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Cryptosporidiosis in Drinking Water: Analysis of Surveillance data from Health Protection Scotland (2006 – 2012)

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***Abstract*- Objective:** This study seeks to update understanding of the public health issues round the epidemiology of cryptosporidiosis in Scotland between 2006 and 2012. By examining the patterns, trends and seasonal effects of cases of cryptosporidiosis amongst different age groups, sex and health boards in Scotland during the reference periods. **Data Sources, Design and Methods:** Data on notified cases of cryptosporidiosis was supplied by Health Board Scotland between 2006 -2012, based on 16 health boards, which were modified to 14 health boards. Other variable used is the population data which was sourced from the website of the General Register office for Scotland. The Harmonic Poisson Regression model was utilized in examining the potential effects of cryptosporidiosis among different age group, sex, health boards as well as their pattern of occurrence in Scotland. **Results:** The models predicted that the highest number of cases of cryptosporidiosis in Scotland occurs in the fourth quarter (Autumn Season). There were 4195 reported cases of cryptosporidiosis in Scotland between 2006 and 2012. Of these number of cases, those associated with the female sex was higher with 2239 (53.27%), compared to the number of cases reported for the male sex 1926(45.91%), while a total of 30 (0.72%) cases were reported as unknown sex. The Age band of all the reported number of cases during the period under consideration were 0-14, 15-44, 45-64, and 65+ and their results were; 1978(47.15%), 1748(41.67%), 331(7.89%), and 138(3.29%) respectively. As regarding the health boards, Greater Glasgow and Clyde, had the highest number of cases of cryptosporidium infection 677(16.14%). Next to Greater Glasgow and Clyde is Lothian with 641(15.28%) number of cases. Those health boards with less than 1% are Shetland, Orkney Western Isles with 0.81%, 0.10% and 0.17% number of cases respectively between 2006 and 2012. **Conclusions:** The study has shown that the season with highest risk of cryptosporidium infection in Scotland is autumn and the higher the population in a health board in Scotland, the more likely the population have a higher risk of cryptosporidium parvum infection.

***Index Terms*-** Cryptosporidiosis, health boards, autumn, cryptosporidium parvum

I. Introduction

Cryptosporidiosis has been identified as a major re-emerging public health issue that is linked to waterborne and foodborne diseases among humans and animals [1, 2]. The causative bacteria, cryptosporidium are chlorine-tolerant protozoan parasites which are the major cause of gastrointestinal illness in humans and animals. Although studies have shown that individuals who have weakened immune systems (HIV Positive individuals) are at a higher risk of more severe effects or protracted illness, there have been outbreaks and incidences in healthy populations as well [3,4]. The incubation period for the illness is between 7 and 12 days [5]. Cryptosporidium is transmitted through the ingestion of contaminated drinking water or recreational water. Occasionally, food sources (such as bagged salad, watermelon) can also be a channel of transmission of cryptosporidium [6]. The disease can further be contracted through surfaces that have been contaminated with the stool from infected persons or animals, through sexual practices that might result in oral exposure to stool e.g. oral-anal contact, as well as humans or domesticated animals that are infected with the illness [6]. The transmission of the disease from human to human is caused by Cryptosporidium hominis while the transmission of the disease from animals (such as cattle, lamb, sheep, etc) to humans is caused by Cryptosporidium parvum [7]. However, apart from the two mentioned species, molecular studies have demonstrated that cryptosporidiosis can be caused by 20 other cryptosporidium species as identified and were described based on the hosts from which they were originally isolated [8,9].

II. Methods

The source of the data for this analysis is Health Protection Scotland. The administration of public health activities in Scotland is divided into 14 Health Boards. These health boards are as follow**;** Ayrshire & Arran(AA), Borders(BR), Dumfries & Galloway (DG), Fife(FF), Forth Valley(FV), Grampian (GR), Greater Glasgow & Clyde(GC), Highland (HG), Lanarkshire(LN), Lothian(LO), Orkney(OR), Shetland(SH), Tayside(TY), Western Isles(WI). Population size was also added to the data. The source of the population variable is the General Registrar's office for Scotland. The reason for introducing population in the data set is to allow us adjust for the different

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sizes of the health boards. The design was based on surveillance data on microbiologically confirmed cases of cryptosporidiosis in Scotland. The reference period under consideration was 2006 to 2012.

Frequency tables, charts and plots were used to explore relationships between and among variables under consideration. Furthermore, in order to assess the relationships between the variables, contingency tables were introduced and the relationships among the variables were analysed.

Contingency table is considered a useful and simple technique for detecting statistical significant association between two variables. We used the quarterly counts of cryptosporidiosis against other explanatory variables. It was also used to capture the patterns and effects of the seasonal (spring, autumn, summer, and winter) cases of cryptosporidiosis on some crucial explanatory variable.

These cyclical parameters are calculated based on values predicted by the harmonic regression

Equation;

$$y = \alpha + \partial 1 \cos(2 \prod x / 53) + \partial 2 \sin(2 \prod x / 53) + \gamma 1 \cos(4 \prod x / 53) + \gamma 2 \sin(4 \prod x / 53) + \epsilon$$

$$y = \alpha + \partial_1 z_1 + \partial_2 z_2 + \epsilon$$

where $z_1 = \cos(2 \prod x / 53)$

$z_2 = \sin(2 \prod x / 53)$

$p_1 = \cos(2 * pi * week/53)$

$p_2 = \sin(2 * pi * week/53)$

$p_3 = \cos(2 * pi * week/53)$

$p_4 = \sin(2 * pi * week/53)$

Therefore, p1, p2, p3 and p4 are the harmonic Parameters.

A Poisson regression may be used when the response variable is a count as in the case of cryptosporidiosis occurring independently. Counts are all positive integers and for rare events the Poisson distribution rather the normal distribution is more relevant since the Poisson mean is greater than zero and it has the special property that the mean and variance are identical.

Poisson distribution

$$f(y_i; \theta) \frac{e^{-\theta} \theta^{y_i}}{y_i!} \qquad y = 0,1,2,3, \ldots$$

where *y* is the response variable (independent cases of cryptosporidiosis)

θ (lambda) is the rate of occurrence of cases of cryptosporidiosis per unit of time.

The model for this study is express below;

$$\log(\mu_i) = \alpha + \partial_1 \, quarter_i + \partial_2 year_i + \partial_3 age_i + offset(population) + \partial_4 sex_i + \partial_5 \, Healthboards_i \rightarrow \textbf{model}$$

Offset term

The offset term in the model is a quantifiable variable whose regression coefficient is known to be 1(one) [10]. The offset is usually used to include the exposure term, which is often taken in terms of log of exposure of the variable.

III. Results

The data was analysed using R Software, version 2.15.2 (2012-10-26) -- "Trick or Treat" Copyright (C) 2012 The R Foundation for Statistical Computing.

Variables	Categories	Pooled (%)
sex	Male	1926(45.91)
	Female	2239(53.37)
	Unknown	30(0.72)
Age - Band	0 - 14	1978(47.15)
	15 - 44	1748(41.67)
	45 - 64	331(7.89)
	65 +	138(3.29)
Health Boards	Ayrshire & Arran	325(7.75)
	Borders	149(3.55)
	Dumfries & Galloway	252(6.01)
	Fife	239(5.70)
	Forth Valley	163(3.89)
	Greater Glasgow & Clyde	677(16.14)
	Grampian	574(13.68)
	Highland	227(5.41)
	Lanarkshire	449(10.70)
	Lothian	641(15.28)
	Orkney	34(0.81)
	Shetland	4(0.10)
	Tayside	454(10.82)
	Western Isles	7(0.17)

Table 1 Demographics of Respondents Reported In Percentage (Pooled results between 2006 - 2012)

Summary statistics show that there were 4195 reported cases of cryptosporidiosis in Scotland between 2006 and 2012. Of these number of cases, those associated with the female sex was higher with 2239 (53.27%), compared to the number of cases reported for the male sex 1926(45.91%), while a total of 30 (0.72%) cases were reported as unknown sex. The Age band of all the reported number of cases during the period under consideration were 0-14, 15-44, 45-64, and 65+ and their corresponding results were 1978(47.15%), 1748(41.67%), 331(7.89%), and 138(3.29%) respectively. This is an indication that cases of cryptosporidiosis in Scotland have higher prevailence among children (0 - 14). As regarding the health boards, Greater Glasgow and Clyde, had the highest number of cases of cryptosporidium infection 677(16.14%). Next to Greater Glasgow and Clyde is Lothian with 641(15.28%) number of cases. Those health boards with less than 1% are Shetland, Orkney Western Isles with 0.81%, 0.10% and 0.17% number of cases respectively, on the average between 2006 and 2012 (see Table 1.1).

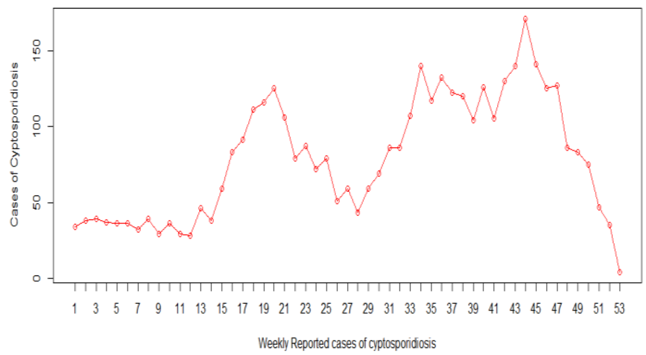

Figure 1 Pooled weekly cases of cryptosporidiosis between 2006 and 2012

Figure 3.1.2, shows the pooled weekly reported cases of cryptosporidiosis for the years under consideration (2006 – 2012). While this shows differences between weeks, the data reflects some seasonality though the seasonality is not regular. Double peak periods were observed at week 20 and week 45 respectively. There was another attenuated increase in week 28 without much significant decrease compared to the initial peak. The autumn cases may be caused by holiday travel and swimming pool use however; there is no substantial evidence to support this claim. In short, routine surveillance in Scotland over the last 7 (seven) years showed that the majority of cases occurred in autumn.

Model: log(μi) = α +∂1 quarteri + ∂2yeari + ∂3agei + offset(population) + ∂4sexi + ∂5 Healthboards

	RR(95% CI)	P-Value
(Intercept)	1.18(0.99,1.40)	0.06
quarter(2)	2.55(2.27,2.87)	<0.001
quarter(3)	2.84(2.53,3.19)	<0.001
quarter(4)	3.15(2.81,3.53)	<0.001
year2007	0.85(0.75,0.96)	0.01
year2008	1.06(0.94,1.19)	0.32
year2009	1.07(0.95,1.20)	0.26
year2010	0.93(0.82,1.05)	0.24
year2011	0.77(0.68,0.88)	<0.001
year2012	1.15(1.03,1.29)	0.02
Age (15-44)	0.89(0.83,0.95)	<0.001
Borders	0.50(0.41,0.62)	<0.001
Dumfries & Galloway	0.79(0.66,0.94)	0.01
Fife	0.75(0.63,0.90)	<0.001
Forth Valley	0.50(0.41,0.62)	<0.001
Greater Glasgow & Clyde	2.19(1.90,2.53)	<0.001
Grampian	1.90(1.65,2.20)	<0.001
Highland	0.69(0.57,0.83)	<0.001
Lanarkshire	1.45(1.25,1.69)	<0.001
Lothian	1.97(1.71,2.29)	<0.001
Orkney	0.11(0.08,0.16)	<0.001
Shetland	0.01(0.00,0.03)	<0.001
Tayside	1.49(1.28,1.74)	<0.001
Western Isles	0.01(0.00,0.03)	<0.001
sex (M)	0.90(0.85,0.96)	0.002

Signif. codes: '***' 0.001 '**' 0.01 '*' 0.05

Table 2 Results from Model: The Poisson Harmonic Model

On the average, number of cases of cryptosporidiosis is 155%, 184% 215% more likely to occur in the second quarter, third quarter and fourth quarter respectively compared to the reference category (first quarter) holding other variable in the model constant. On the average, cases of cryptosporidiosis is 11% less likely to occur among those in the age group (15 - 44) compared to those in the reference age group (0 -14) in Scotland between 2006 and 2012. The reference health board is Ayrshire & Arran. On the average, persons living in Greater Glasgow and Clyde, Grampian, Lanarkshire, Lothian and Tayside were 119%, 90%, 45%, 97%and 49% more likely to be infected by cryptosporidiosis than those living in Ayrshire and Arran. As regarding the years, on the average, in year 2008, 2009 and 2012 the number of cases of cryptosporidiosis in Scotland were 6%, 7% and 15% respectively more likely to be reported compared to the reference year, 2006. On the average, the risk in number of cases of cryptosporidium infection among the male sexes is 10% less likely compared to the female sexes in Scotland between 2006 and 2012. Observing the age group, on the average, those in the age group 15 – 44 are 11% less likely to report the cases of cryptosporidiosis compared to the reference age group (0-14). With respect to statistically significance, quarter 2, quarter 3 and quarter4 are significant predictor of the model. Years 2007, 2011 and 2012 were statistically significant predictors of the model. While Age group (15 – 44), Sex (male) and all the health boards were statistically significant.

IV. Discussion

The total number of cases of cryptosporidiosis reported annually fluctuated during the reference period (2006 -2012). It is unclear whether the fluctuation in the number of cases across the years is associated with the reporting pattern, actual change in the pattern of infection or the diagnostic testing procedures. Year 2012 recorded the highest number of cases of cryptosporidiosis. The high cases of cryptosporidium infection may be associated with the amount of rainfall in that year, according to BBC report; year 2012 exceeds the existing highest record of rainfall of over 50 years in the United Kingdom [11]. Findings from other studies have shown that there is higher rainfall to evaporation ratio associated with increased rate of cryptosporidium infection [12, 13].

As seen in this study, health boards with larger population size tend to have higher number of cases of cryptosporidiosis. It was also observed from all the models that health boards with higher population are more likely to predict increase in the number of cases of cryptosporidiosis compared with health boards with smaller population size. This is consistent with other studies which show a relationship between densely congested area and number of cases of cryptosporidium infection [14, 15]. Finding from this study shows that cases of cryptosporidiosis is predominantly reported among children (0 - 14) compared to other age groups. It has been recognized that there is a degree of bias in the reporting of illness among children for different kinds of disease, this is because parents are more likely to seek medical care for their children. Health personnel are more likely to take specimens for children than for adult. This finding is consistent with other studies on cases of cryptosporidiosis among children [16, 17, and 18]. There are more numbers of cases among male sex in the age group 0 - 4 than other age group in Scotland. Comparing this to the female sex in similar age group shows that the number of cases of cryptosporidiosis tends to be more among those in the age group 15 - 44. The marked difference may be attributed to care services which are predominantly rendered by the female sex, who in the course of discharging their services gets infected through contact with the stool of the babies. Similar results have previously been obtained in surveillance study of cryptosporidiosis in the United States [16].

Some limitations to this study are as follow; variables which would have made the study more robust were not captured by the data provided by the Health Board Scotland. An example of such variables includes; sources of water supply to the different health boards risk factor of cryptosporidium infection by exposure, information on race and ethnicity. Modelling count data is a task that is commonly used in the public health [19]. Secondly, the classical Poisson regression model assumes that the conditional means and variance are equal. This is however, considered as a major limitation for the classical Poisson model. In order to overcome this limitation, a negative binomial harmonic regression model would be used in future study, so as to take into account the issues of over - dispersion and under – dispersion.

V. Conclusion

The study has shown that the season with highest risk of cryptosporidium infection in Scotland is autumn. The higher the population in a health board in Scotland, the more likely the population have a higher risk of cryptosporidium infection. Improving the completeness and quality of data collection methods by the health boards in Scotland would increase knowledge and reduce risk of cryptosporidiosis in Scotland.

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