Investigation of an outbreak of *Escherichia coli* O157 infection caused by environmental exposure at a scout camp

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SUMMARY

In May 2000 a scout camp was held on an agricultural showground in New Deer, Aberdeenshire. There were 337 campers at the event, comprising 233 cubs, scouts, and venture scouts, and 104 adults. The event was abandoned early because of heavy rainfall. Twenty campers who became ill between 28 May and 3 June were confirmed as having *E. coli* O157 infection. Preliminary investigation did not suggest a food vehicle but did indicate environmental exposure at the camp as a risk factor. Subsequent investigations supported the hypothesis that transmission of *E. coli* O157 was from the environment to cases by contaminated hands, either directly from hand to mouth, or via food. As a result of the investigation the Aberdeenshire Council and the Scout Association jointly prepared interim guidelines to reduce the risk of *E. coli* O157 infection at scout camps.

INTRODUCTION

On Friday 2 June the Department of Medical Microbiology reported the isolation of *E. coli* O157 from the stool specimen of an 8-year-old child to the Department of Public Health at the Grampian Health Board. The child's family was interviewed to identify possible risk factors. The child had attended a scout camp between 26 and 27 May in New Deer in Aberdeenshire. On Sunday 4 June the hospital clinicians reported two further probable cases of *E. coli* O157 infection in children who had attended the same scout camp. The children reported that other campers had been unwell. The on-call public health team declared an outbreak and convened an outbreak control team (OCT).

This paper describes the OCT's investigations, which documented the outbreak and confirmed the environment as the source of infection. The investigation also demonstrated that the route of transmission of *E. coli* O157 was from the environment to cases by contaminated hands, either directly from hand to mouth, or via food, the food being an inert vehicle of transmission rather than a growth medium for the organism. To our knowledge this is the first occasion in the United Kingdom that analytical epidemiology has confirmed acquisition of *E. coli* O157 infection so immediately from the environment in a point source outbreak.

METHODS

The three main components of the investigation: environmental, descriptive and analytical epidemiology, and microbiological were carried out concurrently.

Environmental

On Sunday 4 June, an Environmental Health Officer (EHO) visited the campsite and took samples of water from a working standpipe, lying ground water and a

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stream running at the boundary of the site. Samples of lying sheep faeces were taken from four separate areas of the site. Other environmental samples included soil, debris from footwear used at the camp and from the climbing tower. During the following week veterinary officers from the Scottish Agricultural College (SAC) took faecal samples from sheep that had been grazing on the showground prior to the camp. The EHO consulted members of the Scout Association about the arrangements at the camp, including details of the purchase, preparation, storage and cooking of the food consumed and the source of drinking water. The unused food was sent for microbiological analysis. The retail suppliers of meat products to the campers were identified and samples were submitted for microbiological analysis.

Epidemiological

Descriptive

A camp attendee was defined as anyone identified by the Scout Association as having any contact with the site during the period of the camp. Campers were defined as those camp attendees who stayed overnight or participated in any of the activities or who had eaten food at the camp. The remaining camp attendees were designated short-term visitors and were excluded from further investigations. A case was defined as a camper with symptoms compatible with *E. coli* O157 infection and confirmed by culture.

All camp attendees were sent a questionnaire eliciting demographic details, symptoms and possible exposures, including food history and contact with other cases. The data were entered into an Access database and imported into a statistical package (SPSS) for analysis [1]. The data were analysed by time, place and person and attack rates by age group and district were calculated.

Analytical

Hypotheses arising from the descriptive epidemiology were tested by a retrospective cohort study [2, 3]. The cohort was comprised of all 'campers' and they were followed up for 2 weeks from the camp, i.e. the maximum incubation period for *E. coli* O157 infection. The cohort was sub-divided by scout district and into three age groups: 8–11 years (cubs), 12–16 years (scouts) and over 17 years (venture scouts and other adults).

The factors hypothesized to increase the risk of being a case were: eating food prepared at a camp barbecue; not washing hands before eating at the barbecues; not washing hands before meals; not using cutlery; climbing the tower; and eating doughsticks prepared at the camp. Exposure to these risk factors were collected by a short, structured postal questionnaire with closed questions and administered to all campers to minimize bias. The ratio of the incidence in those exposed to the hypothesized risk factors to the incidence in the unexposed, i.e. the relative risks, were calculated and reported with 95% confidence intervals.

A log regression model was used to estimate the probability of each individual becoming a case. A log regression model is similar to logistic regression but instead of estimating the parameters as 'odds ratios' they are estimated as 'relative risks'. This provides a set of probabilities for the risk factors which are then multiplied together to give an individuals' chance of becoming a case. The model was built using district and hypothesized risk factors with age group and age as a continuous variable in a second statistical package (GLIM) [4]. The factors were first fitted singly and then the significant variables were fitted in a stepwise manner as follows: district, age, washing hands before eating, using cutlery, eating food cooked on a barbecue, washing hands before eating food cooked on a barbecue and eating doughsticks. Tests were carried out to detect interactions between the factors.

Microbiological

Stool specimens from 48 symptomatic campers and faecal samples from 15 ewes and 15 lambs were examined. Faecal specimens, both human and ovine, were cultured on Cefixime tellurite sorbitol McConkey agar (CT SMAC) to isolate *E. coli* O157. All human samples were also tested for *Campylobacter*, *Cryptosporidium*, *Salmonella* and *Shigella*. The investigation included examination of six samples of food and two samples of milk consumed at the camp, water samples comprising five from standpipes, one surface water, one from the stream, lying sheep faeces, soil, debris removed from one pair of wellington boots and the steps of the climbing tower. All environmental specimens were examined for the presence of *E. coli* O157 using the Immunomagnetic separation (IMS) technique. The SAC Veterinary Laboratory examined the sheep faeces for *Cryptosporidium*, and for *E. coli* O157 using IMS. Pulsed-field gel electrophoresis (PFGE) was used to distinguish potential outbreak strains of *E. coli* O157 from the background

of unrelated sporadic isolates occurring at the same time.

RESULTS

Environmental

The camp took place on a 20-acre agricultural showground that was normally used for grazing. Approximately 300 sheep (ewes and lambs in ratio of 1:15) had been grazing on the showground (91 938 m²) for 6 days up until the day before the camp. The grass had not been cut prior to the camp and the site had been heavily contaminated with sheep faeces. Heavy rainfall had caused localized flooding and very muddy conditions. The camp was planned to last for 3 days but due to extremely poor weather conditions it was abandoned a day early. Each cub and scout group had its own sleeping tents. The menus and the purchase of food were organized by the individual group leaders. Food was cooked and eaten in each group's own dining shelter, trailer or mess tent, or in shared mess tents. The food was prepared and cooked by the group leaders. The cooking methods varied from cooking on camping stoves to barbecues. All perishable food was stored in cool boxes or similar by each group. Drinking water was supplied by standpipes connected to the mains water supply nearest to each group's tent. Purpose-built toilet blocks with hand-washing facilities were located at convenient sites around the camp and were considered adequate.

Various activities took place at the camp including the preparation and consumption of bread doughsticks cooked over a barbecue. A wooden tower was assembled and was climbed by many of the children and some adults.

Epidemiological

Descriptive

Organizers originally provided the names of 372 people who had attended the camp but 35 were excluded as short-term visitors. No cases of illness were identified among these 35. Of the 337 campers 288 (86%) responded to the first questionnaire. Seventy campers reported diarrhoea and/or vomiting. Faecal samples were obtained from 48 of these 70. Twenty of these 48 were positive for *E. coli* O157 and so fulfilled the case definition.

Table 1. *Age group and sex of campers*

Age group (years)	Sex		
	Male n (%)	Female n (%)	Total n (%)
8–11	147 (100)	0	147 (44)
12–16	75 (93)	6 (7)	81 (24)
>16	85 (79)	33 (31)	108 (32)
Total	297 (88)	40 (12)	336 (100)

Percentages of males and females are shown as proportion of each age group. Age missing for one individual.

Table 2. *Attack rates by age groups and scout district*

	Age (years)			
	8–11	12–16	>16	Total
District A				
Number ill	7	5	1	13
Total number	39	29	27	95
Attack rate	18%	17%	4%	14%
District B				
Number ill	1	0	0	1
Total number	85	29	37	151
Attack rate	1%	0%	0%	0·6%
District C				
Number ill	3	2	1	6
Total number	21	23	31	75
Attack rate	14%	9%	3%	8%
All districts				
Number ill	11	7	2	20
Total number	145	81	95	321
Attack rate	8%	9%	2%	6%

Sixteen campers were not allocated to a district.

A total of 297 (88%) campers were male and 39 (12%) female. Table 1 shows campers by age and sex. The campers were from 14 cub and scout groups from three districts of North East Aberdeenshire. They did not belong to any other common social network and attended schools and leisure facilities local to their district. Nearly half the total number of campers belonged to District B. The district of residence of 16 campers was not known (Table 2).

Dates of onset in the 20 cases were between 28 May and 2 June (Fig. 1). Cases' illness was characterized by abdominal pain (25%), diarrhoea (100%) of which 25% was bloody. Unusually vomiting was noted as a symptom in 25% of the cases. One child developed haemolytic uraemic syndrome (HUS) and required dialysis. All cases recovered.

Table 3. *Attack rate for* E. coli *O157 by activities*

	Participated			Did not participate				
	Case	Total	AR (%)	Case	Total	AR (%)	RR	95% CI
Ate at a barbecue	10	77	13	7	187	4	3·5	1·37–8·78
Did not wash hands before barbecue	8	35	23	2	41	5	4·7	1·06–20·63
Did not wash hands before meals	17	162	10	1	85	1	8·9	1·21–65·89
Did not use cutlery at meals	17	169	10	1	75	1	7·5	1·02–55·66
Climbed tower	11	89	12	7	162	4	2·9	1·15–7·12
Ate doughsticks	7	65	11	11	189	6	1·9	0·75–4·57

95% CI, 95% confidence interval; AR, attack rate; RR, relative risk.
The relative risk is the risk of illness in the exposed divided by the risk of illness in the unexposed. An RR of 1 indicates no difference and therefore no association between illness and exposure. Where the 95% CI does not include 1 the association is unlikely to have occurred by chance.
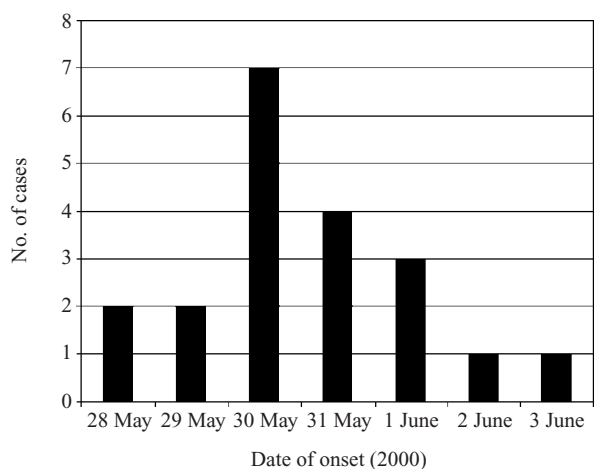

Fig. 1. Epidemic curve of cases of *E. coli* O157 by date of onset.

There was a highly statistically significant difference in attack rates by district with an attack rate of 14% in District A, 8% in District C and only 0·6% in District B ($P<0·0005$) (Table 2). Only two cases occurred in the older age group and these were both venture scouts. There was a highly significant association between the age group of camper and whether they washed their hands. There was no statistically significant difference between the attack rate for male (6%) and female campers (8%), nor between the three age groups.

Analytical

Of the 337 campers, 266 (79%) responded to the risk-factor questionnaire. There was a statistically significant association ($P<0·05$) between being a case and exposure to all hypothesized risk factors, except eating doughsticks (Table 3). Campers who did not wash their hands before meals were nearly nine times more likely to be a case than those who did. Those who did not use cutlery were seven times more likely to become a case than those who did use cutlery. Those who ate at a barbecue were three times more likely to become a case than those who did not, as were those who climbed the tower. A higher proportion of campers in District A participated in the activities that were more likely to increase their exposure to environmental contamination and were less likely to wash their hands or use cutlery. When the attack rates were analysed by district the only risk factor that remained significant was 'not washing hands prior to eating' in District A.

When the individual factors were fitted singly in the log regression model, district explained the largest amount of variation, followed by washing hands before a barbecue, washing hands before meals, using cutlery, eating doughsticks, eating at a barbecue and age as a continuous variable. The grouped ages and climbing the tower did not account for any significant variation. In the multivariate model eating doughsticks and eating at a barbecue were no longer significant. All the other factors, i.e. district, washing hands before eating at a barbecue, washing hands before meals, using cutlery and age as a continuous variable all contributed to the combined model. There were no significant interactions between the remaining factors.

Microbiological

E. coli O157 was isolated from 20 of the 48 faecal specimens and *Cryptosporidium* was also isolated from 1 of these 20 specimens. In addition to these, *Cryptosporidium* alone was isolated in one specimen and *Campylobacter* in another. Twenty-six specimens were negative for all pathogens sought and these included seven faecal samples from individuals who had complained only of vomiting. Electron microscopy and PCR investigation of stool samples failed to confirm a specific viral cause. Twenty-two symptomatic individuals did not submit faecal samples.

The five drinking-water samples and all the food and milk samples were negative for all pathogens, including *E. coli* O157. *E. coli* O157 was isolated from the sample of lying ground water, lying sheep faeces, soil, debris from the Wellington boots and from the climbing tower.

E. coli O157 was isolated in faecal samples from 11 (73%) of the 15 ewes and 3 (20%) of the 15 lambs. *Cryptosporidium* was also isolated in the faecal samples from 5 lambs (33%).

The Scottish *E. coli* Reference Laboratory confirmed that all the animal, human and environmental isolates were *E. coli* O157 phage type 21/28, verotoxin 1 negative, verotoxin 2 positive and were indistinguishable from each other using PFGE.

DISCUSSION

We have demonstrated that this outbreak resulted from an environmental source of infection, and that transmission of *E. coli* O157 was from the environment to cases by contaminated hands. This was either directly to the mouth or via food, the food being an inert vehicle of transmission rather than a growth medium for the organism.

We identified contamination of the environment with a strain of *E. coli* O157 indistinguishable from that which caused illness. Despite extensive sampling, we did not find any *E. coli* O157 in drinking water or food. We have shown, by means of a retrospective cohort study that infection was more likely in people who failed to wash their hands before eating, who did not use cutlery and who climbed a climbing tower contaminated with the outbreak strain of the organism. Those campers who were in District A were more likely to participate in activities that increased their exposure and were less likely to wash their hands and this may explain some of the variation between

districts. When the cohort was grouped by age there was no significant difference between attack rates but the multivariate model showed that there was still some residual effect from age on the likelihood of becoming ill when age was fitted as a continuous variable. The age effect could have been a result of confounding as the younger campers were less likely to wash their hands and there was a significant association between age and hand washing. However children are more susceptible to *E. coli* infection and this may explain the residual age effect.

Although this is the first time environmental exposure and poor personal hygiene has been so convincingly implicated in an outbreak, our findings are compatible with other studies. A case control study of sporadic cases of *E. coli* O157 in Scotland has demonstrated environmental exposure, especially to animal excreta, to be an important risk factor, but did not confirm poor personal hygiene as a risk factor [5]. An outbreak of infection with *E. coli* O157 at a music festival in England in 1997 was also assumed to be the result of environmental exposure, although this assumption was not supported by analytical epidemiology [6]. We therefore believe this to be the first time such a direct route of transmission has been confirmed in the United Kingdom, and certainly the first time the environment has been demonstrated to be the source of infection in a point source outbreak.

That the source of the organism in this outbreak was the environment is compatible with much previous research. *E. coli* O157 has been found in healthy cattle and sheep and other domestic pets [7–9]. In summer 31% of sheep may excrete *E. coli* O157 [10]. *E. coli* O157 can survive in cattle faeces on cattle pastures for 50 days, in associated water courses for 27 days and may persist for long periods in soil cores containing rooted grass [11]. The ability of these organisms to survive adverse environmental conditions, the wide range of the sources, vehicles and modes of spread compounded by the low infectious dose help explain the organism's potential to cause outbreaks. The transmission of the organism from the environment to the mouth is also plausible. It has been shown that children can ingest 30–200 mg of soil per day during camping activities [12]. Using this estimate and the decay data produced by serial sampling of the soil and residual faeces at the site, it has been possible to produce a quantitative dose–response model of the outbreak [13]. This predicts that approximately 60 *E. coli* O157/g were present on the field during the camp. The estimated total soil

ingested over the 2 days was 60–400 mg resulting in an *E. coli* O157 dose of between 4–24 organisms per camper. This low infective dose is comparable to that reported previously for food-borne outbreaks [13].

Subsequent to our investigation the survival of *E. coli* O157 in the soil from the campsite has been studied by serial sampling. This has demonstrated that while visible evidence of faeces did not last longer than 8 weeks the organism was still in the soil after 15 weeks albeit at low levels [14].

This study, like all outbreak investigations, had limitations that might not have attended a pre-designed research study, but we do not believe they invalidate our findings. Our case definition may have been too strict. The requirement for microbiological confirmation might have led to our categorizing a number of true cases as non-cases. If this were so, the power of our study to show differences between cases and non-cases would be reduced, but we would not have identified spurious associations. We erred on the side of specificity rather than sensitivity because of the occurrence of mild, vomiting illness among campers, which we suspected might be due to concurrent viral gastro-enteritis, made a purely clinical case definition impractical. Another potential limitation of the study was that the number of cases was small and detailed risk-factor data was missing for one case. This was obviously outside our control, but it cannot be said to cast doubt on the credibility of the associations we did demonstrate. It is reasonable to infer from our study, therefore, that effective hand washing and the use of cutlery could have reduced the exposure to the organism.

The outbreak investigation has demonstrated the need for better training and supervision of hand hygiene before meals, particularly if attending camps or participating in other outdoor activities. It also demonstrates the need for clear guidance on the selection, preparation and management of agricultural sites that are used for recreational activities and also on the use of public land for occasional agricultural activities. The Scout Association and the Environmental Health Services for Aberdeenshire Council developed interim guidelines which were distributed throughout the United Kingdom in mid June 2000. The guidelines reiterated the importance of personal hygiene, especially hand washing and gave advice on the selection of sites for camping, advising that camping should normally be avoided on land used for grazing.

This outbreak investigation and the subsequent modelling and serial soil sampling [13, 14] were used to inform the deliberations of the Task Force on *E. coli* O157 [15]. The Task Force reviewed the guidelines produced by Aberdeenshire Council and the Scout Association immediately after the outbreak and made recommendations for the recreational use of animal pastures in February 2001 [15]. They recommended that farm animals should be kept off recreational sites for 3 weeks prior to use and during use; visible animal droppings should be removed; grass should be mowed and clippings removed; hands should be washed before eating, drinking and smoking; water from burns and streams should be treated before drinking; and children should be adequately supervised, particularly those under 5 years of age.

Outdoor activities bring many benefits to the participants and risk can never be totally removed from activities of this sort. It is the responsibility of the organizers, parents or guardians and in some circumstances the individuals themselves to assess the risk involved and take steps to minimize that risk. By acting on the recommendations of the Task Force and the findings of this study the risk of acquiring *E. coli* O157 and other infections will be reduced.

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