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Short communication

Modelling risk factors for injuries from dog bites in Greece: a case-only design and analysis

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Abstract

We conducted a study using a newly developed dataset based on Emergency Departments records of a network of hospitals from Greece on injuries from dog bites. Our goal is three-fold: (a) to investigate if surrogate factors of leisure time are associated with increased risk of injury from bites; (b) to address recently reported contradictory results on putative association of lunar periods and injuries from dog bites; and (c) to offer a general methodology for addressing similar case-only designs with combined factors of which some can exhibit cyclical patterns. To address these goals, we used a case-only design of our dataset, and conducted an analysis where we controlled simultaneously for weekday/weekend effects, season of year (winter, spring/fall, summer), and lunar periods, because any one of these factors can contribute to the degree of exposure to injuries from dog bites. We found that increased risk of injury from bites was associated with weekends versus weekdays (RR = 1.19, 95% CI: 1.10–1.29), summer versus winter (RR = 1.24, 95% CI: 1.11–1.39), and fall or spring versus winter (RR = 1.31, 95% CI: 1.19–1.45). The results support the hypothesis that longer leisure time at these levels of factors does increase the risk of having a bite injury. Moreover, after controlling for these factors, risk of bite injury was not associated with moon periods, thereby also helping settle a longstanding argument.

Keywords: Confounding; Dog bites; Leisure time; Lunar periods; Health effects; Cyclicity

1. Introduction

Injuries from dog bites have long been a concern in public health (Chun et al., 1982). Some risk factors are well known, such as, the bites that are inflicted mostly to young children, and, in particular, mostly to males, and have relatively uniformly recognized basis (e.g. Bernardo et al., 2000). However, there are also factors that are either controversial, or have not been as systematically studied. Recently, for example, Bhattacharjee et al. (2000) reported increased risk of bites during full moon, a study motivated by earlier reports (e.g. by Mathew et al., 1991, on the relation between full moon and poisoning, and by Laverty and Kelly, 1998 on the relation between full moon and car accidents), whereas Chapman and Morrell (2000) contradicted such association.

Most studies on bite injuries, including the latter two, use the so-called "case-only" designs in the sense that they use data on only cases of injuries of dog bites, not controls. Case-only designs are practical, but their analysis needs special attention in order to appropriately address the lack of "denominators of exposure" arising from the lack of controls (Greenland, 1999). Of particular relevance to both lack of controls and to the above studies are variables that are surrogates of "leisure time". For example, the analysis of Bhattacharjee et al. (2000) stratified the number of bites in 10 periods of moon but made no adjustment for weekday/weekend or other variables. On the other hand, the analysis of Chapman and Morrell (2000) stratified the number of bite cases by weekday and full versus no full moon, but did not address the continuum among moon periods. However, ignoring either weekday/weekend effects or the continuum of moon periods, as done in both studies above, can possibly create spurious associations between number of bites and full moon simply because of differential exposure. For example, adjusting for weekday is necessary because more people tend to be outdoors (which could imply higher exposure to bites) on certain days (e.g. weekends) and not on others. Similarly, in certain cultures, more people tend to be outdoors at full moon, though not necessarily at periods near full moon, and, therefore, the spurious association arising from such differential exposure due to lack of controls would

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be made less if we modeled the continuum of moon periods, rather than simply stratifying by full versus no full moon.

We have three goals: (a) to investigate if surrogate factors of leisure time are associated with increased risk of injury from bites; (b) to account for (a) in order to address the earlier contradictory reports on the putative association between injuries from dog bites and full moon; and (c) to offer a general methodology for addressing similar case-only designs with combined factors of which some can exhibit cyclicity. We address these issues by using a case-only design of a new dataset from Greece on injury cases of dog bites.

2. Methods: case-only design and analysis

We used records from injury cases inflicted by dog bites and reported from a large Emergency Department Injury Surveillance System (EDISS) in Greece. EDISS covers the Emergency Departments of four large hospitals across the country with explicit or implicit catchment areas. We used the total of 2642 such cases that had occurred within the window of 1 May 1996 and 21 December 1999, which is the earliest and latest full moon, respectively during 1996–1999, in order to draw connections with the articles cited in Section 1. Of the total cases, 61% were males (95% CI = (60–63%)). The average age was 26 (S.D. = 22) years of age, the median was 18, and one-third of the cases was below 11 years of age.

For each injury case, we obtained the gap time between the day of bite injury and the day of the immediately preceding full moon. We classified these gap times, which ranged from 0 to 29 days, to 10 periods, in analogy to the first article (Bhattacharjee et al., 2000) with the minor exception that each of our periods covered 3 days: a bite occurring at gap of 0 days (full moon), 1, or 29 days was labeled period 5; gaps of 26–28 days were assigned period 4; and so on for the other periods. We considered two analyses.

For the first analysis, we constructed the $2 \times 3 \times 10$ cross-classification of Table 1 where each cell i is characterized, respectively, by: a variable W_i (1 if the cell is on a weekend, 0 otherwise); a variable S_i (1 if the cell is on a winter month, 2 if the cell is on a fall or spring month, and 3 if the cell is on a summer month, see Table 1 for definitions); and P_i ($1, \ldots, 10$ if the cell is on moon period $1, \ldots, 10$). For each such cell i we calculated the number N_i of injuries from bites from our dataset that fall in that cell. Because cells of that table naturally occur at different frequencies even if there is no association of the factors with bites, we also calculated the total number E_i of calendar days in the time window of our study that fall in that cell. The numbers N_i of injuries from bites in each cell i were then analyzed with a Poisson regression where the expected number μ_i of bites was allowed to relate to the factors of weekend/weekday, season of year, and period of moon, as follows:

$$\log \mu_i = \log E_i + \beta_{(0)} + \beta_{(\mathrm{w})} W_i + \beta_{(\mathrm{S},2)} I(S_i = 2) + \beta_{(\mathrm{S},3)} I(S_i = 3) + \beta_{(\mathrm{P,amp})} \times \cos\left\{\frac{2p(P_i - \beta_{(\Pi,\max)})}{10}\right\} \tag{2.1}$$

where $\beta_{(\mathrm{P,amp})}$, and I is the indicator function. In the above, the term $\log(E_i)$ adjusts for differential number of days (exposure) in each cell. The term $\exp(\beta_{(\mathrm{w})})$ is the relative risk of bite injury in a weekend versus weekday, $\exp(\beta_{(\mathrm{S},2)})$ is the relative risk of bite injury in fall or spring months versus winter months, and $\exp(\beta_{(\mathrm{S},3)})$ is the relative risk of bites in summer versus winter months. The third line of (2.1) allows for a cyclical pattern of risk of bite injuries with respect to moon periods: the term $\beta_{(\Pi,\max)}$ is the moon period with highest risk of bites, and $\exp(2\beta_{(\mathrm{P,amp})})$ is the amplitude ratio of maximum versus minimum risk of bites across moon periods. Estimation of the parameters of the model is done by maximum likelihood.

For the second analysis, we further cross-classified the cells of Table 1 by gender ($G_i = 1$ for male, 0 for female) and by dichotomous age ($A_i = 1$ if younger than 20 years of age). We analyzed these data by adding

Table 1
Numbers [N_i = injuries from bites, E_i = calendar days] falling in each cell i of the cross-classification by weekend/weekday, season of year, and period of moon between 1 May 1996 and 21 December 1999[a]

Period of moon (P_i)	Weekday ($W_i = 0$)			Weekend ($W_i = 1$)		
	Winter[b] ($S_i = 1$)	Fall/spring ($S_i = 2$)	Summer ($S_i = 3$)	Winter ($S_i = 1$)	Fall/spring ($S_i = 2$)	Summer ($S_i = 3$)
1	[50, 28]	[97, 54]	[55, 26]	[12, 9]	[48, 20]	[21, 10]
2	[38, 24]	[107, 52]	[55, 27]	[19, 12]	[50, 21]	[27, 11]
3	[36, 28]	[121, 53]	[55, 27]	[14, 8]	[38, 21]	[20, 10]
4	[34, 24]	[98, 55]	[36, 24]	[19, 11]	[42, 21]	[23, 12]
5	[18, 18]	[84, 46]	[42, 23]	[7, 10]	[47, 18]	[16, 9]
6	[31, 25]	[94, 52]	[55, 31]	[12, 8]	[47, 21]	[19, 10]
7	[37, 23]	[114, 57]	[45, 23]	[13, 11]	[41, 20]	[22, 13]
8	[52, 28]	[74, 49]	[43, 28]	[11, 8]	[68, 25]	[18, 9]
9	[30, 24]	[90, 54]	[52, 27]	[30, 12]	[44, 18]	[24, 12]
10	[39, 27]	[73, 50]	[34, 26]	[18, 9]	[61, 25]	[22, 10]

[a] Total injuries from bites = 2642.
[b] Winter: December–February; spring: March–May; summer: June–August; fall: September–November.

Table 2
Relative risk for bite injury for the factors considered in Section 2

	Relative risk for bite injury (95% CI)	
	Model: without age and gender	With age and gender
Male victim	–	1.60 (1.48, 1.73)
Age (<20 years)	–	1.17 (1.08, 1.26)
Weekend versus weekday	1.19 (1.10, 1.29)	1.19 (1.09, 1.29)
Season[a]		
Fall or spring	1.31 (1.19, 1.45)	1.31 (1.18, 1.45)
Summer	1.24 (1.11, 1.39)	1.24 (1.11, 1.40)
Moon periods		
Highest versus lowest risk	1.09 (1.00, 1.21)	1.08 (1.00, 1.20)

[a] Reference is winter months.

in (2.1) terms $\beta_{(G)}G_i$ and $\beta_{(A)}A_i$ to adjust for gender and age categories.

With case-only designs, a difference between the above two analyses is that the first adjusts for the factors (weekday, season, and moon period) for which a degree of exposure is known and incorporated in the model (through E_i). In the second approach, we do not know the fraction of females versus males, or the distribution of age, for a relevant exposed cohort (for example, the cohort of dog owners) that underlies our particular sample of cases. Therefore, the parameters $\exp(\beta_{(G)})$ and $\exp(\beta_{(A)})$ measure relative risk in reference to the uniform distribution of these factors in a cohort, that is, the relative number of cases as a function of gender and age. When the distribution of age and gender for the underlying exposed cohort of the case-only design is known (or estimated), then it should be incorporated in the factor E_i in (2.1).

In addition to its straightforward interpretation, the cyclical component in the third line of (2.1) has two desirable properties. First, the component $\beta(\mathrm{P,_{amp}})=0$ if, in truth, moon periods do not relate to the risk of bite injuries after adjusting for differential exposure. Second, if such periodic relation does exist, the cyclical component provides substantially more statistical power to detect it than a model with individual terms for each moon period. The third line of (2.1) generalizes the well-known Edwards' procedure to allow for adjustment for cyclical phenomena simultaneously with adjustment for other factors. This cyclical model component has been used successfully in another application, which supported the hypothesis that low melatonin levels among depressed individuals during summer months may be a trigger of suicidal behavior (Petridou et al., 2001).

3. Results

In the first approach, increased risk of bites was associated with weekends versus weekdays (RR = 1.19, 95% CI: 1.10–1.29), summer versus winter (RR = 1.24, 95% CI: 1.11–1.39), and fall or spring versus winter (RR = 1.31, 95% CI: 1.19–1.45) (see Table 2). This is consistent with the hypothesis that longer leisure time at these levels of factors does increase the risk of injury from dog bites. Moreover, after controlling for these factors, risk of bite injury was not associated with moon periods, (maximum to minimum risk across periods estimated at 1.09, 95% CI: 1.00, 1.21), and the moon period with maximum risk was estimated to be between periods 1–2 (17–22 days of moon), which is far from the period of full moon. These results considered together suggest that, after controlling for the other factors, the finding of no association between injury bites and full moon would persist even with larger sample size.

The results for the above factors remained essentially the same when the model adjusted for age and gender (Table 2). That model also showed that even after controlling for the other variables, there are 60% more male than female victims, and that most of the victims are younger than 20 years of age.

4. Discussion

Our results provide evidence that there is increased risk of injury from dog bites during weekends and during non-winter months, but that there is no increased risk at or near full moon. Additional unknown factors may also exist, but this is always possible in observational studies. Therefore, because competing sources of exposure are addressed better in this study than in earlier ones, any concern about residual confounding would likely create more rather than less doubts about an effect of full moon on risk of dog bites.

Animal bites, and in particular, dog bites is an important source of injuries (Sacks et al., 1996) accounting in Greece for about 20,000 of injuries per year or 1.5% of the total injuries. Thus, any additional predictor of increased risk could be valuable for the development of a preventive strategy. Although our database did not contain more direct information on the circumstances in which each bite occurred, our results of increased risk of injury during weekends and non-winter months for youngsters reinforce evidence that such extra injuries are more likely associated with leisure time and outdoor activities. Therefore, and because such youngsters' activities are generally and correctly encouraged, more attention should be directed to prevent such injuries (and/or infections from those injuries) through measures such as the better control of the growth of stray dog populations in neighborhoods where children play outdoors, in ways that also respects animals' rights, and, as suggested by a reviewer, through more appropriate training of dogs by their owners.

Our results also help resolve a debate following the publication of Bhattacharjee et al. (2000) alleging that dog bites are more common during full moon periods (see also analogous reports relating moon periods to a series of health effects, such as epileptic convulsions, Taylor and Diespecker, 1972; Raison et al., 1999; Salib et al., 1999). Study of such variables as predictors of risk in a case-only design should be done with appropriate methods to account for coexistent factors and exposure in order to avoid misleading conclusions. When our methods were applied to this problem, no apparent association between full moon and injuries from dog bites was evident.

A limitation of case-only designs is, by definition, the lack of direct inclusion of control subjects. Therefore, efforts should be taken to incorporate at least indirectly in the analysis appropriate measures of the degree to which each case in the design has been exposed. The analytic strategy we presented accounts for differential exposure to weekend/weekdays, seasons, and moon periods, by incorporating the distribution, up to proportionality, of the factors modeled in the cohort underlying the cases. This approach can address more general case-only designs of public health importance with potential chronobiological and hypothesized cyclical components. Although such an exposure distribution was calculable directly based on a calendar in our application (expressed through E_i in (2.1)), this approach requires improvement when that distribution is estimated with uncertainty from a different dataset. Therefore, extending our methods to combining datasets under case-only designs with datasets under other designs is an important problem for continued study.

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