken strips	24	23·5	8	9·0	6·8	1·9–38·1	0·0009
Chicken strips prepared at home	23	22·6	6	6·7	21·3	3·0–947·3	<0·0001
Chicken nuggets and/or strips prepared at home	47	45·2	18	19·8	3·8	1·7–8·2	0·0002
Chicken wings	18	18·0	6	7·0	3·8	1·2–15·5	0·0192
Undercooked eggs	16	18·6	2	2·4	5·5	1·2–51·1	0·0225
Deli chicken	19	21·6	6	7·1	6·9	1·8–41·4	0·0020
Roast beef	27	28·7	11	12·6	2·2	1·0–4·9	0·0386

* Odds ratios from univariate conditional logistic regression comparing cases to controls matched by age group (<7, 7–17, >17 years) and geographic area as defined by home telephone exchange. Exact methods were employed where cell counts were less than five and estimates adjusted for gender where inclusion of gender in the model altered parameter estimates by more than 10%.

CIPARS (median age 18 years, range 0–97 years, $P=0·32$, 51% male). Blood samples were drawn from a significantly higher proportion of enrolled cases (29%) than from those reported through CIPARS (12%, $P<0·001$).

Univariate analysis results for exposure variables with statistically significant *P* values are presented in Table 2. Chicken nuggets and strips were both significantly ($P<0·05$) associated with illness. For both products, the mORs increased when only store-bought, home-prepared strips or nuggets were considered. Consumption of chicken strips was more strongly associated with illness than chicken nuggets, however, 15 (65%) of the cases that ate chicken strips also ate chicken nuggets, and more cases reported eating chicken nuggets (38·8%) than chicken strips (22·6%). Both variables remained significant when entered into a model together. A single variable was created to represent consumption of either or both types of products prepared at home and this variable was significantly associated with illness (mOR 3·8, 95% confidence interval (CI) 1·7–8·2). Thirteen variables with *P* values <0·25 were included in subsequent multivariate analyses.

The final model contained three variables. Cases were more likely than controls to have consumed home-prepared chicken nuggets and/or strips (mOR 4·0, 95% CI 1·4–13·8), to have consumed undercooked eggs (mOR 7·5, 95% CI 1·5–75·5), and were less likely than controls to either live on or have visited a farm (mOR 0·22, 95% CI 0·03–1·00). Similar results were obtained excluding matched pairs where cases reported symptom onset more than 2 weeks prior to the study start date. Assuming cases enrolled are representative of all cases in the Canadian population, 34% of all *S.* Heidelberg infections are attributable to consumption of chicken nuggets and strips prepared at home, and 16% are attributable to eating undercooked eggs.

Thirteen different phage types were identified among chicken nugget and strip consumers and six were identified among those reporting consumption of undercooked eggs. Cases purchased 15 different brands of chicken nuggets and strips, with several popular brand names comprising the majority of case purchases. Cases also reported various different sources of eggs.

Sample sizes for individual provinces/territories were insufficient to analyse individually with the exception of Québec. Québec data accounted for 69% of all matched pairs. Results of multivariate analysis were similar to the national findings except that farm exposure was not associated with a lower risk of illness. Québec cases were 5·9 (95% CI 1·2–57·6) times

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more likely to have consumed undercooked eggs and although not statistically significant ($P=0{\cdot}058$), cases were 3·1 (95% CI 1·0–12·0) times more likely to have eaten chicken nuggets and/or strips prepared at home than controls. Multiple sources were named for both risk factors.

When participants (cases and controls combined) were asked who in the household typically eats frozen, processed chicken products such as chicken nuggets, 40% reported their whole family, 23% indicated the children or teenagers in the home, 13% said that only adults eat these products and 25% reported that nobody in the household eats these products. Forty per cent of participants considered frozen, processed chicken products to be pre-cooked. This proportion was similar among case and control households ($P=0{\cdot}58$). Cases (or case parents/guardians) were slightly less likely than controls to always wash their hands after handling raw, uncooked chicken, although this difference was not statistically significant (67% compared to 85%, $P=0{\cdot}20$). Participants were also asked how frequently they washed their hands after handling processed chicken products such as chicken nuggets and strips. Thirty per cent of both cases and controls reported washing their hands less often after handling processed chicken products than after handling raw, whole chicken. Eleven per cent of participants reported using the microwave for cooking chicken nuggets or strips. One quarter (82 participants) of chicken nugget and/or strip consumers reported repackaging large boxes of the product into smaller freezer portions at least some of the time, of whom 32% did not retain the box instructions. Québec study subjects were also asked how often they read cooking instructions before cooking chicken nuggets. Among cases and controls, 57% always read the instructions, 31% read the cooking instructions often or sometimes and 12% never read them.

DISCUSSION

The results of this study indicate that home-prepared chicken nuggets and strips, and undercooked eggs are leading risk factors for endemic *S*. Heidelberg infections in Canada. Cases were 4·0 times more likely than controls to have consumed home-prepared chicken nuggets and/or strips (95% CI 1·4–13·8), were 7·5 times more likely to have consumed undercooked eggs (95% CI 1·5–75·5), and were less likely than controls to be exposed to a farm setting (mOR 0·22, 95% CI 0·03–1·00). Cases enrolled in this study were more likely to have been laboratory confirmed through blood culture compared to all nationally reported cases of *S*. Heidelberg. Some provinces were unable to participate due to resource limitations and no information was requested for those cases not enrolled within participating provinces who may have not been contacted, refused to participate or were excluded for some other reason. Nevertheless, these findings suggest that 34 and 16% of laboratory-confirmed *S*. Heidelberg infections in Canada are attributable to home-prepared chicken nuggets and strips, and undercooked eggs respectively.

The findings of this study suggest that persons exposed to a farm setting may be less likely to become ill as a result of *S*. Heidelberg exposure. Previous studies have demonstrated that farm animals are sources of *Salmonella* infection [28, 29]. Detailed information regarding the type of farm operation, history of illness among the farm animals and the participants reporting farm exposure was not available for analysis; however, it is hypothesized that the protective effect observed here is the result of immunity acquired by previous exposure to infected farm animals.

Results from this study are consistent with the findings of other laboratory and epidemiological studies. *S*. Heidelberg is the most common *Salmonella* serovar isolated from poultry sources including broiler chickens and egg-producing flocks, has been isolated from eggshells and is able to grow inside eggs [30–33]. Undercooked eggs have been identified as important risk factors for sporadic infections of *S*. Enteritidis, *S*. Typhimurium and *S*. Heidelberg in the United States [23, 34]. The US study examining risk factors for sporadic *S*. Heidelberg infection did not identify chicken nuggets/strips as an important source of infection [23]. However, the questionnaire employed did not ask specifically about chicken nugget or strip consumption, only chicken consumption in general.

Other recent studies have implicated frozen processed chicken products as sources of salmonellosis in humans. The case-series investigation conducted in Québec in 2002 and discussed earlier is one example (C. Gaulin, unpublished data). Researchers in Québec also conducted a laboratory survey in 2002. They surveyed 106 chicken nugget samples originating from 14 different manufacturers and 30% were positive for *Salmonella*; 59% of the isolates were serotype Heidelberg of various phage types (D. Ramsay, unpublished data). While these laboratory findings are not unexpected given the prevalence of *S*. Heidelberg in raw poultry and the fact that chicken nuggets from

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Fig. Photograph of raw processed chicken nuggets that have been breaded and par-fried to a golden state and packaged into a plastic bag and large box for freezer storage.

11 of the 14 manufacturers were raw products, results demonstrate the potential health risks associated with these products if not handled and cooked properly. An investigation into a 1998 outbreak of *S*. Typhimurium PT12 infections in Australia lead to the recall of a particular brand of partially cooked frozen chicken nuggets [35]. Finally, the case-control study conducted in British Columbia in early 2003 found a significant association between consumption of frozen chicken nuggets and/or strips and *S*. Heidelberg infection, and food testing identified *S*. Heidelberg in opened and unopened products [24].

Participants' survey responses demonstrate that a substantial proportion of chicken nugget/strip consumers do not perceive, handle or prepare these products as they would raw, unprocessed chicken, although the majority of these products on the Canadian market are raw or only partially cooked (par-fried) (D. Ramsay, unpublished data). Both the Australian and British Columbia studies discussed previously highlight consumer misperceptions about the state of the frozen processed chicken products, and improper cooking and handling of raw products was identified as the root cause of case illnesses. Frozen, breaded and often par-fried products do not appear similar to raw, whole meat in terms of colour, juice and texture (see Fig.). Consumers' misperceptions may also extend to other frozen raw products that lack the cues people normally use to identify raw meat. Manufacturers of chicken nuggets/strips are required to include oven-cooking instructions on the product packaging but labelling seldom indicates whether the product is raw or fully cooked and does not necessarily provide advice for safe handling, or the use or avoidance of microwave cooking.

Results of this study have contributed directly to policy change. Health Canada's Food Directorate is currently drafting an addition to the Food and Drug Regulations requiring mandatory safe handling labels to be applied to raw ground meat and poultry products that have a cooked appearance, including chicken nuggets/strips. The Canadian Food Inspection Agency (CFIA) has also recently proposed amendments to the Meat Inspection Regulations requiring products that have a cooked appearance but are raw to include the expression 'uncooked' or an equivalent term in the name of the product [36]. Findings from this study have also been shared with food safety educators to encourage development of effective consumer education strategies regarding the safe handling and preparation of these products, and with the poultry production and processing industry to encourage industry-led risk reduction strategies.

Finally, this study demonstrates the value of research examining sources for sporadic foodborne infections. Traditionally, public health has relied on the results of outbreak investigations to direct action, but outbreak-related cases often comprise a small proportion of all cases reported nationally [3]. The current endemic study indicated that a substantial proportion of *S*. Heidelberg infections in Canada can be attributed to consumption of home-prepared chicken nuggets and strips, and provides a target for high-impact intervention.

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