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Sporadic salmonellosis in Lower Saxony, Germany, 2011–2013: raw ground pork consumption is associated with *Salmonella* Typhimurium infections and foreign travel with *Salmonella* Enteritidis infections

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SUMMARY

To investigate risk factors for sporadic salmonellosis, for each notified case four randomly selected population controls matched for age, sex and geographical region were interviewed via self-administered questionnaire. Conditional logistic regression analysis of 285 matched pairs revealed significant associations for raw ground pork consumption [odds ratio (OR) 6·0, 95% confidence interval (CI) 1·8–20·1], taking antacids (OR 5·8, 95% CI 1·4–24·5), eating meat outside the home (OR 5·7, 95% CI 2·2–14·6) and daily changing or cleaning of dishcloth (OR 2·1, 95% CI 1·2–3·9). Animal contact and ice cream consumption were negatively associated with salmonellosis (OR 0·5, 95% CI 0·2–1 and OR 0·3, 95% CI 0·1–0·6, respectively). *S.* Typhimurium infections were significantly associated with raw ground pork consumption (OR 16·7, 95% CI 1·4–194·4) and *S.* Enteritidis infections with having travelled abroad (OR 9·7, 95% CI 2·0–47·3). Raw egg consumption was not a risk factor, substantiating the success of recently implemented national control programmes in the poultry industry. Unexpectedly, hygienic behaviour was more frequently reported by cases, probably because they overestimated their hygiene precautions retrospectively. Although animal contact might enhance human immunocompetence, underreporting of salmonellosis by pet owners could have occurred. Eating raw pork products is the major risk factor for sporadic human *S.* Typhimurium infections in Lower Saxony.

Key words: Domestic kitchen hygiene, foodborne zoonosis, matched case-control study, *S. enterica*, social desirability bias.

INTRODUCTION

Non-typhoidal salmonellosis continues to be a substantial burden on public health in the Western world. Lower Saxony reports about 2000 notifications (25/100 000 inhabitants) each year, the majority being sporadic cases with an unknown source of infection [1]. Within Germany, the predominance of the two major serovars, *Salmonella* Typhimurium and *S.* Enteritidis, strongly differs between geographical regions [2]. Since 2009, *S.* Typhimurium has been the most frequently reported serovar in Lower Saxony accounting for 41% of all notified cases in 2012 [3]. In contrast to *S.* Enteritidis infections, which are mainly associated with egg and poultry consumption [4–9], risk factors and infection routes for *S.* Typhimurium serovars are less clear [10].

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Associations with exposures that differ from the classical foodborne transmission [6, 11] substantiate that the agent seems to be widespread in the environment rather than in food only. Besides shifts in serovar prevalence, potential changes in food production industry or consumers' behaviour such as increasing popularity of exotic foods and frequent foreign travel justify re-assessment of risk factors in the same population, in order to tackle prevailing challenges of foodborne hazards [12]. To extend our knowledge about recently described risk factors [13, 14] and to assess the impact of hygiene in the domestic environment, we performed a case-control study on sporadic salmonellosis in Lower Saxony. We matched cases and controls for county district, age and sex. Besides an overall analysis, *S.* Enteritidis and *S.* Typhimurium infections were also considered separately.

METHODS

Study design

Sampling of cases and controls was performed between January 2012 and November 2013. Out of the 46 county districts of Lower Saxony, 14 were selected to participate in the study. We aimed at obtaining a representative sample with respect to population density and location within the Federal state. In order to take regional eating preferences or other behaviours into account, we included county districts that had reported a high proportion of infections with either *S.* Typhimurium or *S.* Enteritidis serovars in previous years. Cases were recruited from *Salmonella* reports of the German infectious disease notification system. Local health departments (LHDs) delivered the questionnaires to persons with laboratory-confirmed *Salmonella* infection and clinical symptoms (diarrhoea, abdominal pain, vomiting, fever). To ensure that only sporadic cases were included, patients were excluded from enrolment in the study if they were part of an outbreak identified by the LHDs' on-site investigations or if they affirmed a question about recent diarrhoea occurring in their contact persons. Controls were selected from a random sampling list provided by the registration offices in the respective areas and received the questionnaire by mail. For each individual case, four controls were selected, matched for age (±3 months), sex and county district. Observation periods were dated 3 days backwards from the day on which the first symptoms of disease were observed in the respective cases. Observation periods of cases and controls were matched for days of the week in order to account for possible differences between weekends and workdays.

Questionnaire

Cases and controls were invited to complete a self-administered questionnaire. Besides basic demographic information (e.g. level of professional education, number of household members, migration background), questions covered leisure activities, contact with animals and various food exposures during the 3 days preceding the illness, in particular consumption of different types of meat, cooking condition (raw, medium, fully cooked) and whether the food was consumed at home or while eating out. Medication over the last 4 weeks and comorbidities were also assessed. Detailed information was collected about consumption of food items that were obtained from either delivery services or takeaways. Other questions covered job-related contact with animals (e.g. farmer, veterinarian), small children (e.g. nurse) or raw meat (e.g. butcher) of the respective person and other household members. Questions about kitchen hygiene as well as practices of meat preparation and consumption were not specifically addressed during the observation period, but inquired about in general routine habits in the respective household. Questionnaires were only used if the attached consent form was signed by the index person or by the parent/guardian of an under-age index person. In some cases, oral consent was obtained via phone. Information about serovars was collected from the reports of the LHDs.

Statistical analysis

Microsoft Access2003 (Microsoft Corp., USA) was used as the database system and Stata statistical software, release 12 (StataCorp., USA) was used to conduct the statistical analyses. Before data entry, questionnaires were controlled for completeness and plausibility. We performed a conditional logistic regression analysis to consider the 1:*n* pair-matched design. Therefore, two versions of odds ratios (OR) are reported: The conditional OR taking into account the matching for sex, age and region and an adjusted OR accounting for multivariable risk factors. Based on the outcome of the univariable analysis, variables with $P < 0{\cdot}2$ and more than four exposed subjects in each group were selected for

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the initial multivariable logistic regression analysis. The cut-off value for step-wise backward elimination of non-significant variables from the model was $P \geqslant 0{\cdot}2$. In all analyses the level of significance α was set to 0·05 (two-sided). To avoid covariation in variables tested in the multivariable logistic regression analysis, certain exposures were combined to construct composite variables. For example 'consumption of meat outside the home' consisted of consumption of poultry, pork, beef (or veal) or lamb outside the home. Associations (Cramer's V) between variables selected for multivariable testing were <0·3. Due to the explorative nature of this study, multiplicity correction to control the number of false-positive results, as well as modelling of interactions were omitted. Sensitivity analyses were performed to validate the final model. The results of the multiple logistic regression analysis were quite stable. Backward and forward selection procedures as well as omitting certain variables did not lead to considerable changes in the calculated OR for the remaining factors.

Ethical approval

The study was exempted from ethical approval by the ethics committee of the Hannover Medical School.

RESULTS

Between January 2012 and November 2013, over 3500 questionnaires were dispatched. Response rates were 60% (425/716 questionnaires) in cases and 28% (800/2864) in controls. Seventy-nine controls were excluded as they reported to have suffered from diarrhoea recently. The final dataset comprised 1127 participants (416 cases, 711 controls) resulting in 285 matched pairs (732 observations). Mean (±S.D.) time lag between cases' and controls' observation periods was 14 (±9) days. Serotyping was performed in 398 isolates. *S.* Typhimurium serovars were found in 180 (43%) cases, *S.* Enteritidis serovars in 80 (19%) cases and *S.* Infantis in 22 (5%) cases. An overview of the sociodemographic characteristics of cases and controls (non-matched dataset) is given in Table 1. Multivariable logistic regression analysis revealed significant associations for consumption of raw ground pork, intake of gastric acidity inhibitors and eating meat outside the home. Affirmative answers to the questions regarding kitchen hygiene were generally more frequent in cases than in controls, and in particular, a significant association between sporadic salmonellosis and the statement that the dishcloth in the respective household was changed daily or cleaned by using a minimum washing temperature of 60 °C on a daily basis was detected. Furthermore, significant associations with OR <1 were detected for

Table 1. *Sociodemographic characteristics of salmonellosis cases and controls in Lower Saxony, 2011–2013 (non-matched dataset)*

	Cases	%	Controls	%
Total	416		711	
Age (years)				
<2	17	4·1	23	3·2
2–6	57	13·7	127	17·9
7–18	107	25·7	172	24·2
19–30	66	15·9	79	11·1
31–45	50	12·0	75	10·5
46–60	49	11·8	96	13·5
>61	70	16·8	139	19·5
Mean age (years)	31		32	
Median age (years)	22		21	
Sex				
Male	217	52·2	380	53·4
Female	199	47·8	331	46·6
Season				
April–October	254	61·1	485	68·2
November–March	162	38·9	226	31·8
Education				
Still in education	61	14·7	95	13·4
No education/no professional training	26	6·3	38	5·3
Trained worker/ apprentice	158	38·0	235	33·1
High school/technical school	62	14·9	113	15·9
University, college	50	12·0	140	19·7
Other/not specified	59	14·2	90	12·7
Number of persons in household				
1	28	6·7	48	6·8
2	116	27·9	177	24·9
3	79	19·0	142	20·0
4	122	29·3	228	32·1
5	42	10·1	81	11·4
⩾6	19	4·6	29	4·1
Not specified	10	2·4	6	0·8
Migration background				
Both parents born outside Germany	41	9·9	44	6·2
One parent born outside Germany	20	4·8	37	5·2
Both parents born in Germany	355	85·3	630	88·6

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animal contact and consumption of ice cream (see Table 2). Serovar-specific risk-factor analyses of 124 cases with sporadic *S.* Typhimurium infections and their respective controls (192 controls; 316 observations) revealed a significant association for raw ground pork consumption in the multivariable analysis (see Table 3*a*). *S.* Enteritidis infections were significantly associated with having travelled abroad in the multivariable analysis of data from 57 cases and 96 controls (153 observations; Table 3*b*).

DISCUSSION

The majority of reported salmonelloses in Germany are sporadic [1] and the source of infection often remains unidentified. In order to develop, implement and update successful control and prevention strategies, a proper understanding of the current epidemiology and potential risk factors of a disease is necessary. To this aim, we investigated notified cases with sporadic salmonellosis in Lower Saxony. Controls were matched on age, sex and region, to exclude these potential confounders. In the present study, 60% of the cases and 28% of the controls returned the questionnaire. Although we approached four controls for each case, still 131 cases remained without a matched control. A similarly designed study on yersiniosis that also used self-administered questionnaires reported response rates of 42% for cases and 36% for controls [15]. In a previous study on sporadic salmonellosis, telephone interviews could be performed successfully with 51% of the recruited *Salmonella* cases whereas only 30% of controls consented to an interview [13]. These data indicate that in controls, response rates are low for both oral and written questionnaires. The serovar distribution found in our study closely reflects the general distribution of serovars in all notified cases in Lower Saxony during the study period (2012: 43% *S.* Typhimurium; 23% *S.* Enteritidis; 3% *S.* Infantis; 2013: 44% *S.* Typhimurium; 16% *S.* Enteritidis; 7% *S.* Infantis; [3]), emphasizing the significance of *S.* Typhimurium serovars for sporadic human infections in this region. Eating 'mett' (raw pork finely minced or ground and used as a spread on bread) is very popular in the northern and eastern regions of Germany, and the current risk-factor analysis revealed the highest OR for this food exposure. In line with previous findings [14], a significant association with *S.* Typhimurium infections for consumption of raw ground pork was also detected. Prevalence in German slaughter pigs as well as transmission of the pathogen along the food chain have been documented [16, 17], emphasizing the relevance of pork as a source for *Salmonella* infections in the German population [13, 14, 18].

For sporadic *S.* Enteritidis infections, foreign travel was identified as a risk factor, whereas in contrast to earlier studies [4, 5, 14] consumption of food items containing raw eggs was not significantly associated with the disease. Across Germany, overall numbers of notified *S.* Enteritidis infections in humans have been decreasing during the past decade, reflecting the decreasing prevalence of this serovar in laying hen flocks and hence eggs [19]. This decline is interpreted as a consequence of the recently implemented national *Salmonella* control and monitoring programmes in egg production sectors in accordance with regulation (EC) No. 2160/2003 [20]. Our current findings demonstrate the first epidemiological evidence at the population level for the success of these measures in Germany. Similarly, human *S.* Enteritidis infections are mostly travel-related in other European countries with low prevalence of *S.* Enteritidis in laying hen flocks [9, 21].

In line with our current findings, taking antacids has been identified previously as a risk factor for sporadic salmonellosis [4, 6, 13, 22]. Intake of antibiotics seems to favour human *S.* Typhimurium [10, 11] but not *S.* Enteritidis infections [9], probably due to different antimicrobial resistance profiles in serovars [6]. In our dataset, treatment with antibiotics was significantly associated with *S.* Typhimurium infections in the single-factor analyses, but the association failed significance in the multivariable analysis.

In the past, ice cream has been identified as a vehicle of *S.* Enteritidis infection, mostly due to cross-contamination with raw eggs [9, 23]. In contrast to these observations, our current analysis revealed a negative association between ice cream consumption and sporadic *Salmonella* infections, which is difficult to interpret. Although contaminated eggs are rarely found nowadays [20], which minimizes infection risk, a truly protective effect of ice cream consumption does not seem biologically plausible and lacks biomedical evidence. Whether ice cream consumption is associated with another, still unidentified protective exposure or whether subjects who consume ice cream reduce their exposure to other risk factors requires further exploration. It should be mentioned that negative associations, in particular for food exposures, are occasionally found in case-control studies

Table 2. *Univariable and multivariable analysis of selected exposures associated with sporadic salmonellosis in a matched case-control study in Lower Saxony, 2011–2013*

Variables Exposures 3 days prior to onset of symptoms	Cases ($n = 285$)	Controls ($n = 447$)	Univariable analysis aOR†	 95% CI	Multivariable analysis aOR‡	 95% CI
Activity						
Travel abroad	38	16	**4·30**	**2·29–8·05**	Removed*	
Swimming in sea	23	10	**3·96**	**1·07–9·21**	Not used**	
Animal contact	136	249	**0·72**	**0·52–1·00**	**0·46**	**0·22–0·99**
Job-related animal contact of household member	7	24	**0·33**	**0·11–0·98**	0·14	0·01–1·38
Playing in sandbox	65	127	0·67	0·42–1·06	0·34	0·11–1·03
Food outside the home						
Eating out	163	205	**1·82**	**1·30–2·54**	Not used**	
Eating at restaurant	57	67	**1·67**	**1·08–2·58**	Removed*	
Eating at takeaway	50	53	**1·60**	**1·03–2·50**	Removed*	
Hamburger	28	35	**1·81**	**1·01–3·24**	Removed*	
Eating at hospital	9	6	2·86	0·93–8·75	Removed*	
Meatball	14	14	2·11	0·90–4·96	Removed*	
Sandwich	35	48	1·56	0·92–2·65	Removed*	
Pre-prepared fruits/berries	25	31	1·59	0·86–2·94	Removed*	
Meat consumption						
Ground lamb	9	4	**7·59**	**1·62–35·67**	Combined***	
Ground venison	5	4	8·06	0·91–71·06	Combined***	
Ground lamb and/or venison	10	6			Removed*	
Poultry outside the home	50	26	**3·91**	**2·19–6·98**	Combined***	
Pork outside the home	43	37	**2·59**	**1·49–4·53**	Combined***	
Beef or veal outside the home	22	14	**2·17**	**1·04–4·53**	Combined***	
Lamb outside the home	12	4	**4·32**	**1·34–13·90**	Combined***	
Meat outside the home	77	61			**5·66**	**2·20–14·58**
Ground pork outside the home	34	21	**3·31**	**1·71–6·38**	Removed*	
Raw ground pork	51	52	**2·39**	**1·42–4·02**	**6·01**	**1·79–20·14**
Ground poultry outside the home	10	6	2·68	0·82–8·81	Removed*	
Ground beef or veal outside the home	10	8	1·97	0·74–5·26	Removed*	
Various food items						
Foods containing raw eggs (e.g. tiramisu, mayonaise)	53	52	**2·04**	**1·33–3·14**	2·68	0·87–8·25
Pre-packed salad	50	56	**1·74**	**1·12–2·70**	Removed*	
Ice cream	107	242	**0·46**	**0·32–0·66**	**0·26**	**0·11–0·58**
Smoked ham (raw)	90	177	**0·69**	**0·49–0·99**	0·49	0·22–1·11
Exposures during the last 4 weeks before onset of symptoms						
Antacids	48	32	**2·83**	**1·65–4·86**	**5·77**	**1·36–24·51**
Antibiotics	32	23	**2·16**	**1·24–3·76**	Removed*	
Assessment of hygiene behaviour						
'In my household it is common practice to …'						
Change or clean the dishcloth on a daily basis	155	176	**1·87**	**1·36–2·55**	**2·13**	**1·18–3·86**
Disinfect kitchen surfaces (in addition to cleaning) on a daily basis	70	82	**1·57**	**1·07–2·30**	Removed*	
Wash hands with soap and water before preparing food	270	410	**2·32**	**1·13–4·78**	Removed*	

aOR, Adjusted odds ratio; CI, confidence interval.
Variables that are significantly ($P \leqslant 0·05$) associated with the disease appear in bold.
† Odds ratio accounting the matching for age, sex, region.
‡ Odds ratio accounting the multivariable risk factors.
* Variable removed ($P > 0·2$) from model; **variable not used in final model; ***variable integrated in composite variable.

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Table 3. *Univariable and multivariable analysis of selected exposures associated with sporadic (a)* S. *Typhimurium or (b)* S. *Enteritidis infections in a matched case-control study in Lower Saxony, 2011–2013*

Variables Exposures 3 days prior to onset of symptoms	Cases ($n = 124$)	Controls ($n = 192$)	Univariable analysis		Multivariable analysis	
			aOR†	95% CI	aOR‡	95% CI
(*a*) *S.* Typhimurium infections						
Food outside the home						
Eating at fast-food restaurant	19	11	**3·23**	**1·44–7·24**	Removed*	
Eating out	72	89	**1·76**	**1·07–2·91**	Not used**	
Sandwich	18	18	**2·54**	**1·06–6·10**	Not used**	
Hamburger	15	12	2·10	0·92–4·78	Not used**	
Eating at takeaway	20	16	1·78	0·90–3·53	Not used**	
Eating at canteen/cafeteria	9	8	2·30	0·81–6·56	Removed*	
Meat consumption						
Raw ground pork	32	17	**5·17**	**2·22–12·00**	**16·65**	**1·43–194·37**
Ground pork outside the home	18	12	**4·83**	**1·77–13·21**	Removed*	
Poultry outside the home	17	10	**5·19**	**1·69–15·92**	4·05	0·83–19·72
Uncooked pork sausage	55	61	1·86	**1·11–3·13**	Removed*	
Various food items						
Foods containing raw eggs (e.g. tiramisu, mayonaise)	24	23	**2·00**	**1·06–3·79**	Removed*	
Pre-packed salad	23	23	1·70	0·90–3·19	Removed*	
Exposures during the last 4 weeks before onset of symptoms						
Medication						
Antacids	19	12	**3·12**	**1·32–7·41**	Removed*	
Antibiotics	20	10	**3·49**	**1·57–7·75**	6·48	0·60–70·36

(*b*) *S.* Enteritidis infections	Cases ($n = 57$)	Controls ($n = 96$)	Univariable analysis		Multivariable analysis	
			aOR†	95% CI	aOR‡	95% CI
Activity						
Travel abroad	16	4	**12·05**	**2·71–53·54**	**9·65**	**1·97–47·31**
Swimming in sea	8	2	**10·99**	**1·31–92·14**	Not used**	
Job-related contact with children aged <6 years	5	6	3·49	0·62–19·62	Removed*	
Food outside the home						
Eating out	35	44	**2·99**	**1·29–6·94**	Removed*	
Chicken doner kebab	7	5	3·65	0·91–14·65	3·45	0·63–18·86
Various food items						
Smoked pork sausage	8	8	2·43	0·76–7·76	3·45	0·83–14·28
Foods containing raw eggs (e.g. tiramisu, mayonaise)	10	12	2·02	0·77–5·27	Removed*	

aOR, Adjusted odds ratio; CI, confidence interval.
Variables that were significantly ($P \leqslant 0·05$) associated with the disease appear in bold.
† Odds ratio accounting the matching for age, sex, region.
‡ Odds ratio accounting the multivariable risk factors.
* Variable removed ($P > 0·2$) from model; **variable not used in final model.

and are usually considered as artefacts or chance associations [6, 7, 11, 24–26].

A variety of domestic and wildlife animal species can host and shed non-typhoidal *Salmonella* spp., thereby contributing to human infections [27]. However, our current data, indicate a lower risk of illness for people that had experienced animal contact, which could signify a protective effect. It is

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conceivable that continuous exposure to foodborne pathogens reduces clinical symptoms due to acquired immunity. The incidence of acute gastrointestinal illness caused by *Escherichia coli*-polluted drinking water decreased with years of residence in the respective area [28]. The risk of *E. coli* and *Salmonella* infection via animal contact has also been found to decrease with age [18, 29]. During childhood, clinical or subclinical *Salmonella* infections caused by repeated animal contact have the potential to modulate the immune system [30], thereby reducing the risk for allergic sensitization [31]. On this evidence, a certain protective effect of animal contact against human salmonellosis appears biologically plausible. On the other hand, pet owners have been found to visit their physician less frequently [32], which could have led to underreporting in the current study. The fact that previous studies identified animal contact as risk factor only when notified *Salmonella* cases and notified rotavirus cases were compared, but not against healthy population controls [13, 18] also indicates a certain pre-selection of notified cases regarding this exposure. Although negative associations between animal contact and other exposures were not detected in the present study, it is also conceivable that pet owners reduce their exposure to other risk factors, for example by travelling less or eating meat outside the home less frequently.

Univariable analysis revealed significant associations between salmonellosis and consumption of poultry, pork, beef (or veal) and lamb outside the home. Due to the high association within these variables, however, not all types of meat could be included in the multivariable model, which found a significant association between consumption of meat outside the home and salmonellosis. It is therefore not possible to discriminate between different types of meat, but all sorts of meat can be contaminated and act as infection vehicles for salmonellosis [20], especially if inadequate food handling behaviour is performed [33]. Similar to our data, eating out or eating chicken prepared outside the home have been identified as risk factors for salmonellosis previously, whereas consumption of food prepared at home has been found to be protective [7, 8]. These reports are, however, in contrast to the assumption that the majority of foodborne infections occur in private settings [34]. Hygiene practices of consumers strongly affect microbial load in prepared meals [35], highlighting the importance of adequate food-handling behaviour in the domestic environment [33]. We therefore chose to assess hygiene behaviour of cases and controls in our questionnaire and found that hygienic behaviour was reported more frequently by cases than controls. Changing the dishcloth on a daily basis or cleaning it daily by using a minimum washing temperature of 60 °C was significantly associated with sporadic salmonellosis in the multivariable analysis. One possible interpretation of this finding is that cases behaved more hygienically than controls. *Salmonella* spp. can develop resistance to disinfecting agents [36], but whether this also increases their virulence remains unclear [37]. It is conceivable that people who do not clean their dishcloth thoroughly are constantly exposed to small doses of bacteria, which could enhance their immunocompetence [28, 30]. A certain limitation of the study is that the respective question did not cover any details regarding the washing procedure, so it was not possible to assess the efficacy of the applied practice. On the other hand, cases tend to retrospectively overemphasize their hygiene precautions by describing their personal behaviour in a more favourable light [38]. Assessment of hygiene behaviour via questionnaire is difficult and results can be inconsistent with the actual microbiological findings [34]. Discrepancies between self-reported and observational data on hygiene behaviour are also common [33, 35]. In a previous investigation, data on hygienic behaviour collected via telephone interviews were biased by social desirability [13]. In the present study we therefore aimed at minimizing social desirability bias by using self-administered questionnaires. Thereby, results cannot be biased by interviewer presence and the perceived anonymity is higher compared to telephone interviews [38]. To avoid recall bias, our questions about kitchen hygiene as well as practices of meat preparation and consumption were phrased in a very general way and did not particularly address the observation period. Our current findings are in contrast to the widely held belief that poor hygiene is a risk factor for salmonellosis. A truly protective effect, however, should be biologically plausible, with underlying mechanisms clarified. To discover whether cases and controls really differ in their hygiene behaviour or whether they just answer differently is the aim of our future research.

CONCLUSION

In conclusion, our results confirm that different risk factors for different *Salmonella* serovars exist. In regions such as Lower Saxony where raw ground

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pork consumption is popular, these food items must be considered as the major vehicles of infection with *S.* Typhimurium serovars. Public education should aim at reducing exposure of vulnerable groups, such as the elderly, children, pregnant or immunocompromised persons to raw pork products. Control measures in farm-to-retail processing may include reducing *Salmonella* prevalence in pigs and minimizing the risk of contamination at all stages of the food chain [16]. Raw eggs now appear to be of decreasing relevance for infections with *S.* Enteritidis serovars in Germany, leaving foreign travel as the major risk factor. Advising travellers to avoid potentially contaminated dishes and beverages might at present be the most promising intervention. The fact that suppressing gastric acid production medically can increase the risk of foodborne infections might not be generally known and should be communicated by practitioners when antacids are prescribed. Our current results do not imply that animal contact or poor domestic hygiene increase the chance of acquiring sporadic *Salmonella* infections, but the potential bias of self-reported data on hygiene behaviour [33–35] must be taken into account. Our findings also illustrate that a sound interpretation of associations found in case-control studies as risk factors or protective effects partly relies on accompanying microbiological and clinical investigations that elucidate the virulence mechanisms of an infectious agent as well as the pathogenesis of a disease.

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DECLARATION OF INTEREST

None.

REFERENCES

1. **Robert Koch-Institute.** *Yearbook of Infectious Disease Epidemiology, 2013*. 2014, pp 175–179.
2. **Held L, *et al.*** Joint spatial analysis of gastrointestinal infectious diseases. *Statistical Methods in Medical Research* 2006; **15**: 465–480.
3. **Robert Koch-Institute.** SurvStat@RKI 2·0 (https://survstat.rki.de). Accessed 18 September 2014.
4. **Banatvala N, *et al.*** Salmonellosis in North Thames (East), UK: associated risk factors. *Epidemiology and Infection* 1999; **122**: 201–207.
5. **Delarocque-Astagneau E, *et al.*** Risk factors for the occurrence of sporadic *Salmonella enterica* serotype *enteritidis* infections in children in France: a national case-control study. *Epidemiology and Infection* 1998; **121**: 561–567.
6. **Doorduyn Y, *et al.*** Risk factors for *Salmonella* Enteritidis and Typhimurium (DT104 and non-DT104) infections in The Netherlands: predominant roles for raw eggs in Enteritidis and sandboxes in Typhimurium infections. *Epidemiology and Infection* 2006; **134**: 617–626.
7. **Kimura AC, *et al.*** Chicken consumption is a newly identified risk factor for sporadic *Salmonella* enterica serotype Enteritidis infections in the United States: a case-control study in FoodNet sites. *Clinical Infectious Diseases* 2004; **38** (Suppl. 3): 244–252.
8. **Marcus R, *et al.*** Re-assessment of risk factors for sporadic *Salmonella* serotype Enteritidis infections: a case-control study in five FoodNet Sites, 2002–2003. *Epidemiology and Infection* 2007; **135**: 84–92.
9. **Mølbak K, Neimann J.** Risk factors for sporadic infection with *Salmonella* enteritidis, Denmark, 1997–1999. *American Journal of Epidemiology* 2002; **156**: 654–661.
10. **Delarocque-Astagneau E, *et al.*** Risk factors for the occurrence of sporadic *Salmonella enterica* serotype *typhimurium* infections in children in France: a national case-control study. *Clinical Infectious Diseases* 2000; **31**: 488–492.
11. **Dore K, *et al.*** Risk factors for *Salmonella* Typhimurium DT104 and non-DT104 infection: a Canadian multiprovincial case-control study. *Epidemiology and Infection* 2004; **132**: 485–493.
12. **Käferstein FK, Motarjemi Y, Bettcher DW.** Foodborne disease control: a transnational challenge. *Emerging Infectious Diseases* 1997; **3**: 503–510.
13. **Ziehm D, *et al.*** Risk factors associated with sporadic salmonellosis in adults: a case-control study. *Epidemiology and Infection* 2013; **141**: 284–292.
14. **Ziehm D, *et al.*** Subtype specific risk factor analyses for sporadic human salmonellosis: a case-case comparison in Lower Saxony, Germany. *International Journal of Hygiene and Environmental Health* 2013; **216**: 428–434.
15. **Rosner BM, *et al.*** Risk factors for sporadic *Yersinia enterocolitica* infections, Germany 2009–2010. *Epidemiology and Infection* 2012; **140**: 1738–1747.
16. **Käsbohrer A, *et al.*** *Salmonella* in slaughter pigs of German origin: an epidemiological study. *European Journal of Epidemiology* 2000; **16**: 141–146.
17. **Hauser E, *et al.*** Pork contaminated with *Salmonella enterica* serovar 4,[5],12:i:-, an emerging health risk for humans. *Applied and Environmental Microbiology* 2010; **76**: 4601–4610.

18. **Ziehm D, *et al.*** Risk factors associated with sporadic salmonellosis in children: a case-control study in Lower Saxony, Germany, 2008–2011. *Epidemiology and Infection* 2014; *in press*
19. **Frank C, *et al.*** Marked decreases in reporting incidence of salmonellosis driven by lower rates of *Salmonella* Enteritidis infections in Germany in 2008: a continuing trend. *Eurosurveillance* 2009; **14**: pii=19154.
20. **Federal Institute for Risk Assessment.** Annual report on the epidemiological situation of zoonoses in Germany 2013. BfR-Wissenschaft 02/2014, pp. 37–39.
21. **Emberland KE, Nygård K, Aavitsland P.** Salmonellosis and charter tourism: epidemiology and trends of imported human cases to Norway from the Canary Islands and Thailand, 1994–2008. *Epidemiology and Infection* 2012; **140**: 1655–1662.
22. **Jansen A, *et al.*** Protracted nosocomial outbreak of *Salmonella* Enteritidis LT 8/7. *Zeitschrift für Gastroenterologie* 2008; **46**: 1270–1274.
23. **Dodhia H, Kearney J, Warburton F.** A birthday party, home-made ice cream, and an outbreak of *Salmonella* enteritidis phage type 6 infection. *Communicable Disease and Public Health* 1998; **1**: 31–34.
24. **Bassal R, *et al.*** Risk factors for sporadic infection with *Salmonella* Infantis: a matched case-control study. *Epidemiology and Infection* 2014; **142**: 820–825.
25. **Rodrigues LC, *et al.*** The study of infectious intestinal disease in England: risk factors for cases of infectious intestinal disease with *Campylobacter jejuni* infection. *Epidemiology and Infection* 2001; **127**: 185–193.
26. **Sethi D, *et al.*** A study of infectious intestinal disease in England: risk factors associated with group A rotavirus in children. *Epidemiology and Infection* 2001; **126**: 63–70.
27. **Hoelzer K, Moreno Switt AI, Wiedmann M.** Animal contact as a source of human non-typhoidal salmonellosis. *Veterinary Research* 2011; **42**: 34.
28. **Strauss B, *et al.*** A prospective study of rural drinking water quality and acute gastrointestinal illness. *BMC Public Health* 2001; **1**: 8.
29. **Werber D, *et al.*** Shiga toxin-producing *Escherichia coli* infection in Germany: different risk factors for different age groups. *American Journal of Epidemiology* 2007; **165**: 425–434.
30. **Pelosi U, *et al.*** The inverse association of salmonellosis in infancy with allergic rhinoconjunctivitis and asthma at school-age: a longitudinal study. *Allergy* 2005; **60**: 626–630.
31. **Riedler J, *et al.*** Austrian children living on a farm have less hay fever, asthma and allergic sensitization. *Clinical and Experimental Allergy* 2000; **30**: 194–2000.
32. **Headey B.** Pet ownership: good for health? *Medical Journal of Australia* 2003; **179**: 460–461.
33. **Redmond EC, Griffith CJ.** Consumer food handling in the home: a review of food safety studies. *Journal of Food Protection* 2003; **66**: 130–161.
34. **Azevedo I, *et al.*** Food safety in the domestic environment. *Food Control* 2014; **37**: 272–276.
35. **Fischer A, *et al.*** Food safety in the domestic environment: an interdisciplinary investigation of microbial hazards during food preparation. *Risk Analysis* 2007; **27**: 1065–1082.
36. **Braoudaki M, Hilton AC.** Mechanisms of resistance in *Salmonella* enterica adapted to erythromycin, benzalkonium chloride and triclosan. *International Journal of Antimicrobial Agents* 2005; **25**: 31–37.
37. **Karatzas KAG, *et al.*** Prolonged treatment of *Salmonella* enterica serovar Typhimurium with commercial disinfectants selects for multiple antibiotic resistance, increased efflux and reduced invasiveness. *Journal of Antimicrobial Chemotherapy* 2007; **60**: 947–955.
38. **Nederhof AJ.** Methods of coping with social desirability bias: a review. *European Journal of Social Psychology* 1985; **15**: 263–280.