Sick leave due to diarrhea caused by contamination of drinking water supply with *Cryptosporidium hominis* in Sweden: a retrospective study

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ABSTRACT

We investigated sick leave from work, studies, preschool, and kindergarten occurring between 1 November 2010 and 31 January 2011 and associated with a waterborne outbreak of diarrhea caused by *Cryptosporidium hominis* in late November 2010 in Östersund, Sweden with 45.2% of 60,000 residents being symptomatic. A questionnaire defining acute watery diarrhoea and/or $\geq$3 diarrhea episodes/day as cryptosporidiosis was sent to 1,508 residents in late January 2011 (response rate 69.2%). Among adults aged 18–60 years, 24.0% took sick leave for a mean of 4.6 (SD $\pm$ 4.0) days due to cryptosporidiosis, and an additional 10.6% were absent from work a mean of 4.0 ($\pm$2.2) days to care for symptomatic children. Among children (aged $\leq$17 years), 35.0% stayed home sick from kindergarten/preschool or school/university for a mean of 5.2 ($\pm$3.8) days resulting in 5.1 ($\pm$4.4) days of absence from work per sick child shared between parents/guardians. The estimated total number of sick leave days was 50,000 for adults and 20,700 for children, with an estimated direct cost of €7 million for employers. The potential impact on society of sick leave caused by waterborne diseases must be considered in decisions regarding the quality of drinking water.

Key words | cryptosporidiosis, disease outbreaks, drinking water, sick leave

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INTRODUCTION

Cryptosporidium is an intestinal parasite found worldwide. There are currently at least 26 known species (Bouzid *et al.* 2013), two of which, *C. hominis* and *C. parvum*, cause the vast majority of human infections. *C. hominis* is probably strictly a human pathogen, whereas *C. parvum* can infect most mammals. The infective dose is low, and the mean incubation time is 5–9 days. Infection occurs primarily through ingestion of oocysts in contaminated water or food or via direct contact with an infected person or animal, although respiratory infections have been described (Chalmers & Davies 2010). The parasite is highly resistant to traditional water purification such as chloramination whereas UV irradiation and ultrafiltration efficiently reduce *Cryptosporidium* oocysts (Nasser 2016). Common acute symptoms are frequent watery diarrhea, abdominal pain, fever, nausea, fatigue, and vomiting (Mac Kenzie *et al.* 1994; Chalmers & Davies 2010), and prolonged fatigue, joint pain, and headache have also been reported in some cases (Hunter *et al.* 2004). Children, especially those under two years of age, are more often and more severely affected than adults. Immunocompetent individuals usually recover within 1–2 weeks, whereas immunocompromised individuals can have long-lasting and severe diarrhea (Chalmers & Davies 2010; Putignani & Menichella 2010).

The widespread occurrence of *Cryptosporidium* in surface water has been noted in a number of studies. In the United States in 1991, samples from 87% of raw surface water locations in 66 water treatment plants contained *Cryptosporidium* (Baldursson & Karanis 2011), and a recent investigation in Canada found *Cryptosporidium* in 7–23%

doi: 10.2166/wh.2017.311

of surface samples near water treatment plants in Lake Ontario (Edge et al. 2013). Of the 200 surface raw water samples tested in Sweden in 2003–2008, 11.5% contained *Cryptosporidium* (Smittskyddsinstitutet 2011), and the corresponding figure for 408 raw water samples analysed in Norway in 1998 was 16% (Robertson & Gjerde 2001). An equivalent prevalence of *Cryptosporidium* in raw water has also been described in other parts of the world, such as Spain (15.4–22.6%) (Carmena et al. 2007), Hungary (26.6%) (Plutzer et al. 2007), and urban Brazil (7.6%) (Razzolini et al. 2010). Future climate changes, including enhanced rainfall, are expected to increase the prevalence of this parasite in surface water and consequently raise the risk of waterborne outbreaks (Young et al. 2015).

In developing countries, *Cryptosporidium* accounts for a large part of diarrheal infections, particularly in children, although this is only sparsely reflected in the literature (Baldursson & Karanis 2011). However, increased mortality due to *Cryptosporidium* has been described in toddlers in developing countries (Kotloff et al. 2013). Globally, the largest disease outbreak caused by *Cryptosporidium* reported to date was waterborne and occurred in Milwaukee, Wisconsin, in the United States in 1993; based on telephone interviews, it was estimated that approximately 400,000 people were infected (Mac Kenzie et al. 1994). Also, an earlier outbreak in the United States in 1987 infected 13,000 people (Hayes et al. 1989), although the number affected by outbreaks is usually much smaller with less than 100 symptomatic individuals (Baldursson & Karanis 2011).

In November 2010 and April 2011, Sweden was hit by two large outbreaks of diarrhea caused by *C. hominis* subtype IbA10G2 in the municipalities of Östersund and Skellefteå, respectively. The source of infection was drinking water from two different surface water sources (Smittskyddsinstitutet 2011; Widerström et al. 2014) located 350 km apart. The number of inhabitants affected in Östersund was approximately 27,000, corresponding to 45.2% of the population (Widerström et al. 2014), and the number in Skellefteå was approximately 20,000 (Smittskyddsinstitutet 2011), representing 28% of the population (Statistics Sweden 2015).

In Östersund, oocysts (the infectious form of the parasite) were detected both in surface water from Lake Storsjön and in drinking water from the waterworks, the latter of which was delivered to about 50,000 of the 60,000 inhabitants of Östersund. As described in a previous report (Widerström et al. 2014), 27,000 of the residents were symptomatic, with watery diarrhea and/or ≥3 diarrhea episodes/day. An online survey initiated on 27 November (Smittskyddsinstitutet 2011) and telephone triage (Andersson et al. 2014) indicated that the number of cases of gastrointestinal illness increased from mid November and peaked on November 29, 3 days after that a boil-water advisory was issued, and thereafter the number of new cases rapidly declined. The mean duration of diarrhea decreased with age, from 10 days in individuals aged <10 years to around 4 days in those ≥60 years; the mean duration in the age groups in between was 6–7 days. The overall attack rate was 45.2%; the rate in children and adults <50 years old was 54.5%, but was lower at 26.1% in those aged >70 years (Widerström et al. 2014).

To our knowledge, previous studies regarding sick leave associated with cryptosporidiosis have done one of the following: focused on absence from certain activities; used extrapolated data in which the number of days with symptoms was set as equal to the number of days with sick leave; did not report the sources of the data used (Mac Kenzie et al. 1994; Corso et al. 2003; Lindberg et al. 2011). The fact that two large outbreaks occurred in Sweden within a relatively short interval (Smittskyddsinstitutet 2011; Widerström et al. 2014) highlights the importance of assessing the impact that substantial outbreaks of waterborne parasitic diseases have on society as a whole. The purpose of the present study was to investigate sick leave from work taken by adults in Östersund to care for themselves or for infected children, as well as sick leave from kindergarten, preschool, or studies taken by the younger inhabitants of this municipality in connection with the outbreak of cryptosporidiosis that occurred in late November 2010.

METHODS

The methodology used in the present study is described elsewhere (Widerström et al. 2014). Briefly, a written questionnaire was sent to 1,508 randomly selected residents of all ages throughout Östersund in late January 2011, and a reminder was sent to those who had not responded within 2 weeks. Information about the distribution of water from the waterworks to the respondents' homes was ascertained through population registers. Free and informed consent was obtained from adult participants or from the parents/ legal guardians of participating minors, and the study protocol was approved by the Research Ethics Committee of the Faculty of Medicine, Umeå University, Umeå, Sweden.

The survey questions covered the following: the presence of new gastrointestinal and other symptoms with onset after 1 November 2010 and before 31 January 2011; all sick leave from work, kindergarten, preschool, school, or university due to the respondents' own symptomatic disease; the need for guardians to stay home to care for children with the symptoms of *Cryptosporidium* infection. *Cryptosporidium* infection was defined as the acute occurrence of watery diarrhea and/or ≥3 episodes of diarrhoea per day. Both the prevalence of those reporting sick leave due to diarrhea and the mean duration of the reported sick leave were analysed by age groups.

All statistical analyses were performed with SPSS software (version 19; SPSS Inc., Chicago, IL, USA). Means and proportions were calculated, and the chi-square test was applied, considering $P < 0.05$ statistically significant. Population data for 31 December 2010 (Statistics Sweden 2015) were used to calculate sick leave in the entire population of Östersund. The total direct sick leave costs for employers were estimated based on the median monthly income of residents of Sweden aged 20–64 years in 2010 (approximately €2,600) (Statistics Sweden 2016), together with their actual social insurance costs during sick leave (Swedish Social Insurance Agency 2016).

RESULTS

The overall response rate to the questionnaire was 69.2%, and men and women responded at the same rate. Also, 82.8% of responders lived in the area with contaminated tap water, and 73.2% of those who met the definition of *Cryptosporidium* infection became ill in November 2010. Table 1 presents data on the following for different age groups: the participation rate; the observed and estimated total sick leave due to symptoms consistent with *Cryptosporidium* infection in Östersund, considering participants' own illness as well as having to care for a sick child; percentage of participants fulfilling the case definition. Among adults <60 years of age, 24.0% took sick leave with a mean duration (±standard deviation) of 4.6 (±4.0) days, and an additional 10.6% were absent from work for a mean of 4.0 (±2.2) days to care for a symptomatic child. Also, 14.2%

Table 1 | Participants and observed and estimated sick leave due to symptomatic *Cryptosporidium* infection of individuals in Östersund from 1 November 2010 to 31 January 2011 stratified by age

	Survey				Sick leave			
	Responders		Case		Observed in survey		Estimated for Östersund	
	n	%	*n*	%	Prevalence %	Duration d	Prevalence *n*	Duration d
Age ≤ 17 years								
Participants	194	62.8	91	50.6				
Sick leave own illness					35.0	5.2 ± 3.8	3,977	20,682
Age 18–60 years								
Participants	546	63.3	270	50.8				
Sick leave own illness					24.0	4.6 ± 4.0	7,860	36,156
Sick leave to care for sick child					10.6	4.0 ± 2.2	3,472	13,886
Age ≥ 60 years	304	86.4	83	30.6				
Sick leave own illness					4.3	2.6 ± 1.1	612	1,591

Values given represent numbers and percentages of the following: all participants and participants fulfilling the case definition for cryptosporidiosis (i.e., watery diarrhoea and/or ≥3 diarrhoea episodes/day); participants with sick leave the mean (±standard deviation) number of sick leave days from work, university, or school (age ≥18 y), or from school, preschool, or kindergarten (age ≤17 y); participants with sick leave the observed duration of their sick leave. Sick leave was estimated for the populations in Östersund on 31 December 2010 of 11,364, 32,750, and 15,302 inhabitants in the age groups ≤17, 18–60, and ≥60 years, respectively (Statistics Sweden 2015). Data missing for case definition for 62 participants.

of symptomatic adults had to concomitantly care for a symptomatic child. No gender differences were found regarding adults' sick leave for own illness or for care of a child. Moreover, no disparity in duration of sick leave was noted between cases in different age groups (20–29.99, 30–39.99, 40–49.99, and 50–59.99 years). Further age-related data not shown.

The adult population aged ≥18 years took sick leave for 37,700 days due to own illness and for 12,300 days to care for a symptomatic child. For employers, this absence from work corresponds to an estimated total direct sick leave cost of €7 million.

In the entire Östersund municipality, 35% of respondents aged ≤17 years who responded to the survey had been home sick from kindergarten, preschool, or school, which represents a total of approximately 20,700 days of sick leave with a mean duration of 5.2 (±3.8) days per individual. Also, each symptomatic child caused a mean of 5.1 (±4.4) days of absence from work shared by parents/guardians.

Less than 50% of adults who fulfilled the definition of *Cryptosporidium* infection took any sick leave from work, university, or school, whereas a majority of children with cryptosporidiosis stayed home from kindergarten, preschool, or school. Among participants aged ≥18 years, sick leave was taken by a non-significantly ($P = 0.10$) larger proportion of the residents in an area supplied with contaminated water compared to the residents with non-contaminated tap water (44.9% vs. 28.6%).

DISCUSSION

The *Cryptosporidium* contamination of the drinking water supply in Östersund had a substantial impact on the population, resulting in an estimated loss of 50,000 workdays for adults and 20,700 preschool/school days for children <18 years of age. In the age group 18–60 years, comprising the highest number of employed individuals, almost one in four took sick leave days. In adults ≥60 years of age, sick leave from work and studies was significantly lower, possibly as a result of the lower degree of active employment/full-time studies in this group (NB: the mean age at retirement was 64.7 years in Sweden in 2010 (Swedish Pension Agency 2016)), and perhaps to some extent also due to partial immunity in the older study participants with less frequent symptoms and thus less need for sick leave. The observation that such a large proportion of all sick leave reported by the participants was concentrated to a period of only a few weeks strengthens the suspected causality, and it also demonstrates the potential vulnerability of society to waterborne infections.

To the best of our knowledge, no previous studies have investigated total sick leave from work and preschool/kindergarten in a population during an outbreak of waterborne disease caused by *Cryptosporidium*. Reports have indicated that a mean sick leave time of 3 days (Lindberg *et al.* 2011) is equivalent to the mean number of days with watery diarrhea seen during the Milwaukee outbreak in 1993 (MacKenzie *et al.* 1994), but that assumption seems to overestimate the total sick leave, considering that only half of the symptomatic residents of Östersund took any sick leave. On the other hand, children and adults aged <60 years who actually did take sick leave stayed home longer than the estimated 3 days.

Among adults aged 18–60 years who reported episodes of diarrhoea indicating an acute *Cryptosporidium* infection, slightly less than 50% took any sick leave. A potential explanation for this finding is that, in addition to individuals who continued to work or study despite being ill, others may have become ill during a period of unemployment or on days with no work or school. In Sweden, it is economically beneficial to take care of a sick child under the age of 12, because there is no qualifying period for such health insurance, whereas there is a one-day qualifying period for an adult's own sick leave. Considering the period of concurrent illnesses among parents/guardians and their children in Östersund, this aspect might have contributed to the relatively low percentage of adults who took sick leave for themselves despite reporting symptoms on the questionnaire. On the other hand, employees in Sweden who work in healthcare and in food industries are required to be on sick leave an extra 24 and 48 hours, respectively, after cessation of symptoms, although we had no information about sick leave in this context among the study participants.

No studies have evaluated the total societal costs linked to short-term sick leave in Sweden, and hence estimates in this regard are uncertain. For employers, in addition to the estimated direct costs of €7 million for sick leave, it is necessary to include indirect costs from losses in production. Also from a societal perspective, costs for medical and hospital care and other aspects (e.g., extra social insurance benefits after 2 weeks of sick leave) must be taken into consideration.

The reliability of retrospective surveys of disease outbreaks and the possibility of recall bias have been discussed previously (Hunter & Syed 2002). The questionnaire used in our study was sent out less than two months after the outbreak in Östersund. We believe that requesting information regarding sick leave due to acute diarrhea is likely to yield more reliable answers than asking about the occurrence of diarrhea in general, because sick leave is linked to economic consequences and potentially also to occurrence of additional symptoms. Furthermore, the incidence curve in our study (Widerström *et al.* 2014) was consistent with data from telephone triage and an online survey conducted during the outbreak (Smittskyddsinstitutet 2011; Andersson *et al.* 2014). This suggests that recall bias did not have a major impact on our results, and it also indicates that the reduced incidence in the number of people taking sick leave after mid December was indeed real and was not caused by an increased fraction of the population being on holiday over Christmas.

A potential weakness of our study is that lower response rates of 48.8% and 55.8% were noted for participants aged 20–29 and 30–39 years, respectively. There was also a trend towards a lower percentage being ill with increasing age in the group aged 20–60 years, although no such trend regarding duration of symptoms was noted in our previous assessment (Widerström *et al.* 2014). Still, inasmuch as the duration of sick leave was the same in the different subgroups in the age category 20–60 years, we assume that the mentioned difference in response rate had no major impact on the results. Another potential drawback of our investigation is that microbiological proof that *Cryptosporidium* was the causative agent was obtained for only a small minority of the studied population, and we did not know the background rate of diarrhea due to other causes in the population. However, no other infectious causes were reported during the study period that could explain the high degree of sick leave. MacKenzie *et al.* (1994) suggested that the monthly background rate of infectious diarrhea due to various causes was 0.5% in the population investigated during the outbreak in the city of Milwaukee, whereas others have argued that the rate may be higher (Hunter & Syed 2002). Our study included neither visitors to Östersund nor those who commuted to work in the city but lived elsewhere, and thus the calculated total sick leave caused by the outbreak is probably a low estimate. This risk for commuters is underlined by the high rate of sick leave observed in Östersund residents living in areas with water distributed from non-contaminated water plants. Moreover, considering potential long-lasting fatigue and other sequelae following cryptosporidiosis (Hunter *et al.* 2004), it is possible that there was also substantial sick leave after the end of the study period. This conclusion is supported by our observation of an increased prevalence of gastrointestinal and joint problems in patients in Östersund and Skellefteå that lasted at least six months after symptomatic infection with *C. hominis* (Rehn *et al.* 2015).

Traditional methods for purification of surface raw water (i.e. ozonation and chloramination) were used in Östersund up to 2010. This conventional approach proved inadequate to inactivate *Cryptosporidium* oocysts, and therefore, after the outbreak, a UV water disinfection system was installed (Widerström *et al.* 2014) to achieve effective drinking water purification (Nasser 2016). The cost for the UV irradiation system might be considered high, but it will never rise to more than a fraction of the societal costs of a large waterborne disease outbreak. In conjunction with UV disinfection, frequent sampling of raw and tap water for *Cryptosporidium* and other protozoan pathogens was also initiated. These measures were taken to address the proven need for awareness of protozoan infections and for functioning sanitation strategies in society.

CONCLUSIONS

We investigated sick leave from work, university, school, preschool, and kindergarten among individuals suffering from diarrhea associated with contamination of drinking water with *C. hominis*. The large proportion of the studied population that took sick leave within a short period of time during the *Cryptosporidium* outbreak underscore the importance to continually and meticulously monitor the effectiveness of the water disinfection treatment system in order to ensure the community access to safe, high-quality drinking water.

ACKNOWLEDGEMENTS

We thank Martin Ferm for help with statistical analysis. This work was supported by grants from the Research and Development Unit, Region Jämtland Härjedalen, Sweden, and the Medical Faculty of Umeå University, Umeå, Sweden.

ETHICAL APPROVAL

Free and informed consent was obtained from the participants or their parents or legal guardians, and the study protocol was approved by the Research Ethics Committee at the Faculty of Medicine, Umeå University, Umeå, Sweden (Reg. no. 2010-392-31M), 11 January 2011.

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First received 22 December 2016; accepted in revised form 3 February 2017. Available online 20 March 2017