

## Time trends of positivity rates from foodborne pathogen testing in Switzerland, 2003 to 2012

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### Summary

**BACKGROUND:** Campylobacteriosis and salmonellosis are important foodborne diseases in Europe, including in Switzerland. In 2014, notification rates for Switzerland were 92.9 per 100 000 population for campylobacteriosis and 15.2 per 100 000 population for salmonellosis. These notification rates originate from laboratory-based surveillance whereby positive test results are reported to the National Notification System for Infectious Diseases. Consequently, notification rates do not directly correspond to the disease burden among the population as the number of positive tests depends on patients' healthcare-seeking behaviour, stool sampling rates and other factors.

**METHODS:** We assessed laboratory positivity rates (proportion of positive tests among all tests performed) of diagnostic tests for *Campylobacter* and *Salmonella* from five private laboratories in Switzerland between 2003 and 2012. We analysed demographic characteristics, temporal and spatial distribution of test numbers and positivity rates. Predictors for a positive test and disease seasonality were assessed with logistic regression analyses.

**RESULTS:** A total of 135 122 (13 095 positive) *Campylobacter* tests and 136 997 (2832 positive) *Salmonella* tests were obtained with positive tests corresponding to 20.4% and 17.2% of notified campylobacteriosis and salmonellosis cases, respectively. The number of tests conducted annually increased for both pathogens by 51% from 2003 to 2012. Annual positivity rates of *Campylobacter* increased from 7.6 to 11.1% and rates of *Salmonella* decreased from 2.7 to 1.5%. The largest increases in annual *Campylobacter* positivity rates were observed for patients older than 85 years (+193.7%), followed by children aged 5–9 years (+131.9%). Positivity rates and test numbers for both diseases by month or calendar week showed a distinct seasonality, with peak rates for *Salmonella* occurring in autumn and for *Campylobacter* in summer and at the turn of the year. These findings were independent of patients' age and sex.

**CONCLUSIONS:** Both positivity rates and notification rates showed increasing trends for *Campylobacter* and decreasing trends for *Salmonella*, suggesting that these

trends reflect changes in disease epidemiology at population level. The continuous assessment of positivity rates remains important to appropriately interpret changes observed in the notification system especially considering the increasing use of multiplex polymerase chain reaction test panels where multiple pathogens are tested simultaneously.

**Key words:** *Campylobacter*, *Salmonella*, disease surveillance, denominator data, Switzerland, foodborne disease, seasonality, positivity, epidemiological trends, notification rate

### Introduction

Human campylobacteriosis and salmonellosis are the most frequently reported foodborne bacterial infections in Europe. In 2014, notification rates in the European Union (EU) were 71.0 cases per 100 000 population (corresponding to approximately 236 900 cases) for campylobacteriosis and 23.4 cases per 100 000 population (approximately 88 700 cases) for salmonellosis [1]. In the same year, in Switzerland, the notification rate for *Campylobacter* infections was 92.9 cases per 100 000 population (approximately 7600 cases) and 15.2 cases per 100 000 population (approximately 1200 cases) for *Salmonella* infections [1]. During the mid-1990s, the annual number of notified human *Campylobacter* infections surpassed that of *Salmonella* infections in Switzerland [2]. This was owing to a reduction of human salmonellosis following the introduction of control measures in the egg and poultry industry, such as mandatory screening of layer hens, in the early 1990s [2]. So far, similar control measures for *Campylobacter* are lacking and campylobacteriosis is currently the most frequently notified foodborne disease in Switzerland [2].

In Switzerland, notifiable diseases are monitored by the Federal Office of Public Health (FOPH) through the National Notification System for Infectious Diseases (NNSID) [3, 4]. Laboratory-based surveillance of *Campylobacter* and *Salmonella* infections, as defined by the Epidemics Act of 1970 and its related ordinances, captured only those cases that tested positive [5–7]. Since the implementation of the new Epidemics Act at the beginning of 2016, the total number of tests conducted for these two pathogens, including the number of positive results, must

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be reported annually as aggregated numbers, stratified by month and test method [4, 8]. Hence, denominator data to help draw inferences from surveillance data about the epidemiological situation in the community have not been collected so far. The number of stool tests performed depends on the healthcare-seeking behaviour of patients with diarrhoea and the stool sampling rate of treating physicians [9–11]. As not all individuals affected by acute gastroenteritis seek medical care or have a stool sample examined for enteric pathogens, there are likely to be many undetected (at community level) and unreported (at healthcare level) campylobacteriosis and salmonellosis cases [12, 13]. Hence, changes in notification rates do not necessarily reflect an epidemiological trend, but could be attributable to changes in healthcare-seeking behaviour or stool sampling rates. A more informed interpretation of surveillance data is made possible by calculating positivity rates (proportion of positive tests among all tests performed). Because positivity rate calculations also consider denominator data, they adjust for the number of tests [14, 15]. We analysed laboratory data for stool tests performed for *Campylobacter* spp. and *Salmonella* spp. by Swiss diagnostic laboratories over a 10-year period to better interpret the trends of campylobacteriosis and salmonellosis case notifications seen in the NNSID.

## Materials and methods

### Selection of diagnostic laboratories

The study aimed to include private diagnostic laboratories from all geographical and linguistic regions of Switzerland to reach an optimal representation of the campylobacteriosis cases reported to the NNSID between 2003 and 2012. Eleven private diagnostic laboratories, each reporting more than 1000 campylobacteriosis cases during that decade, were contacted and invited to provide data for the study. The case-based laboratory data requested comprised patients' demographic characteristics (sex, age, canton of residence, personal identification code assigned by laboratory) and test characteristics (pathogen tested, test result, date of test, test method) on all *Campylobacter* and *Salmonella* tests performed between 2003 and 2012.

### Analysis of positivity rates

Datasets from individual laboratories were transformed uniformly, merged and analysed with STATA™ Version 13.1 (Stata Corporation; College Station, TX, USA). Firstly, double entries, repeated tests and tests for patients without Swiss residency were excluded. The following rules – based on disease durations and durations of organism excretion [16] – were applied to identify and exclude repeated tests: (i) control or follow-up tests, irrespective of result, following a positive result within 42 days for both, *Campylobacter* and *Salmonella*; (ii) negative tests following a negative result within 10 days (*Campylobacter*) or 21 days (*Salmonella*); and (iii) negative tests followed by a positive result within 10 days (*Campylobacter*) or 21 days (*Salmonella*). The patient population was characterised by sex, age, diagnostic laboratory, test year and residence by greater region (corresponding to the Nomenclature of Units for Territorial Statistics (NUTS) 2 level [17]). Age groups for statistical analyses were predefined. Residence by greater region was based on the patients' canton of res-

idence (NUTS 3 level). Descriptive analysis of positivity rates – defined as positive tests divided by total tests performed – and exploratory logistic regression analyses of predictors for and seasonality of positive tests were performed. Characteristics of laboratory-confirmed cases of campylobacteriosis and salmonellosis were additionally compared with national surveillance data. Time trends of annual positivity rates were investigated using stratification and direct standardisation for age groups and sex. Thus, the population of individuals tested from 2003 to 2012 was used as the reference population. The seasonality of monthly and weekly positivity rates was assessed by calculating positivity rates from laboratory data from the whole observation period pooled by month or calendar week.

### Univariable and multivariable regression models

In a first step, univariable logistic regression analyses were performed to estimate the effect of sex, age group, laboratory, residence by greater region, test week, test month and test year on the test result. Afterwards, a multivariable logistic regression model estimated the unconfounded effects of sex, age groups, laboratories, residence by greater region and test year on the test result. The effect of seasonal within-year variations on test outcome were investigated with a second multivariable logistic regression model including test month and adjustments for sex, age groups, laboratories, residence by greater region and test year. For this model, the test month with a positivity rate closest to the mean positivity rate of all test months was used as a baseline and test year was introduced as a random effect. The significance of variables in the multivariable models was assessed by likelihood ratio tests and the category of each variable with the most observations (except for test month) was used as a baseline to make the model more robust. Patients with missing information on the canton of residence were assigned the greater region of their corresponding laboratory.

### Ethics statement

The study was approved by the local ethical committee "Ethikkommission Nordwest- und Zentralschweiz" [Ethical committee of Northwestern and Central Switzerland] (No.: EKNZ:2014-164).

## Results

### Exclusion of test results and representativeness

Eight laboratories agreed to participate in the study and five of them provided complete data for *Campylobacter* and *Salmonella* tests performed as requested. The eight laboratories conducted a total of 196 307 *Campylobacter* tests (17 694 positive) and 199 062 *Salmonella* tests (4163 positive) between 2003 and 2012. Excluding data from the three laboratories with incomplete data led to the exclusion of 43 530 (3345 positive) *Campylobacter* tests and 45 114 (640 positive) *Salmonella* tests. Among the remaining laboratories (A to E), removal of double entries, repeated tests and tests of non-Swiss residents led to the exclusion of a further 17 211 (1245 positive) *Campylobacter* tests and 16 499 (689 positive) *Salmonella* tests. Additionally, we excluded 444 (9 positive) *Campylobacter* tests and 452 (2 positive) *Salmonella* tests because of missing information

on sex and/or age. In the detailed analysis, 135 122 (13 095 positive) *Campylobacter* tests and 136 997 (2832 positive) *Salmonella* tests were included. Culture-based test methods accounted for 98.7% of all *Campylobacter* and *Salmonella* tests conducted, and polymerase chain reaction (PCR) tests accounted for 1.3%. Positive tests included in the analysis corresponded to 20.4% and 17.2% of campylobacteriosis and salmonellosis cases, respectively, registered in the NNSID between 2003 and 2012 (tables 1 and 2).

### Characteristics of the patient population and overview of tests performed

The annual number of tests performed increased by 51.1% from 2003 to 2012 (11 674 to 17 641 tests) for *Campylobacter* and by 50.7% (11 842 to 17 842 tests) for *Salmonella* (fig. 1). For both diseases, annual test numbers decreased by at least 6% for the age groups <5 years and 5–9 years, and increased by at least 31% in the older age groups. The median age of patients tested for *Campylobacter* was 42 years (range <1–108 years) and 41 years

(range: <1–108 years) for *Salmonella*. Patients' age differed significantly between laboratories and test years for both pathogens (Kruskal-Wallis test:  $p < 0.01$  for all four tests). Slightly more tests were conducted among females than among males for *Campylobacter* (54.8%) and for *Salmonella* (54.3%). The sex ratio differed between laboratories and test years for both pathogens (chi-square test:  $p < 0.01$  for all four tests). The patients' residence by greater region was associated with the geographical location of the laboratory that performed the test.

### Annual positivity rates overall and by laboratory

Annual *Campylobacter* positivity rates standardised for age and sex increased by 46.1% from 2003 (7.6%) to 2012 (11.1%) (fig. 2). Annual standardised *Salmonella* positivity rates showed an inverse trend and decreased by 44.4% from 2003 (2.7%) to 2012 (1.5%). *Campylobacter* positivity rates stratified by laboratory (and standardised for age and sex) showed similar annual trends (supplementary fig. S1 in appendix 1). The annual positivity rates of laboratory C were remarkably lower throughout the investigated period compared with other laboratories. Laborato-

**Table 1:** Comparison of campylobacteriosis cases from laboratory data with cases registered in the National Notification System for Infectious Diseases by test year, Switzerland, 2003–2012.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Proportion of NNSID cases reported by study laboratories in %	16.7	16.7	17.6	20.4	21.8	21.1	21.4	21.0	21.1	23.0
Proportion of NNSID cases by greater region reported by study laboratories in %										
Lake Geneva	1.5	2.5	2.0	3.5	3.0	3.0	4.0	4.0	3.5	4.0
Espace Mittelland	17.0	17.0	18.5	26.0	27.0	27.0	28.5	29.0	28.0	28.5
Northwestern Switzerland	26.0	22.5	23.0	25.0	27.5	26.0	27.0	25.0	27.0	33.0
Zurich	24.0	27.0	28.0	29.0	29.5	29.0	23.0	28.0	25.0	26.5
Eastern Switzerland	15.0	18.0	18.0	16.5	18.5	20.5	22.0	19.5	23.0	24.0
Central Switzerland	8.0	7.5	8.5	6.5	7.0	6.5	6.0	7.0	6.5	8.0
Ticino	45.5	47.0	44.0	63.0	69.5	54.5	60.0	52.5	57.0	58.0
Proportion of males in %										
Laboratories	56.6	55.4	53.5	57.7	55.2	53.7	55.8	53.0	54.6	54.9
NNSID	55.4	54.8	54.8	55.0	53.5	53.5	53.6	53.8	53.7	54.0
Median age in years										
Laboratories	34	34	34	35	35	36	37	37	39	36
NNSID	32	33	34	34	35	35	35	37	36	36

**Table 2:** Comparison of salmonellosis cases from laboratory data with cases registered in the National Notification System for Infectious Diseases by test year, Switzerland, 2003–2012.

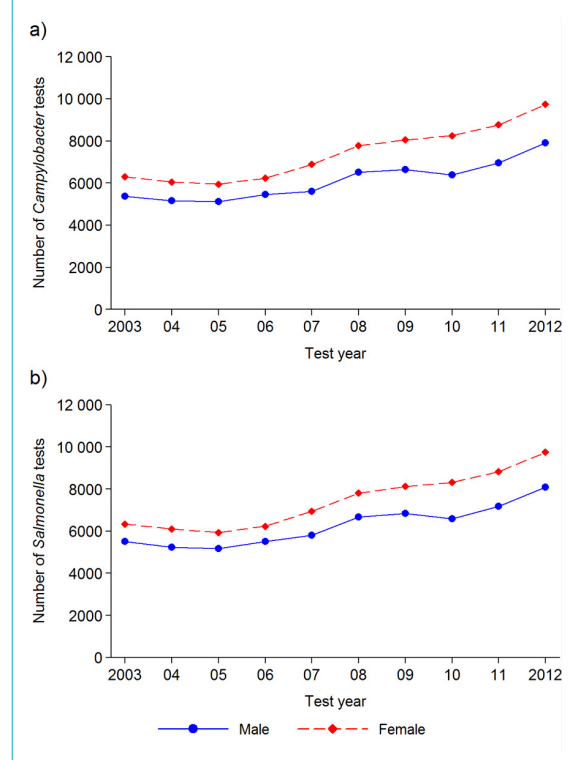
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Proportion of NNSID cases reported by study laboratories in %	15.6	15.9	15.7	16.7	17.7	16.4	17.4	19.0	21.0	19.8
Proportion of NNSID cases by greater region reported by study laboratories in %										
Lake Geneva	0.5	2.5	2.0	3.0	4.5	4.0	2.0	1.0	3.0	1.0
Espace Mittelland	14.5	18.0	14.0	19.0	19.5	19.0	18.5	20.5	28.5	21.0
Northwestern Switzerland	20.0	21.0	21.0	24.0	22.5	17.5	23.0	23.0	19.0	29.5
Zurich	19.0	17.5	18.0	22.0	23.5	21.5	23.0	25.0	14.0	24.5
Eastern Switzerland	9.5	11.0	16.5	12.5	14.5	14.0	17.0	23.0	19.5	18.5
Central Switzerland	6.0	6.5	3.5	7.5	3.5	4.5	4.5	12.0	3.0	10.5
Ticino	49.5	51.0	43.5	48.5	46.0	49.5	45.0	47.0	72.5	48.5
Proportion of males in %										
Laboratories	53.2	53.4	56.0	58.8	57.1	55.0	57.9	52.3	49.6	52.2
NNSID	52.1	49.6	53.1	56.2	54.3	51.4	53.0	52.4	51.2	52.5
Median age in years										
Laboratories	18	23	23	25	30	28	29	25	24	25
NNSID	25	25	26	25	27	28	27	27	28	26

ry-specific *Campylobacter* positivity rates ranged from 3.8 to 9.4% in 2003 and continuously increased to 7.0–13.2% in 2012. For *Salmonella*, annual positivity rates by laboratory differed only slightly between laboratories; the highest rates were observed for laboratory C, with two distinct peaks in 2007 and 2011. Overall, a decreasing trend was observed; positivity rates dropped from 2.1–3.8% in 2003 to 1.2–2.7% in 2012.

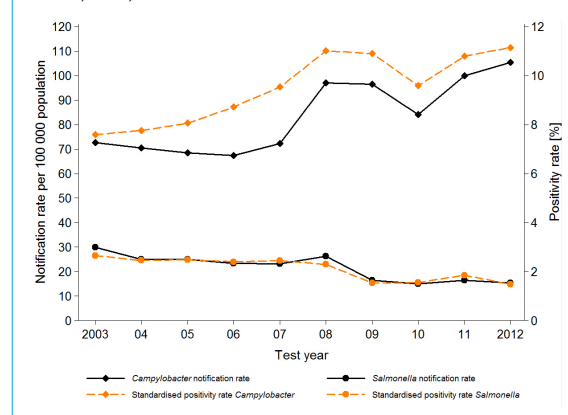
#### Annual positivity rates by sex and age groups

The annual *Campylobacter* positivity rates for males and females increased by 43.6% (from 9.4 to 13.5%) and by 45.2% (from 6.2 to 9.0%), respectively, from 2003 to 2012. In the same decade, annual *Campylobacter* positivity rates

**Figure 1:** Number of stool tests for *Campylobacter* (a) and *Salmonella* (b) by sex in five diagnostic laboratories, Switzerland, 2003–2012.



**Figure 2:** National Notification System for Infectious Diseases (NNSID) notification rates and positivity rates (standardised for age and sex) of *Campylobacter* and *Salmonella*, Switzerland, 2003–2012. NNSID data provided by the Federal Office of Public Health, Bern, Switzerland



by age group increased for all age groups. The largest increase was observed for the age group  $\geq 85$  years (193.7%) followed by the 5–9-year-olds (131.9%). Compared with 2003, annual *Campylobacter* positivity rates of sex-specific age groups were higher in 2012, except for females in the age group 10–14 years (fig. 3a). Annual *Campylobacter* positivity rates were generally higher for males than for females over the entire observation period. For males and females in the age groups <5 years, 5–9 years and  $\geq 85$  years, similar annual *Campylobacter* positivity rates were observed at the beginning of the decade but rates were later slightly higher for males in the age group  $\geq 85$  years and for females in the age groups <5 years and 5–9 years.

Annual *Salmonella* positivity rates decreased from 3.3% to 1.6% (–51.5%) for males and from 2.5% to 1.2% (–52.0%) for females between 2003 and 2012. Annual positivity rates decreased for all age groups between 2003 and 2012 except for the age group 20–24 years, for which the rate remained rather stable. The largest relative decrease of positivity rates was observed for the age groups 10–14 years and  $\geq 85$  years, where rates decreased from 10.5 to 3.7% (–64.8%) and from 0.8 to 0.2% (–75.0%), respectively. Sex-specific *Salmonella* positivity rates were similar or slightly higher for males compared to females in all age groups although for some age groups, positivity rates varied strongly between years (fig. 3b).

#### Seasonal trends in stool sampling and positivity rates

The number of tests performed for *Campylobacter* and *Salmonella* started to increase in spring (fig. 4 panels a and c, fig. 5 panels a and c). Test numbers peaked in late August (calendar week 34) after a brief and strong temporary decline at the beginning of the month (calendar week 31). Afterwards, the number of tests decreased until the end of the year. Monthly test numbers were lowest in February for *Campylobacter* and *Salmonella*, even though calendar week 1 was the week with the fewest tests performed.

After a continuous increase during spring, monthly *Campylobacter* positivity rates peaked during summer months, with the highest monthly rate occurring in July (13.8%) (fig. 4 panels b and d). Likewise, monthly *Salmonella* positivity rates started increasing during the spring. They peaked twice, first in late summer (August) and then in the autumn, with the highest rate occurring in October (3.1%) (fig. 5 panels b and d). The highest weekly positivity rate for *Campylobacter* (17.3%) was in calendar week 1 (January), whereas the peak of weekly *Salmonella* positivity rates (3.5%) was in calendar week 43 (October). The lowest monthly positivity rates for *Campylobacter* and *Salmonella* were in February (5.3%) and March (1.1%), respectively. The seasonal trends of *Campylobacter* and *Salmonella* positivity rates were also observable for sex- and age-specific positivity rates although less pronounced in certain groups.

#### Regression analyses

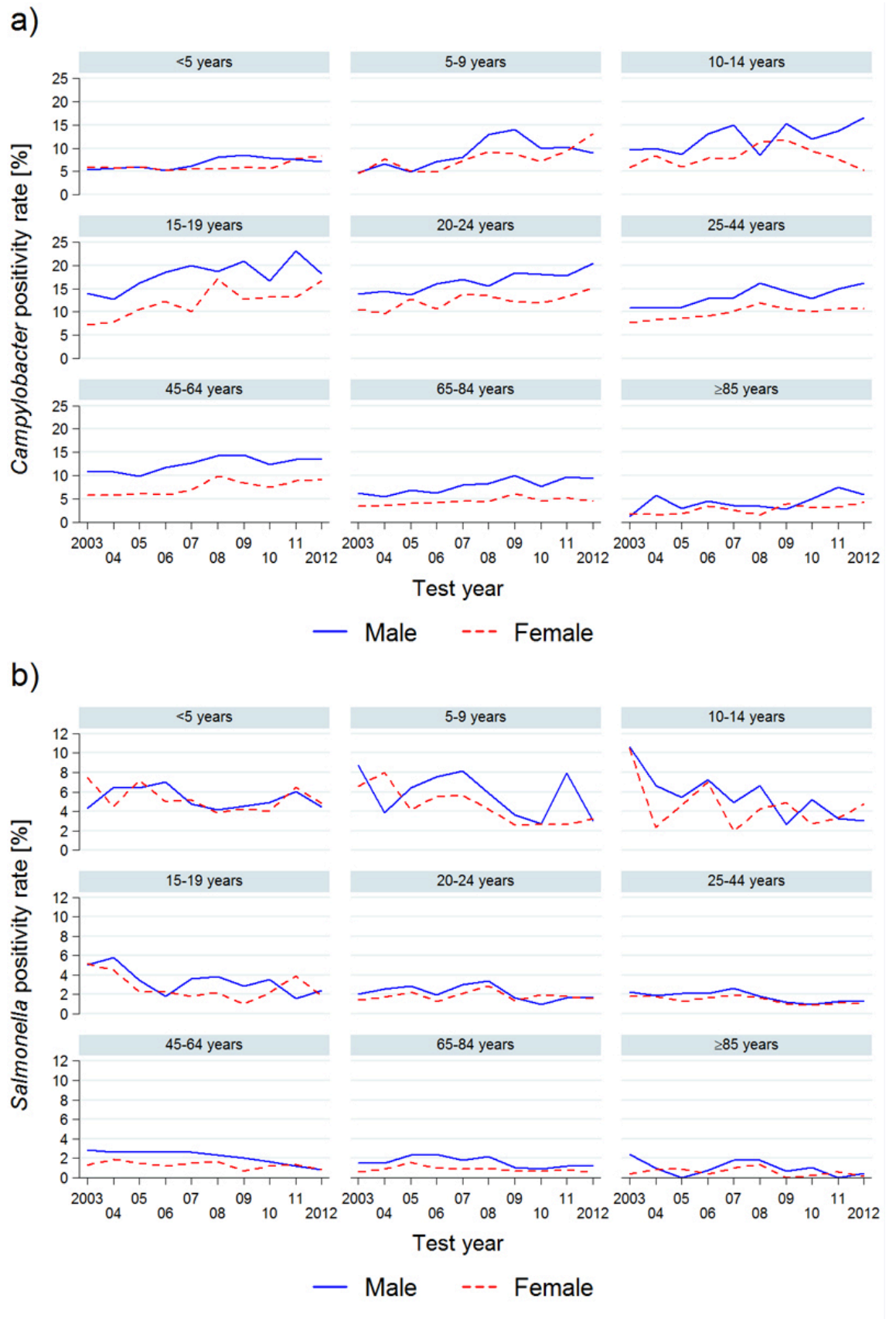
In the univariable regression analyses, sex, age, laboratory, residence by greater region, test week, test month and test year all had a significant effect on the test result for both diseases. The multivariable regression analysis of predictors for a positive *Campylobacter* test showed higher odds of a positive test for males than for females (odds ratio [OR] 1.53, 95% confidence interval [CI] 1.47–1.59)



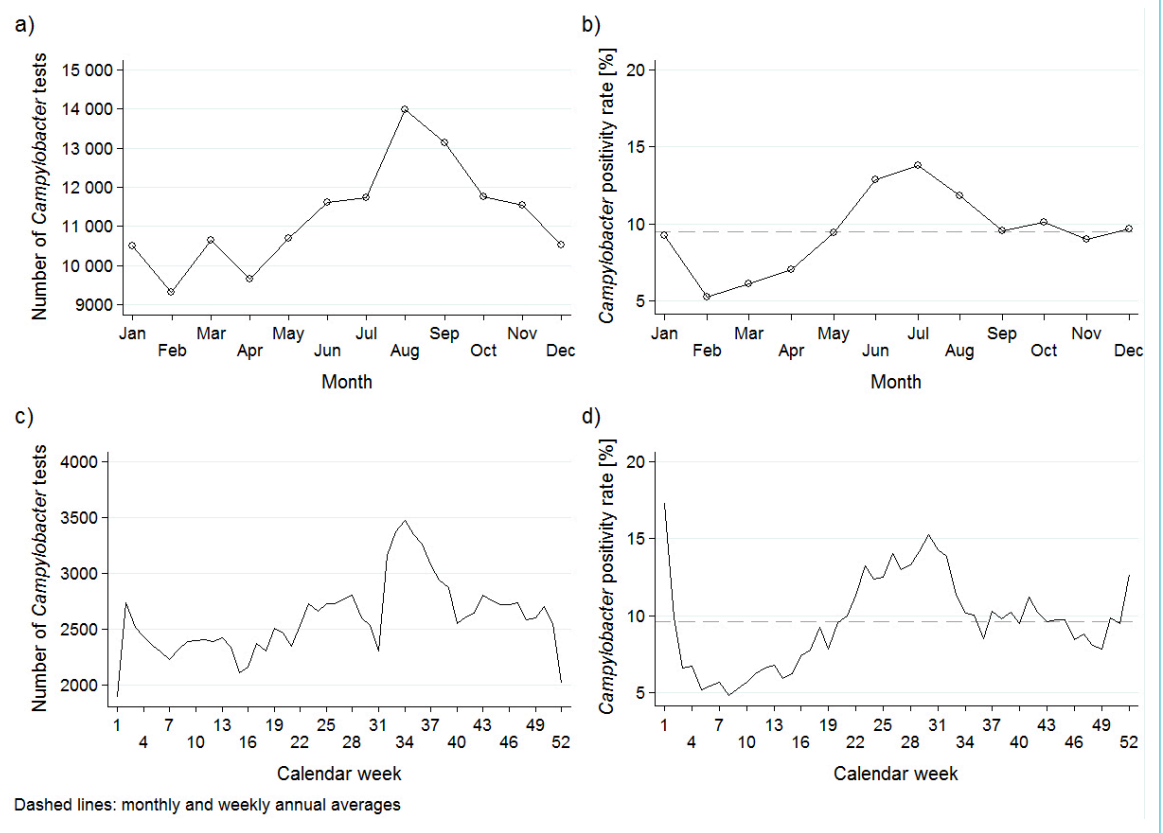
(supplementary table S1, appendix 1). Patients in the age groups 15–19 years and 20–24 years had higher odds for a positive test outcome compared with the age group 25–44

years, whereas patients of other age groups had reduced odds. The patients' place of residence by greater region had similar odds for a positive test, except for patients from

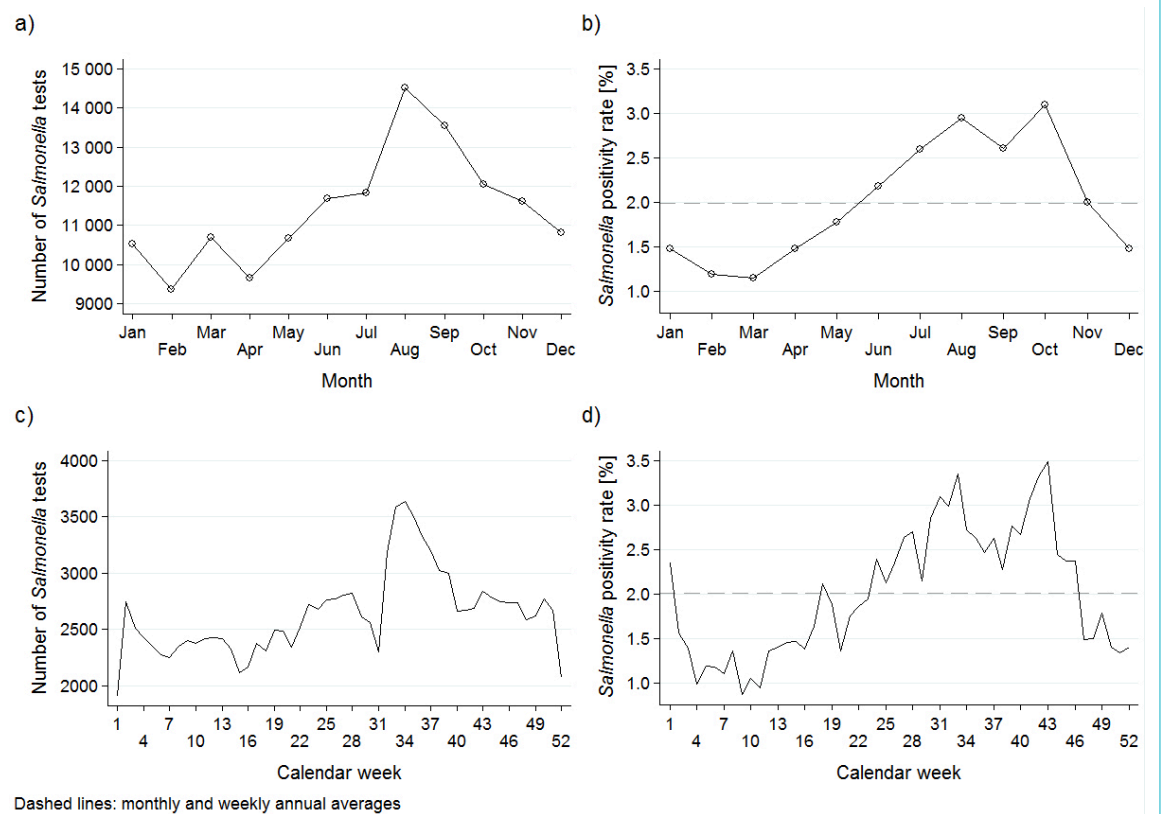
**Figure 3:** Annual positivity rates of *Campylobacter* (a) and *Salmonella* (b) by age group and sex, Switzerland, 2003–2012.



**Figure 4:** Seasonality of *Campylobacter* tests and positivity rates (pooled over study period) per month and calendar week, Switzerland, 2003–2012.



**Figure 5:** Seasonality of *Salmonella* tests and positivity rates (pooled over study period) per month and calendar week, Switzerland, 2003–2012.



the Ticino region (OR 0.44, 95% CI 0.38–0.52). From 2003 to 2008, the odds increased continuously and decreased slightly between 2009 and 2011 compared with 2012.

The regression model for seasonal within-year variations showed that the odds for a positive *Campylobacter* test was highest in July (OR 1.52, 95% CI 1.40–1.65) and lowest in February (OR 0.55, 95% CI 0.49–0.61) compared with May, which had a positivity rate closest to the monthly average (supplementary table S2). Significantly higher odds were also observed for June (OR 1.38, 95% CI 1.26–1.50) and August (OR 1.24, 95% CI 1.14–1.35) compared with May.

In the multivariable regression model for *Salmonella*, males had higher odds (OR 1.30, 95% CI 1.21–1.40) of a positive test than females (supplementary table S3). The odds of a positive test outcome increased threefold for the age groups <5 years, 5–9 years and 10–14 years compared with the age group 25–44 years. Greater region was no longer significantly associated with the outcome in the multivariable regression model. The odds of a positive test outcome steadily decreased during the study period compared with 2012. In the second multivariable model for seasonality, the highest odds of a positive *Salmonella* test were observed in October (OR 1.61, 95% CI 1.36–1.90) and August (OR 1.44, 95% CI 1.23–1.70) compared with November (supplementary table S4). The lowest odds (compared with November) were observed in March (OR 0.55, 95% CI 0.44–0.68) and February (OR 0.57, 95% CI 0.46–0.72).

## Discussion

Annual *Campylobacter* positivity rates standardised for age and sex increased from 2003 to 2012, whereas standardised *Salmonella* positivity rates decreased. During the same time period, campylobacteriosis notification rates increased from 72.7 to 105.5 notifications per 100 000 population, whereas salmonellosis notification rates decreased from 29.8 to 15.4 per 100 000 population. *Campylobacter* positivity rates were generally higher for males than females in all age groups. Monthly and weekly *Campylobacter* positivity rates showed a distinct seasonality, with a peak during the summer months and again at the beginning of the year, which was independent of sex and age group. *Salmonella* positivity rates showed a similar seasonality, but peaked in autumn. Annual *Salmonella* positivity rates were similar or slightly higher for males than for females, with the highest rates observed in the younger age groups, <5, 5–9 and 10–14 years. The observed seasonality and annual trends of positivity rates for both pathogens are congruent with reports from other countries [14, 18].

### Annual positivity rates in relation to NNSID notification rates

Annual positivity rates of *Campylobacter* and *Salmonella* standardised for age and sex and annual NNSID notification rates showed similar trends. Multiple testing, data duplication or simultaneous testing of several pathogens could potentially affect both numerator and denominator data in different ways. However, similar trends were observed for the standardised annual positivity rates presented here and for the crude, non-standardised positivity rates

calculated from raw data from all eight laboratories included in the study (supplementary fig. S2, appendix 1).

The stool test data analysed for this study originated mainly from culture-based test methods, which used to be the standard diagnostic method for detecting *Campylobacter* and *Salmonella*. *Campylobacter*, *Salmonella* and *Shigella* are often tested simultaneously [19]. In terms of relative frequency, more positive *Salmonella* tests (18.9%) than positive *Campylobacter* tests (8.4%) were excluded, whereas the proportion of excluded duplicate and repeated tests was similar for negative *Campylobacter* and *Salmonella* tests (11.2 vs 10.2%). The proportion of negative *Salmonella* tests excluded dropped only slightly from 10.2 to 9.4% when the same time span used for excluding negative *Campylobacter* tests was applied. Hence, only laboratory-confirmed campylobacteriosis and salmonellosis patients differ with regard to repeated testing. In summary, reducing the number of tests per patient and disease episode to one test result is crucial for an accurate calculation of positivity rates whereas the temporal trend of positivity rates is not considerably affected.

The relative increase in standardised annual *Campylobacter* positivity rates (+46.1%) and the relative decrease in standardised annual *Salmonella* positivity rates between 2003 and 2012 (–44.4%) are close to the increase in notification rates of *Campylobacter* (+45.0%) and the decrease in notification rates of *Salmonella* (–48.4%). During the same time period, the number of tests performed for *Campylobacter* and *Salmonella* increased by around 51%. The proportion of cases diagnosed by participating laboratories among NNSID case notifications increased by 37.7% for campylobacteriosis and by 26.9% for salmonellosis over the study period.

The observed increase of test numbers in our study was partially due to a single laboratory (laboratory A), where the number of tests increased 3.5 times for *Campylobacter* and 3.8 times for *Salmonella* between 2003 and 2012. This laboratory was founded a few years before the study period. For the remaining laboratories (B, C, D, E), a smaller increase of 32.0% for *Campylobacter* tests and of 29.0% for *Salmonella* tests was observed. An increase in testing frequency has also been observed in other European countries [14, 20], except in the Netherlands, where testing frequency remained rather stable [21]. Testing frequencies are largely influenced by physicians' stool sampling behaviour and patients' healthcare-seeking behaviour [14, 22–25]. It is also possible that laboratories in the study increased their market shares.

The increase of *Campylobacter* notification rates is probably due to a combination of increasing test numbers and an upward epidemiological trend in the population, as suggested by the increase in positivity rates. The decrease of *Salmonella* notification rates presumably reflects an epidemiological trend in the population, as the notification rate decreased at the same time that testing frequency increased. The increase of campylobacteriosis cases in the population, together with the co-testing of *Salmonella* and *Campylobacter*, is probably responsible for the increase of *Salmonella* test numbers.

In summary, notification rates are influenced by both epidemiological trends in the population and test numbers. More infections in the population will lead to higher notification rates and fewer infections will lead to lower noti-

fication rates. On the other hand, increasing test numbers can lead to the detection of more cases in the population, i.e., higher notification rates without necessarily reflecting an increase in disease frequency. Consequently, an observed increase in notification rates does not necessarily represent an actual increase of disease frequency in the population. A change in test numbers can be due to a number of factors such as changes in the prevalence of risk factors leading to testing, altered healthcare-seeking behaviour, and changes in physicians' testing practices, human susceptibility, and pathogenicity. Assessing the interplay of notification rates and test numbers by positivity rates provides more insights into the epidemiological situation in the population than one of these measures alone. Nevertheless, understanding underlying reasons for changes in one of these measures requires further investigation.

#### Positivity rates in relation to age and sex

A remarkable increase in *Campylobacter* positivity rates was observed for the age groups 5–9 years and  $\geq 85$  years (+131.9% and +193.7%). Test numbers for the age group 5–9 years decreased during the observation period (–6.1%), and they more than doubled for the age group  $\geq 85$  years (+131.5%). During the same time period, notification rates for the  $\geq 85$  years age group increased by 94.9% (47.2–92.0 per 100 000 population) and for the 5–9 years age group by 30.7% (55.3–72.3 per 100 000 population) [2]. It was found that adults and the elderly suffered increasingly more frequently from campylobacteriosis; this could be related to the frequent use of proton pump inhibitors and comorbidities in these age groups [2, 26, 27]. Others have also observed increasing test numbers among the elderly and related it to changes (increases) in healthcare-seeking and physicians' testing behaviour [14, 18, 24]. Additionally, the Swiss population aged  $\geq 85$  years increased by 29% from 2003 to 2012, which probably also contributed to the observed increase in test numbers [28]. *Salmonella* notification rates and annual sex-specific positivity rates showed similar decreasing trends. The strongest decreases in age-specific annual *Salmonella* positivity rates were observed for the age groups 10–14 years and  $\geq 85$  years (–64.8% and –75.0%, respectively). At the same time, notification rates dropped by 55.4% (39.2–17.5 per 100 000 population) for the 10–14 year age group and by 55.6% (23.9–10.6 per 100 000 population) for the  $\geq 85$  years group. It appears, therefore, that these decreases are true epidemiological trends. Age-specific *Salmonella* positivity rates tended to be slightly higher for males but did not remarkably differ between sexes. Similar observations have been made for corresponding NNSID data [2]. The increasing trend in *Campylobacter* positivity rates was similar for males and females. Also, male and female notification rates to the NNSID likewise increased during this time [2]. Both positivity rates and notification rates for *Campylobacter* were higher among males than among females in nearly all age groups. Higher positivity rates for males have also been observed by others [18]. Higher stool sampling rates have been reported for male patients in Canada [18] and for female patients in Wales [14]. Sex-specific differences in healthcare seeking or in risk exposures could account for this observation.

#### Seasonality of positivity rates and notification rates

Monthly and weekly *Campylobacter* and *Salmonella* positivity rates showed seasonal trends corresponding to the NNSID notification rates, which peaked during the summer months and, for *Campylobacter*, also at the beginning of the year [2]. Summer peaks of *Campylobacter* and *Salmonella* positivity rates have also been described previously [18]. Monthly and weekly test numbers also peak in summer. The seasonal variation of test numbers could indicate seasonality of acute gastroenteritis, a temporal variation in the medical care-seeking behaviour of affected individuals and in the proportion of patients being tested. For instance, returning travellers are more likely to undergo stool diagnostics [24, 25, 29], leading to increased test numbers during the public school holiday season in the summer. The combination of high test numbers and high positivity rates in summer and autumn generates the observed peak in case numbers in the NNSID [2]. Peaks of *Campylobacter* and *Salmonella* notification rates during summer months are observed in most European countries [1, 2, 27, 30, 31]. The prevalence of *Campylobacter* in broiler flocks and the contamination of chicken meat with *Campylobacter* at retail are higher during summer months than during the rest of the year [31–34]. This probably explains the observed seasonality as poultry meat from broilers is the main source of *Campylobacter* infections in Switzerland [35–37]. However, it seems that the summer peak is not caused by a single common source of infection and is more likely driven by multiple sources of animal and environmental exposures and climatic conditions [27, 31, 38, 39]. An additional reason for the summer peak in Switzerland and parts of the EU could be related to the culture of barbecuing during summer, which provides multiple occasions for disease transmission through undercooking of and cross-contamination by poultry and red meat [40–43]. Travel abroad is a known risk factor for contracting campylobacteriosis [42–45] – also in Switzerland [46, 47] – and a large proportion of notified *Salmonella* infections in Switzerland is travel-related [48]. Hence, travelling probably contributes to the observed seasonality of campylobacteriosis and salmonellosis test numbers and case notifications in Switzerland. The highest weekly positivity rate for *Campylobacter* was found in calendar week 1 when test numbers were lowest. Notification rates of campylobacteriosis in Switzerland show a strong annual increase over Christmas and New Year (“winter peak”). A similar peak in notification data at the beginning of January has also been observed in Germany [30] and in the *Campylobacter* surveillance data of The European Surveillance System [1]. In Switzerland, the major driver for the winter peak is frequent consumption of meat fondue at festive occasions around this time, especially if it includes chicken meat [47]. The low test numbers over the festive season in December and January are probably related to a different healthcare-seeking behaviour and restricted access to healthcare services during the holiday period. Therefore, the winter peak in *Campylobacter* notification rates is probably attenuated and does not reveal the full magnitude of the problem.

#### Strengths and limitations

In Switzerland, private diagnostic laboratories operate on a regional or national level and predominantly serve the



practices of general practitioners and medical specialists. The study did not consider hospital-based laboratories as their patient profile generally differs from the patient profile in private practices at the primary care level. Hospitalised patients are likely to be more severely affected by acute gastroenteritis and to undergo more extensive diagnostic testing. Hence, their pre-test probability for a positive *Campylobacter* or *Salmonella* test result is different from that of patients consulting at primary care practices [18]. The catchment population of the participating laboratories is not known. Therefore, it was not possible to describe the catchment population, adjust for potential changes therein or to estimate any population-based indicators like stool sampling rates. Similarly, we could not assess how well the data of the five participating laboratories represent the whole tested population in Switzerland, given the latter is not known. We could only assess the representativeness of the patient population by comparing “our” positively tested patients with all notified cases (and hence, supposedly, all positively tested patients in Switzerland; table 1 and table 2). From this comparison we conclude that estimated positivity rates are likely to represent accurately the epidemiological trends and situation in Switzerland as median age and the sex-ratio of cases identified in participating laboratories and in cases from the NNSID were comparable.

## Conclusions

The study results support the assertion that the increase in notification rates of campylobacteriosis and the decrease in notification rates of salmonellosis are epidemiological trends in the population. These trends cannot be solely explained by changing test numbers. Still, we believe it is important to continuously assess test numbers or positivity rates to note changes in stool testing frequency that could lead to changes in case numbers seen in the notification system. This becomes especially important in the light of the increasing use of multiplex PCR panels where multiple pathogens are tested simultaneously and, hence, test numbers can change substantially [49]. The annual collection of test numbers of selected notifiable diseases as stipulated under the newly enforced Swiss Epidemics Act will allow for continuous assessment of positivity rates in the future.

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## Competing interests

The authors declare that they have no conflicts of interest.

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## Appendix 1

## Supplementary data

**Table S1:** Predictors for a positive *Campylobacter* stool test, Switzerland, 2003–2012.

	N <sup>*</sup>	Adj. OR <sup>†</sup>	95% CI <sup>‡</sup>	p-value <sup>§</sup>
<b>Sex</b>	<b>135 122</b>			<b>&lt;0.01</b>
Female	74 006	1		
Male	61 116	1.53	1.47–1.59	
<b>Age group</b>	<b>135 122</b>			<b>&lt;0.01</b>
<5 years	10 196	0.53	0.49–0.58	
5–9 years	5137	0.71	0.64–0.79	
10–14 years	3843	0.89	0.80–0.99	
15–19 years	6362	1.32	1.23–1.43	
20–24 years	9810	1.26	1.18–1.35	
25–44 years	37 693	1		
45–64 years	32 147	0.85	0.81–0.89	
65–84 years	24 712	0.52	0.49–0.55	
≥85 years	5222	0.31	0.26–0.36	
<b>Laboratory</b>	<b>135 122</b>			<b>&lt;0.01</b>
A	18 836	0.93	0.88–0.99	
B	17 687	0.76	0.71–0.81	
C	19 860	0.92	0.79–1.07	
D	33 751	0.95	0.89–1.02	
E	44 988	1		
<b>Greater region</b>	<b>135 122</b>			<b>&lt;0.01</b>
Lake Geneva region	3644	0.84	0.75–0.95	
Espace Mittelland	32 912	1		
Northwestern Switzerland	28 711	0.83	0.78–0.88	
Zurich	29 472	0.73	0.68–0.79	
Eastern Switzerland	14 931	0.93	0.86–1.00	
Central Switzerland	4504	0.90	0.81–1.00	
Ticino	20 948	0.44	0.38–0.52	
<b>Test year</b>	<b>135 122</b>			<b>&lt;0.01</b>
2003	11 674	0.68	0.62–0.73	
2004	11 209	0.69	0.64–0.76	
2005	11 077	0.72	0.66–0.78	
2006	11 692	0.77	0.71–0.84	
2007	12 481	0.85	0.79–0.92	
2008	14 294	1.00	0.93–1.07	
2009	14 685	0.98	0.91–1.05	
2010	14 643	0.85	0.79–0.92	
2011	15 726	0.97	0.91–1.04	
2012	17 641	1		

\* Number of records † Adjusted odds ratio: adjusted for sex, age group, laboratory, greater region and year of test ‡ 95% confidence interval § p-value from likelihood ratio test

**Table S2:** Seasonality of a positive *Campylobacter* stool test by test month, Switzerland, 2003–2012.

	N <sup>*</sup>	Adj. OR <sup>†</sup>	95% CI <sup>‡</sup>	p-value <sup>§</sup>
<b>Sex</b>	<b>135 122</b>			<b>&lt;0.01</b>
Female	74 006	1		
Male	61 116	1.53	1.47–1.59	
<b>Age group</b>	<b>135 122</b>			<b>&lt;0.01</b>
<5 years	10 196	0.54	0.50–0.59	
5–9 years	5137	0.72	0.65–0.80	
10–14 years	3843	0.90	0.81–1.00	
15–19 years	6362	1.31	1.22–1.42	
20–24 years	9810	1.25	1.17–1.34	
25–44 years	37 693	1		
45–64 years	32 147	0.85	0.81–0.89	
65–84 years	24 712	0.53	0.49–0.56	
≥85 years	5222	0.32	0.27–0.37	
<b>Laboratory</b>	<b>135 122</b>			<b>&lt;0.01</b>
A	18 836	0.92	0.87–0.98	
B	17 687	0.76	0.71–0.81	
C	19 860	0.90	0.77–1.04	
D	33 751	0.94	0.89–1.01	
E	44 988	1		
<b>Greater region</b>	<b>135 122</b>			<b>&lt;0.01</b>
Lake Geneva region	3644	0.84	0.75–0.95	
Espace Mittelland	32 912	1		
Northwestern Switzerland	28 711	0.84	0.79–0.89	
Zurich	29 472	0.74	0.68–0.80	
Eastern Switzerland	14 931	0.93	0.87–1.00	
Central Switzerland	4504	0.90	0.81–1.00	
Ticino	20 948	0.46	0.39–0.53	
<b>Test month</b>	<b>135 122</b>			<b>&lt;0.01</b>
January	10 502	0.98	0.89–1.08	
February	9311	0.55	0.49–0.61	
March	10 654	0.64	0.57–0.70	
April	9659	0.74	0.67–0.82	
May	10 691	1		
June	11 607	1.38	1.26–1.50	
July	11 730	1.52	1.40–1.65	
August	13 991	1.23	1.13–1.34	
September	13 126	0.98	0.90–1.07	
October	11 766	1.03	0.95–1.13	
November	11 552	0.93	0.85–1.02	
December	10 533	1.02	0.93–1.12	
<b>Test year (random effect)</b>	<b>135 122</b>			<b>&lt;0.01</b>

\* Number of records † Adjusted odds ratio: adjusted for sex, age group, laboratory, greater region and year of test ‡ 95% confidence interval § p-value from likelihood ratio test

**Table S3:** Predictors for a positive *Salmonella* stool test, Switzerland, 2003–2012.

	N <sup>*</sup>	Adj. OR <sup>†</sup>	95% CI <sup>‡</sup>	p-value <sup>§</sup>
<b>Sex</b>	<b>136 997</b>			<b>&lt;0.01</b>
Female	74 374	1		
Male	62 623	1.30	1.21–1.40	
<b>Age group</b>	<b>136 997</b>			<b>&lt;0.01</b>
<5 years	10 287	3.24	2.88–3.66	
5–9 years	5179	3.19	2.75–3.70	
10–14 years	3845	3.17	2.68–3.74	
15–19 years	6464	1.92	1.62–2.26	
20–24 years	10 159	1.30	1.11–1.53	
25–44 years	38 947	1		
45–64 years	32 609	1.04	0.93–1.17	
65–84 years	24 360	0.67	0.58–0.78	
≥85 years	5147	0.38	0.27–0.55	
<b>Laboratory</b>	<b>136 997</b>			<b>&lt;0.01</b>
A	20 452	1.30	1.14–1.47	
B	17 658	1.29	1.10–1.51	
C	19 557	1.85	1.43–2.40	
D	34 333	1.09	0.94–1.26	
E	44 997	1		
<b>Greater region</b>	<b>136 997</b>			<b>0.13</b>
Lake Geneva region	3643	1.12	0.87–1.46	
Espace Mittelland	32 851	1		
Northwestern Switzerland	28 889	0.87	0.75–1.00	
Zurich	29 651	0.90	0.75–1.08	
Eastern Switzerland	16 658	0.97	0.82–1.14	
Central Switzerland	4595	0.78	0.61–1.00	
Ticino	20 710	0.86	0.65–1.13	
<b>Test year</b>	<b>136 997</b>			<b>&lt;0.01</b>
2003	11 842	1.85	1.56–2.19	
2004	11 342	1.70	1.43–2.02	
2005	11 116	1.72	1.45–2.05	
2006	11 741	1.69	1.42–2.01	
2007	12 750	1.72	1.45–2.04	
2008	14 485	1.61	1.36–1.90	
2009	14 963	1.06	0.88–1.27	
2010	14 910	1.06	0.88–1.28	
2011	16 006	1.25	1.05–1.49	
2012	17 842	1		

\* Number of records † Adjusted odds ratio: adjusted for sex, age group, laboratory, greater region and year of test ‡ 95% confidence interval § p-value from likelihood ratio test

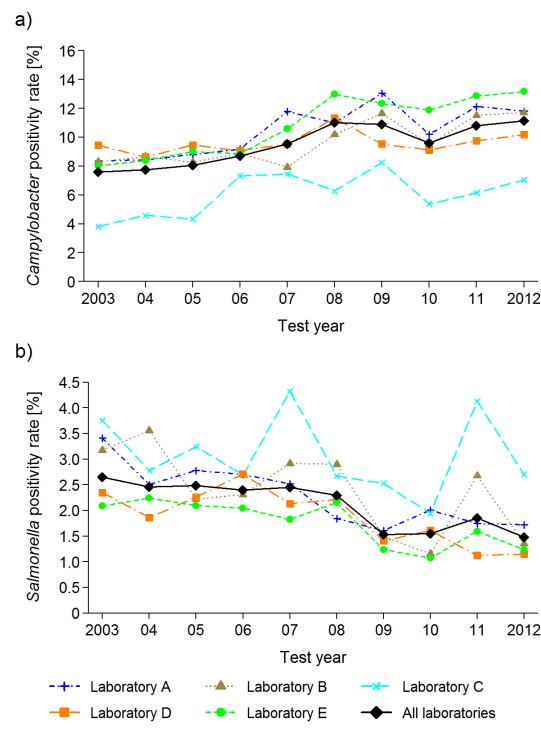
**Table S4:** Seasonality of a positive *Salmonella* stool test by test month, Switzerland, 2003–2012.

	N <sup>*</sup>	Adj. OR <sup>†</sup>	95% CI <sup>‡</sup>	p-value <sup>§</sup>
<b>Sex</b>	<b>136 997</b>			<b>&lt;0.01</b>
Female	74 374	1		
Male	62 623	1.30	1.20–1.40	
<b>Age group</b>	<b>136 997</b>			<b>&lt;0.01</b>
<5 years	10 287	3.38	3.00–3.81	
5–9 years	5179	3.32	2.86–3.85	
10–14 years	3845	3.21	2.71–3.79	
15–19 years	6464	1.90	1.61–2.25	
20–24 years	10 159	1.29	1.10–1.52	
25–44 years	38 947	1		
45–64 years	32 609	1.05	0.94–1.18	
65–84 years	24 360	0.69	0.59–0.80	
≥85 years	5147	0.40	0.28–0.57	
<b>Laboratory</b>	<b>136 997</b>			<b>&lt;0.01</b>
A	20 452	1.25	1.10–1.42	
B	17 658	1.29	1.10–1.51	
C	19 557	1.83	1.41–2.36	
D	34 333	1.07	0.93–1.24	
E	44 997	1		
<b>Greater region</b>	<b>136 997</b>			<b>0.18</b>
Lake Geneva region	3643	1.11	0.86–1.44	
Espace Mittelland	32 851	1		
Northwestern Switzerland	28 889	0.87	0.76–1.01	
Zurich	29 651	0.91	0.76–1.09	
Eastern Switzerland	16 658	0.97	0.82–1.14	
Central Switzerland	4595	0.78	0.61–1.00	
Ticino	20 710	0.91	0.70–1.20	
<b>Test month</b>	<b>136 997</b>			<b>&lt;0.01</b>
January	10 522	0.72	0.59–0.89	
February	9358	0.57	0.46–0.72	
March	10 700	0.55	0.44–0.68	
April	9669	0.73	0.59–0.90	
May	10 678	0.89	0.73–1.08	
June	11 696	1.13	0.94–1.36	
July	11 831	1.33	1.11–1.58	
August	14 525	1.44	1.23–1.70	
September	13 551	1.29	1.09–1.53	
October	12 042	1.61	1.36–1.90	
November	11 612	1		
December	10 813	0.74	0.60–0.91	
<b>Test year (random effect)</b>	<b>136 997</b>			<b>&lt;0.01</b>

\* Number of records † Adjusted odds ratio: adjusted for sex, age group, laboratory, greater region and year of test ‡ 95% confidence interval § p-value from likelihood ratio test



**Figure S1:** *Campylobacter* and *Salmonella* positivity rates stratified by laboratory (and standardised for age and sex).



**Figure S2:** Annual *Campylobacter* and *Salmonella* positivity rates standardised for age and sex in relation to the crude, non-standardised positivity rates calculated from raw data from all eight laboratories included in the study, 2003–2012, Switzerland.

