Investigating an outbreak of *Clostridium perfringens* gastroenteritis in a school using smartphone technology, London, March 2013

B Simone (benedetto.simone@phe.gov.uk)[1,2,3], C Atchison[3,4], B Ruiz[5], P Greenop[5], J Dave[6], D Ready[6], H Maguire[1,2], B Walsh[4], S Anderson[1]

1. Field Epidemiology Services (Victoria), Public Health England, London, United Kingdom
2. European Programme for Intervention Epidemiology (EPIET), European Centre for Disease Control (ECDC), Stockholm, Sweden
3. These authors contributed equally
4. South West London Health Protection Team, Public Health England, London, United Kingdom
5. Commercial Environmental Health, London Borough of Richmond Upon Thames, London, United Kingdom
6. PHE Public Health Laboratory London, The Royal London Hospital, Barts Health NHS Trust, London, United Kingdom

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On 22 March 2013, 150 of 1,255 students (13–17 years) and staff at a school in London reported gastrointestinal symptoms; onset peaked 8 to 12 hours after a lunch served in the school on 21 March. We performed a retrospective cohort study of all students and staff. We defined cases as school attenders on 20 and 21 March with onset of gastrointestinal symptoms between 20 and 23 March. We tested food, environmental and stool samples of cases for common pathogens and bacterial toxins. We administered an online questionnaire via email, encouraging the use of smartphones to respond, to measure risk of illness for food items eaten at school on 20 and 21 March. Survey response was 45%. Adjusted risk ratios were generated in a multivariable analysis. Those who ate chicken balti on 21 March were 19.3 times more likely to become ill (95% confidence interval: 7.3–50.9). *Clostridium perfringens* was detected in all 19 stool samples collected. Within eight school hours of its launch, 412 of 561 (73%) responders had completed the survey. Hygienic standards in the kitchen were satisfactory. The investigation was done rapidly due to smartphone technology and we recommend considering this technology in future outbreaks.

Introduction

The incidence of *Clostridium perfringens* food poisoning presenting to general practice is estimated to be 0.24 per 1,000 persons per year in England and Wales [1,2]. Between 1992 and 2008, *C. perfringens* was identified as the cause of 10% of food-borne outbreaks [2].

C. perfringens causes a mild and short-lived gastrointestinal illness characterised by sudden onset of abdominal pain (80% of cases) followed by diarrhoea (>90%) [3,4]. The incubation period is usually 12 to 18 hours (range: 8 to 22 hours) [3,4]. Illness is due to an enterotoxin produced by *C. perfringens* type A strains [5]. Outbreaks often have a high attack rate and are usually associated with mass catering and a failure of adequate food preparation procedures, including inadequate cooking or inappropriate temperature control of food after initial cooking [6-8]. Meat, meat products and poultry are commonly implicated with inadequate cooking or storage allowing growth of vegetative cells [9,10].

The outbreak we describe involved a secondary school (for children aged 13 to 18 years) in London, with 358 staff members and 897 students. On Friday 22 March 2013 the local Health Protection Unit was notified that 53 students and 32 staff were ill with abdominal pain and diarrhoea. The onset of illness for the majority of cases was reportedly during the evening of Thursday 21 March and the early hours of Friday 22 March. All cases, both students and staff, appeared to have eaten lunch in the school dining hall at least once in the two days before becoming unwell.

On Friday 22 March, an outbreak control team (OCT) was convened to investigate the outbreak. Our investigation aimed to determine the size and nature of the outbreak, to determine the cause, to identify any factors associated as well as to recommend control measures to this outbreak and to prevent any recurrence in future.

Methods

Epidemiology

The study population was the staff and students at the school. The study design was a retrospective cohort study, including all students and staff (cleaning, teaching and kitchen staff) attending the school on

Wednesday 20 and/or Thursday 21 of March 2013. We defined a case as any student or member of staff with onset of gastrointestinal symptoms (any one of the following: diarrhoea, abdominal pain, nausea, vomiting) between 20 and 23 March 2013.

We developed an online structured questionnaire using SelectSurvey, an online commercial software used by Public Health England to develop surveys. A link to the questionnaire was distributed to all students and staff, after piloting, on Wednesday 27 March via email. All students and staff have school email accounts and the school uses these as the main route of communication between staff, students and the school senior management team. The questionnaire was also announced on the school's intranet site with a link.

We excluded those (i) with onset of gastrointestinal symptoms (as described above) in the seven days before 20 March, or (ii) who had a household member with gastrointestinal symptoms in the seven days before 20 March.

We described cases and compared risk of illness for various food items using risk ratios (RR) and 95% confidence intervals (CIs) and Fisher's exact test. We tested the association between eating the various food items and the risk of becoming ill subsequently (for example, in the analysis of exposure to food items eaten on 21 March, we excluded the cases with onset on 20 March). We did not consider in the analysis students or staff who had not attended school on that day.

We calculated attack rates for exposure to each food item on the overall number of responders for the question relative to that specific food item. We applied a robust Poisson multivariable analysis which included variables significantly associated with the occurrence of illness ($p<0.15$) to provide an adjusted risk ratio (95% CI). We chose the best model using the likelihood ratio test.

The questionnaire was structured so as to allow responders to report how much of each food item they had eaten (none, less than a portion, one standard portion, more than one portion). We analysed dose–response effect and tested the p value for interaction among strata with the likelihood ratio test.

Finally, we analysed the timing of responses to our questionnaire survey. All analyses were performed using Microsoft Excel and Stata 12.0.

Microbiology

We collected stool specimens on Friday 22 March from the 19 symptomatic cases who were available because they presented to the school's general practitioner (GP). We requested the GP to obtain samples from them and send them to the Public Health England Public Health Laboratory London, the designated laboratory for the outbreak investigation. Specimens were tested for a range of organisms, including *Campylobacter, Salmonella, Shigella, Escherichia coli o157, Staphylococcus aureus, C. perfringens, Bacillus cereus*, norovirus, adenovirus, astrovirus, sapovirus and rotavirus. The specimens were also tested for the presence of *C. perfringens* enterotoxin at the Public Health England Laboratory of Gastrointestinal Pathogens.

Environmental analysis

We conducted a kitchen inspection at the school on Monday 25 March. Detailed information was collected on the preparation, storage and transportation processes for the food, especially those dishes served at the school at lunch on Wednesday 20 March and Thursday 21 March. A sample of rice served on 21 March which had been kept refrigerated by the catering company was collected and analysed. A further visit on 26 March was made the following day to take hygiene control swabs, further review temperature recording charts for the main cooking pans and to take temperatures at various points in the main cooking pans while food was cooking. Food samples were collected from some of the herbs and spices used in cooking on 20 and 21 March (fresh mint, nigella seeds, dried oregano and ground cumin). On 28 March, samples of cinnamon, salt, black pepper, dried turmeric, dried star anise and coriander seeds were also collected. Other relevant foods were unavailable for sampling.

The rice sample was tested for Enterobacteriaceae, *E. coli, Salmonella, Listeria, S. aureus, C. perfringens* and *Bacillus* sp. The herbs and spices were tested for *E. coli, Salmonella* and *C. perfringens*.

Results

We received responses from 561 of 1,255 (45%) overall, of whom 398 of 897 (44%) were students and 163 of 358 (46%) were staff. We excluded 42 (7.5%, 30 students and 12 staff) based on the criteria described above. The overall attack rate was 19% (100/519) and was 16% and 27%, respectively, in students and staff ($p=0.006$). Attack rates were comparable among different staff groups (teaching, catering, cleaning, support staff; $p=0.228$).

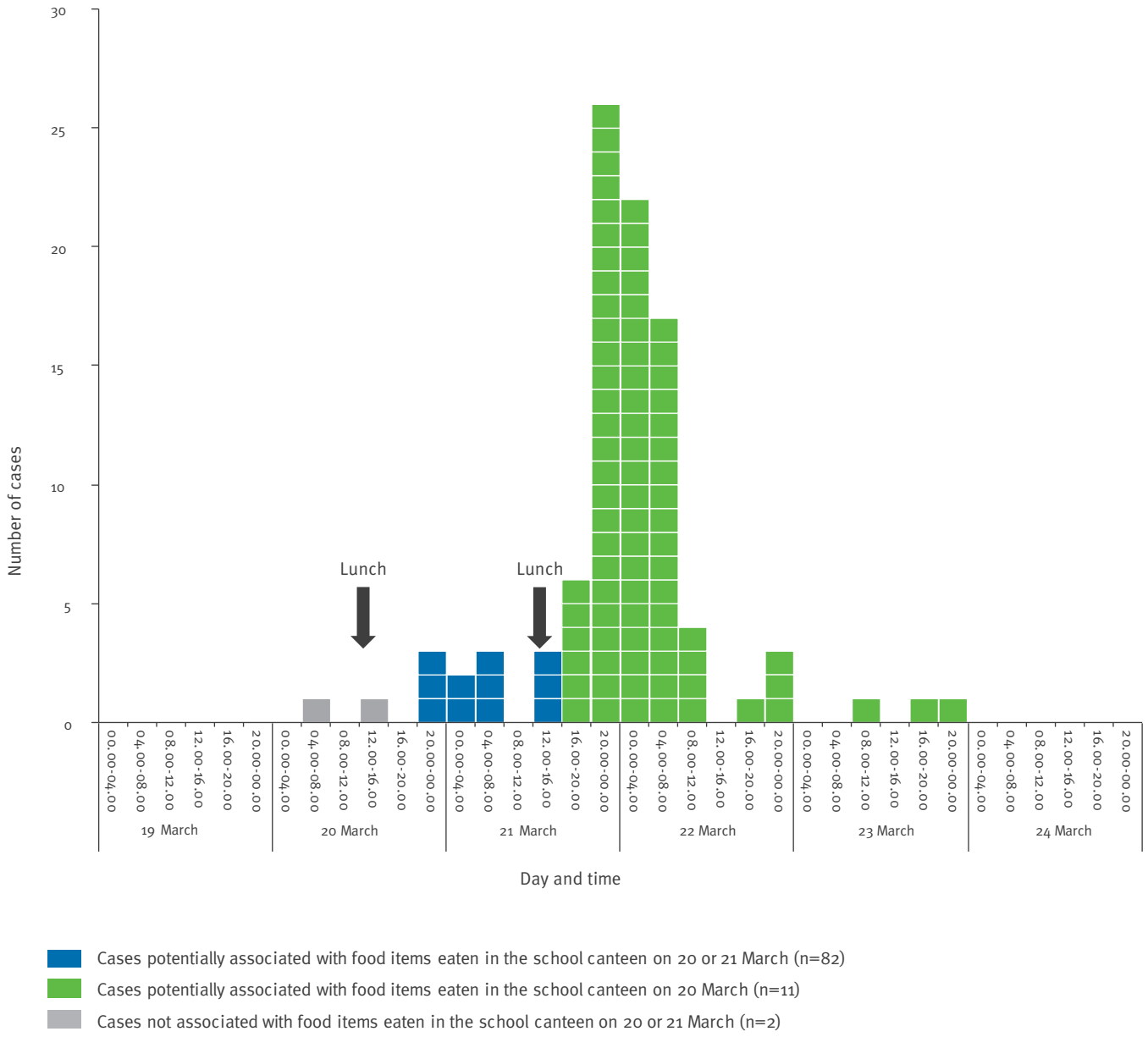
The majority of cases were ill between 16:00 on Thursday 21 March and 8:00 on Friday 22 March, with a peak at 8 to 12 hours after the lunch on 21 March (Figure 1).

The most frequently reported symptoms were diarrhoea, abdominal pain and nausea (90/100, 75/100 and 36/100, respectively); seven reported fever and three reported bloody stools. Symptoms were short-lived. Seventy-one of 100 cases reported symptoms for one day or less.

We had precise times of onset for 95 cases. Of these, two occurred before the lunch served on Wednesday 20 March (in grey in Figure 1), hence we only considered

Figure 1

Epidemic curve, *Clostridium perfringens* gastroenteritis outbreak, London, March 2013 (n=95[a])



[a] Precise time of onset was known for 95 of 100 cases.

the other 93 as potentially associated with the lunch served on 20 March (in blue and green in Figure 1). Those who had eaten in the school dining hall on 20 March were 2.5 more likely to be ill than those who had not (RR=2.5, 95% CI: 1.1–5.3, data not shown). No particular food item served on 20 March, however, was strongly associated with illness in the univariable analysis.

Ten cases had an onset after the lunch served on Wednesday 20 March and before the lunch served on Thursday 21 March (in blue in Figure 1), hence we only considered the remaining eighty-three cases as potentially associated with the lunch served on 21 March (in green in Figure 1). Overall, 425 of 435 responders declared that they had attended school on that day, and 10 responders declared that they had not. Eating in the canteen was strongly associated with increased risk of illness (p=0.001). All the cases with onset after the lunch on the 21 had eaten in the canteen that day (attack rate: 100%).

Those who ate chicken balti on 21 March were 16 times more likely to be ill (RR=15.9; 95% CI: 8.2–30.6) than those who did not, and those eating items served with the chicken (raw red onions, tomatoes and coriander

Table 1

Relative risk of illness (and 95% confidence intervals) for food items served on Thursday 21 March at school, *Clostridium perfringens* outbreak in a secondary school, London, March 2013 (n=425)

	Exposed			Not exposed			RR	95% CI	p value
	Cases	Non-cases	AR %	Cases	Non-cases	AR %			
Went to dining hall	**76**	**292**	**20.7**	**0**	**52**	**0.0**	**n.c.**	**n.c.**	**<0.001**
Ate at the dining hall	**76**	**284**	**21.1**	**0**	**58**	**0.0**	**n.c.**	**n.c.**	**<0.001**
Soup and Main course options									
Mushroom soup	**14**	**27**	**34.2**	**48**	**238**	**16.8**	**2.03**	**1.24–3.35**	**0.008**
Sliced bread	10	32	23.8	54	231	19.0	1.26	0.70–2.27	0.458
Beef lasagne	8	113	6.6	55	164	25.1	0.26	0.13–0.53	0.000
Vegetarian chili	0	15	0.0	63	244	20.5	0.00	n.c.	0.050
Chicken balti	**64**	**41**	**61.0**	**9**	**225**	**3.9**	**15.85**	**8.20–30.62**	**<0.001**
Coriander rice	**54**	**43**	**55.7**	**14**	**219**	**6.0**	**9.27**	**5.41–15.87**	**<0.001**
Jacket potato, fillings and pasta bar									
Jacket potato	1	27	3.6	63	236	21.1	0.17	0.02–1.18	0.026
Pasta (on pasta pod)	4	58	6.5	59	205	22.4	0.29	0.11–0.76	0.004
Baked beans	2	14	12.5	62	243	20.3	0.61	0.17–2.29	0.445
Tuna	1	12	7.7	62	248	20.0	0.38	0.06–2.56	0.273
Cheese topping	2	54	3.6	62	207	23.1	0.15	0.04–0.61	0.001
Tomato sauce	1	12	7.7	62	244	20.3	0.38	0.06–2.53	0.265
Salad bar									
Lettuce	6	33	15.4	58	230	20.1	0.76	0.35–1.65	0.482
Tomatoes	4	25	13.8	60	236	20.3	0.68	0.27–1.74	0.403
Cucumber	3	30	9.1	60	230	20.7	0.44	0.15–1.32	0.111
Hummus	3	9	25.0	60	248	19.5	1.28	0.47–3.51	0.637
Carrots	0	17	0.0	62	242	20.4	0.00	n.c.	0.038
Celery	0	8	0.0	63	250	20.1	0.00	n.c.	0.157
Desserts and fruit									
Peach crumble	24	89	21.2	41	175	19.0	1.12	0.71–1.75	0.625
Custard	16	50	24.2	47	208	18.4	1.32	0.80–2.17	0.289
Orange jelly	3	13	18.8	61	247	19.8	0.95	0.33–2.69	0.918
Lime jelly	2	10	16.7	61	254	19.4	0.86	0.24–3.11	0.816
Strawberry jelly	1	8	11.1	62	251	19.8	0.56	0.09–3.61	0.517
Yoghurt	7	22	24.1	55	242	18.5	1.30	0.66–2.59	0.462
Mango coulis	**5**	**5**	**50.0**	**58**	**253**	**18.7**	**2.68**	**1.38–5.20**	**0.014**

AR: attack rate; CI: confidence interval; RR: risk ratio; n.c.: not computable.
Individuals who did not attend school on that day were excluded.

rice), as well as soup and mango coulis were also more likely to be ill (Table 1). When asked whether they had eaten any chicken, 64 cases (77%) reported they ate chicken, nine reported they had not, and 10 did not respond.

In the multivariable analysis the only risk that remained was for chicken balti, with those eating it 19 times more likely to be ill, taking account of the other variables (Table 2).

We found a strong dose–response effect for eating increasing amounts of chicken balti. The RR of illness went from 14.5 among those who reported eating less than one portion of chicken, to 19.2 among those who had a standard portion, up to 23.1 among those who had more than one portion (p for interaction <0.001; Table 3) after adjusting for the other food items considered in the multivariable model.

Finally, we found that 73% of the questionnaires (412/561) were completed during school hours on the day the survey was launched (Figure 2).

No new cases were reported after 23 March. By Monday 25 March, only nine students and one kitchen staff were still off sick, and by Thursday 28 March, symptoms had resolved in all those affected, and all had returned back to school or work.

All 19 stool specimens tested positive for *C. perfringens*. Isolates from 18 of 19 patients were found to have the enterotoxin gene, and all 18 enterotoxigenic isolates were undistinguishable by molecular typing (fAFLP CLP.39), which was indicative of a common

Table 2

Multivariable analysis showing final model and relative risk of illness for food items, *Clostridium perfringens* outbreak in a secondary school, London, March 2013 (n=425)

Food item	RR	95% CI	p value
Chicken balti	**19.32**	**7.33–50.89**	**<0.001**
Mango coulis	1.40	0.94– 2.08	0.095
Mushroom soup	0.89	0.58– 1.36	0.591
Coriander rice	1.02	0.56– 1.85	0.953

CI: confidence interval; RR: risk ratio.

source. Seventeen stool specimens also tested positive for *C. perfringens* enterotoxin. No other pathogens were detected in the stool samples.

On kitchen inspection, there was no evidence of poor hygiene or poor temperature control during the preparation of food. The temperatures of the pans used for cooking were reviewed and found to be satisfactory. The kitchen's logbooks for temperature recordings from the pans for Wednesday 20 and Thursday 21 March were reviewed and also found to be satisfactory.

No pathogens were isolated from the food samples examined (rice, herbs and spices). The hygiene control swabs were negative for *E. coli, Salmonella* and Enterobacteriaceae.

Discussion and recommendations

We found that eating chicken balti was the likely cause of this outbreak of *C. perfringens* in a large secondary school in London. Microbiological analysis confirmed that *C. perfringens* was the causative organism in this outbreak. We could not establish what factors may have contributed, as environmental investigations revealed satisfactory processes and procedures. The kitchen inspection and the review of the cooking pan temperature recordings revealed no evidence of poor hygiene or poor temperature control during the preparation of food. An inadequate temperature control of food after initial cooking may have contributed to this outbreak.

One of the main challenges in this investigation was the lack of appropriate food samples from food items served at the school on Wednesday 20 March and Thursday 21 March. Although it was not possible to conclusively identify underlying factors contributing to the outbreak, the epidemiological study was very useful to pinpoint the cause of the outbreak as the chicken balti dish.

The chicken balti was prepared on Thursday 21 in the morning. The chicken, which was delivered fresh on the same morning raw and pre-diced from the suppliers, was fried in a big kitchen pan with vegetables and sauce ingredients on the premises. It was kept hot in the pan until serving, and subsequently placed on the hot counter of the dining hall for serving. The garnish, including raw red onion, tomato, fresh coriander and nigella seeds, was added on top of the chicken balti before serving. Once serving started, the garnish would have mixed in with the chicken balti and it would have been unlikely that the two items would have been eaten separately.

Chicken was the likely source of the outbreak, as is often the case with *C. perfringens* outbreaks [5]. However, *C. perfringens* can also be found in spices and herbs sampled from production and retail premises in the United Kingdom [11-13]; spices and herbs have been linked to food poisoning outbreaks in the past [11]. The garnish, therefore, cannot be ruled out as the potential vehicle of the outbreak. The fresh coriander, in particular, was not available for sampling. The nigella seeds tested negative for *C. perfringens*.

We limited our investigation to the food items eaten in the school canteen on 20 and 21 March. From the information received from the school, we knew that the outbreak came from a point source, had an extremely rapid onset and symptoms were short-lived. This directed our suspicions towards a bacterial toxin or a

Table 3

Relative risk of illness associated with increasing amount of chicken balti eaten, *Clostridium perfringens* outbreak in a secondary school, London, March 2013 (n=339)

	Cases	Non-cases	AR %	RR[a]	(95% CI)
I did not eat chicken balti	9	225	3.8	1	Reference
I had a few mouthfuls	6	6	50.0	14.47	4.49–46.58
I had a standard portion	45	30	60.0	19.17	7.19–51.14
I had more than a standard portion	13	5	72.2	23.12	8.56–62.49

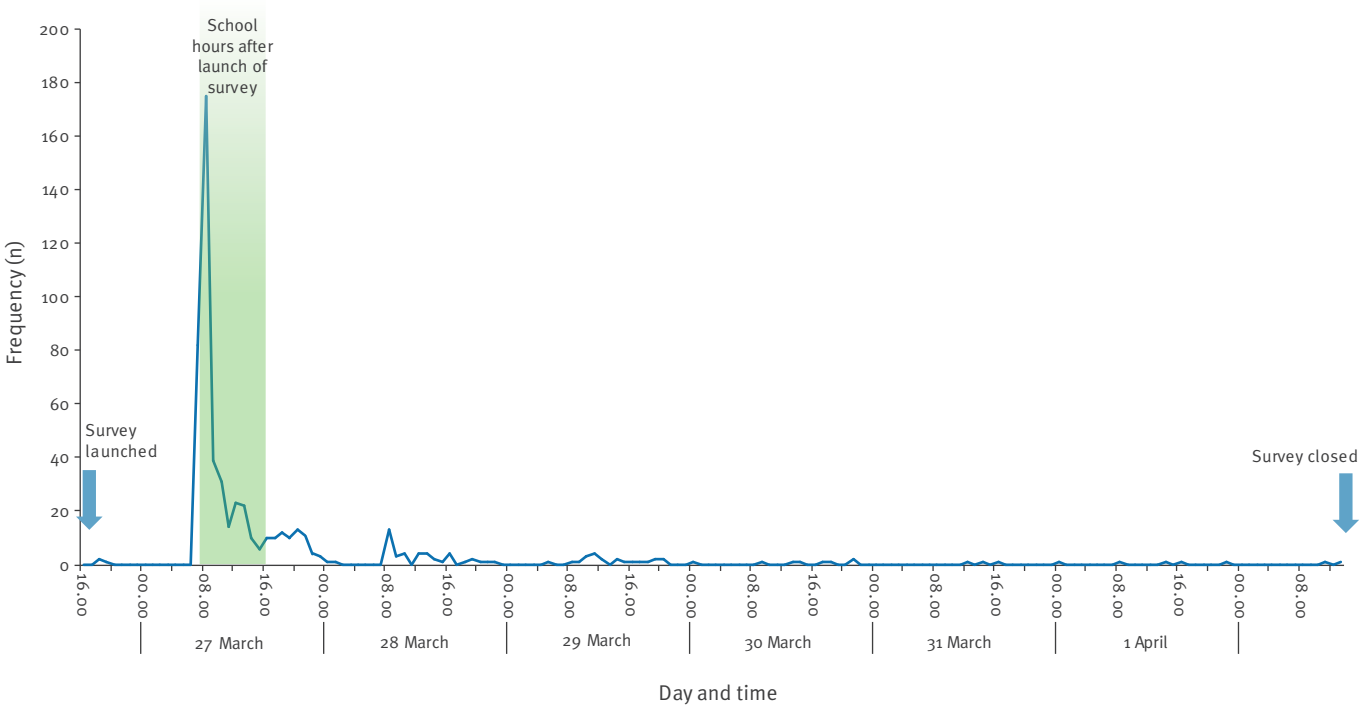
p value for interaction[b] <0.001.

AR: attack rate; CI: confidence interval; RR: risk ratio.

[a] RR adjusted by consumption of nigella seeds, coriander, mango coulis, beef chili topping and vegetarian chili.
[b] By likelihood ratio test.

Figure 2

Date and time of response to survey questionnaire: outbreak of *Clostridium perfringens* in a secondary school, London, March 2013 (n=561)



viral infection, all with short incubation periods. We felt that investigating food items eaten in the canteen over two days back in time would have rendered the questionnaire unnecessarily long, hindering response rates. We also considered that those responses would have been subject to considerable recall bias.

Our case definition included illness occurring on 20 March, and we did observe five cases who were ill on that day and eight who were ill during the evening or early hours of morning before the lunch on 21 March (Figure 1). We can speculate that respondents were ill for other reasons or that they recalled the days incorrectly. It is also possible that some of the food items consumed on 20 March might have been cross-contaminated in the kitchen by food to be served on 21 March. This notion is strengthened by the fact that one of the 19 positive faecal specimens came from a student who had been ill in the morning of Thursday 21 March and the strain isolated from this specimen was the same as that isolated from all the other specimens. This makes it highly unlikely that this early case was unrelated to the outbreak. It is also unlikely that this, or any other of the early cases, were responsible for contaminating the food. Students do not come in contact with food until it is served at the counter by catering staff. None of the catering or cleaning staff were ill before the afternoon of 21 March.

The strength of the outbreak investigation was defined by the rapidity required for the public health response and coordination across multiple organisations. The weakness of the investigation was the retrospective nature of the kitchen inspection which provided a limited picture of the food transport, storage and preparation processes that occurred on site on a specific day. A key strength was the speed with which the outbreak control team was set up and a meeting organised on the afternoon of Friday 22 March. This occurred within 60 minutes of the outbreak being notified to the local Health Protection Unit. In addition, the prompt collection of stool samples on Friday afternoon provided a rapid microbiological diagnosis.

An interesting aspect of the investigation has been the high rate of completion of the questionnaires using smartphones. Figure 2 shows how almost three quarters of the questionnaires were completed during school hours on the day the survey was launched. Currently, however, the tool we use to develop questionnaires does not have templates to build surveys specifically for smartphones, and responders had to scroll and zoom the questions on their phones in order to complete it. The survey could have been made more accessible and readable to the responders if a specific tool to develop questionnaires for smartphones had been available.

It would have been useful to have a question in the survey asking which device participants had used to complete the questionnaire. This is a limitation of the study. Anecdotal evidence, however, suggested that the majority of participants had used smartphones. No laptops or tablet computers are allowed in the school

for security reasons, and the Deputy Head reported to us that teachers had observed the students completing the questionnaires on their phones during lesson time and break time. The school has computer rooms, but they are supervised by teachers and are only open for private use at lunch time and after school. Our analysis showed that most questionnaires were completed in the morning. The teachers reported that approximately 30 to 40 students overall used the computer room on 27 March.

Our previous experience with similar school outbreaks is that it is very difficult to achieve a good response rate, and the process of data collection can take days and several reminders. This delay increases the potential for recall bias among late responders and reduces the possibility of setting up public health interventions. In the outbreak presented here, no reminders were necessary, and the responses collected in one day were sufficient to identify the cause of the outbreak.

This investigation evidenced the need of an assessment of smartphone technology, and of other technologies, as a data collection tool in outbreak settings. Survey participants use a range of devices to complete online questionnaires. Which device is being used is an important question that should be included, to assess which data collection tools and devices perform best under different outbreak circumstances and settings.

In view of the fact that we could not find any issues with the kitchen or the food preparation, but given that poor food preparation practices are the contributing factor in the majority of *C. perfringens* foodborne outbreaks [2], we felt it was still worthwhile recommending to the school/catering company (i) reviewing standards and procedures to ensure adequate heat penetration in bulk cooking processes and adequate temperature control of food after initial cooking, and (ii) reviewing the preparation, storage and serving of raw garnishes.

Our main recommendation for the Health Protection Agency (as of 1 April 2013 Public Health England) and other health agencies is to explore opportunities for using smartphone technology for distributing questionnaires. There is evidence that smartphones are being used for data collection and surveillance purposes with good effect [14,15]. As many people now have access to mobile devices such as smartphones this would provide an alternative distribution channel for questionnaires which may improve the speed and completeness of response rates in future epidemiological studies.

Finally, we recommend an assessment of the validity of different data collection tools, including smartphones, in different outbreak settings.

Conflict of interest

None declared.

Authors' contributions

Benedetto Simone and Christina Atchison conducted the epidemiological investigation and wrote the manuscript; Barbara Ruiz and Paul Greenop conducted the environmental investigation and contributed to the manuscript development; Jayshree Dave and Derren Ready conducted the microbiological investigation and contributed to the manuscript development; Helen Maguire contributed to the manuscript development; Barry Walsh and Sarah Anderson led the outbreak control team and supervised the manuscript development.

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