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1 **Age-related changes in the propensity of dogs to bite**

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24 **Abstract**

25 This retrospective cohort study was aimed at describing the effects of age at
26 acquisition, age, and duration of ownership of dogs on the risk of (a) bites during play
27 and (b) non-play bites to humans. Data was collected on 110 dogs which bit during play
28 with a person, 161 dogs which bit outside of play and 951 non-biting dogs from
29 veterinary clients in Kingston (KGN), Jamaica and San Francisco (SF), USA. Modified
30 Poisson regression was employed to separately model the relationships of both types of
31 bites to each variable.

32
33 Effects of the variables on dog bite risk (a) during and (b) outside of play with the
34 dog, differed from each other and by type of bite. Effects varied with the dog's age and
35 associations were strongest in dogs younger than a year old. Ages at acquisition of dogs
36 at highest risk for bites during play were substantially lower than those at risk for non-
37 play bites. Ages and durations of ownership of dogs at highest risk for bites during play
38 were also lower than dogs at highest risk for non-play bites.

39
40 The propensity of a dog to bite changes as it ages, and relationships of dog bites
41 occurring during and outside of play to a dog's age at acquisition, current age, and
42 duration of ownership, differ from each other.

43 *Keywords:* Age; Play; Non-play; Dog; Bite

44

45 **Introduction**

46 Dog bites are a frequent [sequelae to](#) human-canine interactions (Overall and Love,
47 2001; The American Veterinary Medical Association, 2001). [This has led to much](#)
48 [interest in identifying human and canine](#) risk factors for [both](#) bites and aggression to
49 humans [in many parts of the world](#) (Cornelissen and Hopster, 2010; Feddersen-Petersen,
50 1994; Georges and Adesiyun, 2008; Gershman et al., 1994; Guy et al., 2001; Maragliano
51 et al., 2007; Messam et al., 2008; O'Sullivan et al., 2008; Rosado et al., 2009; Wake et al.,
52 2009). While age is accepted as a risk factor for canine aggression (Borchelt, 1996a, b;
53 Lockwood, 1995; Overall and Love, 2001), little is known about the age or ages at which
54 dogs are most likely to bite (Overall and Love, 2001). Similarly, while a few studies have
55 examined the association between the age of dogs at [their](#) acquisition and [subsequent](#)
56 aggression (Appleby et al., 2002; Hsu and Sun, 2010; Petersen and Deddens, 2006), there
57 is [still](#) need for an understanding of how [age at](#) acquisition is related to dog bites.

58

59 [Knowledge of how a dog's age at acquisition and current age are related](#) to its
60 aggressive behaviour [may](#) help veterinarians to properly contextualize for dog-owners,
61 human-directed [aggression in newly acquired dogs as well as aggression-related](#)
62 [behaviour](#) changes in dogs [as they age](#).

63

64 To investigate the relationships of dog age-related factors to the risk of dog bites,
65 a retrospective cohort study was conducted in Kingston (KGN), Jamaica and San
66 Francisco (SF), USA. [The premise of the investigation was that if the effects of age-](#)
67 [related factors on the risk of a dog biting were not constant over a dog's lifetime, then](#)

68 age-time periods corresponding to higher or lower dog bite risks should be identifiable
69 using analytic methods which permit data to define the shape of the age-time-dog bite
70 relationship. Thus, the goals were: First, to separately describe the relationships of age at
71 acquisition, dog age, and duration of ownership to the risks of bites occurring during and
72 outside of play with the dog; second, to identify ranges of these variables corresponding
73 to highest risks of dog bites; third, to identify ranges of these variables during which the
74 change in dog bite risk is greatest; and fourth, for each variable, compare its relationship
75 to the risk of bites occurring during play with the dog to its relationship to the risk of non-
76 play bites. Age, age at acquisition and duration of ownership are used as surrogate
77 measures for a) the cumulative effect of time-related social and biological changes
78 occurring in the dog since its birth, b) the effect of the timing of the most recent change
79 in the dog's ownership and living environment occurring during this process of change
80 and c) the cumulative effect of these changes in the dog since the most recent change in
81 its ownership and living environment, respectively.

82

83 The bi-national component provided an opportunity to investigate if the effects of
84 dog age-related factors on dog bite-risk differed between the two countries. Previous
85 research points to differences in cultural attitudes to dog rearing between the United
86 States and the Caribbean (Davis et al., 2007; Deddens and Petersen, 2008; Fielding and
87 Mather, 2001).

88

89

90

91 **Materials and methods**

92 *Study protocol*

93 This study constituted a part of a cohort study on dog bites approved by the
94 University of California Davis Institutional Review Board. Most aspects of the materials
95 and methods are identical to those previously described [in detail \(Messam et al., 2012;](#)
96 [Messam et al., 2008\)](#) [and thus only a brief description is provided here.](#)

97

98 *Study Participants*

99 Study participants were clients interviewed in the waiting rooms of eight
100 veterinary clinics in KGN and three veterinary clinics in SF from May 2003-January
101 2004. Clients were eligible to participate if they were at least 18 years old. [Additionally,](#)
102 [the dog in question had to be present at the time of the interview, owned for at least 24](#)
103 [hours and, living seven days a week in the same home as the client. Whenever more than](#)
104 [one dog was present, their names were ranked alphabetically and the first ranked chosen](#)
105 [for participation.](#)

106

107 *Outcome definition*

108 [Dog bite categories were determined using the following questions: a\) “During play, in](#)
109 [the last 2 years, did the dog ever hold onto or catch a part of any person’s body with its](#)
110 [teeth and cause a wound?”; b\) “Not during play, in the last 2 years, did the dog ever hold](#)
111 [onto or catch a part of any person’s body with its teeth and cause a wound?”; and c\) “Not](#)
112 [during play, in the last 2 years, did the dog ever hold onto or catch a part of any person’s](#)
113 [body or clothes with its teeth but not cause a wound?”](#) The outcome was considered a [bite](#)

114 during play if the respondent answered “yes” to (a) but “no” to both (b) and (c), a non-
115 play bite if the respondent answered “yes” to (b) and/or (c) but “no” to (a) and a non-bite
116 if the respondent answered “no” to all three questions. Bites occurring during play, were
117 restricted to those resulting in wounds to exclude cases of playful mouthing where a dog
118 might grasp a person’s body without applying sudden pressure (Messam et al., 2012).
119 “Bite during play,” instead of “play bite” is used whenever the victim was playing with
120 the dog at the time of the bite, as no distinction was made between when the dog was and
121 was not playing. For dogs owned for two years or more, it was assumed that the dog bites
122 occurred one year prior to the date of the interview. For dogs owned for less than two
123 years, it was assumed that the bite preceded the day of the interview by a time period
124 equal to half the duration of ownership.

125

126 *Exposures of interest*

127 The exposures of interest were the dog’s age at acquisition, the dog’s current age,
128 and the duration of ownership (Table 1), with each recorded both as categorical and
129 continuous variables. In the absence of exact dates of birth and acquisition, the following
130 decision rules were used: When an exact age or time period was given, that number was
131 used. When a range was provided, the midpoint of the range was used and when fractions
132 of weeks, months and years were given, the value was rounded to the nearest week,
133 month or year respectively. If a respondent could not provide one of the age or time
134 periods, the value was estimated using the values of the other two variables of interest if
135 possible. When no age or time period was obtained from the respondent the value was
136 omitted. Twenty-eight percent of the ages at acquisition and 18% of dog ages were

137 estimated respectively for continuous variable analysis. No estimation of age-time
138 variables was performed when these exposures were recorded as categorical variables.

139

140 *Statistical analysis*

141 For analyses, modified Poisson regression (Zou, 2004) in SAS version 8.2 was
142 used. Initially, each exposure of interest was used as a continuous variable to model
143 separately play and non-play bites with functional forms (of the exposures of interest)
144 determined using fractional polynomials (Royston et al., 1999). This was necessary to
145 allow the data, as opposed to the statistical model, to define the shape of each age (-time)
146 variable-dog bite relationship. Directed acyclic graphs (DAGs) (Greenland et al., 1999)
147 were used to choose a set of potential confounders of the relationships of age at
148 acquisition to bites occurring during and outside of play. This initial set included city of
149 residence, presence of yard space, source of the dog and reason for the dog's acquisition
150 (Table 2). A priori, no canine characteristics were believed to be confounders of the
151 relationships of current age or duration of ownership to either type of bites as both these
152 variables represent slightly different surrogates for aging in the dog. Since aging is an
153 inherent characteristic of the animal, its effect was not believed to be confounded by
154 other individual-level characteristics or variables. For model selection, the change-in-
155 estimate criterion (Greenland, 1989) was employed to select confounders from the DAG-
156 based subset with a $\geq 10\%$ change in the estimated RR required for a potential
157 confounder to be retained in the model. To detect differences in RRs attributable to city
158 of residence, an interaction term consisting of the exposure of interest and city was added
159 to each model and retained if the corresponding regression coefficient was statistically

160 significant ($P < 0.05$). If no statistically significant interaction was detected, pooled RRs
161 were calculated and city of residence retained in the final model if it caused a $\geq 10\%$
162 change in the estimated RR. Overall, from 110 biters during play, 161 non-play biters
163 and 951 non-biters, data for 1061 and 1112 dogs were used for bite during play and non-
164 play bite analyses respectively. Thus the same group of non-biting dogs was used for
165 both analyses.

166
167 Analyses, using data for the same dogs, were then repeated using age at
168 acquisition and current age as categorical variables to compare results with the
169 continuous variable analysis. Additionally, Spearman's rank correlation (r) between age
170 of dog and duration of ownership for both play and non-play biters was estimated.

171
172 Finally, a sensitivity analysis was performed in order to determine the robustness
173 of the choices of functional forms (Table 3) of the age-time variables by omitting the
174 observations with estimated exposure values and repeating the fractional polynomial
175 procedure.

176
177 From final models, RRs and 95% CIs for comparisons of interest (Tables 4 and 5)
178 were estimated using model-based variances and covariances (Table 3). From each of the
179 six final models, a range of dog bite risks corresponding to the range of its respective
180 exposure of interest was generated. In this way, age-time values corresponding to the
181 95th percentile of dog bite risks were obtained for each exposure of interest.

182

183 **Results**

184 Approximately 50% of KGN respondents compared to 60% of SF respondents
185 were 40 years or younger with most respondents in both countries female (Table 2).
186 Compared to in SF, dogs in KGN were acquired at a younger age (92% versus 77%
187 before 6 months of age), were younger (53% versus 19% less than 6 months old) and
188 owned for less time (46% versus 23% owned for less than 2 months) (Table 1). *The*
189 *relationships between the age-time variables and dog bites were non-linear with the*
190 *exception of the relationship of duration of ownership to bites during play (Fig. 1-3).*

191

192 *Age at acquisition*

193 *Dogs that bit while being played with* were acquired younger than non-play biters.
194 *Medians* and inter-quartile ranges (*M: IQRs*) were *M = 2 months: IQR = 6 weeks-3*
195 *months* and *M = 2.25 months: IQR = 6 weeks-5.75 months* respectively.

196

197 *Dogs acquired at 6 weeks of age were at higher risk for biting during play than*
198 *those* born into their current owner's home. *For dogs acquired between 6 weeks and*
199 *approximately 1 year of age, the risk of biting while being played with, decreased slightly*
200 *with increasing age at acquisition, but for dogs acquired older than 1 year of age, risks*
201 *were essentially the same (Fig. 1a). Correspondingly, while a dog acquired at 6 weeks*
202 *was 3.4 (95% CI: 1.3-8.9) times as likely to bite while being played with, than one born*
203 *into its owner's home, dogs acquired at 3 and 6 months were 2.6 (95% CI: 1.0-8.7) and*
204 *1.8 (95% CI: 0.7-4.9) times, respectively, as likely to bite during play than those born at*

205 their current home. Dogs acquired between 1 and 1.5 months of age had estimated risks
206 of biting during play, in the 95th percentile of the range of risks for bites during play .

207

208 The risk of non-play bites increased sharply with increasing age at acquisition for
209 dogs acquired younger than 6 months old and then was constant (Fig. 1a). Thus, for dogs
210 acquired older than 6 months of age, later ages at acquisition did not appreciably change
211 the RR of a non-play bite (Tables 4 and 5, Fig. 2b) when compared to dogs acquired at 6
212 months. Compared to dogs born at the respondent's home, dogs acquired at 2 months, 6
213 months and a year old were 1.6 (95% CI: 1.1-2.4), 1.8 (95% CI: 1.1-3.0) and 1.9 (95%
214 CI: 1.1-3.3) times as likely to bite outside of play, respectively. Dogs, aged 1.5 years or
215 older when acquired, had estimated risks of non-play bites, in the 95th percentile of the
216 range of non-play bite risks.

217

218 *Current age*

219 Dogs that bit during play, were younger than non-play biters with M: IQRs = 4
220 months: 10 weeks-1 year and 2.5 years: 11 months-6.5 years, respectively. The risk of
221 bites during play increased sharply until approximately 3 months of age, and declined
222 thereafter with increasing age (Fig. 1b). Thus, dogs that were 6, 12 and 24 months old,
223 were 0.7 (95% CI: 0.6-0.8), 0.4 (95% CI: 0.3-0.5) and 0.3 (95% CI: 0.2-0.4) times as
224 likely to bite during play as a 3 month old puppy, respectively. Two to 4-month-old dogs
225 had estimated risks of biting during play, in the 95th percentile of the range of risks for
226 bites during play.

227

228 Regarding non-play bites, the risk increased with age but at a diminishing rate
229 from 2 months to approximately 3 years, after which it declined gradually (Fig. 1b).
230 Correspondingly, while an 8-month-old dog was 3.8 (95% CI: 2.1-6.9) times as likely to
231 bite as a 2-month-old dog, a 1-year-old dog was 1.6 (95% CI: 1.3-1.9) times as likely to
232 bite as a 6-month-old dog. The most rapid increases in risk occurred in the age range 2-12
233 months (Figs. 1b and 2d) and 1-1.5 year-old dogs had essentially no difference in risks of
234 biting. Thus an 18-month-old dog was just 1.2 (95% CI: 1.1-1.3) times as likely to bite as
235 a 12-month-old dog (Table 4). Dogs that were 21-65 months old had estimated risks of
236 non-play bites, in the 95th percentile of the range of non-play bite risks.

237

238 *Age at acquisition vs. current age*

239 For dogs acquired before 4-6 months of age, the effect of increases in age at
240 acquisition on the magnitude of the risk of non-play bites was greater than the effect due
241 to an increase in the dog's age (Fig. 3). For dogs acquired after 6 months of age, this
242 tendency was reversed (Fig. 3).

243

244 *Duration of ownership*

245 Dogs that bit during play were owned for a shorter period before the bite took
246 place than non-play biters with M: IQRs = 2 months: 3 weeks-7 months and 21.5 months:
247 8 months-4.5 years respectively. Dogs owned for 3 months or less, had estimated risks of
248 biting during play, in the 95th percentile of the range of risks for bites during play.

249 The risk of non-play bites, as a function of duration of ownership, showed a
250 similar pattern to the risk of non-play bites as a function of current age. It was highest at

251 24-36 months and decreased gradually thereafter (Figs. 1b and 1c). There was evidence
252 of differences in the association of duration of ownership on non-play bites between the
253 two cities (Table 4 and Fig. 1c). After being owned for 6 months in SF, a further 6
254 months of ownership did not change the risk of biting. In KGN this was the case after
255 being owned for a year. In SF and KGN, dogs owned for 6-33 and 20-97 months,
256 respectively, had estimated risks of non-play bites, in the 95th percentile of the range of
257 non-play bite risk .

258

259 *Current age-Duration of ownership correlation*

260 There were high correlations between the current age and duration of ownership
261 of dogs that bit during play ($r = 0.88$; 95% CI: 0.81-0.95) and for dogs that were non-play
262 biters ($r = 0.89$; 95% CI: 0.82-0.95).

263

264 *Continuous vs. categorized exposures*

265 The sensitivity analysis confirmed the choices of functional forms of the
266 exposures of interest used for final models in the continuous-variable analysis (Table 3).
267 Results using the exposures of interest as categorical variables (Table 5) were similar to
268 the continuous-variable analysis. This is confirmed by the overlap in 95% CIs when the
269 RR estimates for the continuous-variable analyses are calculated at the midpoints of each
270 category used for the categorical-variable analyses (Fig. 4).

271

272

273

274 **Discussion**

275 In this study, age at acquisition, current age and duration of ownership have been
276 used as surrogates for unspecified socio-biologic factors believed to be associated with
277 dog bites. Thus, for instance, while canine age (which is the amount of time transpired
278 since the birth of a dog), cannot in itself be a causative or protective factor with respect to
279 dog bites, it is likely to be correlated with canine socio-biological changes which may be
280 causative or protective.

281 Most biters during play were acquired younger than 6 months old and bites
282 occurring during play with the dog occurred relatively soon after acquisition (75% within
283 6 months of ownership). If bites during play are likely to occur soon after acquisition, the
284 increase in bite risk observed for dogs acquired at 1.5-2 months of age compared to those
285 born at home might be attributable to more physical interaction between the owner and a
286 newly acquired puppy than between the owner and a puppy that he/she has seen develop
287 from birth. Additionally, an increased responsiveness of the 2 month old puppy, the
288 eruption of its teeth, its increased strength and tendency to playfully mouth are possible
289 reasons for increasing risks of biting while being played with during the first 1.5-2
290 months after birth. Progressive decreases in the risk of bites occurring during play for
291 dogs acquired older than 1.5-2 months of age and for dogs older than 3-4 months might
292 be a consequence of a decreasing tendency of older dogs to play or for their owners to
293 play with them, or both. This is consistent with dog age being inversely associated with
294 the frequency of owner-dog play (Rooney et al., 2000) as well as with a reported decline
295 in social play in canines after 6 -7 months (Feddersen-Petersen, 1991).

296

297 Dogs that never changed homes being at the lowest risk for non-play biting is
298 consistent with previous observations that dogs bred at home (Serpell, 1995) or which
299 remained longer (adopted at 60 days versus 30-40 days) with litter mates (Petersen and
300 Deddens, 2006) were under-represented among dogs with behaviour problems. It is also
301 consistent with a previous report which found that while there was an overall positive
302 association between being born outside in a kennel, garage or barn (as opposed to in the
303 residential part of the home) and stranger-directed aggression, there was no association
304 observed among that subset of the same dogs acquired before 8 weeks of age (Appleby et
305 al., 2002). Recently, somewhat contradictory findings have been reported: dogs acquired
306 as puppies (versus as adults) were at higher odds of showing stranger-directed aggression
307 (Hsu and Sun, 2010). However, the authors explain that persons might not adopt
308 aggressive adult dogs while at the same time being unable to recognize signs of future
309 aggressive tendencies in puppies.

310

311 This study suggests that the association between age at acquisition and the risk of
312 dog bites (both during and outside of play with the dog) primarily occurs over a limited
313 time window, i.e., during the first 6-12 months of a dog's life. This lends support to the
314 view that the timing of events in a dog's life is an important determinant of dog bites
315 (Lockwood, 1995; Stein et al., 1994; Wright, 1996) and that early experiences are more
316 important determinants of adult dog behaviour than later ones (Serpell, 1995). For
317 instance, it is possible that the trauma of changing both home and owner can have
318 negative consequences on a dog's development and behaviour, manifesting itself in an
319 increased risk of biting outside of play. It is logical that this could still contribute to

320 aggression in non-play biters even if human-directed aggression caused previous
321 relinquishment.

322

323 Previous studies assuming a constant effect of age on non-play bite risk have
324 reported odds ratios of 0.96 (95% CI: 0.89-1.03) (Guy et al., 2001) and 1.1 (95 % CI:
325 1.0-1.2) (Drobatz and Smith, 2003) for 1-year increases in age. When constant age effects
326 were assumed, in this study, a similar result (RR =1.1 (95% CI: 1.0-1.1)) was obtained.
327 This result suggests that for every 1-year increase in age, there is a 1.1 fold increase in
328 the risk of biting thus implying that the risk of dog bites increases by a constant multiple
329 throughout the lifetime of the dog. These results differ from, and are less plausible, than
330 the results obtained using fractional polynomials (Tables 4 and 5, Fig. 2b), which suggest
331 that the relationship between age and risk of dog bites varies with the dog's
332 developmental stage.

333

334 The rapid increase in non-play bite risk observed in the first year of the dog's life
335 corresponds to the period of most rapid sensory, motor and social development (Estep,
336 1996). Further increases in non-play bite risk up to approximately 3 years of age, with
337 little change for 2-6 year-old dogs (Fig. 1c), are consistent with the appearance, within
338 the first three years of age, of various types of canine aggression towards humans, as
339 noted by others (Borchelt, 1996b; Luescher and Reisner, 2008).

340

341 Comparisons between the effects of age at acquisition and age at time of bite
342 suggest that effects of re-homing are more important than correlates of age in

343 determining non-play bites for younger dogs. However, as the dog matures, correlates of
344 age become more determinant in whether a dog reacts by biting in a given situation (Fig.
345 3).

346 The high positive correlation between duration of ownership and age for both play
347 and non-play biters explains the similarity in their relationships to dog bite risk and
348 supports a belief that both are proxies for similar developmental processes taking place
349 within the dog. If so, then both duration of ownership and current age would be
350 associated with each type of bite through similar mechanisms even if these mechanisms
351 differ between non-play bites and bites occurring during play.. These results also suggest
352 that changes in non-play bite risk with increasing duration of ownership are greatest
353 during the first year (SF) to year and a half (KGN) of ownership. As no city-related
354 differences in RRs were detected for current age, the observed city-related differences for
355 duration of ownership may point to underlying qualitative differences in norms for
356 human-canine interactions between the two countries.

357

358 Some misclassification of the age-time exposures is possible. As most dogs were
359 unregistered, documented dates of birth and acquisition were not available and owner
360 recall remained the only practical source of age-time information. Thus, estimated values
361 of age-time variables based on information provided by owners are not likely to be exact.
362 While this misclassification of the exposures of interest may cause inaccurate RR
363 estimates, consistency between the results from the categorical- and continuous-variable
364 data analyses (Figs. 4a, 4b, 4c and 4d) provide some confidence that results obtained in
365 this study are not artefacts of the estimated values of the exposures of interest.

366 Nevertheless, greater importance is to be attached to the overall relationships that the
367 results describe as opposed to the precise numeric values of RR estimates. Additionally a
368 low prevalence of dogs born in their current home in SF (<1%) suggests that comparisons
369 involving dogs born at home were heavily influenced by KGN (28%) data and the
370 conclusions apply primarily to KGN dogs. Nevertheless these results may still be relevant
371 to other US localities, as one study based on US national estimates reported 26.5% of
372 newly acquired dogs born in the respondent's home (Rothman, 1986). Finally, breed-
373 related differences are also likely to exist between groups of dogs but this was not
374 investigated as it would require much larger breed-specific sample sizes.

375

376 **Conclusions**

377 Despite these limitations, this study suggests: that the associations of a dog's age
378 at acquisition, current age and duration of ownership with the risk of bites occurring
379 during and outside of play with the dog differ from each other; that these associations
380 vary during the life time of the dog in an age-dependent manner; that the association
381 between these age-time variables and dog bites is strongest in the first year of the dog's
382 life and; that dogs most likely to bite while being played with are younger than those
383 most likely to bite outside of play. Using fractional polynomials to model these age time
384 characteristics as continuous variables has been a valuable step in providing insight into
385 how their relationships with dog bites change over the lifetime of the dog. Pending
386 confirmation of these findings, it is hoped that veterinarians can use this information to
387 help owners develop realistic expectations regarding changes in their dogs' behaviour as
388 they age. This is important as incongruencies between dog-owner expectations and

389 canine aggressive behaviour sometimes culminate in relinquishment and/or euthanasia of
390 the dog (Hunthausen, 1997; Patronek et al., 1996).

391

392

393 **Conflict of interest statement**

394 None of the authors of this paper has a financial or personal relationship with
395 other people or organisations that could inappropriately influence or bias the content of
396 the paper.

397

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415 **References**

416

- 417 Appleby, D., Bradshaw, J., Casey, R., 2002. Relationship between aggressive and
418 avoidance behaviour by dogs and their experience in the first six months of life. *Vet*
419 *Rec.* 150, 434-438.
- 420 Borchelt, P.L., Voith V. L., 1996a. Aggressive behavior in dogs and cats. In: Voith, V.L.,
421 Borchelt P. L. (Ed.), *Readings in Companion Animal Behavior*. Veterinary Learning
422 Systems, Trenton, New Jersey, pp. 217-229.
- 423 Borchelt, P.L., Voith, V. L., 1996b. Dominance aggression in dogs. In: Borchelt,
424 V.L.V.a.P.L. (Ed.), *Readings in Companion Animal Behavior*. Veterinary Learning
425 Systems, Trenton, New Jersey, pp. 230-239.
- 426 Cornelissen, J.M., Hopster, H., 2010. Dog bites in The Netherlands: a study of victims,
427 injuries, circumstances and aggressors to support evaluation of breed specific
428 legislation. *Veterinary Journal* 186, 292-298.
- 429 Davis, B.W., Alie, K., Fielding, W.J., Morters, M., Galindo, F., 2007. Preliminary
430 observations on the characteristics of the owned dog population in Roseau, Dominica.
431 *Journal of Applied Animal Welfare Science* 10, 141-151.
- 432 Deddens, J.A., Petersen, M.R., 2008. Approaches for estimating prevalence ratios.
433 *Occupational and Environmental Medicine* 65, 481, 501-486.
- 434 Drobatz, K.J., Smith, G., 2003. Evaluation of risk factors for bite wounds inflicted on
435 caregivers by dogs and cats in a veterinary teaching hospital. *Journal of the American*
436 *Veterinary Medical Association* 223, 312-316.
- 437 Estep, D.Q., 1996. The ontogeny of behavior. In: Borchelt, V.L.V.a.P.L. (Ed.), *Readings*
438 *in Companion Animal Behavior*. Veterinary Learning Systems, Trenton, New Jersey,
439 pp. 19-31.
- 440 Feddersen-Petersen, D., 1991. *The ontogeny of social play and agonistic behaviour in*
441 *selected canid species. Bonner zoologische Beiträge* 42, 97-114.
- 442 Feddersen-Petersen, D., 1994. Social behavior of wolves and dogs. *Veterinary Quarterly*
443 16, 51-52.
- 444 Fielding, W.J., Mather, J., 2001. Dog ownership in the West Indies: A case study from
445 the Bahamas. *Anthrozoos* 14, 72-80.
- 446 Georges, K., Adesiyun, A., 2008. An investigation into the prevalence of dog bites to
447 primary school children in Trinidad. *BMC Public Health* 8, 85.
- 448 Gershman, K.A., Sacks, J.J., Wright, J.C., 1994. Which dogs bite? A case-control study
449 of risk factors. *Pediatrics* 93, 913-917.

- 450 Greenland, S., 1989. Modeling and variable selection in epidemiologic analysis.
451 American Journal of Public Health 79, 340-349.
- 452 Greenland, S., Pearl, J., Robins, J.M., 1999. Causal diagrams for epidemiologic research.
453 Epidemiology 10, 37-48.
- 454 Guy, N.C., Luescher, U.A., Dohoo, S.E., Spangler, E., Miller, J.B., Dohoo, I.R., Bate,
455 L.A., 2001. Risk factors for dog bites to owners in a general veterinary caseload.
456 Applied Animal Behaviour Science 74, 29-42.
- 457 Hsu, Y.Y., Sun, L.C., 2010. Factors associated with aggressive responses in pet dogs.
458 Applied Animal Behaviour Science 123, 108-123.
- 459 Hunthausen, W., 1997. Effects of aggressive behavior on canine welfare. Journal of the
460 American Veterinary Medical Association 210, 1134-1136.
- 461 Lockwood, R., 1995. The ethology and epidemiology of canine aggression. In: Serpell, J.
462 (Ed.), The Domestic Dog: Its Evolution, Behaviour and Interactions with People.
463 Cambridge University Press, Cambridge, pp. 131-138.
- 464 Luescher, A.U., Reisner, I.R., 2008. Canine aggression toward familiar people: A new
465 look at an old problem. Veterinary Clinics of North America: Small Animal Practice
466 38, 1107-1130.
- 467 Maragliano, L., Ciccone, G., Fantini, C., Petrangeli, C., Saporito, G., Di Traglia, M.,
468 Natoli, E., 2007. Biting dogs in Rome (Italy). International Journal of Pest
469 Management 53, 329-334.
- 470 Messam, L.L., Kass, P.H., Chomel, B.B., Hart, L.A., 2012. Risk factors for dog bites
471 occurring during and outside of play: are they different? Preventive Veterinary
472 Medicine 107, 110-120.
- 473 Messam, L.L.M., Kass, P.H., Chomel, B.B., Hart, L.A., 2008. The human-canine
474 environment: A risk factor for non-play bites? Veterinary Journal 177, 205-215.
- 475 O'Sullivan, E.N., Jones, B.R., O'Sullivan, K., Hanlon, A.J., 2008. Characteristics of 234
476 dog bite incidents in Ireland during 2004 and 2005. Veterinary Record 163, 37-42.
- 477 Overall, K.L., Love, M., 2001. Dog bites to humans - demography, epidemiology, injury,
478 and risk. Journal of the American Veterinary Medical Association 218, 1923-1934.
- 479 Patronek, G.J., Glickman, L.T., Beck, A.M., McCabe, G.P., Ecker, C., 1996. Risk factors
480 for relinquishment of dogs to an animal shelter. Journal of the American Veterinary
481 Medical Association 209, 572-581.
- 482 Petersen, M.R., Deddens, J.A., 2006. Re: "Easy SAS calculations for risk or prevalence
483 ratios and differences". American Journal of Epidemiology 163, 1158-1159; author
484 reply 1159-1161.

485 Rooney, N.J., Bradshaw, J.W.S., Robinson, I.H., 2000. A comparison of dog-dog and
486 dog-human play behaviour. *Applied Animal Behaviour Science* 66, 235-248.

487 Rosado, B., Garcia-Belenguer, S., Leon, M., Palacio, J., 2009. A comprehensive study of
488 dog bites in Spain, 1995-2004. *Veterinary Journal* 179, 383-391.

489 Rothman, K.J., 1986. *Modern Epidemiology*. Little, Brown, Boston.

490 Royston, P., Ambler, G., Sauerbrei, W., 1999. The use of fractional polynomials to model
491 continuous risk variables in epidemiology. *International Journal of Epidemiology* 28,
492 964-974.

493 Serpell, J., Jagoe, J. A., 1995. Early experience and the development of behaviour. In:
494 Serpell, J. (Ed.), *The Domestic Dog: Its Evolution, Behaviour and Interactions with*
495 *People*. Cambridge University Press, Cambridge, pp. 79-102.

496 Stein, D.J., Dodman, N.H., Borchelt, P., Hollander, E., 1994. Behavioral-Disorders in
497 Veterinary Practice - Relevance to Psychiatry. *Comprehensive Psychiatry* 35, 275-
498 285.

499 The American Veterinary Medical Association, 2001. A community approach to dog bite
500 prevention. *Journal of the American Veterinary Medical Association* 218, 1732-1749.

501 Wake, A.A.F., Minot, E.O., Stafford, K.J., Perry, P.E., 2009. A survey of adult victims of
502 dog bites in New Zealand. *New Zealand Veterinary Journal* 57, 364-369.

503 Wright, J.C., 1996. Canine aggression: Dog bites to people. In: Borchelt, V.L.V.a.P.L.
504 (Ed.), *Readings in Companion Animal Behavior*. Veterinary Learning Systems,
505 Trenton, New Jersey, pp. 240-246.

506 Zou, G., 2004. A modified Poisson regression approach to prospective studies with
507 binary data. *American Journal of Epidemiology* 159, 702-706.
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517 **Table 1**
518 **Distribution of biting and non-biting dogs by exposures of interest and city of origin:**
519 **Kingston (KGN), Jamaica and San Francisco (SF), USA**

Exposure	Exposure categories	Total	Bites during play		Non-play bites		Non-bites	
			KGN	SF	KGN	SF	KGN	SF
			<i>n (%)^a</i>	<i>n (%)^a</i>	<i>n (%)^a</i>	<i>n (%)^a</i>	<i>n (%)^a</i>	<i>n (%)^a</i>
Age at acquisition	Birth	149	5 (3)	0 (0)	12 (8)	1 (<1)	129 (87)	2 (1)
	≤ 2 months	481	35 (7)	28 (6)	38 (8)	22 (5)	242 (50)	116 (24)
	> 2 months - ≤ 6 months	317	8 (3)	21 (11)	19 (6)	27 (9)	111 (35)	131 (41)
	> 6 months - ≤ 1 year	84	0 (0)	4 (5)	4 (5)	9 (11)	24 (29)	43 (51)
	> 1 year - ≤ 2 years	48	0 (0)	2 (4)	1 (2)	8 (17)	10 (21)	27 (56)
	> 2 years - ≤ 5 years	43	0 (0)	3 (7)	0 (0)	5 (12)	7 (16)	28 (65)
	> 5 years	34	0 (0)	3 (9)	1 (3)	6 (18)	3 (9)	21 (62)
	Total:	1156 ^b	48	61	75	78	526	368
Current age	≤ 2 months	123	7 (6)	2 (2)	2 (3)	1 (<1)	106 (86)	5 (4)
	> 2 months - ≤ 6 months	326	28 (9)	30 (9)	9 (3)	4 (1)	200 (61)	55 (17)
	> 6 months - ≤ 1 year	145	9 (6)	7 (5)	15 (10)	9 (6)	65 (45)	40 (28)
	> 1 year - ≤ 2 years	153	3 (2)	8 (5)	15 (10)	16 (10)	58 (40)	53 (35)
	> 2 years - ≤ 5 years	184	1 (<1)	6 (3)	23 (12)	22 (12)	53 (29)	79 (43)
	> 5 years	233	0 (0)	8 (3)	13 (6)	26 (11)	52 (22)	134 (58)
Total:	1164 ^b	48	61	77	78	534	366	
Duration of ownership	≤ 2 months	425	27 (6)	29 (47)	10 (2)	8 (2)	273 (64)	78 (18)
	> 2 months - ≤ 6 months	183	13 (7)	12 (20)	8 (4)	8 (4)	97 (53)	45 (25)
	> 6 months - ≤ 1 year	139	4 (3)	8 (13)	16 (12)	18 (13)	48 (35)	45 (32)
	> 1 year - ≤ 2 years	95	3 (3)	2 (3)	7 (7)	7 (7)	42 (44)	34 (36)
	> 2 years - ≤ 5 years	154	1 (<1)	4 (7)	22 (14)	18 (12)	47 (31)	62 (40)
	> 5 years	193	0 (0)	6 (10)	13 (7)	20 (10)	48 (25)	106 (55)
Total:	1189 ^b	48	61	76	79	555	370	

^aRow percentages. Not all percentages sum to 100 due to rounding error

^bDifferences in totals reflect differences in number of responses to each question

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537 **Table 2**
538 **Distribution of biting and non-biting dogs by selected exposures and city of origin:**
539 **Kingston (KGN) Jamaica and San Francisco (SF), USA**

Exposure	Exposure categories	Total	Bites during play		Non-play bites ^a		Non-bites ^a	
			KGN	SF	KGN	SF	KGN	SF
			<i>n</i> (%) ^b	<i>n</i> (%) ^b	<i>n</i> (%) ^b	<i>n</i> (%) ^b	<i>n</i> (%) ^b	<i>n</i> (%) ^b
Respondent's age (years)	≤ 20	45	2 (4)	2 (4)	6 (13)	0 (0)	30 (67)	5 (11)
	21 – 30	254	14 (6)	14 (6)	19 (7)	13 (5)	100 (39)	94 (37)
	31 – 40	338	14 (4)	25 (7)	21 (6)	31 (9)	136 (40)	111 (33)
	41 – 50	244	8 (3)	11 (5)	19 (8)	14 (6)	113 (46)	79 (32)
	51 – 60	175	9 (5)	6 (3)	12 (7)	12 (7)	91 (52)	45 (26)
	61 – 70	108	2 (2)	0 (0)	3 (3)	7 (6)	70 (65)	26 (4)
	≥ 71	49	0 (0)	2 (4)	2 (4)	1 (2)	35 (71)	9 (18)
	Total:	1213 ^c	49	60	82	78	575	369
Respondent's gender	Male	533	18 (3)	35 (7)	32 (6)	28 (5)	270 (51)	150 (28)
	Female	689	31 (4)	26 (4)	50 (7)	51 (7)	308 (45)	223 (32)
	Total:	1222 ^c	49	61	82	79	578	373
Method of response	Alone	962	33 (3)	46 (5)	63 (7)	67 (7)	444 (46)	309 (32)
	Spouse/Companion helped	105	5 (5)	7 (7)	4 (4)	5 (5)	45 (43)	39 (39)
	Child helped	99	8 (8)	5 (5)	12 (12)	4 (4)	59 (59)	11 (11)
	Other individual helped	56	3 (5)	3 (5)	3 (5)	3 (5)	30 (54)	14 (25)
	Total:	1222 ^c	49	61	82	79	578	373
Dog's sex and neuter Status	Male (intact)	441	24 (5)	18 (4)	40 (9)	14 (3)	298 (68)	47 (11)
	Male (castrated)	222	1(<1)	15 (75)	4 (2)	33 (15)	19 (9)	150 (68)
	Female (intact)	336	23 (7)	18 (5)	34 (10)	11 (3)	221 (66)	29 (9)
	Female (spayed)	214	0 (0)	9 (4)	4 (2)	20 (9)	36 (17)	145 (68)
	Total:	1213 ^c	48	60	82	78	574	371
Housing	Yard space	1017	47 (5)	34 (3)	80 (8)	47 (5)	569 (56)	240 (24)
	No yard space	200	2 (1)	26 (13)	2 (1)	31 (16)	6 (3)	133 (67)
	Total:	1217 ^c	49	60	82	78	575	373
Reason for acquisition	Included protection ^d	173	6 (3)	1 (1)	16 (9)	1 (1)	144 (83)	5 (3)
	Included companionship ^e	623	31 (5)	44 (7)	38 (6)	56 (9)	194 (31)	260 (42)
	Included prot. and comp. ^f	75	5 (7)	1 (1)	7 (9)	1 (1)	56 (75)	5 (7)
	Love dogs	208	2 (1)	4 (2)	15 (7)	10 (5)	126 (61)	51 (25)
	Take care of dog	49	1 (2)	5 (10)	0 (0)	5 (10)	8 (16)	30 (61)
	Other ^g	93	4 (4)	6 (16)	6 (6)	6 (6)	49 (53)	22 (24)
	Total:	1221 ^c	49	61	82	79	577	373
Dog's origin	Born at home	144	4 (3)	0 (0)	12 (8)	1 (1)	125 (87)	2 (1)
	Gotten from someone	423	19 (4)	14 (3)	38 (9)	22 (5)	259 (61)	71 (17)
	SPCA or shelter	158	1 (1)	12 (8)	0 (0)	25 (16)	11 (7)	109 (69)
	Purchased	455	22 (5)	33 (7)	31 (7)	28 (6)	166 (36)	175 (38)
	Stray/Found	39	3 (8)	2 (5)	1 (3)	3 (8)	15 (38)	15 (38)
	Total:	1219 ^c	49	61	82	79	576	372

^a Messam et. al., 2008

^b Row percentages. Not all percentages sum to 100 due to rounding error.

^c Differences in totals reflect differences in the number of responses to each question

^d Acquired for protection or for protection and other reasons excluding companionship

^e Acquired for companionship or for companionship and other reasons excluding protection

^f Acquired for both protection and companionship

^g Acquired for reasons which did not include those listed above

540 **Table 3**
541 **Final modified Poisson regression equations modeling the natural log relative risk**
542 **(ln(RR)) of i) bites occurring during play with the dog and ii) non-play bites as**
543 **separate functions of a dog's a) age at acquisition (X₁), b) current age (X₂) and c)**
544 **duration of ownership (X₃)**

Exposure	Outcome	Regression equations ^a
Age at acquisition	Bites during play ^{b,c}	$\ln(\text{RR}) = -2.86 + 0.52(0.14)\left(\frac{X_1+1}{10}\right)^{-1} - 0.05(0.01)\left(\frac{X_1+1}{10}\right)^{-2} - 0.55(0.18)(C)$
	Non-play bites	$\ln(\text{RR}) = -0.99 - 0.07(0.03)\left(\frac{X_1+1}{10}\right)^{-1}$
Current age	Bites during play ^{c,d}	$\ln(\text{RR}) = -3.18 + 1.40(0.25)\left(\frac{X_2}{10}\right)^{-1} + 0.61(0.13)\left(\frac{X_2}{10}\right)^{-1} \ln\left(\frac{X_2}{10}\right) - 0.96(0.19)(C)$
	Non-play bites ^e	$\ln(\text{RR}) = -1.11 + 0.57(0.11)\ln\left(\frac{X_2}{10}\right) - 0.22(0.06)\left(\ln\left(\frac{X_2}{10}\right)\right)^2$
Duration of ownership	Bites during play ^c	$\ln(\text{RR}) = -1.47 - 0.22(0.06)\left(\frac{X_3}{10}\right) - 0.79(0.18)C$
	Non-play bites ^{c,f,g}	$\ln(\text{RR}) = -0.76 - 0.17(0.20)C + 0.07(0.07)\ln\left(\frac{X_3}{10}\right) - 0.10(0.04)\left(\ln\left(\frac{X_3}{10}\right)\right)^2 + 0.30(0.10)\ln\left(\frac{X_3}{10}\right) \times (C) - 0.02(0.06)\left(\ln\left(\frac{X_3}{10}\right)\right)^2 \times (C)$

^a Equations are of the form $\ln(\text{RR}) = \beta_1 + \beta_2 A_2 + \dots + \beta_n A_n$ where $\beta_n = n^{\text{th}}$ regression coefficient in the equation (from left to right), $A_n =$ variable in the equation, standard errors of regression coefficients are in parentheses and $\text{cov}(\beta_i, \beta_j) =$ covariance of the i^{th} and j^{th} parameters in the regression equation.

^b $\text{cov}(\beta_2, \beta_3) = -0.002$

^c $C =$ City (Kingston = 1, San Francisco = 0)

^d $\text{cov}(\beta_2, \beta_3) = -0.032$,

^e $\text{cov}(\beta_2, \beta_3) = -0.006$

^f $\text{cov}(\beta_3, \beta_4) = -0.0006$, $\text{cov}(\beta_3, \beta_5) = -0.005$, $\text{cov}(\beta_3, \beta_6) = -0.0006$, $\text{cov}(\beta_4, \beta_5) = -0.0006$,

$\text{cov}(\beta_4, \beta_6) = -0.002$, $\text{cov}(\beta_5, \beta_6) = -0.001$

^g Interaction with city (C). $P = 0.0047$ and $P = 0.76$ for first and second interaction terms respectively.

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Table 4
Adjusted relative risks (RRs) and 95% confidence intervals (CIs) for the associations between 6 month increases in a) age at acquisition, b) current age and c) duration of ownership and i) non-play bites and ii) bites occurring during play with the dog when the exposures are modeled as continuous variables: Kingston, JA and San Francisco, USA

Exposure	Months	Non-play bites		Bites during play	
		RR	95 % CI	RR	95 % CI
Age at acquisition ^{a,b}	6 vs. 0	1.8	1.1-3.0	1.8	0.7-4.9
	8 vs. 2	1.2	1.0-1.3	0.5	0.4-0.8
	12 vs. 6	1.0	1.0-1.1	0.8	0.7-0.9
	18 vs. 12	1.0	1.0-1.03	0.9	0.8-0.9
	24 vs. 18	1.0	1.0-1.02	0.9	0.9-1.0
			<i>n</i> = 1033 ^h		<i>n</i> = 989 ^h
Current age ^{c,d}	8 vs. 2	3.8	2.1-6.9	0.6	0.4-1.0
	12 vs. 6	1.6	1.3-1.9	0.6	0.5-0.7
	18 vs. 12	1.2	1.1-1.2	0.7	0.7-0.8
	24 vs. 18	1.1	1.0-1.1	0.8	0.8-0.9
	30 vs. 24	1.0	1.0-1.1	0.9	0.86-0.93
			<i>n</i> = 1029 ^h		<i>n</i> = 986 ^h
Duration (SF) ^e of ownership	8 vs. 2	1.4	1.2-1.7	0.9 ^{f,g}	0.8-0.9
	12 vs. 6	1.1	1.0-1.2	0.9 ^{f,g}	0.8-0.9
	18 vs. 12	1.0	0.9-1.1	0.9 ^{f,g}	0.8-0.9
	24 vs. 18	1.0	0.9-1.0	0.9 ^{f,g}	0.8-0.9
(KGN) ^e	8 vs. 2	2.3	1.2-4.2		
	12 vs. 6	1.3	1.1-1.7		
	18 vs. 12	1.1	1.0-1.3		
	24 vs. 18	1.0	0.9-1.2		
			<i>n</i> = 1029 ^h		<i>n</i> = 986 ^h

^a Unadjusted age at acquisition–non-play bite association. No variable caused ≥ 10% change in RRs
^b Age at acquisition–bites during play association adjusted for city
^c Unadjusted current age–non-play bite association. No variable caused ≥ 10% change in RRs
^d Current age–bites during play association adjusted for city
^e Duration of ownership–non-play bite association: interaction with city
^f Duration of ownership–bites during play association (linear model): RR for each additional 6 months of ownership
^g Duration of ownership–bites during play association adjusted for city
^h Differences in totals reflect missing data for each exposure of interest

553 **Table 5**
 554 **Adjusted relative risks (RRs) and 95% confidence intervals (CIs) for the**
 555 **associations between age at acquisition and non-play bites, age at acquisition and**
 556 **bites occurring during play with the dog, current age and non-play bites and**
 557 **current age and bites occurring during play with the dog, when the exposures are**
 558 **modeled as categorical variables: Kingston, JA and San Francisco, USA**

Exposure	Non-Play Bites		Bites during play	
	RR	95% CI	RR	95% CI
Age at acquisition ^{a,b}	Birth	1	1	
	> 0 months - ≤ 2 months	1.4	3.6	1.4-9.4
	> 2 months - < 6 months	1.5	2.5	1.0-6.8
	≥ 6 months - < 2 years	1.5	1.0	0.3-3.4
	≥ 2 years - < 5 years	1.4	1.2	0.3-5.2
	> 5 years	1.8	2.1	0.6-7.2
		<i>n</i> = 1032 ^e		<i>n</i> = 989 ^e
Current age ^{c,d}	≤ 2 months	1	1	
	> 2 months - < 6 months	1.0	1.9	0.7-4.9
	≥ 6 months - < 2 years	3.6	1.3	0.5-3.5
	≥ 2 years - < 5 years	5.3	0.5	0.2-1.6
	> 5 years	4.6	0.3	0.1-0.9
		<i>n</i> = 1026 ^e		<i>n</i> = 984 ^e

^a Age at acquisition-non-play bite association adjusted for city .

^b Age at acquisition-bites during play association adjusted for city and reason for acquisition

^c Unadjusted current age-non-play bite association. No variable caused ≥ 10% change in RR

^d Current age-bites during play association adjusted for city

^e Differences in totals reflect missing data for each exposure of interest

559

560 **Figure legends**

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562 Fig. 1. Comparisons of the risk of non-play bites to bites during play with the dog plotted
563 as separate functions of a dog's (a) age at acquisition, (b) current age and (c), duration of
564 ownership.

565

566 Fig. 2. Plots of the relative risk (RR) of bites for 6 month increases in ages at acquisition
567 for the a) age at acquisition - bites during play, b) age at acquisition - non-play bites, and
568 for 6 month increases in current ages for the c) current age - bites during play and d)
569 current age - non-play bites associations assuming both linear and non-linear
570 (polynomial) relationships to dog bites. For example, in (a), The risk of biting while
571 being played with for a dog acquired at age 12 months would be 0.8 times its risk of
572 biting had it been acquired at age 6 months and (d), a 12 month old dog's risk of non-play
573 biting is 1.4 times a 6 month old dog's. Regardless of which age categories are
574 compared, RRs are constant when linearity is assumed (dashed lines).

575

576 Fig. 3. Plot comparing the effects of age at acquisition and current age on the risks of
577 non-play bites

578

579 Fig. 4. Plots of estimated relative risks (RR) and 95% confidence intervals from
580 categorical- and continuous-variable analyses for the a) age at acquisition - bites during
581 play, b) age at acquisition - non-play bites, c) current age - bites during play and d)
582 current age - non-play bites associations. RR estimates for the continuous variable

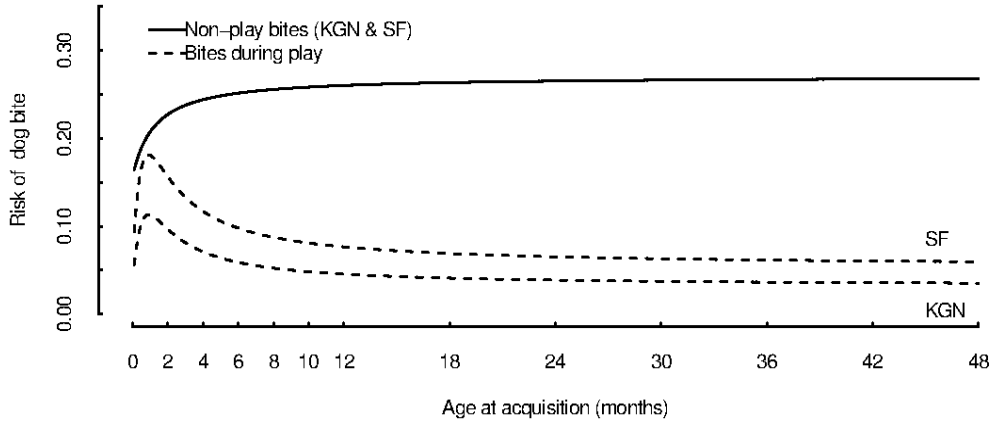
583 analysis are calculated at the midpoints of categories used for the categorical-variable
584 analyses. Straight lines used to connect point estimates from continuous-variable analyses
585 are used for comparison purposes only. In reality lines connecting these point estimates
586 are not straight.

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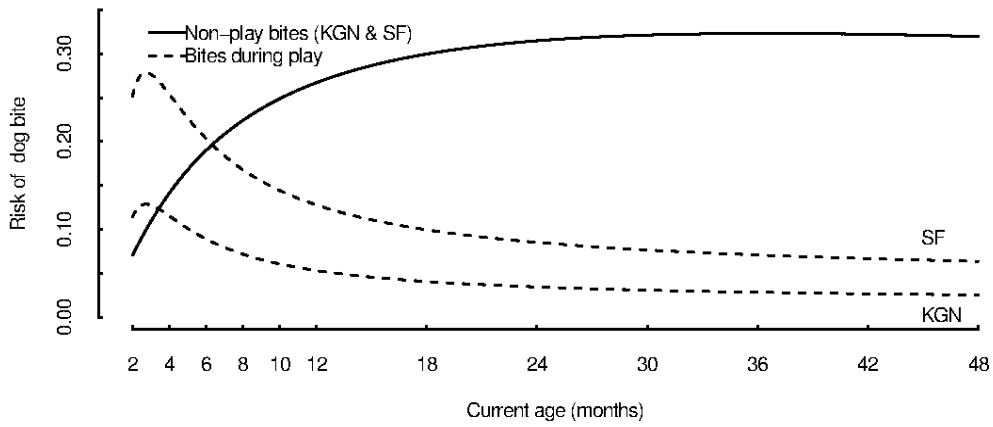
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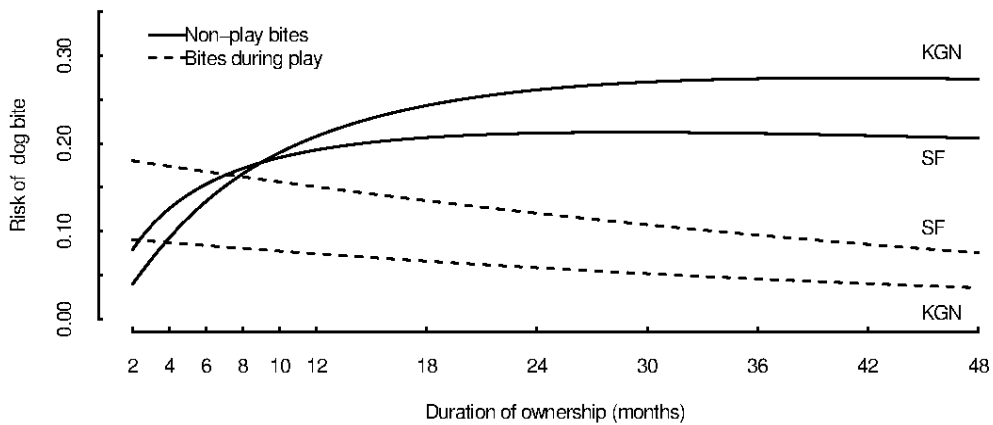
(a)

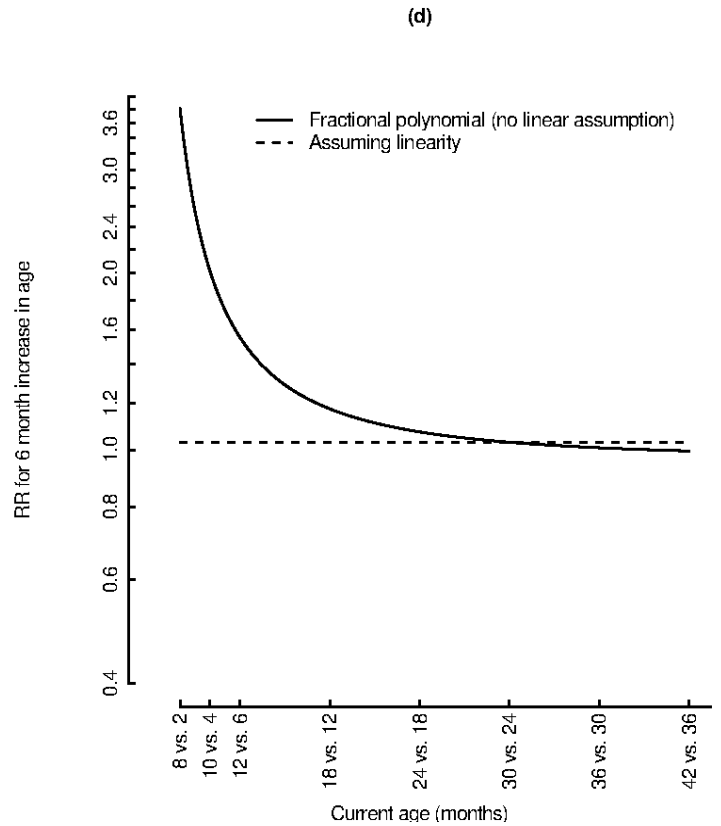
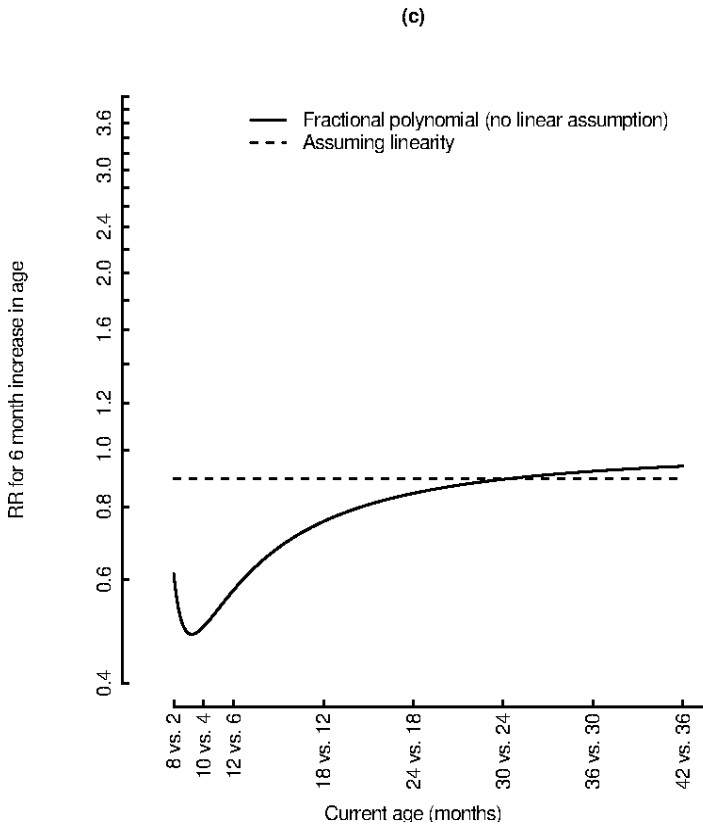
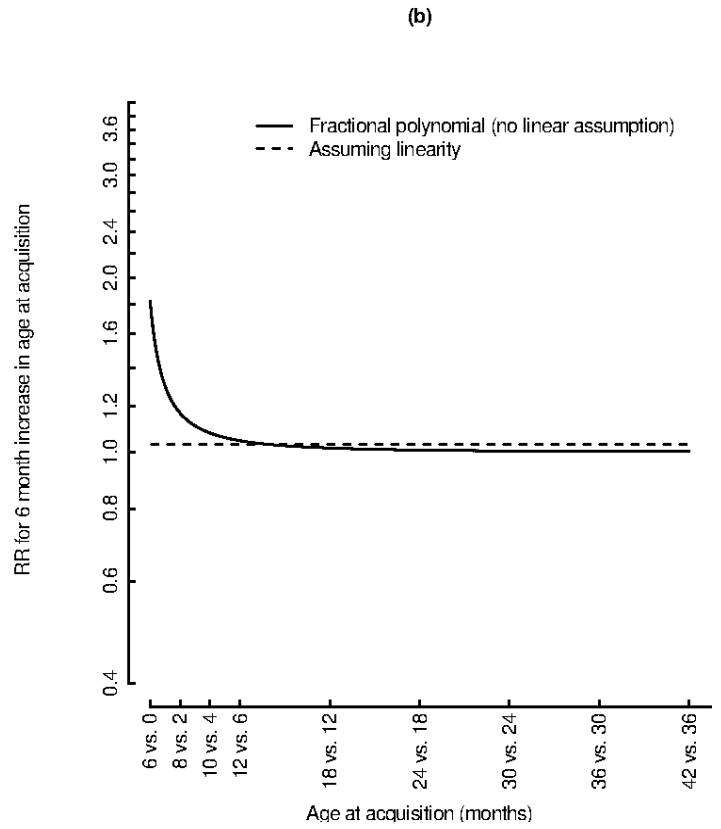
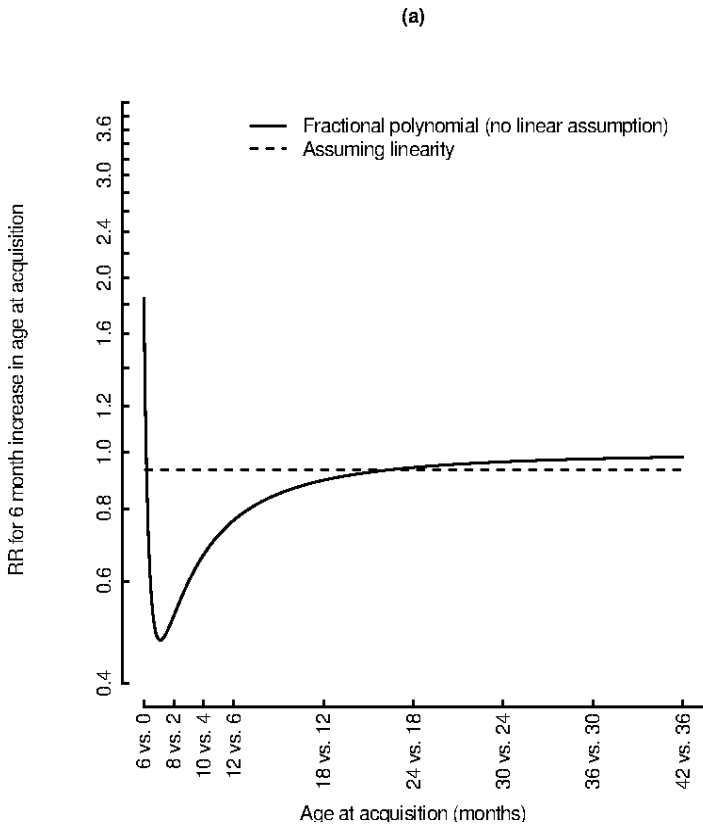


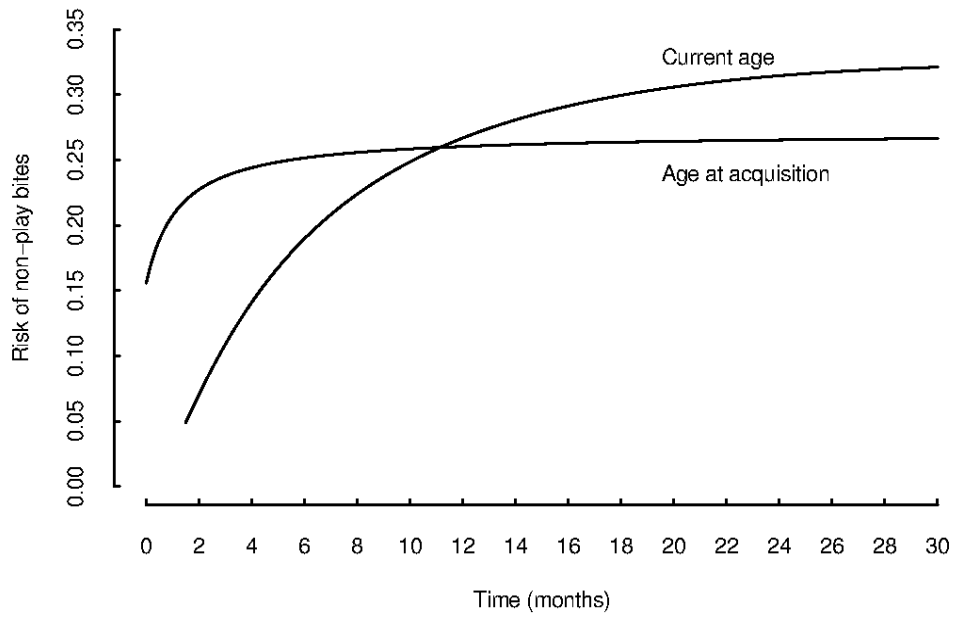
(b)



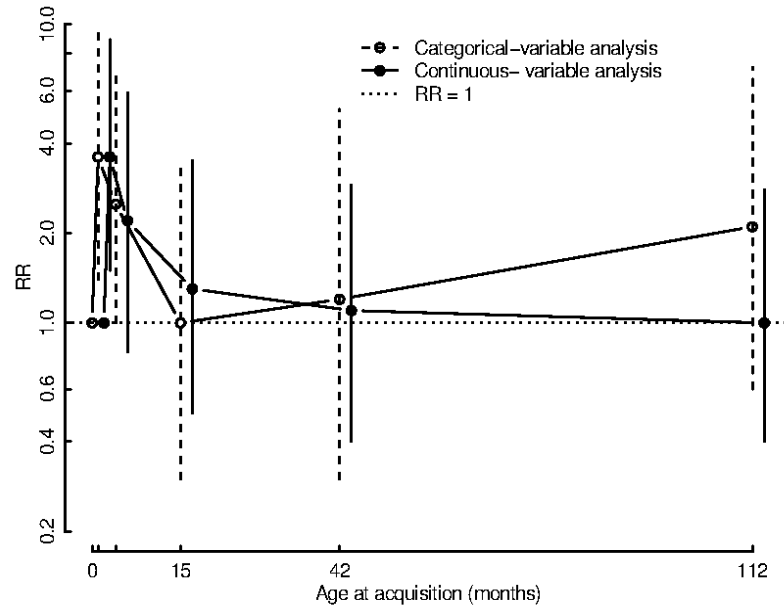
(c)



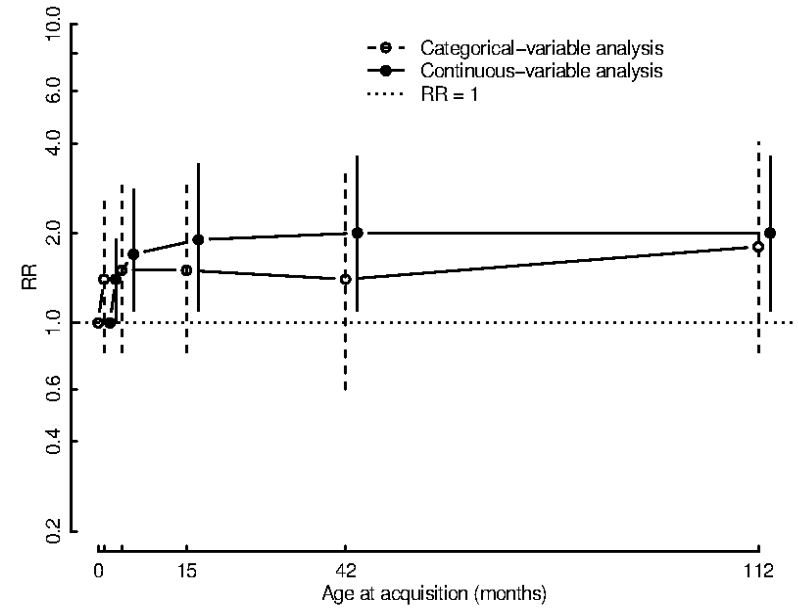




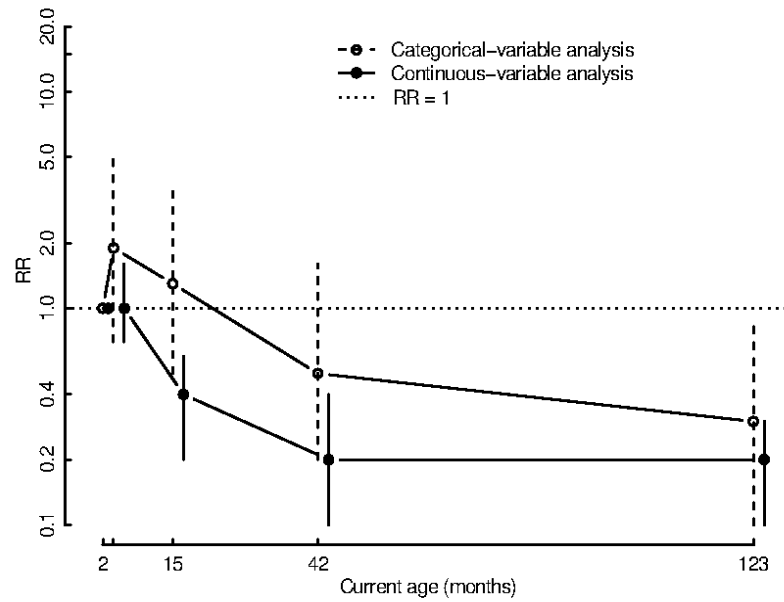
(a)



(b)



(c)



(d)

