The human-canine environment: A risk factor for non-play bites?

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Abstract

Few dog bite risk factor studies have been conducted. This veterinary clinic-based retrospective cohort study was aimed at identifying human-canine environmental risk factors for non-play bites in Kingston, Jamaica (660) and San Francisco (SF), USA (452). Data were analysed using modified Poisson regression with confounders selected using directed acyclic graphs (DAGs) and the change-in-estimate procedure.

Dogs acquired for companionship were more likely (RR = 1.66; 95% CI 1.02-2.70) to bite than those acquired for protection. Routinely allowing a dog into the presence of visitors was also positively associated with it biting. A dog sleeping in a family member's bedroom was a risk factor for biting in Kingston (RR = 2.54; 95% CI 1.43-4.54) but not in SF, while being able to leave the yard unaccompanied was a risk factor for biting in SF (RR = 3.40; 95% CI: 1.98-5.85) but not in Kingston. Overall, dogs which were less restricted in their interactions with humans were at elevated risk for biting. An observed association with dog bites in one cultural setting might not exist in another.

Keywords: Kingston, Jamaica, San Francisco, USA, non-play, dog, bite, risk factor

Introduction

Dog bites to humans are a worldwide problem (Chomel and Trotignon, 1992; Bhanganada et al., 1993; Thompson, 1997; Kumar, 1999; Chen et al., 2000; Ozanne-Smith et al., 2001; Frangakis and Petridou, 2003; Horisberger et al., 2004; Van Eeckhout and Wylock, 2005; Morgan and Palmer, 2007). In the United States there are 300-1000 bites per 100 000 persons per year (Beaver, 1997; Cornwell, 1997) and reports from Switzerland and Belgium have indicated national bite rates of 180 (Horisberger et al., 2004) and 900 (Gisle et al., 2002) per 100 000 per year, respectively. These figures are striking given that some studies suggest that far less than 50% of dog bites are reported (Beck and Jones, 1985; Chomel and Trotignon, 1992; Kahn et al., 2003; De Keuster et al., 2006).

Research has focused on the circumstances of incidents (Beck et al., 1975; Beck and Jones, 1985; Szpakowski et al., 1989; Mathews and Lattal, 1994; Thompson, 1997; Guy et al., 2001a; Frangakis and Petridou, 2003; Horisberger et al., 2004), characteristics of both biting dogs (Beck and Jones, 1985; Szpakowski et al., 1989; Gershman et al., 1994; Mathews and Lattal, 1994; Cornwell, 1997; Thompson, 1997; Guy et al., 2001b; Horisberger et al., 2004) and persons bitten (Beck and Jones, 1985; Bhanganada et al., 1993; Mathews and Lattal, 1994; Cornwell, 1997; Thompson, 1997; Savino et al., 2002; Horisberger et al., 2004), the estimation of public health costs (Bhanganada et al., 1993; Weiss et al., 1998), the pathological sequelae to attacks (Fishbein and Robinson, 1993; Mendez Gallart et al., 2002; Peters et al., 2004; Van Eeckhout and Wylock, 2005), and wound care for the victims (Van Eeckhout and Wylock, 2005; Morgan and Palmer, 2007). Unfortunately, few investigators have employed a formal reference series in their studies (Gershman et al., 1994; Chen et al., 2000; Guy et al., 2001c; Drobatz and

Smith, 2003; Reisner et al., 2005), and thus research to date has been of limited value in identifying risk factors. In addition, because hospital based data has formed the basis for inferences for all except a few studies, it is questionable whether these results are applicable to the general dog population. An analysis of a case series of 227 biting dogs obtained from a veterinary clientele has reported that 73%, 17.9% and 21.5% had bitten an adult (> 18 years), a teenager (13-18 years), and children (≤12 years) respectively, at least once (Guy et al., 2001a). This stands in contrast to hospital data which suggest that children are over represented among dog bite victims (Ozanne-Smith et al., 2001). A consequence of the limited scope of dog bite research is the paucity of epidemiologic evidence supporting the belief that a dog's tendency to bite depends on an interaction of genetics (including sex), early experiences, later socialization and training, reproductive status, quality of ownership, supervision, and the potential victim's behaviour (The American Veterinary Medical Association., 2001).

We conducted a retrospective cohort study in San Francisco (SF) USA, and Kingston, Jamaica (JA) to identify human-canine environmental risk factors for non-play bites to humans. Work by a few authors suggest that both human-canine attitudes and interactions in the Caribbean differ considerably from those in the continental United States with some studies from Caribbean territories reporting that 56-70% of dogs are kept entirely outdoors (Fielding and Mather, 2001; Davis et al., 2007; Ortega-Pacheco et al., 2007). In the US, this figure is 15-20% (American Pet Products Manufacturers Association., 2005-2006). In selecting divergent cultures with respect to attitudes to human-canine relationships, we hoped to identify, if present, heterogeneity by country.

Materials and Methods

Study protocol

The study was approved by the Human Subjects Review Committee at the University of California, Davis, USA.

Study participants

Study participants were clients in the waiting rooms of eight veterinary clinics from May 30th to August 9th 2003, in Kingston and from three veterinary clinics in SF from 20th October 2003 to 10th January 2004. Both sets of clinics were located within areas ≤ 5 square miles in their respective cities. All clinics were privately owned with caseloads of > 90% companion animal (dogs and cats). Clients were eligible to participate only if they had a dog present at the time of the interview, owned the dog for ≥ 24 h, lived seven days a week in the same home as the dog, and were ≥18 years.

Data collection

Respondents were approached, following clinic registration but prior to being seen. The same interviewer administered the questionnaire to over 99% of respondents and dog-related information pertained only to the dog present. Whenever more than one dog was present, their names were ranked alphabetically and the first ranked chosen for participation.

Exposure assessment

For biters and non-biters the exposure period pertained only to the time period up to the incident and interview respectively. Exposure information included respondent's characteristics,

canine characteristics, factors related to owner-dog habitual interactions, and factors related to the dogs' living environment (Fig. 1 and Table 1). Except for three age-time-related questions, all responses were categorical.

Identical data collection protocols were employed in both cities and 1120 (667 in Kingston and 453 in SF) interviews were conducted with 41 (11 in Kingston and 30 in SF) persons electing not to participate. One San Franciscan and seven Kingstonian questionnaires were disqualified due to participant ineligibility.

In constructing the final data set, the functional forms of "age at acquisition", "current age" and "length of ownership" were determined using fractional polynomials (Royston et al., 1999). To create the variable "Dog breed size" we used breed weights listed in dog breed standards (Hart and Hart, 1988; American Kennel Club., 1997). "I don't know" responses were considered missing data.

Outcome determination

Outcome categories were based on answers to the following questions: (1) "Not during play, in the last two years, did the dog ever hold onto or catch a part of any person's body with its teeth and cause a wound?", (2) "Not during play, in the last two years, did the dog ever hold onto or catch a part of any person's body or clothes with its teeth but not cause a wound?" and (3) "During play, in the last two years, did the dog ever hold onto or catch a part of any person's body with its teeth and cause a wound?" A dog was considered a non-play biter (hereafter a "biter") if the respondent said "yes" to either or both of questions 1 and 2 and a non-biter if the

respondent said “no” to all three questions. We were primarily concerned with factors motivating a dog to attack and bite and assumed that the factors under consideration would motivate the attack but not determine whether injury occurred. When possible, it was noted whether the victim was a family member and/or lived in the same home as the dog though no distinction was made in later multivariable analyses. Dogs that had bitten during play were excluded from analysis.

Statistical methods

We used directed acyclic graphs (DAGs) to create a causal diagram (Fig. 1) defining a hypothesized causal web for dog bites. This master DAG provided the basis for confounder selection (Greenland et al., 1999), and a necessary set of confounders was identified for each exposure of interest (Fig. 2 and Table 2). Relationships in the causal diagrams were determined by subject matter considerations inclusive of results of previous studies.

We used modified Poisson regression (Zou, 2004) to analyze the data in SAS/STAT. version 8.2. For each exposure of interest, variables included in the relevant DAG-based subset were used in analysis (Table 2). We employed the change-in-estimate procedure (Greenland, 1989) using forward selection to select confounders from each DAG-based subset with a ≥10% change in the estimated relative risk (RR) required for retention in the model. For each exposure of interest, we excluded all observations that had missing values for any of the variables in the DAG-based subset of potential confounders (Table 2). Differences in RR between cities were investigated by including an interaction term comprised of the exposure of interest and city in the model. The term was retained in the model if statistically significant at the 5% level. Otherwise

157 pooled RRs were calculated. Relative risks and their associated 95% confidence intervals (95%
158 CIs) were calculated using the "estimate" syntax in Proc Genmod (Table 2) (Spiegelman and
159 Hertzmark, 2005).
160
161 **Results**
162 *Study population characteristics*
163 Data for 161 biters and 951 non-biters were analysed. Of these, 660 (59%) were from
164 Kingston and 452 (41%) were from SF. Most respondents were female, though more so in SF
165 (61%) than in Kingston (54%) and 17% of SF respondents versus 23% in Kingston answered
166 jointly with another person. Respondents in Kingston were slightly older (53% >40 years) than
167 in SF (43% >40 years), but more frequently had a child aged 5-15 years living with them (35%
168 versus 12%). Twenty-one percent of Kingstonian dogs were born at home compared to 1% in SF
169 and more Kingston (99%) than SF (64%) dogs had yard space at their disposal. Overall 70%
170 (55% in Kingston versus 99% in SF) of dogs with yard space spent some portion of the day
171 inside the house (or apartment). In the SF sample, dogs born at home and dogs acquired for
172 protection and other reasons excluding companionship both had prevalences of approximately
173 1%.
174
175 The 2 year incidence of non-play bites was 12.5 (Kingston) and 17.4 (SF) per 100 dogs
176 and proportionately more SF (91%) than Kingstonian respondents (76%) witnessed the incident.
177 In Kingston, 34 (41%) bites broke the victim's skin compared to 26 (33%) in SF. Of the victims
178 for which we had relevant information, 57% (49% in Kingston versus 62% in SF) were family
179 members and /or lived in the same home as the dog. Overall thirty-six percent of victims were

family members and/or lived with the dog, while 27% were not. Most persons in this latter category were familiar with both dog and owner. The relationship of the remaining 37% of victims was not specified. In Kingston, 76% and 64% of the bites sustained by family and non-family members, respectively, were witnessed by the respondent. In SF these percentages were 95 and 87 respectively.

Dogs in Kingston were acquired at younger ages than in SF. The inter-quartile ranges (IQR) were 3-11 weeks and 8-12 weeks, respectively. Dogs in Kingston were also more recently acquired (IQR = 1 month - 1.5 years versus 4 months - 6.75 years) and younger (IQR = 10 weeks - 2 years versus 11 months - 7.5 years). Neuter status was markedly different between cities, with intact dogs accounting for 90% of Kingston and 22% of SF dogs.

Canine characteristics

Being born at the respondent's home was inversely associated with biting. Compared to spayed female dogs, all other categories of dogs had elevated risks for biting (Table 2). Intact males were 1.68 (95% CI 1.05-2.71) times as likely to bite as castrated males, but 0.80 (95% CI 0.55-1.14) times as likely to bite as intact females. Both Rottweilers and Labradors had lower risks of biting compared to German Shepherds with RR = 0.38 (95% CI 0.13-1.09) and 0.24 (95% CI 0.07-0.82), respectively. Shih Tzus had similar risks of biting to German Shepherds (Table 2). A sight or hearing problem in the dog was inversely associated with biting.

Environmental factors

The presence of children (5-15 years) in the home had a slight positive association with dog bites (Table 2), while having yard space was inversely associated with biting (RR = 0.86; 95% CI 0.57-1.30). Dogs that spent 1-6 h per day inside were no more likely to bite than those that were not allowed inside, but dogs that spent ≥7 h per day inside, were twice as likely to bite than those not allowed inside (Table 2). In Kingston, dogs that slept in a family member's bedroom were more than twice as likely to bite, while in SF they were no more likely to bite than those that did not.

As no chained dogs were biters in San Francisco it was impossible to estimate a San Francisco specific RR for biting. When the data from both cities were pooled chaining was weakly associated with biting and the pooled RR = 1.15 (95% CI 0.66-1.99) not substantially different from the Kingston specific RR =1.28 (95% CI 0.71-2.31). Compared to dogs that were not confined, dogs confined for 1-6 and 7-12 h per day had increased risks of biting, while those confined for 13-18 and 19-24 h per day had decreased risks of biting (though the estimates in the latter two categories were very imprecise) (Table 2). Leaving the owner's premises unaccompanied was strongly associated with biting in SF but not in Kingston.

Human-canine interactions

Dogs acquired or kept for reasons that included companionship but not protection were 1.66 (95% CI 1.02-2.70) times as likely to bite as those acquired or kept for reasons including protection but not companionship. Allowing a dog into the presence of strangers or visitors to the home was also associated with an increased risk of biting (RR = 1.77; 95% CI 1.03-3.04).

Not routinely removing (versus always removing) a dog/allowing it to retreat was associated with an elevated risk of biting both when it was fearful (RR = 2.21; 95% CI 1.14-4.28) and when it growled (RR = 1.30; 95% CI 0.90-1.90). These two categories of dogs also had elevated risks of biting compared to those for which the situation never occurred (Table 2).

Discussion

Epidemiologic studies on dog bites have differed in their sources of study populations. Various investigators have used geographic location (Gershman et al., 1994), place of occupation (Drobatz and Smith, 2003), registration status (Reisner et al., 2005) and, presence at a veterinary clinic (Guy et al., 2001c). Both reported (Gershman et al., 1994; Drobatz and Smith, 2003) and unreported (Guy et al., 2001c; Reisner et al., 2005) bites have been used as outcomes. This study differs from previous studies in including bites which did not break the skin and in excluding play bites. We reasoned that from a point of view of risk factors for biting, all dogs that attack and make contact with the teeth belong to the same source population. Play bites were excluded on the grounds that they were likely to be etiologically distinct from non-play bites. In using two questions in parallel to determine outcome status, we increased the sensitivity of detecting instances when a dog attempted to bite and made contact. The refusal rate of 3.7% is similar to that reported by Guy et al. (2001c) and confirms the effectiveness of using veterinary clients as a data source.

The inverse association between being born at home and dog bites is consistent with a previous report that dogs bred at home were under-represented among dogs showing dominance

aggression and social fears (Serpell, 1995). This association might be a manifestation of the effects of the origin of the dog and/or the age at which the dog was acquired. Some evidence for the effect of origin is provided by Serpell and Jagoe (1995) who report that among dogs found unowned and those acquired from pet shops or breeders there was a higher prevalence of dominance aggression when compared to dogs bred at home. In this data set approximately a quarter of all canine participants were 11 weeks or older when acquired and incidence of biting was higher with increased age at acquisition for dogs acquired at up to approximately 6 months of age and remained constant thereafter (L.L.McV. Messam, unpublished Ph.D thesis). Previously reported associations between sex-neuter status and dog bites are inconclusive, with stronger associations reported for males (Gershman et al., 1994; Drobatz and Smith, 2003; Reisner et al., 2005), females (Guy et al., 2001c), intact (Gershman et al., 1994; Guy et al., 2001c), and neutered dogs as well (Drobatz and Smith, 2003; Reisner et al., 2005). These conflicting results are not surprising because the relationship between sex and aggression varies with aggression type (Borchelt, 1996) and age. This study found intact dogs more likely to bite and that neuter status modifies the effect of sex. These results concur best with results from the only other study to estimate the effect of sex and neuter status while controlling for age (Guy et al., 2001c).

Both studies with reference series (Gershman et al., 1994) and those without (Beck et al., 1975; Szpakowski et al., 1989; Thompson, 1997; Ozanne-Smith et al., 2001; Mendez Gallart et al., 2002; Horisberger et al., 2004) have reported German Shepherds as having among the highest frequencies within samples of aggressive and biting dogs. While these results are consistent with those findings, to the best of our knowledge it has not been previously reported

that Shih Tzus have similar risks for biting as German Shepherds and higher risks than Rottweilers and Labradors. We speculate that the inverse association between a sight or hearing problem and dog bites is due to reduced interaction with humans. Owners, as a precaution might restrict the interactions of these dogs with humans, recognising that the dog's diminished vision and/or hearing might render it more uncertain and thus more likely to respond to human interaction with aggression.

Previous studies found more than one child (Gershman et al., 1994) and the presence of teenagers (Guy et al., 2001c) in the home to be positively associated with dog bites. Though not contradicting those findings, the association seen in this study was weak. An inverse association between bites and having yard space is consistent with the increased risk of biting among dogs allowed inside for more than 6 h daily compared to dogs not allowed inside. Though possibly consistent with a negative correlation between problem behaviour in dogs and the size of yard space at their disposal (Kobelt et al., 2003) there is no obvious explanation for the threshold effect at 6 h or why the RRs of biting are essentially equal for dogs inside for 7-12, 13-18 and 19-24 h per day. If this relationship is causal, it might indicate that >6 h per day inside is necessary to facilitate the development of certain human-canine interactions or dynamics which facilitate dog bites. A time dependent threshold effect would be consistent with territorial aggression being at the root of many of these incidents as the dog would need to be established in the area for it to then become territorial (Moyer, 1968). However we did not have information on the proportion of dog bite incidents occurring inside and/or in the context of territorial aggression.

Gershman et al. (1994) found that dogs that were chained versus not chained had increased odds of biting. After adjusting for age, our results show a slightly increased risk for biting though a negative association with chaining is also compatible with the data. This RR for chaining is heavily influenced by the data collected in Kingston as there were no chained biters in SF. Compared to dogs that are never confined, only for dogs locked up for 1-6 h daily did our results show both a substantially increased risk of biting and exclude with high probability, a protective role of confinement. Similarly, we found proportionately more biters among dogs chained from 1-6 h daily than for any other time periods. If aggression is indeed caused by poor socialization secondary to chaining or other confinement, as has been claimed (Lockwood, 1995), these results would indicate that only in the case of shorter daily periods of restraint or confinement do the aggression-promoting influences of restraint and/or confinement counteract their obviously beneficial effect on limiting dog bite opportunity.

Dogs that sleep in a family member's bedroom were at higher risk of biting only in Kingston, while dogs that are able to leave their owner's premises unaccompanied were at higher risks for biting only in SF. It is noteworthy that the owners of both categories of dogs are a minority (18% in Kingston and 3% in SF) and in these regards, display ownership characteristics atypical of their environments. These results are an indication that circumspection should be exercised in generalizing results from one cultural milieu to another.

That dogs kept for reasons including companionship but not protection were more likely to bite than those kept for reasons including protection but not companionship might seem surprising. Having a dog for reasons including protection but not companionship was positively

associated with restraint (chaining, locking up) and negatively associated with the dog being allowed inside the house and with it being allowed around visitors or strangers to the home (results not shown). It is likely, therefore, that the effect of reason for acquisition on a dog's likelihood of biting is a result of its effect on the frequency and nature of the dog's interactions with humans. This is given credence by a number of Kingstonian participants reporting that they restricted their dog's interaction with non-household members to enhance its capabilities as a watchdog. Less restriction may be proffered for why dogs allowed around visitors or strangers to the home had elevated risks of biting.

The higher risks of biting among dogs that are not removed, left alone or allowed to retreat from a situation after they growl or show fear can be reconciled with fear and growling being possible warning signs of impending aggression. Though we are unable to tell if the dog bites actually occurred within the context of such events, these results may indicate that dogs living in homes where they are not allowed to retreat after growling or showing fear were also likely to experience other circumstances in which their management or lack thereof induced them to bite.

Our estimates would be biased if potential canine participants were censored prior to study enrolment but consequent to dog bites or to exposures related to dog bites. From 2000 to 2006, nine of the 15 veterinarians employed at the Kingston clinics euthanized 6 dogs because of aggression to humans, while approximately 2% of the SF dog population are confiscated/relinquished yearly due to aggression to humans (SF Animal Care and Control: personal communication, 2006). We therefore suspect that bias due to censorship is negligible in

this study. Residual confounding of RR estimates is also possible due to absence of data on potentially confounding variables. If some exposures occurred consequent to dog bites, temporal bias could occur in which an apparent causal exposure-dog bite relationship may actually be a dog bite–exposure relationship. As information was garnered only by respondent recall we could not independently verify this. Also, if recall on the part of respondents was imprecise this could result in biased estimates due to misclassification of exposures. There are restrictions on the applicability of the results of this study to the general population of dog owners. Though the percentages of dogs taken to veterinarians is not known precisely for SF and Kingston, in the US approximately 84% of dog owners report taking their dog to the veterinarian within the previous year (The American Veterinary Medical Association., 2002). While no such information is available for Jamaica, this figure is likely to be similar to the 58% reported for New Providence, Bahamas (Fielding and Plumridge, 2005). It is likely therefore that the SF sample comprises a larger percentage of the dog owning population in SF than the Kingston sample in Kingston. For both cities some exposures had low prevalence and thus low statistical power may have mitigated against us detecting differences in city specific RRs. In these circumstances the pooled RR estimates were heavily influenced by the city with higher exposure prevalence (Table 2 superscripts e and f).

Nevertheless, this study contributes uniquely to the epidemiologic literature on dog bites: it explicitly states its analytic assumptions regarding the causal web of dog bites; it examines exposures not previously studied; it is the first dog bite study to quantify associations in terms of relative risks; and, the first to compare populations from different countries. This comparison of both cities has highlighted two issues worth considering. Firstly, important sample-based

differences between the distributions of human-canine environments between cities exist. The low prevalence of dogs born at home, dogs acquired for reasons which included protection but not companionship, dogs always kept outdoors, dogs chained on an average day (in SF) and dogs without yard space at their disposal (in Kingston), suggest that causal pathways of dog bites involving these environments might not be important in these cities. Secondly the differences between SF and Kingston specific relative risks observed for "sleeping in a family member's bedroom" and "being able to leave the yard unaccompanied" suggest that an environmental risk factor may have different effects in different countries.

Conclusions

This study suggests that dogs acquired for companionship, dogs allowed into the presence of strangers and visitors to the home, dogs with fewer restrictions placed on their daily freedom of movement, and possibly, interactions with humans, are at elevated risk for biting. This study also suggests that distinct differences exist between countries with regard to both the prevalence of certain human-canine environmental exposures and their effect on the risk of dog bites. For each cultural context, prevention strategies for dog bites would benefit from a consideration of which types of human-canine interaction or environmental factors frequently place dogs in situations in which they are more or less likely to respond by biting. Being modifiable, these factors are amenable to public health intervention in the form of public education.

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Table 1 Distribution of biting and non-biting dogs by exposure status and city of origin: Kingston (KGN), Jamaica and San Francisco (SF), USA

Exposure	Exposure categories	Non-play bites		Non-bites	
		KGN n (%)[1]	SF n (%)[1]	KGN n (%)[1]	SF n (%)[1]
	By characteristics of the respondents				
Respondent's age (years)	≤ 20	6 (7)	0 (0)	30 (5)	5 (1)
	21 – 30	19 (23)	13 (17)	100 (17)	94 (26)
	31 – 40	21 (26)	31 (40)	136 (24)	111 (30)
	41 – 50	19 (23)	14 (18)	113 (20)	79 (21)
	51 – 60	12 (15)	12 (15)	91 (16)	45 (12)
	61 – 70	3 (4)	7 (9)	70 (12)	26 (7)
	≥ 71	2 (2)	1 (1)	35 (6)	9 (2)
	Total: 1104	**82**	**78**	**575**	**369**
Respondent's gender	Male	32 (39)	28 (35)	270 (47)	150 (40)
	Female	50 (61)	51 (65)	308 (53)	223 (60)
	Total: 1110	**82**	**79**	**578**	**373**
Method of response	Alone	63 (77)	67 (85)	444 (77)	309 (83)
	Spouse/Companion helped	4 (5)	5 (6)	45 (8)	39 (11)
	Child helped	12 (15)	4 (5)	59 (10)	11 (3)
	Other individual helped	3 (4)	3 (4)	30 (5)	14 (4)
	Total: 1112	**82**	**79**	**578**	**373**
	By characteristics of the dog				
Dog's origin	Born at home	12 (15)	1 (1)	125 (22)	2 (<1)
	Acquired	70 (85)	78 (99)	452 (78)	371 (99)
	Total: 1112	**82**	**79**	**577**	**373**
Dog's sex and neuter status	Male (intact)	40 (49)	14 (18)	298 (52)	47 (13)
	Male (castrated)	4 (5)	33 (42)	19 (3)	150 (40)
	Female (intact)	34 (41)	11 (14)	221 (38)	29 (8)
	Female (spayed)	4 (5)	20 (26)	36 (6)	145 (39)
	Total: 1105	**82**	**78**	**574**	**371**
Breed	German Shepherd	9 (11)	2 (3)	29 (5)	2 (<1)
	Rottweiler	4 (5)	0 (0)	33 (6)	4 (1)
	Labrador	1 (1)	2 (3)	4 (1)	27 (7)
	Shih Tzu	9 (11)	2 (3)	24 (4)	7 (2)
	Other	59 (72)	73 (92)	488 (84)	333 (89)
	Total: 1112	**82**	**79**	**578**	**373**
Dog breed size (based on breed standard)	≥ 9.0 kg (20 lbs)	32 (39)	50 (63)	257 (44)	232 (62)
	< 9.0 kg (20 lbs)	35 (43)	23 (29)	110 (19)	119 (32)
	Unknown	15 (18)	6 (8)	211 (37)	22 (6)
	Total: 1112	**82**	**79**	**578**	**373**
Sight/hearing problems	Yes	2 (2)	2 (3)	18 (3)	34 (9)
	No	80 (98)	76 (97)	549 (97)	325 (91)

	Total: 1086	**82**	**78**	**567**	**359**

[1]Percentages don't add to 100 due to rounding error

Table 1 continued

Exposure	**Exposure categories**	**Non-play bites**		**Non-bites**	
		KGN n (%)[1]	**SF n (%)[1]**	**KGN n (%)[1]**	**SF n (%)[1]**
	By characteristics of the dog's living environment				
Children (5-15 years) in home	Yes	33 (40)	8 (10)	199 (34)	44 (12)
	No	49 (60)	71 (90)	379 (66)	329 (88)
	Total: 1112	**82**	**79**	**578**	**373**
Housing	Yard space	80 (98)	47 (60)	569 (99)	240 (64)
	No yard space	2 (2)	31 (40)	6 (1)	133 (36)
	Total: 1108	**82**	**78**	**575**	**373**
Dog in house (h/day)	19-24	34 (41)	56 (71)	114 (20)	271 (73)
	13-18	4 (5)	13 (17)	35 (6)	59 (16)
	7-12	6 (7)	9 (11)	26 (4)	29 (8)
	1- 6	11 (13)	0 (0)	132 (23)	10 (3)
	0	27 (33)	1 (1)	269 (47)	4 (1)
	Total: 1110	**82**	**79**	**576**	**373**
Sleep in family member's bedroom	Yes	34 (42)	61 (78)	84 (15)	273 (73)
	No	47 (58)	17 (22)	492 (85)	100 (27)
	Total: 1108	**81**	**78**	**576**	**373**
Dog chained (h/day)	19-24	1 (1)	0 (0)	20 (4)	0 (0)
	13-18	1 (1)	0 (0)	6 (1)	1 (<1)
	7-12	2 (2)	0 (0)	24 (4)	2 (<1)
	1- 6	9 (11)	0 (0)	19 (3)	7 (2)
	0	69 (84)	79 (100)	508 (88)	363 (97)
	Total: 1111	**82**	**79**	**577**	**373**
Dog locked up (h/day)	19-24	1 (1)	1 (1)	49 (8)	3 (<1)
	13-18	3 (4)	2 (3)	27 (5)	5 (1)
	7-12	9 (11)	9 (12)	64 (11)	47 (13)
	1- 6	5 (6)	7 (9)	27 (5)	19 (5)
	0	63 (78)	59 (76)	410 (71)	299 (80)
	Total: 1110	**81**	**78**	**577**	**373**
Can leave premises unaccompanied	Yes	16 (20)	8 (10)	95 (16)	4 (1)
	No	65 (80)	70 (90)	480 (84)	369 (99)
	Total: 1107	**81**	**78**	**575**	**373**

[1]Percentages don't add to 100 due to rounding error

Table 1 continued

Exposure	Exposure categories	Non-play bites		Non-bites	
		KGN n (%)[1]	SF n (%)[1]	KGN n (%)[1]	SF n (%)[1]
	By characteristics of human-canine interactions				
Major reason for getting dog	Included protection (no comp.)[a]	16 (20)	1 (1)	144 (25)	5 (1)
	Included comp. (no protection)[b]	38 (46)	56 (80)	194 (34)	260 (70)
	All other combinations	28 (34)	22 (28)	239 (41)	108 (29)
	Total: 1111	**82**	**79**	**577**	**373**
Allowed into presence of strangers	Yes	47 (62)	68 (88)	239 (48)	353 (95)
	No	15 (20)	3 (4)	206 (41)	12 (3)
	Sometimes	14 (18)	6 (8)	56 (11)	7 (2)
	Total: 1026	**76**	**77**	**501**	**372**
Dog removed/ allowed to retreat when fearful	Yes	7 (9)	8 (10)	67 (12)	49 (13)
	No	5 (6)	2 (3)	19 (3)	15 (4)
	Sometimes	0 (0)	5 (7)	1 (<1)	1 (<1)
	Situation never occurred	70 (85)	62 (80)	485 (85)	302 (82)
	Total: 1098	**82**	**77**	**572**	**367**
Dog removed/ allowed to retreat when growls	Yes	25 (31)	8 (10)	110 (20)	16 (4)
	No	34 (42)	21 (27)	97 (17)	40 (11)
	Sometimes	4 (5)	7 (9)	13 (2)	8 (2)
	Situation never occurred	18 (22)	41 (53)	345 (61)	308 (83)
	Total: 1095	**81**	**77**	**565**	**372**

[a]Acquired for protection or for protection and other reasons excluding companionship
[b]Acquired for companionship or for companionship and other reasons excluding protection
[1]Percentages don't add to 100 due to rounding error

Table 2 Adjusted relative risks (RR) for associations between selected variables and non-play bites, Kingston (KGN), Jamaica and San Francisco (SF), USA

Exposure	Exposure categories	RR	95% CI	Variables[a] causing change in RR	
				≥ 10%[b]	< 10%[c]
	By characteristics of the dog				
Dog's origin	Born at home	0.71[e]	0.41 - 1.25	A	B, C, D,
	Acquired	1			O
	Total: 1100[d]				
Dog's sex and neuter status	Male (intact)	2.56	1.51 - 4.34	A, F	B, C, D,
	Male (castrated)	1.52	0.94 - 2.46		E, L, M
	Female (intact)	3.22	1.86 - 5.59		N
	Female (spayed)	1			
	Total: 1026[d]				
Breed	German Shepherd	2.27	1.33 - 3.88	A	B, C, D,
	Rottweiler	0.86	0.33- 2.22		K, M, O
	Labrador	0.54	0.18 - 1.64		
	Shih Tzu	2.09	1.22 - 3.59		
	Other	1			
	Total: 1100[d]				
Sight/hearing problems	Yes	0.41	0.15 - 1.09	F	A, B, C
	No	1			D,
	Total: 1025[d]				

[a]Both sets of variables together comprise hypothesized necessary set of confounders in causal web. [b]Retained in final model (sufficient set). [c]Not retained in final model. [d]Total number of participants (1112) minus the number of participants with missing data for atleast one of the variables in the necessary set of confounders. [e]Pooled RR heavily influenced by Kingston estimate. A = Country, B = Respondent's age, C =Respondent's gender, D = Method of response, E = Age at acquisition, F = Current age, K = Children (5-15 years) living at home, L = Length of ownership, M = Major reason for getting dog, N = Dog's origin, O = Housing.

Table 2 continued

Exposure	Exposure categories	RR	95 % CI	Variables[a] causing change in RR ≥ 10%[b]	Variables[a] causing change in RR < 10%[c]
By characteristics of the dog's living environment					
Children (5-15 years) in home	Yes	1.13[g]	0.80 - 1.58	A	B, C, D
	No	1			
	Total: 1104[d]				
Housing	Yard space	0.86[f]	0.57 - 1.30	A	B, C, D
	No yard space	1			K
	Total: 1101[d]				
Dog in house (h/day)	19-24	1.97[e]	1.17 - 3.32	A, F, H	B, C, D
	13-18	1.90[e]	0.99 - 3.62	I	M, O
	7-12	2.18[e]	1.18 - 4.02		
	1- 6	1.00[e]	0.51 - 1.96		
	0	1			
	Total: 1044[d]				
Sleep in family member's bedroom	Yes (KGN)	2.54[h]	1.43 - 4.54	F, H, P	B, C, D,
	Yes (SF)	1.11	0.67 - 1.85		I, M,O
	No	1			
	Total: 1042[d]				
Dog chained/leashed (h/day)	1-24	1.15	0.66 - 1.99	F	A, B, C
	0	1			D, H, I,
	Total: 974[d]				M, U
Dog locked up (h/day)	19-24	0.44	0.07 - 2.76	F, U	A, B, C
	13-18	0.93	0.35 - 2.46		D, H, I,
	7-12	1.15	0.72 - 1.83		M
	1- 6	1.71	1.02 - 2.86		
	0	1			
	Total: 973[d]				
Can leave premises unaccompanied	Yes (KGN)	1.04	0.63 - 1.72	F	B, C, D
	Yes (SF)	3.40[i]	1.98 - 5.85		M, O, Q
	No	1			R
	Total: 1042[d]				

[a]Both sets of variables together comprise hypothesized necessary set of confounders in causal web. [b]Retained in final model. [c]Not retained in final model. [d]Total number of participants (1112) minus the number of participants with missing data for atleast one of the variables in the necessary set of confounders. [e]Pooled RR heavily influenced by Kingston estimate. [f]Pooled RR heavily influenced by SF estimate. [g]Effect measure is prevalence ratio. [h]Interaction with country (p = 0.02). [i]Interaction with country (p = 0.002). A = Country, B = Respondent's age, C = Respondent's gender, D = Method of response, F = Current age, H = Breed, I = Dog breed weight based on breed standards, K = Children (5 -15 years) living at home, M = Major reason for getting dog, O = Housing, P = Dog in house, Q = Dog chained, R = Dog locked up, U = Allowed in presence of strangers.

Table 2 continued

Exposure	Exposure categories	RR	95 % CI	Variables[a] causing change in RR ≥10%[b]	Variables[a] causing change in RR < 10%[c]
	By characteristics of human-dog interactions				
Major reason for getting dog	Included protection (no comp.)[g]	0.82[e]	0.49 - 1.38		A, B, C,
	Included comp.(no protection)[h]	1.36[e]	0.99 - 1.99		D, K, O,
	All other combinations	1			
	Total: 1100[d]				
Allowed into presence of strangers	Yes/Sometimes	1.77	1.03 - 3.04	F, H, I	A, B, C
	No	1			D, J, O, M
	Total: 948[d]				
Dog removed/ allowed to retreat when fearful	Yes	0.78	0.46 - 1.30	F	A, B, C,
	No/Sometimes	1.71	1.06 - 2.76		D, H, I, K,
	Situation never occurred	1			M, O, U
	Total: 961[d]				
Dog removed/ allowed to retreat when growls	Yes	2.97	1.95 - 4.52	F, G, U	A, B, C, D
	No/Sometimes	3.55	2.54 - 4.97		H, I, J, K,
	Situation never occurred	1			M, O, V
	Total: 892[d]				

[a]Both sets of variables together comprise hypothesized necessary set of confounders in causal web. [b]Retained in final model. [c]Not retained in final model. [d]Total number of participants (1112) minus the number of participants with missing data for atleast one of the variables in the necessary set of confounders. [e]Pooled RR heavily influenced by Kingston estimate. [g]Acquired for protection or for protection and other reasons excluding companionship. [h]Acquired for companionship or for companionship and other reasons excluding protection. A = Country, B = Respondent's age, C = Respondent's gender, D = Method of response, F = Current age, G = Dog's sex/neuter status, H = Breed, I = Dog breed weight based on breed standards, J = Sight or hearing problem, K = Children (5-15 years) in home, M = Major reason for getting dog, O = Housing, P = Dog in house, Q = Dog chained, R = Dog locked up, U = Allowed in presence of strangers, V = Dog removed/allowed to retreat when fearful.

Figure legends

Fig. 1.

Master directed acyclic graph (DAG) showing hypothesized causal web of dog bites. Bold lines represent causal relationships between exposures and non-play bites. Dotted lines represent causal relationships between exposures.

Fig. 2.

Directed acyclic graph (DAG) used to select a sufficient set of potential confounders for control of the effect of "Allowed around visitors/strangers" on dog bites (heavy arrows). Bold arrows show confounder (ovals) relationships. Dotted lines show relationships with variables on causal pathway (rectangles).

1

Figure 1

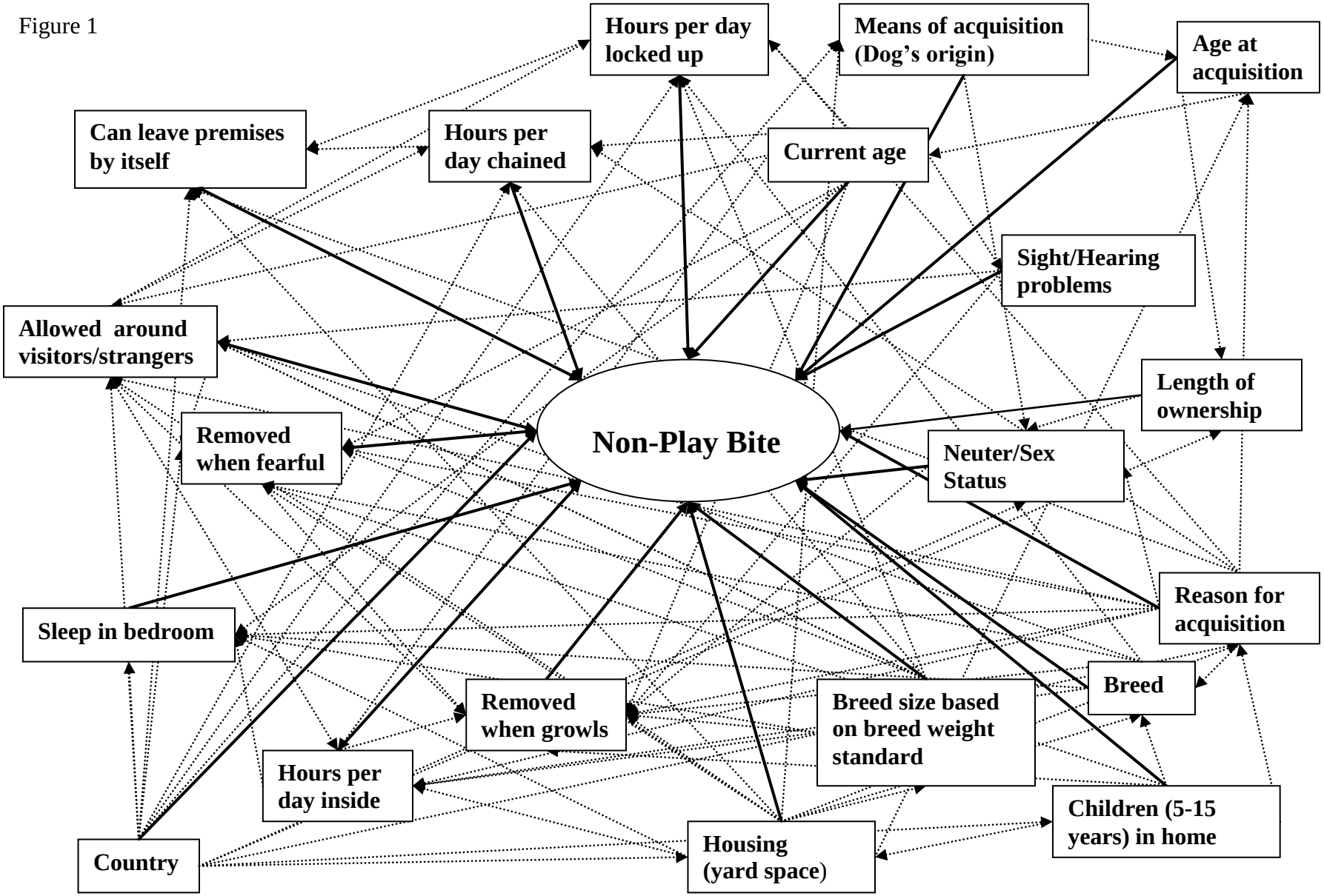
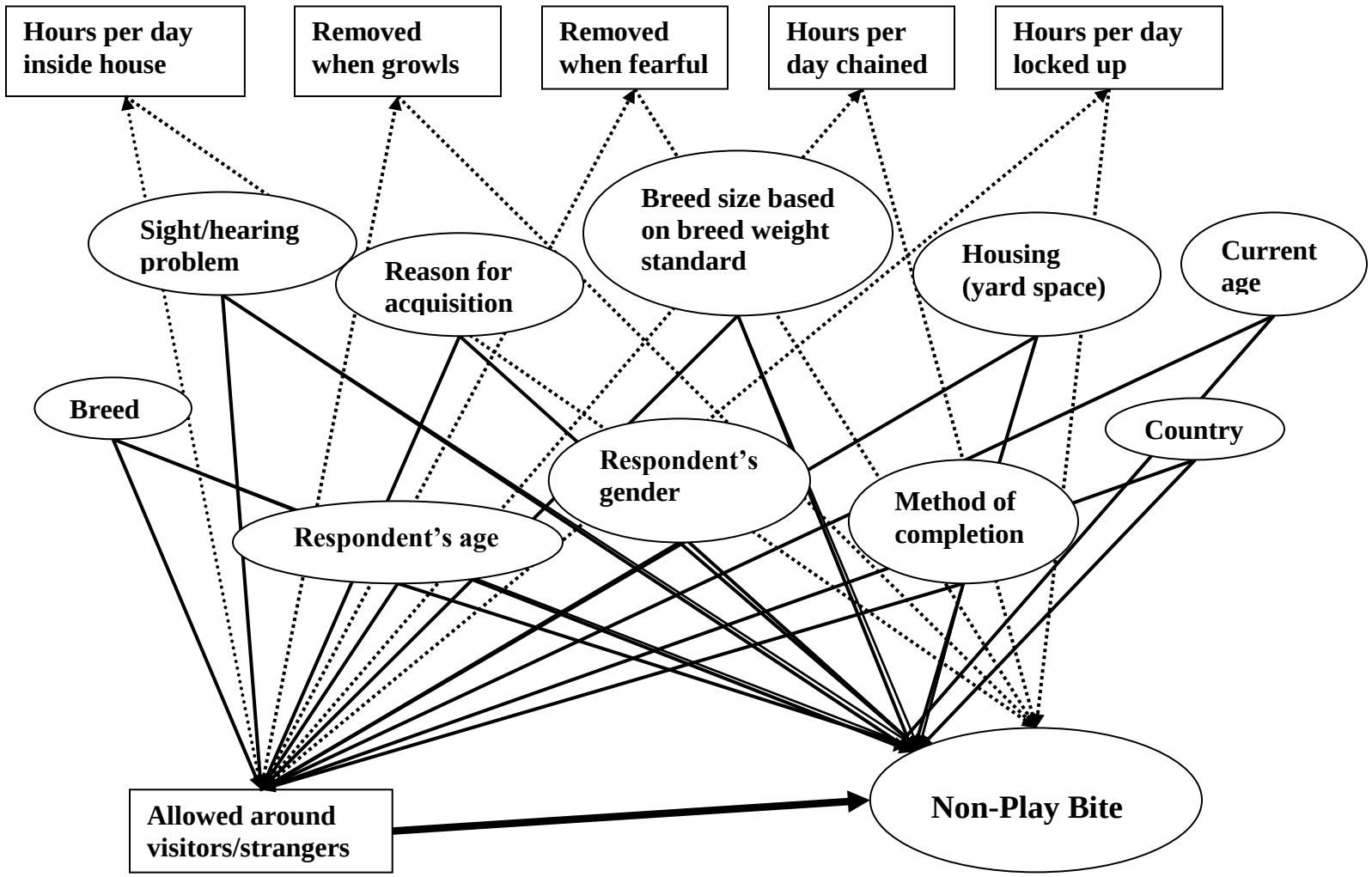

Hours per day locked up
Means of acquisition (Dog's origin)
Age at acquisition
Can leave premises by itself
Hours per day chained
Current age
Sight/Hearing problems
Allowed around visitors/strangers
Length of ownership
Removed when fearful
Non-Play Bite
Neuter/Sex Status
Reason for acquisition
Sleep in bedroom
Breed
Removed when growls
Breed size based on breed weight standard
Hours per day inside
Children (5-15 years) in home
Country
Housing (yard space)

Figure 2


Hours per day inside house
Removed when growls
Removed when fearful
Hours per day chained
Hours per day locked up
Sight/hearing problem
Reason for acquisition
Breed size based on breed weight standard
Housing (yard space)
Current age
Breed
Country
Respondent's gender
Method of completion
Respondent's age
Allowed around visitors/strangers
Non-Play Bite

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