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Factors associated with bites to a child from a dog living in the same home: A bi-national comparison

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Author contribution statement

LM conceived the study, collected and analysed the data and wrote the initial draft of manuscript. LM, PK, BC and LH contributed to the design of the questionnaire, the design of the study and to successive drafts of the manuscript.

Keywords

dog bite, risk factor, cohort study, Home, Child, anthrozoology, human-animal interaction

Abstract

Word count: 333

We conducted a veterinary clinic-based retrospective cohort study aimed at identifying child-, dog- and home-environment factors associated with dog bites to children aged five to fifteen years old who live in the same home as a dog in Kingston, Jamaica (236) and San Francisco, USA (61). Secondly we wished to compare these factors to risk factors for bites to the general public. Participant information was collected via interviewer-administered questionnaire using proxy respondents. Data were analysed using log-binomial regression to estimate relative risks and associated 95% confidence intervals (CIs) for each exposure-dog bite relationship. Using the correspondence between X% confidence intervals and X% Bayesian probability intervals obtained from a uniform prior distribution, for each exposure, we calculated probabilities of the true (population) RRs ≥ 1.25 or ≤ 0.8 , for positive or negative associations, respectively.

Boys and younger children were at higher risk for bites, than girls and older children, respectively. Dogs living in a home with no yard space were at an elevated risk (RR = 2.97; 95% CI: 1.06 - 8.33) of biting a child living in the same home compared to dogs that had yard space. Dogs routinely allowed inside for some portion of the day (RR = 3.00; 95% CI: 0.94 - 9.62) and dogs routinely allowed to sleep in a family member's bedroom (RR = 2.82; 95% CI: 1.17 - 6.81) were also more likely to bite a child living in the home than those that were not.

In San Francisco, but less so in Kingston, bite risk was inversely related to the number of children in the home. While in Kingston but not in San Francisco, smaller breeds and dogs obtained for companionship were at higher risk for biting than larger breeds and dogs obtained for protection, respectively.

Overall, for most exposures, the observed associations were consistent with population RRs of practical importance (i.e. RRs ≥ 1.25 or ≤ 0.8). Finally, we found substantial overlap between risk factors for child bites and previously reported risk factors for general bites.

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This study was authorised by the University of California Davis' Human Subjects Institutional Review Board and respondents provided verbal informed consent.

In review

1 Factors associated with bites to a child from a dog living in the same home: A bi-
2 national comparison

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20 Abstract

21 We conducted a veterinary clinic-based retrospective cohort study aimed at identifying
22 child-, dog- and home-environment factors associated with dog bites to children aged five to
23 fifteen years old who live in the same home as a dog in Kingston, Jamaica (236) and San
24 Francisco, USA (61). Secondly we wished to compare these factors to risk factors for bites to
25 the general public. Participant information was collected via interviewer-administered
26 questionnaire using proxy respondents. Data were analysed using log-binomial regression to
27 estimate relative risks and associated 95% confidence intervals (CIs) for each exposure-dog bite
28 relationship. Using the correspondence between X% confidence intervals and X% Bayesian
29 probability intervals obtained from a uniform prior distribution, for each exposure, we calculated
30 probabilities of the true (population) RRs ≥ 1.25 or ≤ 0.8 , for positive or negative associations,
31 respectively.

32 Boys and younger children were at higher risk for bites, than girls and older children,
33 respectively. Dogs living in a home with no yard space were at an elevated risk (RR = 2.97; 95%
34 CI: 1.06 – 8.33) of biting a child living in the same home compared to dogs that had yard space.
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36 dogs routinely allowed to sleep in a family member's bedroom (RR = 2.82; 95% CI: 1.17 – 6.81)
37 were also more likely to bite a child living in the home than those that were not.

38 In San Francisco, but less so in Kingston, bite risk was inversely related to the number of
39 children in the home. While in Kingston but not in San Francisco, smaller breeds and dogs
40 obtained for companionship were at higher risk for biting than larger breeds and dogs obtained
41 for protection, respectively.

42 Overall, for most exposures, the observed associations were consistent with population
43 RRs of practical importance (i.e. RRs ≥ 1.25 or ≤ 0.8). Finally, we found substantial overlap
44 between risk factors for child bites and previously reported risk factors for general bites.

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48 *Keywords*

49 Dog bite, child, home, risk factor, cohort study, anthrozoology, human-animal interaction

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61 **1.0 Introduction**

62 Children, particularly those younger than ten years old are generally considered to be at
63 highest risk for dog bites. The immediate consequences of such events include both physical and
64 mental trauma as well as infection by zoonotic agents (1-6). Studies have reported that children
65 are more likely to be bitten in the face, neck or head than adults, sometimes resulting in
66 permanent scars and/or loss of function to sensitive areas of the body (2, 4-6). Post-traumatic
67 stress disorder is also a potential sequel to a bite event, with some child-victims requiring
68 psychological treatment and displaying emotional distress for extended periods (3, 4, 7). Quite
69 likely because of their relatively small size, children are also overrepresented among persons
70 who are hospitalized or die consequent to a dog attack (2, 4-6, 8-11). A dog bite also threatens
71 the welfare of the offending animal as consequences often include removal from the home due to
72 relinquishment to a shelter (12).

73 Most dog bites to children occur at home by the family's own dog (6, 13-15). This is not
74 surprising given that the home is where both child and dog spend most of their day and,
75 consequently, the most likely place where children who have dogs would interact with one. It is
76 likely that characteristics of the home determine the types of contact occurring between child and
77 dog, and whether these lead to a bite. Factors such as the presence or otherwise of yard space, the
78 number of hours per day the dog is confined, leashed or allowed into the house, and where it
79 sleeps are all likely to affect the frequency and nature of daily child–dog contact. Additionally,
80 other human- and canine-environmental factors such as the presence of other children, other dogs
81 and the ages of child and dog might contribute to the frequency and quality of daily child-dog
82 interactions.

83 Given these observations, surprisingly little research has focused on the home
84 environment as a risk (or protective) factor for dog bite injuries, and no studies focusing on
85 factors associated with dog bites to children in the context of the family home were found in the
86 literature. From a prevention point of view, it is important to know to what extent home-
87 environment characteristics are associated with family-dog bites to the family-child.

88 Previously, we reported on a retrospective cohort study comparing risk factors for general
89 dog bites in Kingston, Jamaica and San Francisco, USA (16-18). We now report on an
90 investigation of a sub-cohort of 297 persons, from both cities, who resided in a household along
91 with a child and dog. The aims of this particular analysis were threefold: first, to quantify
92 associations between selected home-environment factors and the risk of a dog biting a child
93 living in the same home; second, to evaluate the practical importance of these associations in the
94 context of dog bites and third, to compare them to previously reported associations between
95 these factors and dog bites in general (hereafter referred to as “general bites”). In maintaining the
96 bi-national nature of the investigation, we also hoped to identify differences in risk (protective)
97 factor - dog bite associations attributable to city of origin.

98

99

100 2.0 Methods

101 2.1 Study protocol

102 This study was authorised by the University of California Davis’ Human Subjects
103 Institutional Review Board and respondents provided verbal informed consent. Most aspects of
104 the materials and methods are identical to those previously reported in detail (16-18). This report
105 focuses on information gathered from a subset of persons (hereafter referred to as the

106 respondents) who lived in a home with at least one child-dog pair (hereafter referred to as the
107 participants).

108 Study respondents were clients interviewed in the waiting rooms of eight veterinary clinics in
109 Kingston (KGN), Jamaica and three veterinary clinics in San Francisco (SF), USA using
110 identical questionnaires. Respondents were required:

- 111 a) To be 18 years or older,
- 112 b) To have a dog present with them in the waiting room with which they lived seven days a
113 week, and
- 114 c) To be living seven days a week in the same home as a child aged five to 15 years-of-age
115 for whom they were either a parent or guardian.

116 Whenever more than one dog was present, their names were ranked in alphabetical order and
117 the dog with the first-ranked name was chosen. Similarly, when more than one child aged five to
118 15 years-of-age lived in the same home as the respondent, the children's names were ranked
119 alphabetically and the child with the first-ranked name was chosen for participation. This was
120 done to reduce the possibility of selection bias resulting from preferential enrollment of either the
121 dog- or child-participant based on the perceptions of the respondent. We restricted the age
122 criterion to five to 15 years-of-age in order to render the child-participants' age range as narrow
123 as possible without limiting our ability to obtain a reasonably large sample. The presence of the
124 child in the clinic was not a requirement for participation. If a respondent was accompanied by
125 another person, that person was allowed to contribute to answering the interviewer's questions, if
126 the respondent wished. We chose to use proxy respondents rather than the index participants for
127 several reasons; first, we wished to ensure that data obtained for younger children were of
128 comparable quality to that obtained for older children. Second, study enrollment of minors (a

129 vulnerable population) necessitates additional study participant-related safeguards that would
130 have rendered data collection more time-consuming without any guaranteed increase in data
131 quality. Third, in lieu of the index participant, this was the most efficient way to ensure that
132 information was obtained from a person who could reliably report on both child and dog, as well
133 as on the home environment. This was particularly advantageous, given that a substantial
134 proportion of veterinary consultations occur while children are at school and unavailable.

135

136 2.2 Outcome determination

137 Dog bite categories were determined based on responses to the following questions:

- 138 a) During play, in the last two years, did the dog ever hold onto or catch a part of the child
139 in question's body with its teeth and cause a wound?
- 140 b) Not during play, in the last two years, did the dog ever hold onto or catch a part of the
141 child in question's body with its teeth and cause a wound?
- 142 c) Not during play, in the last two years did the dog ever hold onto or catch a part of the
143 child in question's body with its teeth and not cause a wound?

144 The outcome was considered a bite if the respondent replied in the affirmative to one or more
145 of a, b or c, and a non-biter if the respondent replied in the negative to all three questions. When
146 the respondent answered in the affirmative to more than one question, the event that occurred
147 earliest was chosen as the outcome. "During play" in this context referred to while the child was
148 playing; no assumptions were made regarding whether the dog was playing or not. We assumed
149 that respondents could accurately report on whether a child was playing with the dog but felt that
150 this was not necessarily the case for when the dog was playing. We based this view on reports
151 suggesting that owners often misread the body language of dogs (19, 20).

152 2.3 Exposure information

153 Exposure information included characteristics of the respondent (e.g., age and sex), the
154 five-15-year-old child (e.g., age, sex, presence of disabilities) living in the same household as the
155 dog, the child-dog interactions (e.g., whether the dog routinely avoided the child, frequency of
156 energetic play etc.), the dog (e.g., age, sex and neuter status), and the child-dog home
157 environment (e.g., number of children/dogs in home, presence of yard space, dog's habitual
158 sleeping location).

159

160 2.4 Analysis

161 Data for 297 participants were used for final analyses in SPSS version 24. This included 22
162 bite victims with 13 children bitten during, and 9 bitten outside of play with the dog. In a
163 previous report comparing bites occurring during and outside of play, we demonstrated that,
164 from a point of view of the exposures examined, the two types of bites were not etiologically
165 distinct (18). As the outcome and the majority of exposures used in this analysis were identical to
166 those used in that report, bites that occurred “during play” and bites that occurred “not during
167 play” were grouped together for analysis (hereafter referred to as “bites” or “child bites”)

168 First, a comprehensive directed acyclic graph (DAG) (21) was created incorporating all
169 exposures of interest and potential confounders for which information was available (Figure 1).
170 We then used Dagitty version 2.3 (22) to identify minimally sufficient sets of potential
171 confounders for each exposure of interest (Table 1 and example in Figure 2). In each sufficient
172 set, we included a variable indicating whether or not the respondent had answered alone, as this
173 was thought to be a confounder, i.e., a determinant in identifying a dog bite and also related to
174 the exposures under consideration (23). For constitutional characteristics such as age and gender

175 of the child and age, sex and breed of dog, there were no confounders. Log-binomial regression
176 was then employed to estimate the relative risks (RRs) and 95% confidence intervals (CIs) for
177 the association of each exposure of interest with dog bites (24). Using forward selection and the
178 change-in-estimate procedure (25), for each exposure of interest, we selected potential
179 confounders **one at a time** from **its respective** DAG-based set (Table 1) for inclusion in the
180 model. For retention in a model, addition of a potential confounder had to result in a change in
181 the RR estimates of at least 10% (26). All continuous variables were added to models as linear
182 terms, as initial analyses using fractional polynomials (27) confirmed that this form produced the
183 best model fit. In estimating the RR of child bites for a given exposure of interest, we excluded
184 all individuals who had missing values for any variables in its DAG-based subset of potential
185 confounders. This was necessary to ensure that changes in RR estimates did not result from
186 changes in numbers of missing observations, as potential confounders were added to or deleted
187 from the model (28). In order to test for differences in exposure-dog bite associations attributable
188 to city of origin, an interaction term consisting of the exposure **of interest** and city of origin was
189 included in each model. This was retained if the p-value was 0.1 or less and the differences **in**
190 **RR between cities** were **substantial**. Where there was no evidence of differences attributable to
191 city of origin, we estimated a pooled RR. **In order to test the assumption that risk factors for bites**
192 **occurring “during play” and bites occurring outside of play were etiologically similar, we re-fit**
193 **all final models, omitting data from participants bitten outside of play and compared the resulting**
194 **RRs to those from the models based on both types of bites. The RRs from both models were**
195 **similar in magnitude and direction and the limits of each 95% CI obtained from a model based**
196 **on both bites were completely nested within the corresponding model based solely on just bites**
197 **occurring “during play”. We therefore used the models with both types of bites for inferences.**

198 We used a magnitude-based approach to inferences as suggested by Braitman (29) and
199 Batterham and Hopkins (30). We selected thresholds of the RR which we felt would be of
200 practical importance in the context of dog bites to children in the home. RRs of magnitudes
201 consistent with a 25% or more increase in dog-bite incidence ($RR \geq 1.25$) and less than 0.8 (the
202 inverse of 1.25) were considered of practical importance. Thus we used the following
203 classifications:

- 204 a) $RR \geq 1.25$ - Substantial positive association (of practical importance)
- 205 b) $0.80 < RR < 1.25$ - Weak association (of no practical importance)
- 206 c) $RR \leq 0.80$ - Substantial negative association (of practical importance)

207
208 While $RRs \geq 1.25$ or ≤ 0.80 might not be considered practically important in every
209 context, we based our categorizations on the following reasoning:

- 210 1. The victim of the bite is a vulnerable individual, a minor.
- 211 2. The injury occurs in the domestic context, where the child should be safe from harm.
- 212 3. The perpetrator of the injury, the dog, is a part of the child's household.
- 213 4. The consequences of the injury negatively affect the welfare of the dog, in addition to the
214 wellbeing of the victim.

215 To derive our inferences,

- 216 a) First, we compared the magnitude of the estimated RRs, and the location and width of
217 each 95% CI to the RR threshold (Figure 3). Specifically, we qualitatively evaluated the
218 extent to which each 95% CI contained RR values which were or were not consistent
219 with RRs of practical importance.

220 b) Second, we used the results of our frequentist analysis to estimate the probability (Prob)
221 that, based on our data and vague prior information on the magnitude of the exposure-bite
222 relationships, the population RRs were at least 1.25 ($\text{Prob}(\text{RR} \geq 1.25)$) or no greater than
223 0.80 ($\text{Prob}(\text{RR} \leq 0.80)$), for positive and negative associations, respectively. To estimate
224 these probabilities, we used a MS Excel spreadsheet (Available at:
225 <http://www.sportsci.org/resource/stats/xcl.xls> (“3. Rate Ratio and other Log-Normally
226 Distributed Effect Statistics”)) (31). The spreadsheet makes use of the result that a
227 conventional X% confidence interval corresponds directly to a Bayesian X% probability
228 interval when the Bayesian analysis is conducted using the same likelihood function and
229 a uniform prior distribution (32-34). This direct congruence legitimises the use of
230 confidence intervals to generate probabilistic statements under assumptions of vague
231 prior knowledge (32, 33, 35).

232 c) Third for each exposure-dog bite relationship we qualitatively described the probability
233 of the population RR exceeding the specified value, applying a modification of the
234 scheme (Table 2) proposed by Hopkins (36). Thus for example, if $\text{Prob}(\text{RR} \geq 1.25) =$
235 78%, the positive association was deemed “likely of practical importance” and if
236 $\text{Prob}(0.80 < \text{RR} < 1.25) = 97\%$ the association was deemed very likely of no practical
237 importance (Table 2).

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243 3.0 Results

244

245 3.1 Demographic information

246 Data for 236 (79%) Kingstonian and 61 San Franciscan (21%) child-dog pairs were
247 analysed. Over the two-year period, the incidence of bite events was 9 and 11 per 100 dog-child
248 pairs in KGN and SF, respectively. Demographic information for both the respondents and
249 participants is displayed in Table 3. Slightly more than half of the respondents were female, with
250 approximately equal distributions in both cities (KGN: 55%, SF: 57%). San Franciscan
251 respondents were older than Kingstonian respondents (67% > 40 years versus (vs.) 42% > 40
252 years) and slightly fewer answered with the help of another person (34% vs. 38%, respectively).
253 Almost all Kingstonian (97%) and San Franciscan (90%) respondents answered by themselves or
254 jointly with another member of their household (Table 3). Among respondents reporting a bite,
255 this percentage was 100% in both jurisdictions (Table 3). Homes in KGN tended to have more
256 children below the age of 18 years than those in SF, with median (M) and inter-quartile ranges
257 ($Q_1 - Q_3$) of $M = 2$; $Q_1 - Q_3 = 1 - 3$ and $M = 2$; $Q_1 - Q_3 = 1 - 2$, respectively. Kingstonian child
258 participants were older ($M = 10.9$ years; $Q_1 - Q_3 = 7.9 - 12.8$ years) than their SF counterparts
259 ($M = 9.5$ years; $Q_1 - Q_3 = 7.4 - 13.0$ years). KGN homes also had more dogs than SF homes (M
260 $= 2$ dogs; $Q_1 - Q_3 = 1 - 4$ dogs vs. $M = 1$ dog; $Q_1 - Q_3 = 1 - 2$ dogs). Compared to those in SF,
261 dogs in KGN homes generally were acquired earlier (93% vs. 78% ≤ 6 months), were younger
262 (59% vs. 37% ≤ 6 months), and had been owned for slightly less time (35% vs. 34% ≤ 2
263 months). Additionally, fewer Kingstonian (46%; 95% CI: 39 – 52%) compared to San
264 Franciscan (70%; 95% CI: 59 - 82%) dogs were acquired for reasons that included
265 companionship but not protection.

266

267 3.1 Location and widths of 95% CIs with respect to the hypothesized population RR

268 RR estimates for most exposure-bite relationships were imprecise, though consistent with
269 population RRs ≥ 1.25 or ≤ 0.8 (Figure 3).

270

271

272 3.2 Characteristics of the child and child-dog interactions

273 Males were 1.59 times more likely (95% CI: 0.78 – 3.25) to be bitten than females with
274 $\text{Prob}(\text{RR} \geq 1.25) = 75\%$ (Figure 3(a), Table 4). The risk of being bitten was inversely related to
275 the child's age (RR = 0.64; 95% CI: 0.36 – 1.13 - for a 5 year increase in age) with $\text{Prob}(\text{RRs} \leq$
276 $0.8) = 78\%$. Dogs that were obtained for companionship and other reasons excepting protection
277 were 2.21 (95% CI: 0.50 – 9.84) times more likely to bite ($\text{Prob}(\text{RR} \geq 1.25) = 77\%$) than dogs
278 that were obtained for protection and other reasons excluding companionship. Dogs that
279 sometimes avoided the child were no more likely to have bitten that child than those that never
280 avoided the child (Figure 3(a), Table 4).

281

282

283 3.3 Characteristics of the dog

284 The age of the dog at acquisition was inversely related to a child being bitten (RR = 0.77:
285 95% CI: 0.44 – 1.37 - for a one-year increase). Conversely, dogs that were acquired (as opposed
286 to being born in the owner's home) were at higher risk (RR = 3.5: 95% CI: 0.49 – 24.98) for
287 biting than dogs that were not (Figure 3(b) and Table 4). Both one-year increases in dog age (RR
288 = 0.90: 95% CI: 0.76 – 1.05) and length of ownership (RR = 0.91: 95% CI: 0.77 – 1.07) showed

289 inverse associations with bites. Intact dogs were at overall higher risk for biting (RR = 2.74; 95%
290 CI: 0.71 – 10.55) than neutered (Figure 3(b) and Prob(RR ≥ 1.25) = 87%). This was also true
291 when males (RR = 2.25; 95% CI: 0.3 – 16.67) and females (RR = 2.37; 95% CI: 0.30 – 16.89)
292 were considered separately ((Figure 3(b) and Table 4) with Prob(RR ≥ 1.25) = 72 and 74%
293 respectively. In KGN, smaller breeds (< 9 kilograms or 20 pounds) were at higher risk for biting
294 (RR = 2.43; 95% CI: 1.16 – 5.10) than larger breeds (≥ 9 kilograms or 20 pounds), but not so in
295 SF (RR = 1.08; 95% CI: 0.26 – 4.41) (Figure 3(b)). The Prob(RR ≥ 1.25) for the KGN and SF
296 comparisons were 96% and 42%, respectively. No dog with a sight or hearing problem had bitten
297 a child in the preceding two years (Table 1).

298
299

300 3.4 Characteristics of the child-dog home environment

301 The risk of a child bite was inversely associated with the number of children in the home,
302 though more so in SF (RR = 0.37; 95% CI: 0.12 – 1.10) than in KGN (RR = 0.84; 95% CI: 0.63
303 – 1.14) (Figure 3 (c)). The Prob(RR ≤ 0.80) and Prob(0.80 < RR < 1.25) for the SF and KGN
304 comparisons were 91% and 62%, respectively. Similarly, bites were inversely associated with
305 the number of dogs present in the home (Figure 3(c), Table 4). Dogs that lived in a home with no
306 yard space were at elevated risk of biting (RR = 2.97; 95% CI: 1.06 – 8.33) compared to dogs
307 that had yard space (Figure 3 (c)). Dogs allowed inside for some portion of the day (1 - 24 hours)
308 were three times more likely to bite a child in the home (95% CI: 0.94 – 9.62) than those that
309 were not (Prob(RR ≥ 1.25) = 93%). Additionally, dogs that spent 13 - 24 hours a day inside
310 were approximately twice as likely to bite as those that spent 1 - 12 hours per day (Table 4). Both
311 these groups were at higher risk for biting than those that were not allowed inside (Table 4). Both

312 chaining and confining to a kennel, pen, crate or room for some portion of the day showed strong
313 associations with child bites ($\text{Prob}(\text{RR} \geq 1.25) > 99.9\%$) though the 95% CIs were wide (Table 4,
314 Figure 3 (c)). Finally, a dog being able to leave the premises unaccompanied was positively
315 associated with biting a child in the home (Figure 3 (c), Table 4).

316

317

318 **4.0 Discussion**

319 Studies of risk factors for dog bites are generally either dog- (16-18, 37-39) or victim-
320 focused (40-42). This study differs from most others in placing equal emphasis on victim (child)
321 - and dog-related factors contributing to a child bite. Additionally, as this study population is
322 nested within a larger cohort study on dog bites, it facilitates comparisons of these results to
323 previous findings on risk factors for general bites (16-18).

324 The associations with bites to children found for “lack of yard space”, “increased hours
325 spent by the dog inside” and “routinely sleeping in a family member’s bedroom” are likely
326 substantial and of practical importance ($\text{Prob}(\text{RR} \geq 1.25) \geq 90\%$). These associations are similar
327 to those found for bites in general (Table 5). A history of sleeping in a family member’s bed has
328 also previously been found to be associated with bites to owners (39). It is probable that these
329 effects are mediated through the frequency of child-dog interaction. If so, it seems paradoxical
330 that increased chaining or confinement are also associated with relative risks for biting the child
331 that are very likely of practical importance ($\text{Prob}(\text{RR} \geq 1.25) > 99.9\%$) (Figure 3 (c), Table 4).
332 One possible explanation is that while chaining and confinement might effectively restrict the
333 interaction of dogs with non-household members, the same is not necessarily true for its
334 interaction with a child that lives in the home. In fact, if not properly monitored, chaining and

335 confinement may just limit the dog's ability to retreat from the child if it wishes to, and thus
336 increase the risk of a bite incident. This could **potentially** explain the increased RRs compared to
337 the general cohort (16) (Table 5). It is also possible that some dogs might be routinely chained
338 or confined because they may have bitten the child previously. If so, this raises the possibility of
339 temporal bias (43). Comprehensively, while we do not know whether these bites actually
340 occurred within the context of such events (i.e. while being inside the house, sleeping in a family
341 member's bedroom, while being chained or confined etc.) these results may indicate that these
342 management factors are correlated with others that result in dog bites.

343 The finding that male children are more likely to be bitten than females is consistent with
344 previous reports (4, 5, 42). It has been suggested that gender-based differences in the nature of
345 human-dog interactions play an etiological role in differences in dog-bite frequency between
346 males and females (15). If true, this is likely to be relevant in the home environment as well.
347 **These results suggest that** this association is possibly of practical importance. The observed
348 inverse relationship between child-bite risk and child-age is likely due to a combination of
349 increased size, increased knowledge of dogs and less unpredictable behavior on the part of the
350 child (4, 15). The true (population) effect of five-year increases in child age is a **likely substantial**
351 **reduction** in dog bite risk ($\text{Prob}(\text{RRs} \leq 0.8) = 78\%$). Dogs obtained for reasons that included
352 companionship but not protection are **likely at substantially higher risk** for biting a child
353 ($\text{Prob}(\text{RR} > 1.25) = 77\%$) even after controlling for breed size. This is consistent with the results
354 for general bites in the larger cohort as evident from the similarity of the corresponding RR
355 estimates and overlap in the 95% CIs (Tables 4 and 5)(16). **While** these results might still be
356 **explained, in part,** by residual confounding by breed, parents may **also** be more watchful and/or
357 **restrictive of** children's interactions with a dog obtained for household protection. Data from

358 Kingstonian participants disproportionately influenced these results as no SF dogs were obtained
359 for reasons that included protection but not companionship (Table 3).

360 The inverse, though likely weak association ($\text{Prob}(0.80 < \text{RR} < 1.25) = 93\%$) between
361 dog age and bites to the family child is consistent with estimates from other studies (39, 41) but
362 different to our findings in the larger cohort (17). It is reasonable to expect a substantial positive
363 association between dog age and dog bites because of the relationship between age and the
364 development of canine aggressive behavior. As mentioned elsewhere (17), a weak observed dog
365 age-dog bite association could be attributable to age being used in this analysis in linear, as
366 opposed to in polynomial form as in the larger cohort (17). Similar results for length of
367 ownership (essentially the time the dog has lived in the home environment) can be explained by
368 its high correlation (Pearson's correlation coefficient = 0.91; 95% CI: 0.84 – 0.98) with dog age.
369 Higher risks for general bites observed for intact, compared to neutered dogs have been
370 previously observed in the larger cohort (Table 5) (16) and by other authors (37, 39). This
371 study's results suggest that the association between bites and neuter status is likely substantial
372 and of practical importance ($\text{Prob}(\text{RR} \geq 1.25) = 87\%$). The finding that acquired dogs were likely
373 at substantially higher risks for bites ($\text{Prob}(\text{RR} \geq 1.25) = 90\%$) than dogs born into their current
374 owner's home is also consistent with findings in the larger cohort (Table 5). Lower risks for dogs
375 born into their current owner's home could plausibly result from the positive socializing effects
376 of spending a longer time in the maternal environment and/or not experiencing the trauma of
377 changing home (44). A recent review, highlighting increased risks for biting by intact compared
378 to neutered dogs has suggested that mandatory neutering of dogs in addition to education might
379 reduce dog bite frequency (45). This would preclude the realization of any beneficial effects on
380 dog bite frequency by dogs being born into their owner's home in those jurisdictions in which it

381 is currently practiced. Additionally, based on recent data from the United States, early neutering
382 could have adverse effects on dog health especially for some large breeds (46, 47).

383 It is not clear why smaller breeds in KGN were likely at **substantially higher risk** for
384 biting but not in SF or why the association between the number of children in the home and bites
385 **was likely substantial** in SF but not KGN. However, these results suggest that there may be local
386 conditions acting to modify these relationships. Consistent with our findings in **KGN**, a study in
387 Canada **found that** smaller dogs were more likely to bite family members than larger dogs (39).
388 A contributing factor may be that smaller breeds in general tend to be more reactive with a
389 higher activity level than larger breeds (48). The **Canadian** researchers also found that bites were
390 positively associated with the number of teenagers in the home (39), contrary to our findings in
391 both **KGN** and SF.

392 393 **Limitations**

394 This study has a number of limitations. Small numbers of dog bite cases resulted in low
395 precision of our estimates for most exposures. In addition, this low number of outcomes as well
396 as the low prevalence of some exposures, **may have** mitigated against us detecting **other**
397 differences in city-specific RRs. Second, we did not have information on some potential
398 important confounders (for example, extent of training of dogs) which might have affected some
399 of our estimates (e.g., **time spent** in house, chaining and confinement). Third, our inferences are
400 based on an assumption that $RRs \geq 1.25$ and $RRs \leq 0.80$ are indicative of substantial population
401 associations. Different thresholds for associations of practical importance could plausibly be
402 used. Nevertheless we believe that this approach is helpful to the investigation of dog bites. **In**
403 **focus**ing inferences on the magnitude of the parameter of interest (the RR), **we** encourage readers

404 to ask and decide for themselves whether or not the observed effects are of practical importance.
405 In addition to being data-based, the probabilistic statements made are based on assumptions of
406 having little prior knowledge of the actual magnitude of the associations of these exposures with
407 dog bites. This is commensurate with information currently available on the topic.

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410 **Conclusions**

411 Notwithstanding limitations, this study suggests that the risk of a bite to the family-child
412 by the family's dog is associated with home-environment characteristics. These include factors
413 characteristic of the child, the dog and the child-dog environment. The study also suggests that
414 the relationships with dog bites, for most exposures examined, were of practical importance and
415 are consistent with population RRs of at least 1.25 and no greater than 0.8, for positive and
416 negative associations, respectively. Finally, these results suggest overlap between risk factors for
417 dog bites to children at home and risk factors for dog bites to the general population.

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425 Cruelty to Animals, the Avenues (SF).

426 **Conflict of interest**

427 The authors have no conflicts of interest to declare.

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430 **Author Contributions**

431 LM conceived the study, collected and analysed the data and wrote the initial draft of
432 manuscript. LM, PK, BC and LH contributed to the design of the questionnaire, the design of the
433 study and reviewed successive drafts of the manuscript for intellectual content.

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448 **Figure 1**
449 Master directed acyclic graph showing hypothesized causal web of dog bites. Solid lines
450 represent causal relationships between exposures and dog bites. Dotted lines represent causal
451 relationships between exposures.

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454 **Figure 2**
455 Directed acyclic graph used to select a minimally sufficient set of potential confounders for
456 control of the association of “Number of hours per day locked in kennel, crate or room” with dog
457 bites. Solid lines represent hypothesized causal relationships between exposures and dog bites.
458 Dotted lines represent hypothesized causal relationships between exposures. All shaded boxes
459 together form a sufficient set of variables for confounder control. All darkly shaded boxes
460 together form a minimally sufficient set of variables for confounder control.

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463 **Figure 3**

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465 **Location of** Relative Risk estimates and associated 95% confidence intervals for bites to a child
466 by a dog living in the same home **with respect to threshold values of RR = 0.8 and 1.25** by (a)
467 characteristics of the child and child - dog interactions, (b) characteristics of the dog and (c)
468 characteristics of the child–dog home environment.

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In review

588 **Tables**

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Table 1

Variables included in each hypothesized **minimally** sufficient set of confounders during the regression procedure analysing risk factors for bites to a child from the family dog.

Exposures	Hypothesized sufficient set of potential confounders
	<i>By characteristics of the child and child-dog interactions</i>
Child's gender	r3
Physical or mental disability	c1, r3
Major reason for getting dog	d7, r1, r2, r3
Dog avoids child?	c1, c3, c4, c5, c6, c7, d1, d3, d4, d5, d6, d7, d8, e1, e3, e4, e6, e7, r3
	<i>By characteristics of the dog</i>
Dog's origin	r3,r4
Dog's sex and neuter status	r3
Breed	r3
	<i>By characteristics of the child-dog home environment</i>
Number of dogs in home	e3, r3
Housing	
Dog in house?	d2, d3, d4, d5, d6, d7, d8, e2, e3, e6, r3, r4
Dog sleeps in family member's bedroom?	d3, d4, d6, d7, d8, r3, r4
Dog chained?	d2, d4, d5, d6, d7, d8, e2, e3, r3, r4
Dog locked in kennel, pen, crate or room?	d2, d4, d5, d6, d7, d8, e2, e3, r3, r4
Dog can leave premises unaccompanied?	d2, d4, d5, d6, d8, e2, e3, e4, e6, e7, r3, r4

r1 = Respondents Age, r2 = Respondents gender, r3 = Method of response, r4 = Reason for dog acquisition, c1 = Child's gender, c3 = Physical/Mental Disability? c4 = Frequency of energetic play with dog, c5 = Frequency of petting dog? c6 = Touch dog's food while eating, c7 = Touch dog while asleep, d1 = Dog's Origen, d2 = Dog's sex/neuter status, d3 = Dog's age at acquisition, d4 = Dog's current age, d5 = Length of ownership, d6 = Dog breed, d7 = Dog size, d8 = Dog sight/hearing problems, d9 = Dog sleeps in family member's bedroom, e2 = Number of dogs, e3 = Housing, e4 = Dog in house?, e6 = Dog chained? e7 = Dog Locked up?, e8 = Number of dogs in home, e9 = Dog avoids child?, e10 = dog can leave premises unaccompanied

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Table 2. Qualitative interpretations of the **probabilities** that the (true) population RR lies in **the given** ranges. Adapted with modification from Hopkins, 2002 (36)

Probability (%)	Practically important RR ≤ 0.8	Not practically important 0.80 < RR < 1.25	Practically important RR ≥ 1.25
< 1%		Almost certainly not	
> 1 - 25%		Very unlikely	
> 25 - 50%		Unlikely	
> 50 - 75%		Possibly	
> 75 - 95%		Likely	
> 95%		Very likely	

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In review

Table 3 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	Bites		Non-bites	
		KGN n (%) ^a	SF n (%) ^a	KGN n (%) ^a	SF n (%) ^a
<i>By characteristics of the respondents</i>					
Respondent's age (years)	≤ 20	1 (4)	1 (14)	4 (2)	0 (0)
	21 – 30	5 (23)	0 (0)	30 (14)	5 (9)
	31 – 40	10 (45)	3 (43)	85 (40)	11 (21)
	41 – 50	4 (18)	2 (29)	61 (29)	28 (53)
	51 – 60	2 (9)	1 (14)	18 (8)	7 (13)
	61 – 70	0 (0)	0 (0)	12 (6)	1 (2)
	≥ 71	0 (0)	0 (0)	2 (1)	1 (2)
	Total: 294	22	7	212	53
Respondent's gender	Male	6 (27)	2 (29)	101 (47)	25 (46)
	Female	16 (73)	5 (71)	113 (53)	29 (54)
	Total: 297	22	7	214	54
Method of response	Alone	13 (59)	2 (29)	133 (62)	38 (70)
	Spouse/Companion helped	2 (9)	0 (0)	18 (8)	4 (7)
	Child helped	7 (32)	5 (71)	55 (26)	9 (17)
	Other individual helped	0 (0)	0 (0)	8 (3)	3 (6)
	Total: 297	22	7	214	54
Major reason for getting dog	Included protection (no comp.) ^b	2 (9)	0 (0)	48 (22)	0 (0)
	Included comp.(no protection) ^c	14 (64)	5 (71)	94 (44)	38 (70)
	All other combinations	6 (27)	2 (29)	72 (34)	16 (30)
	Total: 297	22	7	214	54
<i>By characteristics of the child and child-dog interactions</i>					
Child's gender	Male	14 (36)	3 (43)	103 (48)	25 (46)
	Female	8 (64)	4 (57)	110 (52)	29 (54)
	Total: 296	22	7	213	54
Physical or mental disability	Yes	1 (4)	0 (0)	1 (<1)	4 (8)
	No	21 (96)	7 (100)	206 (99.5)	47 (92)
	Total: 297	22	7	214	54

^aPercentages don't add to 100 due to rounding error^bIncluded protection and other reasons (e.g. "love dogs", "to take care of dog" etc.) but not companionship^cIncluded companionship and other reasons (e.g. "love dogs", "to take care of dog" etc.) but not protection643
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Table 3 continued

Exposure	Exposure categories	Bites		Non-bites	
		KGN n (%) ^a	SF n (%) ^a	KGN n (%) ^a	SF n (%) ^a
<i>By characteristics of the dog</i>					
Dog's origin	Born at home	1 (4)	0 (0)	33 (15)	0 (0)
	Acquired	21 (86)	7 (100)	181 (85)	54 (100)
	Total: 297	22	7	214	54
Dog's sex and neuter status	Male (intact)	7 (32)	4 (57)	98 (46)	14 (26)
	Male (castrated)	1 (4)	0 (0)	5 (2)	19 (36)
	Female (intact)	14 (64)	2 (29)	105 (49)	7 (13)
	Female (spayed)	0 (0)	1 (14)	5 (2)	13 (24)
	Total: 295	22	7	213	53
Breed	Pure Bred	5 (23)	5 (71)	61 (29)	36 (67)
	Mixed	17 (77)	2 (29)	152 (71)	18 (33)
	Total: 296	22	7	213	54
Dog breed size (based on breed standard)^b	≥ 9.0 kg (20 lbs.)	7 (32)	4 (57)	106 (49)	32 (59)
	< 9.0 kg (20 lbs.)	11 (50)	3 (43)	42 (20)	22 (41)
	Unknown	4 (18)	0 (0)	66 (31)	0 (0)
	Total: 297	22	7	214	54
Sight/hearing problems	Yes	0 (0)	0 (0)	6 (3)	6 (12)
	No	22 (100)	7 (100)	205 (97)	44 (88)
	Total: 290	22	7	211	50
Avoid child	≥ 50% of the time	1 (5)	0 (0)	5 (2)	3 (6)
	< 50% of the time	2 (9)	2 (29)	22 (11)	9 (18)
	Never	19 (86)	5 (71)	182 (87)	38 (76)
	Total: 288	22	7	209	50

^aPercentages don't add to 100 due to rounding error^bBased on breed standards (48, 49)

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Table 3 continued

Exposure	Exposure categories	Non-play bites		Non-bites	
		KGN n (%) ^a	SF n (%) ^a	KGN n (%) ^a	SF n (%) ^a
<i>By characteristics of the child-dog home environment</i>					
Number of Dogs	1 dog	11 (50)	5 (71)	62 (30)	36 (68)
	>1 dog	11 (50)	2 (29)	148 (70)	17 (32)
	Total: 292	22	7	210	53
Housing	Yard space	21 (95)	5 (71)	211 (99)	47 (89)
	No yard space	1 (5)	2 (29)	2 (1)	6 (11)
	Total: 295	22	7	213	53
Dog in house (h/day)	19-24	10 (45)	7 (100)	42 (20)	29 (55)
	13-18	1 (5)	0 (0)	10 (5)	12 (23)
	7-12	0 (0)	0 (0)	12 (6)	6 (11)
	1 - 6	7 (32)	0 (0)	51 (24)	4 (7)
	0	4 (18)	0 (0)	99 (46)	2 (4)
	Total: 296	22	7	214	53
Dog sleeps in family member's bedroom?	Yes	8 (36)	6 (86)	26 (12)	27 (51)
	No	14 (64)	1 (14)	188 (88)	26 (49)
	Total: 296	22	7	214	53
Dog chained? (h/day)	19-24	0 (0)	0 (0)	6 (4)	0 (0)
	13-18	3 (14)	0 (0)	2 (1)	0 (0)
	7-12	0 (0)	0 (0)	12 (4)	0 (0)
	1- 6	17 (77)	1 (14)	11 (3)	1 (2)
	0	2 (9)	6 (86)	183 (88)	52 (98)
	Total: 296	22	7	214	53
Dog locked up? (h/day)	19-24	1 (4)	1 (14)	24 (11)	0 (0)
	13-18	1 (4)	0 (0)	7 (3)	2 (4)
	7-12	3 (14)	2 (29)	30 (14)	11 (21)
	1- 6	15 (68)	0 (0)	7 (3)	4 (7)
	0	2 (9)	4 (57)	146 (68)	36 (68)
	Total: 296	22	7	214	53
Dog can leave premises Unaccompanied?	Yes	9 (41)	1 (14)	34 (16)	2 (4)
	No	13 (59)	6 (86)	178 (84)	50 (96)
	Total: 293	22	7	212	52

^aPercentages don't add to 100 due to rounding error

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Table 4 Adjusted relative risks (RRs), 95% confidence intervals (CIs), confounders (C) causing $\geq 10\%$ change in RRs, and probabilities that population RRs (Prob(RR)) lie in the given range, for associations between selected variables and family dog-family child bite incidents, Kingston (KGN), Jamaica and San Francisco (SF), USA

Exposure	Exposure categories	RR	95% CI	C	Prob(RR) (%)		
					≤ 0.8	0.8 – 1.25	≥ 1.25
<i>By characteristics of the child and child-dog interactions</i>							
Child's gender	Males	1.59	0.78 - 3.25		3	22	75
	Females	1					
	Total: 296^a						
Physical or mental disability	Yes	1.67	0.27 - 10.32		22	16	62
	No	1					
	Total: 296^a						
Major reason for getting dog	Included protection (no comp.) ^b	0.55 ^d	0.12 – 2.57	d7	68	17	15
	Included comp.(no protection) ^c	1.22 ^d	0.54 – 2.78		15	37	48
	All other combinations	1					
	Total: 296^a						
Avoid child	Sometimes	1.02	0.61 – 1.70	d7, e7	17	61	22
	Never	1					
	Total: 214^a						
<i>By characteristics of the dog</i>							
Dog's origin	Acquired	3.5 ^d	0.49 – 24.98		7	8	85
	Born at home	1					
	Total: 296^a						
Dog's sex and neuter status	Male (intact)	1.71	0.23 – 12.52		23	15	62
	Male (castrated)	0.76	0.05 – 11.38		51	13	36
	Female (intact)	2.37	0.33 – 16.89		14	12	74
	Female (spayed)	1					
	Total: 296^a						
Breed	Pure Bred	1.08	0.52 – 2.23		21	44	35
	Mixed	1					
	Total: 295^a						

^aTotal number of participants (297) minus the number of participants with missing data for at least one of the variables in the necessary set of confounders.

^bIncluded protection and other reasons (e.g. "love dogs", "to take care of dog" etc.) but not companionship.

^cIncluded companionship and other reasons (e.g. "love dogs", "to take care of dog" etc.) but not protection.

^dRR heavily influenced by Kingston data.

d7 = Dog size, e7 = Dog Locked up?

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Table 4 continued

Exposure	Exposure categories	RR	95 % CI	C	Prob(RR) (%)		
					≤ 0.8	0.8 – 1.25	≥ 1.25
<i>By characteristics of the child-dog home environment</i>							
Number of dogs in home	More than one	0.52	0.26 – 1.06		88	11	1
	One	1					
	Total: 29^a						
Housing	No yard space	2.97	1.06 – 8.33		1	4	95
	Yard space	1					
	Total: 294^a						
Dog in house (h/day)	13-24	4.5	1.58 – 12.81	d2, d7	< 0.1	1	99
	1-12	2.26	0.69 – 7.45		4	12	84
	0	1					
	Total: 272^a						
Sleep in family member's bedroom?	Yes	2.82	1.17 – 6.81	d4, d7	< 0.5	3	97
	No	1					
	Total: 270^a						
Dog chained? (h/day)	1-24	15.65 ^b	6.77 – 36.28	e3	0	0	> 99.9
	0	1					
	Total: 266^a						
Dog locked in kennel pen, crate or room? (h/day)	1-24	11.73	6.26 – 21.99	e3	0	0	> 99.9
	0	1					
	Total: 266^a						
Can leave premises Unaccompanied?	Yes	1.88	1.10 -3.23	e7	0.1	6.8	93.1
	No	1					
	Total: 264^a						

^aTotal number of participants (297) less the number with missing data for at least one of the variables in the necessary set of confounders.

^bRR heavily influenced by Kingston estimate.

d2 = Dog's sex/neuter status, d4 = Dog's current age, d7 = Dog size, e3 = Housing, e7 = Dog Locked up?

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Table 5 Adjusted relative risks (RR) and 95% confidence intervals for associations between Selected variables and dog bites in general, Kingston (KGN), Jamaica and San Francisco (SF). Adapted from Messam, et. al. 2008 (16)

Exposure (Sample size)	Exposure categories	RR	95% CI
<i>By characteristics of the child and child-dog interactions</i>			
Major reason for getting dog (1100)	Included protection (no comp.) ^a	0.82 ^c	0.49 - 1.38
	Included comp.(no protection) ^b	1.36 ^c	0.99 - 1.99
	All other combinations	1	
<i>By characteristics of the dog</i>			
Dog's origin (1100)	Acquired	1.41	0.8 – 2.44
	Born at home	1	
Dog's sex and neuter status (1026)	Male (intact)	2.56	1.51 - 4.34
	Male (castrated)	1.52	0.94 - 2.46
	Female (intact)	3.22	1.86 - 5.59
	Female (spayed)	1	
<i>By characteristics of the child-dog home environment</i>			
Housing (1101)	No yard space	1.16 ^d	0.77 – 1.75
	Yard space	1	
Dog in house (h/day) (1044)	19-24	1.97 ^c	1.17 - 3.32
	13-18	1.90 ^c	0.99 - 3.62
	7-12	2.18 ^c	1.18 - 4.02
	1- 6	1.00 ^c	0.51 - 1.96
	0	1	
Sleep in family member's bedroom (1042)	Yes (KGN)	2.54 ^h	1.43 - 4.54
	Yes (SF)	1.11	0.67 - 1.85
	No	1	
Dog chained/leashed (h/day) (974)	1-24	1.15	0.66 - 1.99
	0	1	
Dog locked in kennel, pen crate or room (h/day) (973)	19-24	0.44	0.07 - 2.76
	13-18	0.93	0.35 - 2.46
	7-12	1.15	0.72 - 1.83
	1- 6	1.71	1.02 - 2.86
	0	1	
Can leave premises unaccompanied (1042)	Yes (KGN)	1.04	0.63 - 1.72
	Yes (SF)	3.40 ^e	1.98 - 5.85
	No	1	

^aAcquired for protection or for protection and other reasons excluding companionship.

^bAcquired for companionship or for companionship and other reasons excluding protection.

^cRR heavily influenced by KGN data.

^dRR heavily influenced by SF data.

^eInteraction with country (p = 0.002).

In review

Figure 3.JPEG

