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Temporal patterns of human and canine *Giardia* infection in the United States: 2003–2009☆

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ABSTRACT

Giardia protozoa have been suspected to be of zoonotic transmission, including transmission from companion animals such as pet dogs to humans. Patterns of infection have been previously described for dogs and humans, but such investigations have used different time periods and locations for these two species. Our objective was to describe and compare the overall trend and seasonality of *Giardia* species infection among dogs and humans in the United States from 2003 through 2009 in an ecological study using public health surveillance data and medical records of pet dogs visiting a large nationwide private veterinary hospital. Canine data were obtained from all dogs visiting Banfield hospitals in the United States with fecal test results for *Giardia* species, from January 2003 through December 2009. Incidence data of human cases from the same time period were obtained from the CDC. Descriptive time plots, a seasonal trend decomposition (STL) procedure, and seasonal autoregressive moving-average (SARIMA) models were used to assess the temporal characteristics of *Giardia* infection in the two species. Canine incidence showed a gradual decline from 2003 to 2009 with no significant/distinct regular seasonal component. By contrast, human incidence showed a stable annual rate with a significant regular seasonal cycle, peaking in August and September. Different temporal patterns in human and canine *Giardia* cases observed in this study suggest that the epidemiological disease processes underlying both series might be different, and *Giardia* transmission between humans and their companion dogs seems uncommon.

1. Introduction

Giardia protozoal parasites infect many species of domestic and wild animals as well as humans. Zoonotic transmission of some *Giardia* species/genotypes has been demonstrated experimentally, but its occurrence and clinical significance under natural conditions is unclear (Plutzer et al., 2010). Assemblages A and B which were considered to be human-specific have been isolated from a wide range of domestic, wild, and marine animals (Thompson et al., 2000), and these zoonotic assemblages have been

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shown to occur more commonly in dogs from the western United States compared to dog-specific assemblages (C and D) (Covacin et al., 2011). However, the relative importance of zoonotic transmission of *Giardia* spp. remains to be determined (Hunter and Thompson, 2005).

Human giardiasis in the United States is a nationally notifiable disease, with most states voluntarily reporting (Yoder et al., 2010). Approximately 20,000 human giardiasis cases were reported annually to the Centers for Disease Control and Prevention (CDC) from 2002 to 2009 (Yoder and Beach, 2007; Yoder et al., 2010), but CDC estimates the actual number of cases to be closer to 1.2 million cases per year due to under-reporting and under-diagnosis (Scallan et al., 2011). Documented cases of human giardiasis have been associated with a history of travel, outdoor recreational activities, and drinking contaminated water, but many cases may be subclinical (Eisenstein et al., 2008).

Cases of human giardiasis in the United States generally increase in late summer and early fall (Katz et al., 2006; Nakada et al., 2012; Yoder et al., 2010). The peak incidence of human giardiasis occurs during the spring in Europe and summer in Canada and the UK (Lal et al., 2012). The seasonality of canine giardiasis has been the subject of conflicting findings. For example, no seasonal pattern of canine giardiasis in the US was found in one study (Nolan and Smith, 1995), whereas a more recent study reported a highest prevalence in the month of November (Mohamed et al., 2013). The peak incidence of canine giardiasis has been reported to occur in the winter in Italy (Bianciardi et al., 2004), the summer in Spain (Díaz et al., 1996), and in the fall in Argentina (Fontanarrosa et al., 2006).

Time-series analysis is a method for describing the occurrence of common events over time while accounting for the serial correlation (autocorrelation) between observations. Few studies have used a time-series approach to describe the temporal pattern of *Giardia* (Naumova et al., 2000; Nolan and Smith, 1995). However, no studies have compared the temporal patterns of *Giardia* infections across species. Similarities in temporal patterns could potentially indicate common source etiologies or cross-species transmission.

The objective of this ecological study therefore was to describe the temporal pattern of giardiasis among dogs and humans in the United States using medical records of dogs visiting private veterinary hospitals and reports of human giardiasis by state health departments to the CDC for the period from January 2003 through December 2009. Our hypothesis was that temporal correlations of human and canine infection could provide supportive evidence for either zoonotic transmission or a common source of infection affecting both species.

2. Materials and methods

2.1. Data

2.1.1. Canine

Fecal test information was obtained from Banfield, The Pet Hospital, Portland, Oregon. Banfield, The Pet Hospital, is a small animal general practice with more than 700 hospital locations in metropolitan areas in the United States. The practice estimates that their hospitals provide health care for approximately 5% of the US pet population. Fecal testing was performed as part of routine diagnostic or preventive veterinary care of symptomatic and asymptomatic pet dogs during visits to Banfield veterinary hospitals. Fecal flotation without centrifugation using 1.18 SG $ZnSO_4$ was performed to detect *Giardia* cysts in the stool and the results reported as positive or negative; no attempt was made to identify specific *Giardia* assemblages. All fecal tests were conducted by trained hospital staff following a standard protocol. The medical records from all Banfield hospitals nationwide are downloaded weekly and stored in a central electronic data warehouse using proprietary software (PetWare, Banfield, The Pet Hospital, Portland, OR). Each record includes a unique patient and hospital identifier. Demographic data for each dog including hospital visit date and the results of fecal flotation tests from January 1, 2003, through December 31, 2009, were downloaded from the central database. All dogs had a recorded fecal flotation test, and only results from the first fecal test for each dog were used in the analysis. Data related to clinical signs and specific treatments were not available.

The main dataset for canine data was organized into a subset containing all positive fecal test results indexed by the test date and a second full set containing all fecal tests (positive and negative) indexed by the test date. A monthly incidence ($MP_{d,i}$) per 100 dogs was estimated as the number of positive fecal tests for each month i (NPT_i) divided by the total number of tests for the same month (TNT_i): $MP_{d,i} = (NPT_i/TNT_i) \times 100$.

2.1.2. Human

The number of human *Giardia* cases reported to CDC's National Notifiable Disease Surveillance System from each state by month ($TNRC_i$) from January 2003 through December 2009 was obtained from CDC. Confirmed and probable cases of giardiasis are reported voluntarily by states. Positive diagnostic testing includes visual detection of cysts via staining or direct fluorescent antibody methods, or *Giardia* antigen detection by immunodiagnostic tests (Yoder et al., 2010). An estimate of the total population for each state included in the study for each of the seven years was obtained from the federal census website (US Census Bureau, 2009). The total population (TP_i) for each state was used as the denominator to estimate a monthly incidence of *Giardia* ($MP_{h,i}$) per 100,000 people: $MP_{h,i} = (TNRC_i/TP_i) \times 100{,}000$.

2.2. Analysis

Monthly incidence rates of canine and human *Giardia* infection were graphed. The seasonal-trend decomposition procedure based on loess (STL) method (Cleveland et al., 1990; Barnett and Dobson, 2010) was then used to decompose the complete time series in order to visualize temporal patterns. This procedure is based on decomposing the time-series into trend, seasonal, and remainder components. The seasonal component is found by local linear regression (loess) smoothing the seasonal sub-series of the overall time series. The seasonal values are removed, and the deseasonalized remainder smoothed to find the