

Co-occurrence of potentially preventable factors in 256 dog bite-related fatalities in the United States (2000–2009)

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Objective—To examine potentially preventable factors in human dog bite-related fatalities (DBRFs) on the basis of data from sources that were more complete, verifiable, and accurate than media reports used in previous studies.

Design—Prospective case series.

Sample—256 DBRFs occurring in the United States from 2000 to 2009.

Procedures—DBRFs were identified from media reports and detailed histories were compiled on the basis of reports from homicide detectives, animal control reports, and interviews with investigators for coding and descriptive analysis.

Results—Major co-occurrent factors for the 256 DBRFs included absence of an able-bodied person to intervene ($n = 223$ [87.1%]), incidental or no familiar relationship of victims with dogs (218 [85.2%]), owner failure to neuter dogs (216 [84.4%]), compromised ability of victims to interact appropriately with dogs (198 [77.4%]), dogs kept isolated from regular positive human interactions versus family dogs (195 [76.2%]), owners' prior mismanagement of dogs (96 [37.5%]), and owners' history of abuse or neglect of dogs (54 [21.1%]). Four or more of these factors co-occurred in 206 (80.5%) deaths. For 401 dogs described in various media accounts, reported breed differed for 124 (30.9%); for 346 dogs with both media and animal control breed reports, breed differed for 139 (40.2%). Valid breed determination was possible for only 45 (17.6%) DBRFs; 20 breeds, including 2 known mixes, were identified.

Conclusions and Clinical Relevance—Most DBRFs were characterized by coincident, preventable factors; breed was not one of these. Study results supported previous recommendations for multifactorial approaches, instead of single-factor solutions such as breed-specific legislation, for dog bite prevention. (*J Am Vet Med Assoc* 2013;243:1726–1736)

Dog bite-related injury has been viewed as a preventable public health problem. Although extremely rare events, human DBRFs have assumed a disproportionate role in the discussion of prevention and public understanding of the much larger issue and far more frequent event of nonfatal injuries from dog bites.^{1,2} Two early case series^{3,4} of DBRFs set the stage for use of media reports as sources of data for analysis. Subsequently, 4 related and highly influential reports incorporated national mortality rate data to improve case

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ABBREVIATIONS

| | |
|------|----------------------------|
| BSL | Breed-specific legislation |
| DBRF | Dog bite-related fatality |

ascertainment but still relied on media reports, which may be impossible to verify for completeness and accuracy, to characterize DBRFs during the periods 1979 to 1988,⁵ 1989 to 1994,⁶ 1995 to 1996,⁷ and 1979 to 1998.⁸

Of the factors related to dog bites reported in the media as well as in scientific literature, the breed of dog has come to dominate public policy discussions about prevention and control. The undue emphasis on breed has contributed to a lack of appreciation of the ownership and husbandry factors that more directly impact dogs and the complex genetic factors that work in combination with husbandry to influence a dog's behavior and responses to a given set of stimuli. This is unfortunate because even studies that relied on media accounts and described the reported breeds reiterated the importance of a more nuanced understanding of the circumstances leading to DBRFs and dog bites in general.^{5–8} More recently, the advent of commercially available DNA technology,^a along with studies demonstrating the unreliability of visual breed identification of mixed-breed dogs of known parentage⁹ and dogs of

undocumented heritage,¹⁰⁻¹³ has cast further doubt on the accuracy of news accounts and published reports of studies that relied on third-party reporting of breed.

Indeed, what is striking is the consistency with which experts agree that dog bites cannot be adequately understood by examining single factors in isolation.¹⁴⁻²² Furthermore, major professional bodies (eg, veterinary associations in the United States^{21,22} and Europe,^{23,24} the American Bar Association,²⁵ the National Animal Control Association,²⁶ and major humane organizations^{27,28}) have not recommended single-factor solutions such as BSL (ie, enacting regulations that either prohibit dogs on the basis of presumed breed or appearance or that impose additional requirements and expense with respect to their keeping) as dog-bite prevention strategies. It has been shown mathematically that BSL is unlikely to be effective²⁹; moreover, in a recent Canadian study,³⁰ there was no significant reduction in hospitalization rates for dog-bite injury in communities before and after BSL was introduced. Nevertheless, BSL has been promoted as an effective single-factor solution to the problem of dog bites.³¹ Accordingly, some communities have enacted BSL in the hope of improving public safety, potentially ignoring other more policy-relevant factors and diverting resources from more effective prevention measures.

To improve the evidence base for understanding and prevention of dog bites, the purpose of the study reported here was to examine potentially preventable factors in DBRFs on the basis of data from sources that were more complete, verifiable, and accurate than media reports used in previous studies. Our intent was to analyze data from previously unused sources (ie, in-depth investigations based on police reports and homicide investigations as well as coroner reports, animal control reports, and photographs); examine previously unreported behaviorally relevant and potentially policy-relevant factors associated with the victims, the dogs, the husbandry of the dogs, and the situational factors attendant to these incidents; describe the co-occurrence of these factors; and characterize the reliability and accuracy of breed attribution in media accounts of DBRFs.

Materials and Methods

Case ascertainment and definition—We attempted to identify all DBRFs in the United States during the 10-year period from 2000 to 2009. A DBRF was defined as a death resulting from the mechanical trauma of a dog bite. Persons dying of causes such as infection following a dog bite or other trauma associated with a dog-related incident (eg, a fall) were not considered DBRFs in this study. Initially, cases were identified through media reports via a daily Internet search^b with the following terms: dog bite, dog mauling, dog mauled, dog attack, dog bite injuries, dog bite death, and fatal bites. Investigation of cases and collection of data commenced as soon as a case was identified and were conducted prospectively beginning in 2000 with follow-up on existing cases continuing through December 2011. In approximately 20 cases involving dog bites where the cause of death was not clearly identified in the media reports, we contacted the relevant medical examiner or coroner to confirm the cause of death.

As a completeness check for DBRFs occurring from 2000 to 2007, we used national death data, searching for deaths with the International Classification of Disease Revision 10 (ICD-10) code W54 (bitten or struck by dog) as the underlying or contributory cause of death. For deaths identified in media reports but missing from the national death data (ie, not coded as W54 [approx 5 cases/y]), we used confirmation from the coroner or medical examiner as the criterion for inclusion. When cases were listed in the national death reports but not identified through media reports, this was often because the cause of death was due to an excluded cause (eg, an infection following a dog bite). For DBRFs occurring after 2007, this cross-check was no longer possible because national death reporting suppressed identifiers that allowed such cross-checks to occur.

Data sources—The primary source of the data was law enforcement agencies. The primary investigator (usually a homicide detective or other law enforcement officer) who interviewed witnesses, performed a detailed examination of the scene, compiled case reports, and obtained an in-depth narrative account of the investigation was contacted. In cases where the investigation resulted in criminal charges, the investigator could only be interviewed after the case was closed. When law enforcement investigators were unable to provide information through interviews, attempts were made to obtain police reports or to locate or interview other sources. Attempts were made to obtain all other documentation that might be relevant to the case (eg, animal control bite reports, autopsy reports, crime scene photos, and photographs of the dog). Because a DBRF may involve criminal liability on the part of a person or persons, investigators initially determine either that criminal charges are not applicable, in which case their investigation closes quickly (eg, weeks to months), or that criminal charges may be applicable, in which case their investigation is more protracted (months to years). Contact with the investigator was maintained for the duration of the case, and new facts were obtained as they became available. During the study, information was compiled over a sufficiently long period for the entire range of available facts surrounding an incident to have come to light.

Definition of variables—With respect to the decedent's relationship to a dog (or dogs), an owner was defined as an adult with an established relationship with a dog who provided care and maintained custody of the dog for ≥ 90 days. A familiar relationship was defined as an established positive relationship with the dog other than owner or primary caretaker (eg, someone who is regularly present and familiar to the dog, such as a spouse, parent, child, other relative, or roommate, and who regularly interacts with the dog in positive and humane ways); an incidental relationship was defined as an association with the dog other than owner or primary caretaker (eg, someone who is regularly present at the home, such as a spouse, parent, child, other relative, or roommate, and who does not regularly interact with the dog in positive and humane ways); and no established relationship was defined as a visitor to the home, an intruder to property, or a passerby. Victims

were deemed unable to interact appropriately with the dog if they were < 5 years of age or they had limited mental or physical capacity that increased their vulnerability (eg, dementia, alcohol intoxication, impairment from drugs, or uncontrolled seizure disorders).

The status of a dog in a household was differentiated as either a resident dog or family dog. A resident dog was a dog, whether confined within the dwelling or otherwise, whose owners isolated them from regular, positive human interactions. A family dog was a dog whose owners kept them in or near the home and also integrated them into the family unit, so that the dogs learned appropriate behavior through interaction with humans on a regular basis in positive and humane ways.

Evidence that an owner allowed the dog to be a danger to others (eg, previous bite incidents and running at large) was classified as mismanagement. A history of neglect by the owner included instances of dogs not given access to shelter, food, water, or shade and dogs with untreated medical conditions. More extreme events (eg, severe starvation, seemingly more deliberate than simple neglect; an owner witnessed beating a dog previously; an owner sexually abusing a dog; an owner using a dog for dog fighting; or evidence of deliberate physical punishment or deprivation) were classified as owner abuse. For example, an owner bragged that after his dogs had eaten food off the stove, “as punishment he fed the dogs dish soap for a week; no dog food, just dish soap.”

Coding and verification—A standardized instrument⁶ for abstracting information from the case report narratives was developed after a review of scientific literature and extensive discussion, with the intent to capture basic human and dog demographic information as well as environmental and situational variables that would be behaviorally relevant from a dog’s perspective. Categories were defined and coded as follows: victim’s age (< 90 days, 3 to < 12 months, 1 to 4 years, 5 to 9 years, 10 to 14 years, 15 to 69 years, or > 69 years); victim’s gender (male or female); victim’s relationship to dog (none, familiar, incidental, owner or primary caretaker, or unknown); duration of ownership on date of incident (≤ 90 days, > 90 days, or unknown); occurrence of bite in presence of owner or primary caretaker (yes, no, or unknown); presence of able-bodied person able to intervene on behalf of the victim at the time of the incident (yes, no, or unknown); victim’s vulnerability increased on the basis of age or limited mental or physical capacity (no [ie, victim able to assist in the interaction via perception or communication between a dog and a human; persons ≥ 13 years of age], yes [ie, children < 5 years of age; cognitive impairment due to age, mental disability, physical disability, alcohol or drug-related intoxication, or seizures], possibly [ie, victim possibly unable to interact appropriately (eg, children 5 to 12 years of age or persons with cognitive impairment due to age or other mental disability, physical disability, alcohol or drug-related intoxication, or seizures)]), or unknown); evidence of animal abuse or neglect (yes, no, or unknown); owner mismanagement of dog (yes, no, or unknown); criminal charges filed against owner, parent, or primary caretaker in

connection with incident (yes, no, or unknown); status of dog in household (resident dog, family dog, or undetermined [evidence of human-canine relationship not available or inconclusive]); typical housing of dog (chained, confined [kennel, shed, or pen in yard], loose in fenced yard, loose in unfenced yard, indoor isolation [basement, garage, porch, laundry room, or crate], regular roaming loose off owner’s property, inside home and not in isolation, indoor and outdoor, or unknown); location of incident with respect to property where dog normally resided (off property, on property, both [ran off property to attack victim], or unknown); duration of dog’s residence on property if incident occurred on resident property (≤ 90 days, > 90 days, unknown, and not applicable [ie, off-property incident]); number of dogs known to have been involved in incident (1 dog, 2 dogs, 3 dogs, ≥ 4 dogs, or unknown); sex of dog or dogs involved (male, female, both male and female, or unknown); reproductive status of dog or dogs (spayed or castrated, sexually intact, both spayed or castrated and sexually intact, and unknown); breeding status of sexually intact dog or dogs involved in incident (not applicable [ie, dogs that are neutered or do not match other categories]; female in estrus; pregnant female; sexually intact female with puppies; sexually intact female with subadult offspring; sexually intact male in vicinity of female in estrus, pregnant, or with puppies; both sexually intact male and female; or unknown).

To verify the coding categories and definitions were understandable and repeatable, 2 individuals (KMD and Kara Gilmore, JD) separately coded 20 case reports and compared results. Based on discrepancies and problems identified, the form was revised and the same 2 individuals recoded the same 20 case reports, plus an additional 30 new cases. For the 19 variables coded with 3 to 9 possible assignments of value, there was exact agreement in value assignment in 915 of 950 (96%) cells. A third person (ARM) coded a sample of 20 case reports, and there was exact agreement in value assignment in 355 of 380 (93%) cells. The final coding of the remaining case narratives was done by 1 person (KMD).

Reliability and accuracy of breed identifications—It should be noted that the source of breed descriptors in media reports is usually unknown, potentially being neighbors, first responders, or other witnesses who may or may not have any first-hand knowledge of the dog or dogs involved in an incident. Homicide detectives typically made no independent determination of breed for inclusion in their reports. We defined a valid determination of breed as documented pedigree, parentage information, or results of DNA analysis. With the understanding that the number of such cases would be limited, we also allowed for agreement of news accounts, animal control assessment, and the photographic evidence for a given dog involved in a DBRF to conclude that it was reasonable to identify the dog as a purebred dog. In cases without pedigree information, parentage, DNA test results, or photographic evidence, validity of breed attributions could not be determined. As a second level of analysis and to provide additional information about the reliability of media reports, the concordance of the reported breed descriptors among

sources was assessed, with the understanding that it would still be very difficult to know whether the assigned breed was correct even if there was agreement among sources.

Concordance was defined on the basis of both a strict and expanded definition. First, for the strict scenario, concordance was defined as an exact match in the reported breed descriptor between 2 accounts. Therefore, if one account reported a purebred dog (eg, Rottweiler) and another reported the same dog as mixed breed (eg, Rottweiler–German Shepherd Dog mix), the reports were considered discordant (not a match). For the expanded definition of concordance, breed descriptors did not need to be exact matches. For example, if one account reported a purebred dog (eg, Rottweiler) and another reported the same dog as a mixed breed that included that pure breed (eg, Rottweiler–German Shepherd Dog mix), it was considered to have an overlap of 1 breed descriptor and was therefore concordant by the expanded definition.

Pit bull–type dogs posed a special challenge because this colloquial designation is not a breed *per se* but a descriptor of a heterogeneous group whose membership includes various purebred dogs and presumed mixes of breeds; this descriptor varies according to the definition used in various statutes and ordinances and the opinions of the observer.^{32–40} The 3 breeds most commonly grouped under the term pit bull in US BSL are American Pit Bull Terrier, American Staffordshire Terrier, and Staffordshire Bull Terrier. Thus, for our strict definition to be concordant, the terms used in differing reports had to be: pit bull, pit bull terrier, American Pit Bull Terrier, American Staffordshire Terrier, or Staffordshire Bull Terrier (without the term mix). Thus, pit bull and American Staffordshire Terrier would be concordant, but pit bull and pit bull mix would be discordant, as would American Staffordshire Terrier and American Staffordshire Terrier mix. For the expanded definition, concordances related to pit bull–type dogs were considered when reported as pit bull, pit bull terrier, pit bull mix, pit bull terrier mix, American Pit Bull Terrier, American Staffordshire Terrier, Staffordshire Bull Terrier, or any alleged mix thereof.

Single dog incidents and multiple dog incidents were analyzed separately. For multiple dog incidents, we truncated those studied to events involving 2 to 6 dogs because some DBRFs involved an unknown number of dogs or dogs that could not be located (hence lacked an animal control assessment). Discordance rates for breed reports from differing sources were calculated as per 100 dogs.

Finally, in cases without documented pedigree, parentage, or DNA information but where photographs of the dog or dogs involved were available, a veterinary behaviorist (ARM), who was unaware of the breed descriptor used in the media or animal control reports, attempted to determine whether the dog could reasonably be described as a recognized purebred dog but did not attempt to guess at possible breed mixes. Concordance with the media report was assigned on the basis of the expanded definition.

Statistical analysis—Data were entered into an electronic spreadsheet and imported into a commercial

software package.^d Descriptive statistics were compiled and cross-tabulations were performed to explore relationships between variables. Co-occurrence among factors was examined with respect to factors that we believed had independent effects and minimal opportunity for overlap in definition (victim having no familiar relationship to the dog, no able-bodied person being present, victim being compromised in ability to interact appropriately with the dog, dog being a resident dog instead of a family dog, owner failing to have the dog spayed or castrated, evidence of mismanagement of dog by owner, and owner having a history of abuse or neglect of dog). Fatal bite rates per 1 million person-years were calculated on the basis of intercensal estimates.⁴¹ Fatal bites per 1 million dogs were calculated for 2 years (2001 and 2006)^{42,43} when pet survey ownership data were available and then the mean was calculated.

Results

Primary sources—Law enforcement sources (homicide detectives, chiefs of police, sheriffs, or other investigators) were interviewed with regard to 177 of the 256 (69.1%) DBRFs. Animal control officers were interviewed with regard to 44 of 256 (17.2%) DBRFs. Other persons familiar with the cases (eg, veterinarians, prosecutors, owners, and witnesses) were interviewed with regard to 24 of 256 (9.4%) DBRFs. For 11 (4.3%) cases, no primary source could be interviewed but 2 of these DBRFs were reported extensively in the media and were the subject of high-profile trials.

Frequency of fatal bites—Fatal dog bites were extremely rare throughout the 10-year period of study, with a mean of 25.6 events/y in an annual human population of approximately 295.5 million and an annual dog population of approximately 68.8 million. This corresponded to approximately 0.087 fatal bites/1,000,000 person-years and 0.38 fatal bites/1,000,000 dogs in the United States.

Victim-related factors—Nearly half (116/256 [45.3%]) of victims were < 5 years of age, and a slight majority (140/256 [54.7%]) were male (Table 1). Only 17 (6.6%) victims were established owners; most victims (218/256 [85.2%]) either had an incidental relationship with the dog or no relationship to the dog. In 143 of 256 (55.9%) DBRFs, the victim was deemed unable to interact appropriately with the dog and, in another 55 (21.5%) instances, deemed possibly unable to interact appropriately (eg, children aged 5 to 12 years or persons with cognitive impairment due to age or other mental disability, physical disability, intoxication [alcohol or drugs], and seizures).

Among the 143 DBRFs where the victim was deemed unable to interact appropriately with the dog, this inability was due to age (< 5 years) in 116 (81.1%) cases. However, of the remaining 27 victims whose ability to interact was compromised, 24 were persons ≥ 15 years. Most of these older individuals (16/24 [66.7%]) were adults compromised as a result of drug or alcohol intake. Five others were compromised because of Alzheimer's disease, dementia, or an uncontrolled seizure disorder. Increased vulnerability as a result of be-

Table 1—Victim-related and situational factors involved in 256 DBRFs in the United States (2000–2009).

| Variable | No. (%) of DBRFs |
|---|------------------|
| Age | |
| < 90 d | 21 (8.2) |
| 90 d–< 1 y | 9 (3.5) |
| 1–4 y | 86 (33.6) |
| 5–9 y | 35 (13.7) |
| 10–14 y | 9 (3.5) |
| 15–69 y | 60 (23.4) |
| > 69 y | 36 (14.1) |
| Gender | |
| Male | 140 (54.7) |
| Female | 116 (45.3) |
| Relationship to dog* | |
| Owner or primary caretaker | 17 (6.6) |
| Familiar relationship | 16 (6.3) |
| Incidental relationship | 28 (10.9) |
| No relationship to dog | 190 (74.2) |
| Unknown | 5 (2.0) |
| Ability to interact appropriately with dog compromised in some manner† | |
| Yes | 143 (55.9) |
| No | 58 (22.7) |
| Possibly | 55 (21.5) |
| Presence of able-bodied adult able to intervene at time of incident | |
| Yes | 28 (10.9) |
| No | 223 (87.1) |
| Unknown | 5 (2.0) |

Data regarding DBRFs were identified from media reports, and detailed histories were compiled on the basis of reports from homicide detectives, animal control reports, and interviews with investigators.

*A familiar relationship was defined as an established positive relationship with the dog by someone other than the owner or primary caretaker (eg, someone who is regularly present and familiar to the dog, such as the owner or primary caretaker's spouse, parent, child, other relative, or roommate, and who regularly interacts with the dog in positive and humane ways); an incidental relationship was defined as an association with the dog by someone other than the owner or primary caretaker (eg, someone who is regularly present at the home, such as the owner or primary caretaker's spouse, parent, child, other relative, or roommate, and who does not regularly interact with the dog in positive and humane ways); and no established relationship was defined as a visitor to the home, an intruder to property, or a passerby. †Victims were deemed unable to interact appropriately with the dog if they were < 5 years of age or they had limited mental or physical capacity that increased their vulnerability (eg, dementia, intoxication [alcohol or drugs], or uncontrolled seizure disorders).

ing unable to interact appropriately with a dog was an important factor because, in 223 of 256 (87.1%) cases, no able-bodied person was near enough to the victim to be able to intervene.

Dog-related factors—The weight range of most dogs was 23 to 45 kg (approx 50 to 100 lb; Table 2). Most DBRFs (224/256 [87.5%]) involved male dogs, either single or multiple male dogs (148/224 [66.1%]), or male dogs together with female dogs (76/224 [33.9%]). Incidents involving only male dogs were 5 times as frequent as incidents involving only female dogs. In slightly more than half of the 256 DBRFs (148 [57.8%]), only a single dog was involved. When a single dog was involved, it was a male dog in 127 of 148 (85.8%) incidents. Most (26/30 [86.7%]) deaths among infants (< 1 year of age) were attributable to single

Table 2—Dog-related factors involved in 256 DBRFs in the United States (2000–2009).

| Variable | No. (%) of DBRFs |
|--|------------------|
| Weight | |
| < 23 kg | 13 (5.1) |
| 23–45 kg | 203 (79.3) |
| > 45 kg | 19 (7.4) |
| Multiple weights | 7 (2.7) |
| Unknown | 14 (5.5) |
| Sex of dogs involved | |
| Male exclusively | 148 (57.8) |
| Female exclusively | 26 (10.2) |
| Both male and female | 76 (29.7) |
| Unknown | 6 (2.3) |
| No. of dogs involved | |
| 1 | 148 (57.8) |
| 2 | 59 (23.0) |
| 3 | 13 (5.1) |
| ≥ 4 | 23 (9.0) |
| Unknown | 13 (5.1) |
| Sex status of dogs | |
| Spayed or castrated only | 18 (7.0) |
| Sexually intact only | 212 (82.8) |
| Both spayed or castrated and sexually intact | 4 (1.6) |
| Unknown | 22 (8.6) |
| Reproductive status of dogs at time of incident | |
| Female dog in estrus, pregnant, or with puppies | 18 (7.0) |
| Sexually intact male involved in incident in the vicinity of female dog in estrus, pregnant, or with puppies | 25 (9.8) |
| Sexually intact male with sexually intact female (both involved in incident) | 40 (15.6) |
| Unknown | 103 (40.2) |
| Not applicable (spayed or castrated dogs or sexually intact dogs with none of the reproductive status factors present) | 70 (27.3) |

dogs, whereas over half the deaths (63/96 [65.6%]) in persons ≥ 15 years of age involved multiple dogs. Regardless of whether all or most of the dogs participated, there was > 1 dog kept either on the premises or in the immediate vicinity of the incident in 210 (82%) cases; in 19 DBRFs, there was only 1 dog kept on the premises or in the immediate vicinity of the incident, and for 27 DBRFs, the number of dogs kept on the premises or in the immediate vicinity of the incident was unknown.

Most cases (216/256 [84.4%]) involved dogs whose owners had not had them spayed or castrated. Of the nearly one-third (76/256 [29.7%]) of DBRFs involving both male and female dogs, almost all involved a sexually intact dog (70/76 [92.1%]). Only 18 of 256 (7.0%) DBRFs involved only dogs that were neutered. Spayed females were known to be involved in only 2 (< 1%) DBRFs. Among the 195 DBRFs involving resident dogs, their owners had failed to have the dogs neutered in 182 (93.3%) cases. Among the 40 DBRFs involving family dogs, the owners had failed to have the dogs neutered in 24 (60%). In 83 cases, owners maintained dogs in reproduction (eg, a female in estrus, a pregnant female, or a female with nursing or young puppies present) or in circumstances conducive to reproduction (eg, a sexually intact male being kept with a sexually intact female). Not all of these dogs were deemed by the investigators to be involved in the DBRF despite being in the general vicinity; however, the presence of dogs with these reproductive issues could have influenced the behavior of the dogs involved in the bite.

In only 57 of the 256 (22.3%) DBRFs did the owners know or were investigators able to determine with any degree of reliability the age of the dog. In only 39 of the 256 (15.2%) incidents was it possible to assign a single, distinct function to the dog. Therefore, given the extent of missing data for these 2 variables, detailed results for categories of age and function are not reported.

It was not possible to precisely determine the total number of dogs involved in these 256 DBRFs because, in some cases when multiple dogs were present, the total numbers were not reported or it was simply unknown exactly how many dogs were involved. Conservatively, we estimated at least 455 individual dogs.

Determination of breed—To examine breed of dogs, we used media reports, animal control reports, pedigree, parentage information, or results of DNA analysis, when available. To evaluate the reliability of breed determinations reported by the media, we attempted to use concordance among reporting sources of breed descriptors, recognizing that even with concordance, sources could still be in error, particularly when dogs were of mixed breeding. For single dog incidents (148 incidents), on the basis of the strict definition (exact match), breed descriptors in media reports were discordant for 32 of 148 (21.6%) dogs; animal control or local law enforcement assessment of breed differed from the media account for 45 of 129 (34.9%) dogs. On the basis of the expanded definition (any agreement between alleged breeds and mixes), breed descriptors among media reports were discordant for 19 of 148 (12.8%) dogs; animal control or local law enforcement assessment of breed differed from the media account for 18 of 129 (14.0%) dogs.

For multiple dog incidents (96 deaths involving 256 dogs), on the basis of the strict definition (exact match), breed descriptors in media reports were discordant for 92 of 253 (36.4%) dogs; animal control or local law enforcement assessment of breed differed from the media account for 94 of 217 (43.3%) dogs. On the basis of the expanded definition (any agreement between alleged breeds and mixes), breed descriptors among media reports were discordant for 43 of 253 (17.0%) dogs; animal control or local law enforcement assessment of breed differed from the media account for 24 of 217 (11.1%) dogs.

Breed was inaccurately represented in the media in other ways. For example, 7 deaths were originally reported by the media as involving multiple dogs; further investigation revealed that 8 dogs were not involved and the deaths were actually single dog incidents. For another 9 deaths reported by the media as involving multiple dogs, later investigation revealed that although multiple dogs were involved, 13 media-implicated dogs were not involved. Thus, 16 of 256 (6.3%) deaths involved inaccurate media reporting of the number of individual dogs involved, yet all of these dogs had media-reported breed descriptors.

With respect to pedigree or results of DNA analysis for single dog cases, pedigree documentation, parentage, or DNA information was available for 19 dogs. These data were discordant with media reports for 7 of 19 cases on the basis of the strict breed definition and 0 of 18 cases on the basis of the expanded breed defini-

tion. Results of review of photographs of 66 other dogs by a veterinary behaviorist agreed with news reports of purebred status for 9 of 66 (13.6%) dogs.

For multiple dog cases, pedigree documentation, parentage, or DNA information was available for 28 dogs. These data were discordant with media reports for 7 of 28 (25.0%) cases on the basis of the strict breed definition and 0 of 28 (0%) cases on the basis of the expanded breed definition. On review of photographs of 95 other dogs, the veterinary behaviorist could confirm the media report of purebred status for only 3 of 95 (3.2%) dogs but did not attempt to guess breed mixes when a dog did not appear to conform to the breed standard for purebred dogs. It should be noted that 354 of 393 (90.1%) dogs that were assigned a breed descriptor were assigned a single breed descriptor (ie, not reported as a mixed breed) in at least 1 media report.

Table 3—Husbandry-related and other factors involved in 256 DBRFs in the United States (2000–2009).

| Variable | No. (%) of DBRFs |
|---------------------------------------|------------------|
| Duration of ownership | |
| ≤ 90 d | 28 (10.9) |
| > 90 d | 200 (78.1) |
| Unknown | 28 (10.9) |
| Status of dog in household | |
| Resident dog* | 195 (76.2) |
| Family dog | 40 (15.6) |
| Unknown | 21 (8.2) |
| Location in which dog was kept | |
| Home | 20 (7.8) |
| Indoors and outdoors | 37 (14.5) |
| Loose in fenced yard | 35 (13.7) |
| Loose in unfenced yard | 11 (4.3) |
| Roaming | 30 (11.7) |
| Pen | 19 (7.4) |
| On a chain | 74 (28.9) |
| Indoor isolation | 14 (5.5) |
| Unknown | 16 (6.3) |
| Location of dog at time of incident | |
| On owner's property | 190 (74.2) |
| Off owner's property | 51 (19.9) |
| Both on and off property | 13 (5.1) |
| Unknown | 2 (0.8) |
| Evidence of mismanagement by owner† | |
| Yes | 96 (37.5) |
| No | 112 (43.8) |
| Unknown | 48 (18.8) |
| History of neglect or abuse by owner‡ | |
| Yes | 54 (21.1) |
| No | 170 (66.4) |
| Unknown | 32 (12.5) |
| Owner present at time of bite | |
| Yes | 12 (4.7) |
| No | 223 (87.1) |
| Owner was victim | 17 (6.6) |
| Unknown | 4 (1.6) |
| Criminal charges filed | |
| Yes | 67 (26.2) |
| No | 177 (69.1) |
| Unknown | 12 (4.7) |

*A resident dog was a dog kept isolated from regular, positive human interactions. †Evidence that an owner allowed the dog to be a danger to others (eg, previous bite incidents and running at large) was classified as mismanagement. ‡Neglect by the owner included instances of dogs not given access to shelter, food, water, or shade and dogs with untreated medical conditions; abuse was classified as more extreme events (eg, severe starvation, seemingly more deliberate than simple neglect; an owner witnessed beating a dog previously; an owner sexually abusing a dog; an owner using a dog for dog fighting; or deliberate physical punishment or deprivation).

Overall, breed status was assigned for dogs involved in 45 of 256 (17.6%) DBRFs from documented pedigree, parentage information, or DNA test results or on the basis of concordance among media breed descriptor, animal control breed descriptor, and the veterinarian-assigned breed from a photograph. These 45 DBRFs involved 20 recognized dog breeds, including 2 dogs of known mixed breed.

Husbandry-related factors—Most DBRFs involved dogs known to be owned > 90 days (200/256 [78.1%]), and only a small proportion involved dogs known to be owned ≤ 90 days (28/256 [10.9%]; Table 3). Over three-quarters of cases (195/256 [76.2%]) involved dogs kept by their owners as resident dogs rather than as family dogs. In incidents involving resident dogs, those dogs were kept in a manner that isolated them from the humans in the family, such as chained (74/195 [37.9%]); kept isolated in a fenced area, an outdoor pen, or an isolated indoor area (68/195 [34.9%]); or

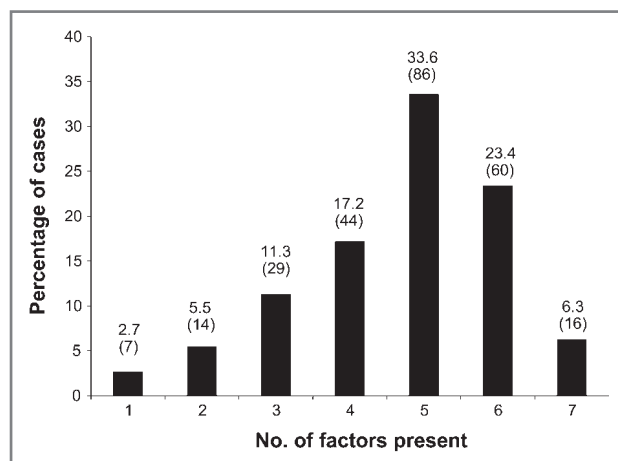


Figure 1—Co-occurrence of preventable factors in 256 DBRFs in the United States from 2000 to 2009. Values above each bar indicate the percentages; values in parentheses indicate the number of cases. Data regarding DBRFs were identified from media reports, and detailed histories were compiled on the basis of reports from homicide detectives, animal control reports, and interviews with investigators. Numbers over the bars indicate the percentage of cases (actual number of cases) in which 1 or more of the following factors were present: victim having no familiar relationship to the dog, no able-bodied person being present during incident, victim compromised in ability to interact appropriately with the dog, dog being a resident dog (ie, kept isolated from regular, positive human interactions) instead of a family dog, owner failing to have the dog spayed or castrated, evidence of mismanagement of dog by owner, and owner having a history of abuse or neglect of dog. A familiar relationship was defined as an established positive relationship with the dog by someone other than the owner or primary caretaker (eg, someone who is regularly present and familiar to the dog, such as the owner or primary caretaker's spouse, parent, child, other relative, or roommate, and who regularly interacts with the dog in positive and humane ways). Victims were deemed unable to interact appropriately with the dog if they were < 5 years of age or they had limited mental or physical capacity that increased their vulnerability (eg, dementia, intoxication [alcohol or drugs], or uncontrolled seizure disorders). Evidence that an owner allowed the dog to be a danger to others (eg, previous bite incidents and running at large) was classified as mismanagement. Neglect by the owner included instances of dogs not given access to shelter, food, water, or shade and dogs with untreated medical conditions; abuse was classified as more extreme events (eg, severe starvation, seemingly more deliberate than simple neglect; an owner witnessed beating a dog previously; an owner sexually abusing a dog; an owner using a dog for dog fighting; or deliberate physical punishment or deprivation).

allowed to roam (30/195 [15.4%]). There were no instances in which resident dogs and family dogs were jointly involved in a DBRF.

In 96 of 256 (37.5%) DBRFs, there was evidence that the owner or caretaker had foreknowledge of either prior dangerous action by the dog or had repeatedly allowed the dog to run loose. In 54 of 256 (21.1%) cases, there was evidence of prior abuse or neglect of the dog. Nearly three-quarters (190/256 [74.2%]) of the deaths occurred on the owner's property, and only 51 deaths occurred entirely away from the owner's property. In 32 of 51 (62.7%) off-property incidents versus 55 of 190 (29%) on-property incidents, there was a history of mismanagement of dogs by owners. Past mismanagement was also associated with the number of dogs involved in an incident. That is, where there had been past mismanagement by the owner, multiple dogs were involved in 54 of 96 (56.3%) DBRFs; where there had been no documented prior mismanagement, multiple dogs were involved in 27 of 112 (24.1%) DBRFs.

Criminal charges for misdemeanors or felonies (in addition to animal control violations) were filed for 67 of 256 (26.2%) DBRFs. Nearly half (47/96 [49.0%]) of owners with a history of dog mismanagement were criminally charged, compared with only 13 of 112 (11.6%) owners without such a history. Of the 67 criminal charges, legal proceedings resulted in convictions (sentences of 1 to 15 years) for 34 and dismissed charges, mistrials, or sentences of probation or < 1 year for 33.

Many of the factors described regarding the victim, dog, and husbandry were co-occurrent in a large number of DBRFs (Figure 1). Co-occurrence of ≥ 4 of these factors was evident in more than three-quarters (206/256 [80.5%]) of cases.

Discussion

These study data were obtained over many years of investigation and collection from multiple sources (eg, interviews with and police reports from homicide investigators, interviews with animal control personnel, and multiple sources of written documentation). In our opinion, the present study represents the most comprehensive analysis of factors—behaviorally relevant factors in particular—associated with dog bites to date. Personal interviews with credible investigators were successfully conducted in 221 of 256 (86.3%) cases. During this data-gathering process, we found that law enforcement personnel provided firsthand information not reported in the media and often identified errors of fact in the media reports.

In the present study, the most striking finding was the co-occurrence of multiple factors potentially under the control of dog owners: isolation of dogs from positive family interaction and other human contact; mismanagement of dogs by owners; abuse or neglect of dogs by owners; dogs left unsupervised with a child or vulnerable adult who may be unfamiliar to the dog; and maintenance of dogs in an environment where they are trapped, neglected, and isolated and have little control over either the environment or choice of behavior. These conditions potentially predispose dogs to enhanced territorial, protective, and defensive behaviors toward stimuli that occur commonly in everyday life.

The most preventable incidents involved very young children left alone with dogs to whom they were unfamiliar or toddlers allowed to wander off and encounter unfamiliar dogs. In at least 19 DBRFs, authorities considered the lack of supervision in such incidents so negligent that criminal charges were filed against the parent or caretaker.

When interpreting these incidents, it is critical to keep in mind what factors may be behaviorally relevant from a dog's perspective and how human decisions to maintain, confine, and treat the dogs may predispose them to inflict a severe bite. Dogs that have not developed a close relationship or bond with humans (ie, resident dogs) generally act without relying on input from a human. Tópal et al⁴⁴ reported that dogs living in homes (in contrast to dogs living outdoors) developed bonds with people and were more dependent on their owners when solving tasks. In agreement with other studies,^{9,45,46} those authors concluded that the individual past experiences of dogs strongly influence their later social behavior with people.⁴⁴ Appropriate, humane, and clear interactions with people provide dogs with information about how to interact with humans in ways that are neither scary nor injurious to the dog or human. This can occur through daily interaction but cannot occur when dogs are reared apart from daily, freely offered (not while chained) human interactions. The effect of that bond is that dogs that interact frequently with humans read human signals well and are encouraged to act on them accordingly. Dogs that are deprived of human interaction or direction are denied access to accurate information about appropriate behaviors with humans. Consequently, dogs in stressful, potentially dangerous situations or when maltreated may behave in ways primarily to protect themselves. Mirkó et al⁴⁷ emphasized the importance of environment in influencing the personality of individual dogs. Those authors found that the dogs' environment had a stronger influence on personality than did genetically determined breed differences.

In the present study, the finding that most dogs were not recently acquired (ie, were owned > 90 days) and therefore presumably were acclimated to their environment and to at least some of the people in it bears discussion. Adults, being familiar with the dog, may assume this familiarity will be automatically extended unto their children (unfamiliar to the dog) or to other unrelated children or adults. It is incorrect to assume that because a dog has been around some people for a period of time that the dog will feel comfortable around all people in all circumstances. It may well be that an unfamiliar child or adult entering the environment has changed the dog's environment (introduced novelty relevant to the dog) and perhaps the dog's comfort level. For example, in 1 case, a 2-year-old child wandered over to a chained resident dog. This dog had had the same owner for 12 years, and during that time, the dog was kept on a chain in the backyard during the summer months and confined in the basement during the winter months. Thus, most of the time, the dog was separated from the owner and other people and had little opportunity for a healthy human-dog bond to develop. A dog that has not been exposed to children in a posi-

tive and nonthreatening manner that would allow the dog not to fear children and to understand their pattern of behaviors is likely to be afraid of them. A fearful dog will avoid stimuli that invoke the fear, but if unable to avoid, as when tied, may become aggressively defensive. Maintained in this way, it is extremely unlikely that a dog, notwithstanding its uninterrupted habitation on the same property, would have had the opportunity to interact in positive and humane ways with humans, including a child. Discouraging maintenance of dogs in isolation from the family; stressing the importance of a secure, stable, predictable environment; and encouraging positive relationships with people may have considerable preventive benefits.

According to the 2007 AVMA Pet Ownership Survey,⁴⁸ 62.2% of US dog-owning households have only 1 dog, 24.8% have 2 dogs, 7.5% have 3 dogs, and 5.5% have 4 or more dogs. Yet, we found that in 210 of the 256 (82%) DBRFs, there were multiple dogs either on or near the scene, regardless of whether > 1 dog was involved and whether all of the dogs present were owned by the same person. Appropriate management of dogs, which is important in all situations, may be more challenging when multiple dogs and other complicating conditions are present. Furthermore, maintaining multiple dogs that have no history of good and close relationships with people, in conjunction with dogs being in various reproductive conditions, may increase their reactivity to certain stimuli, even those present in daily life.

In the present study, most DBRFs (224/256 [87.5%]) involved a male dog, and most of those incidents involved at least 1 dog that was sexually intact (216/256 [84.4%]). Several studies⁴⁹⁻⁵³ of aggression in dogs have found that male dogs bite more frequently than do female dogs, and male dogs that are sexually intact bite more often than do those that are castrated. Although it is unknown whether castration directly affects the incidence of aggression toward people, studies^{54,55} have shown that castration decreases aggression toward other dogs. Overall and Love¹⁴ suggested that testosterone may modulate behavior, and thus sexually intact male dogs react more intensely, more quickly, and for a longer period of time. It is also possible that people who desire protective dogs choose males and decide not to have them castrated, expecting or encouraging any tendency to be protective or aggressive. It is easy to envision that when sexually intact male dogs are raised as resident dogs, tied outside, and left unsupervised, they could be even more likely to bite. In the present study, 182 of the 195 (93.3%) DBRFs associated with resident dogs involved sexually intact dogs, whereas only 24 of the 40 (60%) DBRFs associated with family dogs involved sexually intact dogs. This suggests that owner failure to have their dog spayed or castrated may co-occur with other factors that more directly influence a dog's social competence.

The issue of breed merits special discussion because of its prominence in the scientific literature and influence on public policy. The data obtained in the present study indicated 2 problems with media characterization of dog breeds: poor reliability and poor accuracy. One source of media error was the misclassifica-

tion of whether individual dogs are even involved in a death, which by our estimate occurred in at least 6% of the cases. By use of the strict definition of discordance, combination of single dog and multiple dog DBRFs revealed that for the 401 involved dogs described in > 1 media account, reported breed differed for 124 (30.9%); for 346 dogs with both media and animal control breed reports, breed differed for 139 (40.2%). By use of the expanded definition of discordance, reported breed differed for 62 of 401 (15.5%) dogs described in > 1 media account and 42 of 346 (12.1%) dogs with both media and animal control breed reports. Whichever definition of concordance is used, disagreement occurs with sufficient frequency to cast doubt on the reliability of these reports as a source of information about presumed breed. It is also important to remember that, even when concordance was documented, this does not mean the assessment of breed was valid (ie, correct); it simply means that 2 sources reported the same information. According to media reports, 90.1% of the dogs were characterized in at least 1 media report with a single breed descriptor and not as a mixed breed. This distribution is in contrast to the known distribution of breeds in the general population of dogs; population-based studies indicate that a large (approx 46%) proportion of dogs are mixed breed,⁵⁶ suggesting either that in media reports and perhaps animal control reports, designation of breed is done very loosely without regard to mixed-breed status or that purebred dogs were heavily overrepresented in DBRFs. The latter conclusion seems unlikely to us, particularly in light of the photographic evidence available.

The lack of concordance among breed descriptors was not surprising because identification of the breed composition of a dog of unknown heritage has been shown to be unreliable; this may reflect the diverse appearance of offspring even from deliberate breeding of known parents⁹ or, as revealed in more recent studies,¹⁰⁻¹³ the fact that opinions (even those of animal professionals with years of experience) correlate poorly with each other and with results of DNA analysis. Enforcement of BSL must therefore grapple with imprecise and subjective identification of dogs presumed subject to regulation. Breed-specific legislation must also be viewed in light of study findings^{9,57} that indicate a lack of correlation between behavior and physical phenotype. This imprecision in breed assignment also brings into question the reliability of the breed information used in previous studies⁵⁻⁸ of DBRFs, which were based solely on media reports of breed.

The coding system used for abstracting information from official reports and interviews, despite being repeatable among different coders, nevertheless requires subjective assessment. The information available for each case varied, depending on officials' interest in conducting an investigation and pursuing a criminal prosecution. Some information that might be highly relevant to an animal professional might not be reported by police investigators (eg, animal abuse or neglect); therefore, those situations may be underreported. Most detectives had little knowledge about dogs and relied on what owners or animal control personnel told them. If the case detective could not document a previous bite

history or acts of aggression, he or she may have had no further interest in pursuing a more detailed history. We were not able to contact or obtain an interview with the lead investigator for all DBRFs in the present study. Photographs of the scene and the dogs were of variable quality. Media reports were collected primarily as a trigger to pursue information from primary sources such as local law enforcement, and no attempt was made to comprehensively and systematically collect every media report associated with each DBRF; thus, the discordance among media reports of breed, discordance between media reports and animal control reports, and the number of dogs erroneously reported as being involved in a DBRF were all likely underestimated. Finally, it was not possible to explore owner-level socioeconomic characteristics because these data were not obtained by investigators. Future studies may wish to consider such factors, but it is important to note that as with dog-related factors, it is likely that owner-level socioeconomic factors could be misleading when considered in isolation. Persons of all socioeconomic levels are able to be responsible dog owners, although it is possible that animal control enforcement efforts and access to veterinary care and other resources available to support responsible ownership could well be different in different neighborhoods.

Results of the present study were derived from new and more extensive sources of data than those used in previous studies⁵⁻⁸ of DBRFs. However, these data have fully supported the recommendations in those study reports⁵⁻⁸ and of experts on the subject of dog bite-related injuries, including the AVMA Task Force on Canine Aggression and Human-Canine Interaction²¹ and the CDC,⁵⁸ who have consistently stressed the complex and multifactorial nature of dog bites and the need for multiple approaches to address this complexity. The present study findings also have supported recommendations by the AVMA²² and others²³⁻²⁸ regarding the inadvisability of single-factor solutions such as BSL, which may actually divert resources from more effective measures and regulations. For example, in Prince George's County, Md, following enactment of BSL in 1997, a task force established in 2002 found that the cost to animal control for maintenance of banned dogs was > \$500,000 during a 2-year period.⁵⁹

Animal services programs that insist on responsible ownership should be promoted and adequately funded. Information about dog behavior and bite prevention must be disseminated to an audience that extends beyond animal care professionals. Maintenance of dogs in ways (ie, as family pets instead of as resident dogs that are isolated from the family) that allow them to interact regularly with humans in positive and humane ways may help dogs learn to read human signals, understand their meaning, and respond to them appropriately. As a result, dogs would be less likely to be afraid of and defensive in the presence of unfamiliar people, including children, because they have had positive experiences with their patterns of behavior.

Given the disproportionate number of dog bites occurring among children, it is critical to revisit existing recommendations concerning managing the interactions between children and dogs.^{21,60} Most children

have never received dog bite prevention education,⁶¹ and lack of supervision is common in reports of dog bites.⁶² As 1 review⁶⁰ indicated, children cannot be expected to show good judgment in their interactions with dogs until at least 6 years of age. Thus, veterinarians, pediatricians, child care workers, and any other professional interacting with the parents of young children should take the opportunity to remind them that children < 6 years of age should not be left unattended with a dog: supervision by an adult or an older child who is capable of correctly reading and responding to the dog is necessary to ensure safety.

The present study data collected over a 10-year period support the conclusions of a considerable body of previous work, including empirical investigations and expert recommendations,^{5,6,814,15,21,22,60} which all stress the multifactorial nature of dog bites. These data shed additional light on how co-occurrence of factors may promote the occurrence of a fatal or serious bite, when individually those factors may be less relevant. The coding form used in the present study could be a model for enhancing the quantity and quality of information collection in future investigations of dog-bite related injuries. Finally, this information could help human health professionals who may not be familiar with dog behavior to appreciate the importance of collaborating with professionals in animal behavior when attempting to understand and prevent dog bite-related injuries to humans.

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