Special Report

Dog bites to humans—demography, epidemiology, injury, and risk

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Dog bite injuries to humans have recently received much attention, probably because the impact of these injuries has finally been recognized.[1-5] During the 1940s and 1950s, the medical and public health monetary costs of domestic animal bites were reported to be between $1 and $5 million.[6] One report cites a current annual cost of $102.4 million for dog bite-related emergency services in the United States.[3] Recent estimates indicate that hospitalization costs are approximately $62.5 million, raising the total direct medical care cost to $164.9 million.[7] During the first half of the 1990s, US insurance companies paid mean annual claims in excess of $1 billion for dog bite-related injuries, and a third of all liability claims associated with home owners were dog bite-related.[8,a-c] Ancillary costs (eg, lost income, torn clothing) were estimated in the 1970s to total $25 million annually in the United States.[9,10] The dogs involved are affected too, because bite incidents, like other behavioral problems, often result in euthanasia or relinquishment of pets to shelters.[11-15] Furthermore, there are direct and indirect adverse economic effects on the veterinary profession. These effects include direct loss of practice income caused by loss of patients and the possibility that fewer people will consider owning dogs because of negative publicity (indirect). The costs associated with these latter issues are not well-documented.

Some people have suggested that the incidence of dog bites could be reduced through legislative initiatives.[16-18] If these initiatives are to be effective and reasonable, they must be based on accurate information about why and which dogs bite. The purpose of this report is to review major studies of the past 40 years that have focused on dog bites and critically evaluate factors related to victims (eg, age, gender, relationship to dog, activity, injury) and dogs (eg, age, gender, size, breed, behavior). Relevant aspects of normal canine behavior, genetic implications of breed development, behavioral conditions that can lead to dog bites, and misconceptions about these factors as they relate to dog bites are also explored.

Incidence of Dog Bites

There are between 52.9 and 58.2 million pet dogs in the United States[19] that reside in approximately 35% of all households.[20] Estimates of dog-bite incidence vary widely and range from 0.5 to 1 million bites/y (late 1950s through the early 1970s) to 3.5 to 4.7 million bites/y (late 1970s through the 1990s; **Table 1**).[2,3,6,9,10,21-33,c] Data for other countries, when available, are similar.[34-37]

The proportion of dog bites reported to medical or legal authorities appears to be low; published estimates range from 10 to 50%.[23-25,38,39] Recent data from a national telephone survey[2] provide an estimated overall incidence of 18 bites/1,000 people per year and an estimated incidence for those seeking medical attention of 3 bites/1,000 people per year. To the limited extent that the frequency of medically treated bite injuries can be used to estimate the frequency with which bites are reported, only about 17% of dog bites are reported.[2] Therefore, accumulated data indicate that dog bites occur more often and that the frequency of bites reported to any authority (eg, hospital, animal control, Centers for Disease Control and Prevention) may be substantially lower than commonly believed.

Approximately 17 to 18% of dog bite injuries receive medical attention, and approximately 1 to 2% of bite injuries require hospitalization of victims.[1,2,36,40-42] Dog bite-related injuries comprise 0.4 to 1.5% of emergency department visits,[23,36,43-46] 1.2% of surgical cases seen in emergency departments, and 0.3 to 1% of emergency room visits by pediatric patients.[44] Approximately 3.6% of emergency department visits by male children between 5 and 9 years old are dog bite-related.[3]

Current information about factors affecting dog bites may be biased, because most data used to assess these factors have been obtained from bite incidents that required medical or surgical treatment. The nature and magnitude of this bias is, of course, unknown. Usually, the age of the victim, the type of dog, the ownership status of the dog, and the type of human injury sustained are recorded, but information about canine and human behaviors surrounding the bite is rarely included. When such information is available, it is seldom recorded in a manner that allows critical comparison.

Demographics of Dog Bites

Effect of victim's age—The type of human injury incurred from a dog bite depends on the physical attributes of the human and the dog. With few notable exceptions,[47] available studies do not define what con-

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Table 1—Bite incidences as cited or calculated in published studies

Type of study	Incidence and time period (bites/population)	Comments Study reference*	Study reference*
Retrospective study of bites reported in Pittsburgh, Pa	362/100,000; July and August 1958	Animal bites. Most were inflicted by dogs but percentage not specified	6
Retrospective study of bites reported to a rabies control program, Norfolk, Va, Department of Health	281/100,000; 1971	6-month sampling period	24
Retrospective study of bites reported to the Baltimore City Health Department	288–480/100,000; 1953–1964	Calculated from dog-associated portion (95%) of animal bites reported in Baltimore, Md	29
Retrospective survey of victims of dog bites reported to the Baltimore City Health Department	467/100,000; 1969	For state of Maryland. Calculated from data, assuming dog bites constituted 95% of all reported animal bites	29
Retrospective survey of victims of dog bites reported to the Baltimore City Health Department	700/100,000; 1969	For city of Baltimore. Calculated assuming that dog bites constituted 95% of all reported animal bites	9
Retrospective study of bites reported to the New York City Health Department	353/100,000; 1965 361/100,000; 1966 376/100,000; 1967 407/100,000; 1968 419/100,000; 1969 457/100,000; 1970 475/100,000; 1971 483/100,000; 1972		25
Centers for Disease Control and Prevention prospective 2-year surveillance program covering 15 departments	20/100,000; 1971 in South Carolina 927/100,000; 1971 in Arizona 207/100,000; 1971–1972	207/100,000 was the mean rate for 12 states and 3 districts. Calculated assuming that dog bites constituted 83.8% of animal bites during this 2-year period	15
Retrospective study of bites reported to the Baltimore City Bureau of Animal Control	791/100,000; 1970–1976		30
Retrospective study of bites for which victims sought medical advice on 2 US Air Force bases	1,390/100,000; January 1976–December 1977	Authors noted that this was 1.7 times the incidence reported by Berzon and DeHoff	31
Retrospective study of bites reported through the Indian Health Service	586/100,000; 1981 691/100,000; 1982 539/100,000; 1983	Follow-up by telephone to obtain specific data	55
Retrospective study of bites reported to the Guelph Health Unit	160/100,000; 1986–1987		34
Retrospective telephone survey of past experience	18/1000; 1994	Estimated incidence	2
Retrospective telephone survey of past experience	3/1000; 1994	Estimated incidence rate of those receiving medical attention	2
Retrospective survey, National Center for Health Statistics	12.9/10,000; 1992–1994	Based on visits to emergency departments in United States	3

*Study reference refers to citation in reference list. Studies are listed in chronologic order in this table.

stitutes a bite and do not distinguish between minor injuries (eg, bruises) and more severe injuries (eg, punctures, lacerations).[10,23,31,48] Data from reported bites requiring medical attention indicate that most dog bites affect children younger than 15 years old.[2,3] Other studies indicate that approximately 60 to 75% of those who are bitten are < 20 years old, and most are children 5 to 9 years old.[38,49,50] After the age of 1 year, bite incidence increases through ages 5 to 9 years.[24,25,29,50] If all bites are distributed equally over victim age, children are bitten 2 to 3 times more frequently than would be expected on the basis of their population proportion.[2] Estimates indicate that most children have been bitten by a dog, usually one known to them, by the time they are 11 years old.[23,51-53] In 1 study involving > 3,200 randomly chosen children 4 to 18 years old, 45% reported being bitten during their lifetime.[51] Children are at least 3 times more likely to experience a medically attended bite than are adults,[2] and 48% of dog bite-related emergency room visits at 1 center were by children under 10 years old.[23]

Effect of victim's gender—Three types of study reports are available that examine the association between gender of victim and likelihood of being bitten: those containing actual data that allow relative risk to be calculated, those in which only calculated relative risk or odds ratios are reported, and those that include bite incidence without population data that would permit calculation of relative risk. Detailed data that per-

Table 2—Relative risk of dog bites for male and female victims in various age groups

Age	No. of human males bitten/No. of males in population	No. of females bitten/No. of females in population	G_{adj}*	Study reference†
0 to 4 y	101/31,390	73/30,622	3.988	6
5 to 9 y	185/25,123	104/24,566	21.400	
10 to 19 y	184/41,743	65/44,714	63.748	
All ages	639/328,407	308/348,399	137,927	
5 to 9 y	162/13,809	90/13,412	18.900	24
10 to19 y	148/29,780	62/26,173	26.063	
20 to 24 y	33/50,753	28/25,077	4.333	
All ages	539/166,453	304/141,198	33.480	
Children	831/1,525	662/1,713	81.762	51
Children	58/1,825	34/1,685	4.662	2
Adults	63/2,682	31/2,554	9.729	

†Study number refers to citation in reference list. *G_{adj} is the log-likelihood ratio χ^2 test statistic. $P < 0.05$ for all values listed.

mit comparison of relative risks of dog bites for male and female victims are available from 4 studies (**Table 2**).[52] Males are bitten significantly more often than females for all age groups examined in each of these studies.

In reports of 13 other studies, the at-risk population cannot be determined; however, most of these studies indicate that male victims incur a significantly larger proportion of reported bites than do female victims.[5,9,25,34,35,46,48,50,54-58] Dog bites to human males are reported 1.4[51] to 3 times[4] more frequently than are bites to human females.[23,31] The ratio of males to females bitten ranged from 1.5:1[46] to 1.7:1 for a population in which males outnumbered females 1.2:1.[47] Proportions of bites to male children compared with female children vary with age of victim: boys outnumber girls 1.6:1 in the younger than 4 years age group and 2.3:1 in the 4- to 16-year age group.[59] When compared with females 19 years or older (relative risk, 1.0), males 19 years or older have a relative risk of 1.9, females 0 to 18 years old have a relative risk of 4.2, and males 0 to 18 years old have a relative risk of 5.4.[31] This pattern indicates an interaction between age and sex that is consistent among various geographic and cultural locales.[60]

In a 3-year annualized study of new dog bite injuries seen in US emergency departments, the highest incidence rate (60.7 bites/10,000 people) was for boys age 5 to 9 years.[3,6,29] Males were bitten significantly more often than were females in all age groups other than human males over 60 years old.[6,25] The only exception to this pattern was found on an Indian reservation where dogs were neither owned pets nor stray but took shelter where people worked.[55] These statistics strongly indicate that some patterns of interaction (possibly including play) between dogs and humans are gender-biased and that some aspects of these interactions may be conducive to aggression. The view that some bites are largely attributable to human behavior, whereas others are largely attributable to dog behavior, is indirectly supported by lack of a sex prevalence in 1 study that examines only severe attacks.[48] Many of the 16 incidents reviewed in that study involved predatory behaviors and chained animals, strongly indicating that this group of dogs was a distinct subset of dogs that bite.

Finally, males comprise a significantly larger proportion of dog bite-related fatalities than do females.[50,51,53-56]

Relationship of dog to victim—Most dog bite injuries in the United States are inflicted by owned pet animals and not by strays.[51,56,61-63] Three of 5 bite victims were bitten by the family dog or one living in the neighborhood[9] in a population where strays were responsible only for 13 to 25% of bites.[29,30] Results of other studies are consistent with these.[10,34,35,48,64] Family dogs appear to be involved in 25 to 33% of bites.[35] Free-ranging owned dogs may be more aggressive than strays when approached and may be more aggressive when they are closer to home.[57,61] Results of 1 well-conducted study indicated that only for dogs identified as pit bull-type ($P < 0.001$) were most bites attributable to freely roaming dogs that did not belong to the person bitten.[46]

For 96 dog bites for which data on locale and the relationship of the victim to the dog were available, 52 (54%) involved victims younger than 15 years old, and 82 (85%) occurred in the dog's own home. Twenty-eight of 44 (62%) adults were bitten by their own dog, and 39 of 52 (75%) children were bitten by dogs belonging to neighbors or friends.[37] These data strongly indicate that human behavior plays a major role in dog bite injuries.

In 1 study, 85% of dog-bite victims treated in emergency rooms were bitten by their own dog.[23] Data collected for 1,724 bite injuries indicated that owned dogs delivered more bites, were larger, bit more victims on the head and neck, delivered more bites needing medical treatment, and, in short, were more dangerous than strays.[25] This type of data is potentially biased, because it is possible that if the dog is owned by the person bitten, the victim is likely to report only serious bites. This hypothesis is supported by results of 1 study that indicate that bites inflicted by strays (50.3%) are more likely to be examined by a physician than are bites inflicted by family pets (29.1%).[62] It is important to realize that not all stray dogs are unowned. Many dogs described as strays are actually owned dogs that

are allowed to run free.[35] Regardless, the frequency with which dog bites are reported is disturbingly low. Underreporting and incomplete data are typical even when reports are mandated by law and bite injuries are treated by emergency personnel.[63] Unfortunately, urban emergency departments, which fit the demographic profile for a potentially large number of dog bite-related visits, have the least discretionary time with which to pursue epidemiologic information related to dog bites.

Victims' behaviors and dog bites—Human behaviors factor into dog bites and contribute to the amount of damage done. Children age 5 years or younger are significantly more likely to provoke animals prior to injury than are older children ($P < 0.001$).[46]

Most dog bites, particularly to children, occur in the summer and on weekends. The diurnal peak in bite incidence is late afternoon and early evening.[23] Most children hospitalized for dog bites incur those bites on weekends.[35] The temporal environment matters, because children are more likely to come into contact with dogs at certain times. The physical environment also contributes to the likelihood of a bite. More children and dogs are outdoors and active during the periods listed. The greater the number of children and dogs, the greater the potential reactivity of each group. Again, there are no objective measures of this, but empirical evidence from "pack" situations involving dogs and people (an example of the latter would be a mob at a soccer game) indicates that the more excited any participant, the less stable and predictable the situation.[53] Such circumstances are ideal for unilateral or joint misinterpretation by the participants of any signaling behavior. Proximity facilitates violence, rather than retreat, as a response in such conflicts.

In the case of canine aggression toward children, there are 2 participants with enough overlap in patterns of sociality that it is possible to misunderstand the extent to which the same signal has 2 different messages and meanings.[64,65] Just as humans can misinterpret a wagging tail, dogs can misinterpret a screaming child. Children may be uncoordinated and may appear unpredictable to dogs because of their sudden shifts in postures and vocal range when excited. Some behaviors and some intensities of behaviors in young children can frighten dogs. Other behaviors, like shrill squealing, could be misinterpreted by dogs as sounds and signals given by prey. Excitable states facilitate misunderstanding by making all participants less aware of changes in signaling and interactive behaviors. The potential for bilateral misunderstanding and inappropriate reaction with concomitant disastrous circumstances is particularly great for children who may not have the sophistication or maturity to correctly interpret and react in rapidly changing interactions.

One study examining owner demographics revealed that when equal numbers of biting and nonbiting dogs were compared, those without a license, those without current vaccination, those that were not neutered, males, and those that were left chained in the yard bit more frequently than did licensed dogs, those with current vaccinations, those that were neutered, females, and those that were not left chained, respectively.[4] Such findings indicate that associations among owner behavior, breed, and dog and human behaviors that owners tolerate or encourage should be more intensively investigated.

Epidemiology of Dog Bites

Location of injuries to humans—Whereas most injuries to adult humans affect the extremities,[3,4,38,56] > 70% of injuries to children involve the head, neck, and face.[3,5,66] Because of their height, children commonly incur bites on the upper extremity, shoulder, head, and neck regions.[35] In 1 study, 67% of bites inflicted on children 0 to 4 years old and 56% of bites inflicted on children 5 to 9 years old involved the face and neck.[23] The converse information—the proportion of individuals of each age who are bitten and locations of bites—is not available, because such poor records are kept for dog bite injuries.

Fatalities caused by bites—Although dog bites are epidemic, the per capita death rate attributable to dog bite injuries is relatively low (1 fatal attack/5 million dogs/y, based on a dog population of approximately 50 million).[46] Seventy percent of dog bite-related fatalities occur in children younger than 10 years, whereas 10.2% occur in individuals older than 69 years. The death rate for neonatal humans is 370 times that of adults 30 to 49 years old.[50] Of 74 deaths attributable to dog bites reported over a 5-year period, 23 were children < 1 year old.[56] The 3-year, annualized, adjusted, and weighted estimate of new dog bite-related injury visits to US emergency departments is 333,687 or a rate of 12.9 visits/10,000 people. For each fatality, there were approximately 670 hospitalizations and 16,000 emergency department visits.[3]

Pit bull-type dogs, although not necessarily biting more often or being inherently more aggressive than any other breed, are overrepresented in the population of dogs inflicting fatal bites and those causing serious trauma.[50] Forty-three of 101 (42%) dog bite-related deaths reported between 1979 and 1988 involved dogs identified as pit bull-type. Dogs identified as pit bull-type were involved in 4 of 10 incidents where an infant was pulled from a crib. A high proportion of stray dogs (37%) identified as pit bull-type have been implicated in dog bite-related fatalities.[50] For no other breed is this scenario true, indicating that when we examine data for pit bull-type dogs, we need to understand their demographics. Unowned free-ranging dogs may be more likely to come from an environment that promotes, enhances, or accepts aggression, whereas owned dogs may have a completely different history.[36,57] In other words, there may be > 1 population of pit bull-type dogs, and if so, the data from these groups should be analyzed separately.

In 1 study, the breeds most commonly identified in fatal bite incidents were German Shepherd Dogs and German Shepherd Dog crossbreeds; however, dogs of other breeds were responsible for 3 dog bite-related fatalities (2 Rottweilers [same attack], 1 Siberian Husky, and 1 Akita).[36] Another study found that German Shepherd Dogs were responsible for more fatal

bites than any other breed at a time when the number of registrations with the **American Kennel Club (AKC)** for German Shepherd Dogs was greater than for any other large breed.[56] Regardless, a Spearman rank correlation performed on incidence data for fatal bites comparing breed and number registered by the AKC during a sample year reveals no association between fatal bites and popularity rank (r_s = 0.066; $P \geq 0.806$; 15 *df*). During the same period, pit bull-type dogs were responsible for more deaths than would be expected given their relative rarity at the time of that study.[56] Judicious interpretation of these data indicate that fatalities are rare, most dogs involved are members of fairly common large breeds, and that relative representation within AKC registrations is less informative than population-specific breed prevalence data may be. Most dogs inflicting fatal bites are large dogs; fatal bites from small dogs may be associated with a tendency to cuddle them around the face and neck.

Associations between size of dog and injury—An analysis of breed information for 43 dogs involved in 40 attacks on children treated in emergency departments revealed that most dogs involved were members of large breeds.[36] These breeds included German Shepherd Dog (n = 10), German Shepherd Dog crossbreed (5), Rottweiler (7), pit bull-type dog (4), and Siberian Husky (3). Single individuals of various other larger breeds (Siberian Husky crossbreed, Labrador Retriever, Akita, Doberman Pinscher, Australian Shepherd, and Chow Chow) were also implicated in these attacks.[36]

Odds ratios from another study that compared dogs involved in bite incidents with dogs not involved in bite incidents indicated that dogs that bit were more likely to be members of common large breeds such as German Shepherd Dogs (odds ratio, 16.4) or Chow Chows (odds ratio, 4.0). Results of that same study also revealed that Chihuahuas, Golden Retrievers, Labrador Retrievers, Poodles, Scottish Terriers, and Shetland Sheepdogs were unlikely to be involved in bite incidents.[4]

Bites from pit bull-type dogs are more often associated with serious injury or fatalities,[7] but this may be a consequence of the build and musculature of pit bull-type dogs, rather than a breed characteristic per se. Furthermore, a bite of the same force, administered by the same jaw configuration, could be more injurious when delivered to a victim's head and neck than when delivered to the torso or extremities. Lunging chasing dogs may become airborne and may hit their victims with more force, come in contact with the victim's neck and head more frequently, and potentially inflict more shearing damage than would dogs that bite from ground level.

Sex of dog—If bite incidents for which sex of dog is reported are examined, male dogs bite more frequently than female dogs. However, to completely and correctly interpret such information, it is necessary to know the actual numbers of each sex in the dog population. In 1 British study for which complete information was available, 82 dogs involved in 96 bite incidents were male. Intact dogs, particularly males, are often involved in dog bites,[57] possibly because of their greater tendency to roam within their neighborhoods.[67]

Studies identifying only aggression, rather than a specific diagnosis involving aggression, indicate that intact male dogs are more often implicated in aggression than are castrated ones.[68-70] Most dogs for which dominance aggression is diagnosed are male.[68-70] Although dog bite data often do not indicate whether dogs are intact or neutered, data for dominantly aggressive dogs seem to indicate that reproductive status has little effect on whether a dog receives a diagnosis of dominance aggression.[68-70] Testosterone acts as a behavior modulator that makes dogs react more intensely. When an intact dog decides to react, it reacts more quickly, with greater intensity, and for a longer period of time. If that dog reacts to a strange person or another dog, it will be quicker to bark, growl, or bite and will continue that behavior longer than would a neutered dog.[67-71] Castration decreases aggression exhibited toward other dogs[67]; however, few data exist regarding its effect on other specific aggressive behaviors.

Age of dog—Little information is available concerning the age of dogs that bite. On the basis of their size, most dogs that bite appear to be adults, but no further conclusions can be drawn. Most dogs receiving a behavioral diagnosis of aggression are entering or are in the midst of social maturity (usually 18 to 24 months at onset; range, 12 to 36 months) when they begin to demonstrate problem behaviors.[71,72] For most behavioral diagnoses, 1 sex is not more commonly represented than the other; however, the diagnosis of dominance aggression presents a complicated contrast. Most dogs for which dominance aggression is diagnosed are male and becoming socially mature when they first show signs of aggression. When females exhibit dominance aggression, they are significantly younger than males, usually 8 weeks to 11 months old.[73,74,d] Puppies can exhibit inappropriate out-of-context aggression, and because of the nature of their appeal to children, they may be more easily provoked by children. Because of complex age-sex associations like this, any conclusions about likelihood to bite and sex or age should be viewed cautiously.

Breeds, perceptions, behavior, and bites—A number of investigators have attempted to find a relationship between breed and dog bites (**Table 3**). There are 3 methods by which we can estimate the effect of breed on reported bite incidence.[34] Breed-specific bite rates indicate what percentage of dogs of a specific breed were involved in biting incidents. This requires that we know populations of all biting and nonbiting individuals—data that are rarely available. Relative risk indicates how much more or less likely a specific breed is to be involved in a bite incident, compared with other breeds. Again, this requires a good estimate of populations of all breeds. The **population attributable fraction percentage (PAF%)** is a measure of a breed's impact on the overall population. The PAF% is often calculated by using license records to estimate breed populations. Numbers obtained from this approach may be quite different from actual breed populations, because in many locales, licensing compliance is low.

Table 3—Data from dog bite injury studies that contain breed-specific information for at least 3 breeds

Description	3 breeds most often involved (± level of significance if available or calculable)	Study reference
1993 breed distribution of dogs quarantined for bites by a Wisconsin humane shelter, compared with total number of dogs belonging to the listed breeds entering the shelter for other reasons	Chow Chow, 13/170; 7.6%; $P < 0.05$; $G_{adj} = 9.49$* Cocker Spaniel, 23/316; 7.3%; $P < 0.05$; $G_{adj} = 15.543$* Lhasa Apso, 14/203; 6.9%; $P < 0.05$; $G_{adj} = 8.261$*	58
Incidence rates of dog bites by breed at 2 United States Air Force bases January 1976 through December 1977	**Bites/100 animals per year; relative risk compared with mixed breed†** Collie, 20/100; 2.9 German Shepherd Dog, 17.4/100; 2.6 Cocker Spaniel, 13.7/100; 2.0	31
Case-controlled study of 178 nonbiting and 178 biting dogs	**Biting; nonbiting** Chow Chow, 31 (17.4%); 9 (5.1%)‡ German Shepherd Dog, 34 (19.1%); 13 (7.3%)‡ Collie, 8 (4.5%); 1 (0.6%)§	4
Prospective study of dog bite-related injuries seen at the Children's Hospital of Philadelphia in 1989; 156 dogs of identifiable breeds plus those identified as mixed breeds	German Shepherd Dog, 35 (20.8%) Pit bull-type dogsII, 33 (19.6%) Rottweiler, 8 (5.4%)	46
Bites seen in 1975 at University of California, Los Angeles, emergency department and referred for surgery	Mixed breed, 41/135 (31%) German Shepherd Dog, 28/135 (37%) Terrier (unspecified), 5/135 (7%)	23
Survey of 455 families in a Denver pediatric practice comparing breeds of dogs that had bitten with those owned by families in the practice	**Biting No. of breed (%); No. owned by families (%)** German Shepherd Dog and crosses, 34 (17.5); 21(11.0)# Mixed breed > 30 lb 24 (12.4); 27 (14.2) Poodle 20 (10.3); 27 (14.2)	47
Retrospective study of breed of dogs involved in 835 bite injuries reported in Norfolk, Va, between Jan 1 and Jun 30, 1971	Mixed breed, 350 (41.5%)¶ German Shepherd Dog, 211 (25%) Poodle, 37 (4.4%)	24
Retrospective study of 16 severe or fatal dog bites in 5 South Carolina counties between Jul 1, 1979, and Jun 30, 1982	American Staffordshire Terrier, 5¶ Saint Bernard, 3 Cocker Spaniel, 2	48
Retrospective study of breeds of dogs involved in reported bites, compared with frequency of registration of those breeds in Baltimore, Md, between 1974 and 1976	**Registered; involved in bites (%)** German Shepherd Dog,** 1974; 2,437; 1,291 (44.2) 1975; 3,759; 1,149 (46.1) 1976; 2,648; 1,031 (44.4) Mixed breed,** 1974; 2,646; 1,078 (36.9) 1975; 4,222; 766 (30.7) 1976; 2,766; 643 (27.7) Collie,*** 1974; 519; 78 (2.6) 1975; 944; 75 (3.0) 1976; 647; 65 (2.8)	30
Poll conducted for Victim Injury Surveillance Survey (Australia, 1989)	****No. attacks (%); population** German Shepherd Dog, 1,300 (33.6); 1,440 Bull Terrier, 519 (13.4); 450 Doberman Pinscher, 310 (8.0); 360	36
Retrospective study of 250 dog bites recorded by Guelph Health Unit between 1986 and 1987	**Relative risk; population %** American Staffordshire Terrier, 39.81; 0.6 Duck Tolling Retriever, 39.81; 0.6 Saint Bernard, 26.72; 1.3	34

*Log-likelihood χ^2; our statistics. †All $P < 0.01$. ‡$P < 0.001$; Yates corrected χ^2 test. §$P = 0.04$; Fishers exact test, 2-tailed. IIPit bull-type dogs were overrepresented in unprovoked bites and those inflicted by roaming dogs; $P < 0.01$ or better; χ^2 test. ¶No further statistical analysis possible. #$P < 0.05$; χ^2 test; based on distribution of breeds, when known. **$P < 0.05$; log-likelihood χ^2; our statistics; all $G_{adj} > 100$. ***Not significant.

Relative risk = Biting rate of breed (No. licensed biters of breed/total No. licensed X 1000)/biting rate of all other breeds.

No single database is available that would provide complete information for any of these methods.

As individual breeds gain popularity, and assuming an equal probability that any dog will bite, the number of bites reported for that breed should increase. How great this increase is can be affected by apparency of the breed and skewed by media attention given purpose-bred dogs (eg, those bred for fighting, protection, or other specific behaviors). The problem with media attention and apparency may be worse for dogs identified as pit bull-type. In response to a perceived increase in pit bull-type dog-related injuries, 1 investigator ascertained the dogs' breeds and relationships to victims for 168 bites inflicted on children.[44] Bite injuries involving dogs of a given breed were: German Shepherd Dog (n = 35); pit bull-type dog (33); Rottweiler (9), Doberman Pinscher (7), terriers (individual breeds grouped 6); Siberian Husky (5); other (10), unknown (2), and mixed breed (61). The numerically dominant breed involved in bites in this study, the mixed breed, is likely to be the numerically dominant breed in the overall dog population.

On the basis of these data, bites from pit bull-type dogs receive disproportionate attention when compared with bites from other breeds. Newspaper accounts from which many data are collected may not be reliable.[56] Dog license data have been employed to create a more reliable database.[34] Such data may be important when evaluating the association between owner behavior, breed, and dog behaviors tolerated or encouraged by owners. In the United States, American Pit Bull Terrier owners are less likely to license their dogs than are German Shepherd Dog owners.[36] Biting dogs, in

general, are also more often unlicensed in case-control studies.[4]

A 1991 case-control study evaluating biting and control (nonbiting) dogs[4] produced a ranking that indicates an association between popularity of breed and incidence of dog bites in that breed. Biting dogs were more likely to be German Shepherd Dogs ($P < 0.01$) or Chow Chows ($P < 0.001$). Nonbiting dogs were more likely to be Golden Retrievers ($P < 0.01$) or Standard Poodles ($P < 0.03$). None of the biting and only 1 control dog were of the pit bull-type at a time when new ownership of pit bull-type dogs was outlawed, but retention of previously owned dogs was not.[4] It is impossible to draw breed-based conclusions from this small sample. Without knowing the number of dogs of a given breed within the local pet population, breed-specific comparisons of those that bite (or kill) and those that do not are not possible.

Many behavioral and physical factors that correlate with breed are also associated with injury and potential to injure. Evaluating these factors separately from breed would go a long way toward dispelling myths about canine aggression. Physical factors that may affect the amount of injury that an aggressive dog can inflict include size (mass and height), age (younger dogs are more energetic and less inhibited by physical disability), jaw structure (tenacity of purchase [Mastiffs and Rottweilers]), and physique (distribution of muscle mass and relative strength). Rottweilers and Doberman Pinschers, dogs with poor reputations in the popular press, are responsible for a small percentage of injuries requiring plastic surgery, whereas sustained attacks most commonly involve German Shepherd Dogs, Doberman Pinschers, and Staffordshire Bull Terriers.[37] These associations illustrate the interplay between physical and behavioral factors. Behavioral factors that correlate with degree of injury include age of onset of aggression, duration of aggressive behavior, intensity of aggressive bout, frequency of aggression, and response to correction and other contextual information.[71] These behavioral factors emphasize the roles of learning and context-appropriate behavior, which are often ignored in behavioral evaluations.

Results of studies available to date indicate that the population sizes of specific breeds and the behaviors of individual dogs should be considered before drawing conclusions about breed propensities.

Canine Behavioral Tendencies and Their Associations with Dog Bites

Normal canine behavior—Hundreds of years of artificial selection have yielded canine size and shape variations that exceed thousands of years of natural selection effects on wolves.[75-77] Much of the physical variation in dog breeds is a consequence of overt selection for specific behavioral suites (eg, herding vs retrieving behaviors). Similarly, the manner in which dogs communicate with each other and with people is likely to be influenced by these selected traits. Some dogs' behavioral problems are simply different manifestations of traits that have been selected for by humans.

Dogs share characteristics with humans that make them good working and social companions: they engage in extended and extensive parental care, other family members contribute to the care and social development of offspring, they are socially mature after they are sexually mature, their social systems are based in deference, they have rules governing behaviors so that signaling is often redundant, and most signaling or affirmation of signaling is nonvocal rather than vocal.[71,78] Unfortunately, these similarities may lead people to underrate subtleties of canine behavior and to anthropomorphize or anthropocentrize. For example, a dog that wags its tail may or may not be happy; a wagging tail is indicative of a willingness to interact and a stiff tail with a wagging tip is common in confident aggressive dogs.[71] If the dog has a problem with aggression, staring at or reaching for the dog may be sufficient to trigger further agonistic behavior and frank aggression. Progressive children's books are beginning to indicate such distinctions.[79-81]

In the case of most aggressions and anxieties related to social maturity, the condition manifest by the dog has actually been changing because of changes in the interactive social environment. Most aggressive dogs are clinically behaviorally abnormal; the abnormality is usually progressive and is influenced by the social environment, so the signs noted by the client and clinician have been changing. We can easily understand such progressive changes in infectious and noninfectious disease and so should be able to understand them as conditions that manifest as behavioral illness; yet, regular screening for behavioral propensities is not a common part of routine veterinary examinations.

Role of selection for breed-associated traits—Before breed-specific legislation is seriously considered, it is necessary to ask whether such legislation can be substantiated by science. To do this, we must understand how we have actively or passively selected for inappropriate or aggressive behavior. Data previously reviewed indicate that the breed of dog most often involved in dog bites covaries with the popularity of the breed, and that these changes may be relevant for 1 group of children (males between 5 and 9 years old) who appear to have a greater propensity for injury. Behaviors of breeds do not remain constant as breeds become popular, but change in ways that are consistent with population genetics.

A breed may be bred to display a narrow suite of behaviors that are considered acceptable, and individuals outside the bounds of acceptability are culled or not bred. When dog breeds become popular, 2 things happen: first, selection is relaxed, and because there is underlying genetic variance, less favorable traits are expressed; and second, individuals expressing these traits and behaviors are not selected against, rather they are desired, because the dogs are "hot," "tough," "sexy," or "sharp." In this situation, owners tolerate, select for, and enhance inappropriate out-of-context behaviors **(Fig 1 and 2)**.

Breeds may also be bred and selected to look a particular way or to perform a suite of behaviors (eg, guarding, herding), and breeders deliberately move the

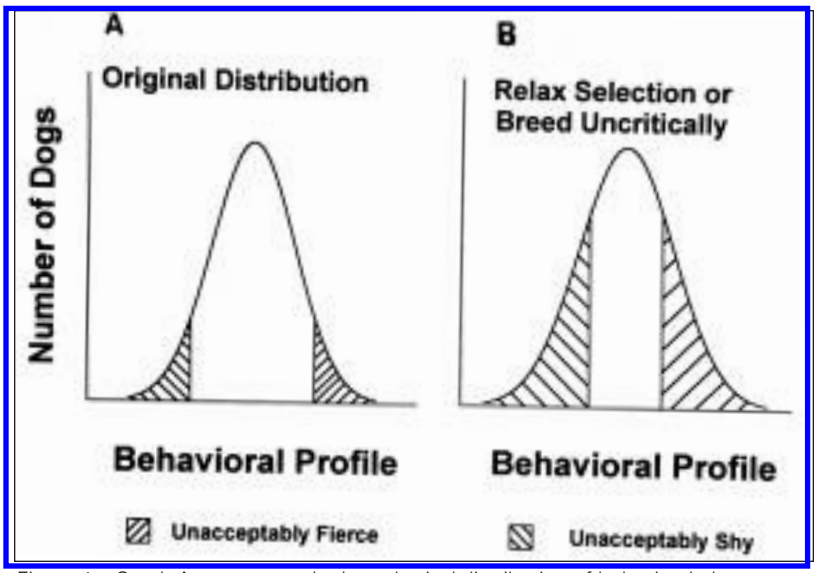

Figure 1—Graph A represents the hypothetical distribution of behavioral phenotypes for a random breed. The individuals under the left hatched area of this curve are considered too shy to perform the task for which the breed was developed or are too shy to be desirous in the pet population. The individuals under the right hatched area of this curve are considered too fierce to perform the task for which the breed was developed or are too fierce to be desirous in the pet population. Selection has limited the spread of the less desirable population members by not breeding them, and in this example breeding of unaffected members maintains the represented distribution. Graph B shows what happens, all other forces being unchanged, if selection is relaxed or breeding is uncritical, and the undesirable members are included or encouraged in the breeding population. The relative proportion of dogs with both undesirable phenotypes of behaviors increases.

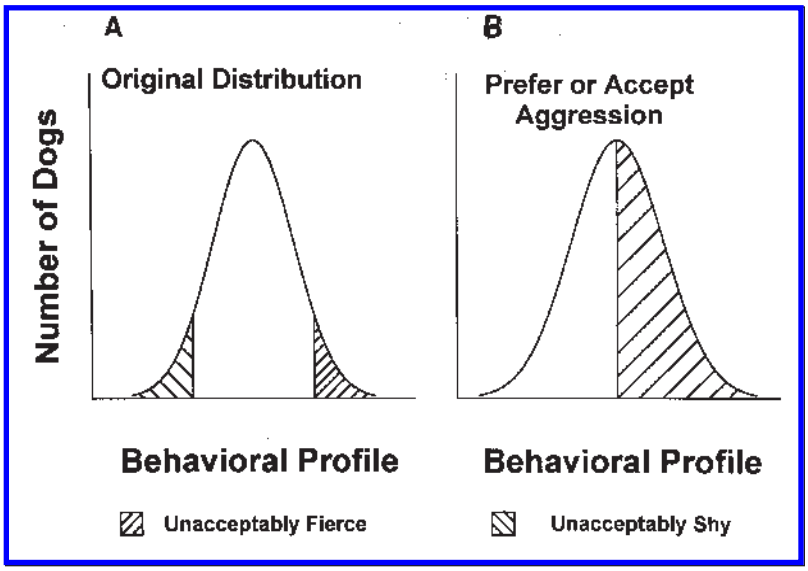

Figure 2—Graph A is the same as graph A in Figure 1 and is originally maintained in the same way. Graph B represents what happens when the unacceptably fierce animals are preferred, and selection acts to reinforce this through preferential breeding and culling of unacceptably shy animals. The relative proportion of the unacceptably fierce phenotype of dog increases.

mean of the population to a slightly more perfect dog. In doing so, they forget that in the absence of selection against undesirable traits, the entire normal distribution shifts, and the proportion of dogs with undesirable traits or ones that behave inappropriately also increases (**Fig 3**).

Other than these broad population level associations, not much is currently understood about canine behavioral genetics, even when normal behavior is involved. Studies designed to identify heritable components of breed-specific performance traits have not yielded definitive results. Tracking and scenting ability in German Wirehaired Pointers appear moderately heritable (ie, they have high additive genetic variance) and should respond rapidly to selection.[82] For more complex behaviors such as sheep herding, the mode of inheritance and the extent to which any behaviors comprising style of approach and instinct are heritable are complicated and arguable.[82,83] Investigations of unpredictable aggression have produced no firm results regarding heritability[84]; however, for many breeds in which dominance aggression is common, each generation may contain affected individuals, indicating that inheritance may be of the simple dominant type.[e,f] Shyness or lack of exploratory behavior has been investigated in pointers.[85,86] Whereas these behaviors appear to run in breeding lines, environmental contributions cannot be eliminated. A fearful shy breeding line of mixed-breed dogs, sired by a Siberian Husky, has been produced under conditions designed to minimize environmental influences.[g] Evidence exists that links temperament and the probability of developing hip dysplasia in German Shepherd Dogs[87,88]; however, this assessment involved a scoring system for rating temperament that may have obscured individual behaviors.

Role of illness and veterinary intervention—Although not specifically implicated in many reported dog bites, dog owners and veterinarians should be aware that pain, certain endocrine and neurologic conditions,[89,90] and many sedative, tranquilizing, and anesthetic agents (eg, benzodiazepines, neuroleptics, xylazine) can make dogs more reactive and less predictable.[71] Stimuli to which the dog may not have previously reacted (eg, a noise or hug) may induce or facilitate aggression under these influences. Veterinarians should provide anticipatory guidance in these cases.

Abnormal or problem canine behavior and its association with dog bites—Aggression is best defined within a particular context as an appropriate or inappropriate threat, challenge, or contest that is ultimately resolved by combat or deference.[71] This definition is consistent with those for hierarchical terms that focus on the ability to control access to resources.[91] The question of whether a behavior is contextually appropriate is seldom raised when

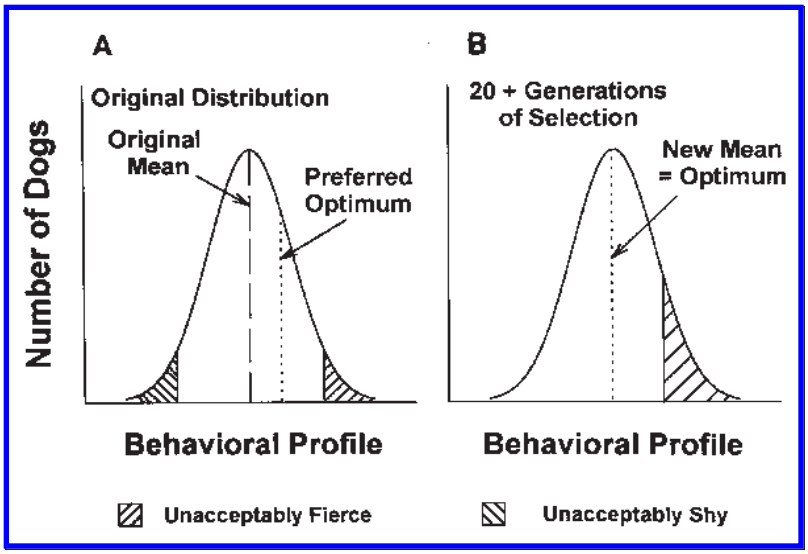

Figure 3—Graph A shows a distribution like that in graph A in Figure 1 and is originally maintained in the same way. In this case, the original mean represents the mean phenotype of the selected behavior in the breeders' populations. The line marked preferred optimum represents the phenotype of the behaviors that breeders prefer and have selected for by breeding only dogs that have phenotypes close to it. Graph B indicates what happens after 20+ generations of breeding for the preferred optimum. In this case, the mean of the behavioral phenotypes in the population has shifted to the preferred optimum, and as a result, the proportion of dogs with the undesirable behavioral phenotype of unacceptably shy has decreased to nil, whereas the proportion of dogs with the undesirable behavioral phenotype of unacceptably fierce has increased, along with an increase in the proportion of dogs with the highly desirable optimum phenotype.

dogs save someone from attack. Conversely, police and guard dogs are useless (and dangerous) if their first recourse in any situation is to bite. These dogs are usually trained to act in a contextually appropriate coordinated manner with their human partners and to inhibit their own inappropriate behaviors. Inappropriate bites from these dogs are the exception rather than the rule.

Provocation must be discussed in the context of a dog known to be aggressive in certain circumstances, compared with a dog that has never reacted aggressively in those same circumstances. If a dog is known to have behaved inappropriately in certain contexts (ie, petting, reaching over its head), it may be unintentionally provoked[34] by what would otherwise be considered a normal gesture. For behaviorally abnormal animals, normal gestures may not be perceived as such; this part of the clinical picture can be understood and treated. Available data on dog bites and children indicate that many of these dogs and children are interacting in provocative or inappropriate circumstances, and that misinterpretation of canine behavioral signals may be a problem.

If a dog is provoked, even unintentionally, inappropriate, undesirable, and dangerous behavior is reinforced. Although available data are inadequate to address this issue, it is possible that this is exactly the circumstance under which most dog bites (ie, those to male children, by owned and known dogs) occur. If we persist in blaming breeds, the valid issues of distinguishing between appropriate and inappropriate behaviors and dangerous versus nondangerous breed- or species-typical behaviors will be ignored.

Data from dogs for which a behavioral diagnosis has been made—A comparison between dog breeds seen at the **Veterinary Hospital of the University of Pennsylvania (VHUP)** Behavior Clinic and breeds seen as part of the general VHUP population revealed only 4 breeds that were overrepresented in the behavior clinic between 1992 and 1996[71]: Chow Chows (**log-likelihood ratio** χ^2 [G_{adj}], 4.830; $P < 0.05$ [1 dog was responsible for the statistical difference]), American Cocker Spaniels (G_{adj}, 8.739; $P < 0.05$), Dalmations (G_{adj}, 6.537; $P < 0.05$), and English Springer Spaniels (G_{adj}, 76.315; $P < 0.05$). This distribution may not represent those breeds seen a decade ago. In 1993, the 5 top breeds registered by the AKC were, in order, Labrador Retriever, Rottweiler, German Shepherd Dog, Cocker Spaniel, and Golden Retriever. Careful questioning of clients reveals another factor that has been ignored in discussions of breed prevalence: English Springer Spaniel owners seeking help at the VHUP appear to do so readily, because they know that some lines of English Springer Spaniels bred for conformation in the United States have problems with aggression.[71,92,e,f] Purebreds are significantly overrepresented when compared with mixed breeds for dominance aggression only.[68]

Breeds for which at least 10 individuals received a diagnosis of dominance aggression at the VHUP between 1996 and 1998 included mixed breed (n = 38), English Springer Spaniel (18), Cocker Spaniel (18), Labrador Retriever (13), Golden Retriever (12), Dalmatian (12), Rottweiler (19), and German Shepherd Dog (10). Dominance aggression was diagnosed for < 10 dogs of 49 other breeds. The breeds represented by 10 or more individuals include 4 of the 5 most commonly registered AKC breeds in 1993. If patterns of popularity interact with social maturation, clustering for breed associations and problem behaviors should be expected.

Issues of Fact and Myth

An extensive review of the literature concerning dog bite injuries reveals that the only robust data are those supporting the following conclusions: there is a substantially greater injury and fatality rate for children when compared with adults; male children are injured and killed more often than female children, indicating that human behavior may be a major factor; and there is a preponderance of owned family dogs involved in bites and fatalities.

Breeds presently most involved in dog bites include mixed breeds, German Shepherd Dogs, German Shepherd Dog crossbreds, pit bull-type dogs, and pit-bull type crossbreds[23,50,56]; the latter 4 breeds are most often involved in fatalities.[50,56] A careful reading of the literature supports 3 conclusions regarding breed:

the breeds most represented in dog bite data vary over time (which may indicate changes in breed preference by owners rather than changes in breed-specific aggressive tendencies per se); breeds most often represented in published data are popular ones, and no 1 breed may be represented in bite data in proportion to its actual population (good data on population sizes of each breed and mixed breeds relative to human victim populations studied are not available but are essential if legitimate statements about breed overrepresentation are to be made); and "pit bull" is often applied, without biological basis, to a range of dog types, regardless of the underlying genetic stock[50,93] (this problem may be magnified in communities that have experienced a previously publicized pit bull-type dog attack).

There is no question that dog bites are a problem, but even after an extensive review of the data, we know little about the actual behaviors of dogs involved in bites, regardless of breed. If we want to know why dogs bite and minimize morbidity and mortality, the following goals must be met.

First, the prevalence of dog breeds and ages, sex, and reproductive status within these breeds must be known for the population of bites to be investigated. Any discussion of breed-specific aggressive propensities must be critically reviewed. Caution is urged regarding any generalization about inappropriate breed-specific behaviors. Selection for specific behaviors should be viewed as a risk assessment analysis: breeds that have been selected for 1 or a few specific behaviors may be more at risk for developing undesirable variations on those behaviors. This does not mean that breeds for which protective behaviors are selected are more aggressive than breeds for which this selection pressure is absent. Any dog, regardless of breed, can exhibit inappropriate behaviors. It does mean that certain breeds may be more at risk of having a disproportionate number of dogs that exhibit inappropriate out-of-context protective aggression. Furthermore, dogs selectively bred for tenacity and jaw strength (eg, American Pit Bull Terriers, Rottweilers, Rhodesian Ridgebacks) will exhibit these same characteristics when they respond with inappropriate behaviors. Coupling inappropriate behaviors and physical strength (eg, large dogs, heavy musculature) results in infliction of severe damage on a first strike.

Second, canine and human behaviors that limit or increase exposure need to be defined and quantified. Any dog breeder, owner, or veterinarian who accepts displays of inappropriate aggression or who believes that such aggression is normal for their breed (or not dangerous because the dog is small) is contributing to the problem.

Third, it is important to know which dogs bite and whom they bite.[60] Behavioral profiles of dogs that do and do not bite and of their owners' behaviors must be developed. These studies will help determine whether dog bites are associated with a behavioral diagnosis of aggression and the extent to which certain human behaviors foster aggression.

Fourth, situations in which bites occur need to be thoroughly, rigorously, and consistently reviewed and documented by healthcare personnel, using validated assessment tools.[71] The appropriateness of the situation, the extent to which a bite is provoked, the nature of the provocation, and the behavioral tendencies of the dog involved (including whether the dog has received a behavioral diagnosis involving aggression) must be evaluated. This aspect is particularly important given the association between dog abuse and child abuse and the extent to which violent behaviors are learned and practiced.[94-97]

Achieving these goals will require a tremendous amount of work, and anyone who is serious about dogs should have a vested interest in seeing projects that address these issues get funded, accomplished, and published. In the absence of actual numerical demographic data, conclusions and legislation based on breed are being drawn from incomplete and skewed data and are premature.[16-18] Our analysis of the data also suggests that initiatives[81,98-101] that teach children how to react appropriately in specific situations involving dogs may only be addressing exceptional situations. If this is true, such initiatives may have limited benefit in reducing dog bite-related injuries and fatalities.

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[a]Courtesy of the Insurance Information Institute, New York, 1994.
[b]Courtesy of State Farm General Insurance Co, Bloomington, Ill, 1995.
[c]Courtesy of the Insurance Information Institute, New York, 1996.
[d]Overall KL, School of Veterinary Medicine, University of Pennsylvania, Philadelphia, Pa: Unpublished data, 1993–1998.
[e]Reisner IR. *Neurophysiologic, familial, and environmental correlates of canine dominance-related aggression*. PhD dissertation, Department of Physiology and Behavior, Cornell University, Ithaca, NY, 1996.
[f]Overall KL, School of Veterinary Medicine, University of Pennsylvania, Philadelphia, Pa: Unpublished data, 1997–1998.
[g]Overall KL, Acland G, School of Veterinary Medicine, University of Pennsylvania, Philadelphia, Pa: Unpublished data, 1991–1998.

References

1. Matthews JR, Lattal KA. A behavioral analysis of dog bites to children. *Dev Behav Pediatr* 1994;15:44–52.
2. Sacks JJ, Kresnow M, Houston B. Dog bites: how big a problem? *Injury Prev* 1996;2:52–54.
3. Weiss HB, Friedman DI, Coben JH. Incidence of dog bite injuries treated in emergency departments. *JAMA* 1998;279:51–53.
4. Gershman KA, Sacks JJ, Wright JC. Which dogs bite? A case-control study of risk factors. *Pediatrics* 1994;93:913–917.
5. Brogan TV, Bratton SL, Dowd MD, et al. Severe dog bites in children. *Pediatrics* 1995;96:947–950.
6. Parrish HM, Clack FB, Brobst D, et al. Epidemiology of dog bites. *Public Health Rep* 1959;10:891–903.
7. Quinlan KP, Sacks JJ. Hospitalizations for dog bite injuries. *JAMA* 1999;281:232–233.
8. Daristotle L. Conference proposed to explore dog-bite issues. *J Am Vet Med Assoc* 1994;204:1853.
9. Berzon DR, DeHoff JB. Medical costs and other aspects of dog bites in Baltimore. *Pub Health Rep* 1974;90:377–381.
10. Moore RM, Zehmer RB, Moulthrop JL, et al. Surveillance of animal-bite cases in the United States, 1971–1972. *Arch Environ Health* 1977;32:267–270.
11. Houpt KA, Honig SU, Reisner IR. Breaking the human-companion animal bond. *J Am Vet Med Assoc* 1996;208:1653–1659.
12. Miller DD, Staats SR, Partlo C, et al. Factors associated with the decision to surrender a pet to an animal shelter. *J Am Vet Med Assoc* 1996;209:738–742.
13. Patronek GJ, Beck AM, Glickman LT. Dynamics of dog and cat populations in a community. *J Am Vet Med Assoc* 1997;210:637–642.
14. Rowan AN. Companion animal demographics and unwanted animals in the United States. *Anthrozöos* 1992;5:222–225.

15. Scarlett JM, Salman MD, New JG Jr, et al. Reasons for relinquishment of companion animals in US animal shelters: selected health and personal issues. *J Appl Anim Welfare Sci* 1999;2:41–57.

16. Reinhardt T. Thinks veterinarians should unite against dangerous dog breeds (lett). *J Am Vet Med Assoc* 1998;212:489.

17. Singer C, Sheffield MJ, Lake T. More on dangerous dog breeds (lett). *J Am Vet Med Assoc* 1998;212:1186–1187.

18. Clifford DH, Green KA, Scott JP. *Dos and don'ts concerning vicious dogs*. Chicago: AVMA Professional Liability Insurance Trust, 1993.

19. American Veterinary Medical Association. *US pet ownership and demographics sourcebook*. Schaumburg, Ill: AVMA Center for Information Management, 1997;1–105.

20. Wise JK, Yang JJ. Dog and cat ownership. 1991–1998. *J Am Vet Med Assoc* 1994;204:1166–1167.

21. Rice RG, Starbuck GW, Reed G. Accidental injuries to children. *N Engl J Med* 1956;255:1212–1219.

22. Winkler WG. Human deaths induced by dog bites, United States, 1974–1975. Public Health Rep 1977;92:425–429.

23. Kizer KW. Epidemiologic and clinical aspects of animal bite injuries. *JACEP* 1979;8:134–141.

24. Morton C. Dog bites in Norfolk, Va. *Health Serv Rep* 1973;88:59–64.

25. Harris D, Imperato PJ, Oken B. Dog bites—an unrecognized epidemic. *Bull NY Acad Med* 1974;50:981–1000.

26. Scarella J. Management of bites: early definitive repair of bite wounds. *Ohio State Med J* 1969;65:25–31.

27. Brobst D, Parrish HM, Clack FB. The animal bite problem in selected areas of the United States. *Vet Med* 1959;54:251–256.

28. Carithers HA. Mammalian bites of children. *Am J Dis Child* 1958;95:150–156.

29. Berzon DR, Farber RE, Gordon J, et al. Animal bites in a large city—a report on Baltimore, Maryland. *Am J Public Health* 1972;62:422–426.

30. Berzon DR. The animal bite epidemic in Baltimore, Maryland: review and update. *Am J Public Health* 1978;68:593–595.

31. Hanna TL, Selby LA. Characteristics of the human and pet populations in animal bite incidents recorded at two Air Force bases. *Public Health Rep* 1981;96:580–584.

32. Beck AM. *The ecology of stray dogs: a study of free-ranging urban animals*. Baltimore: York Press, 1973.

33. Sosin DM, Sacks JJ, Rattin RW. Causes of non-fatal injuries in the United States, 1986. *Accid Anal Prev* 1992;24:685–687.

34. Szpakowski NM, Bonnett BN, Martin SW. An epidemiological investigation into the reported incidents of dog biting in the City of Guelph. *Can Vet J* 1989;30:937–942.

35. Podberscek AL, Blackshaw JK. Dog attacks on children: report from two major city hospitals. *Aust Vet J* 1991;68:248–149.

36. Anonymous. Dog bites in Adelaide Australia. *Anthrozöos* 1993;6:52–53.

37. Anonymous. News & reports—public health: survey of dog bites reveals common causes. *Vet Rec* 1991;129:539.

38. Beck AM, Loring H, Lockwood R. The ecology of dog bite injury in St Louis, Missouri. *Public Health Rep* 1975;90:262–267.

39. Elliot DL, Tolle SW, Goldberg C, et al. Pet-associated illness. *N Engl J Med* 1985;313:985–995.

40. Callaham M. Dog bite wounds. *JAMA* 1980;244: 2327–2328.

41. Marcy SM. Infections due to dog and cat bites. *Pediatr Infect Dis J* 1982;1:351–356.

42. August JR. Dog and cat bites. *J Am Vet Med Assoc* 1988;193: 1394–1398.

43. Aghababian RV, Conte JE. Mammalian bite wounds. *Ann Emerg Med* 1980;9:79–83.

44. Douglas LG. Bite wounds. *Am Fam Physician* 1975;11: 93–99.

45. Sokol AB, Houser RG. Dog bites: prevention and treatment. *Clin Pediatr (Phila)* 1971;10:336–338.

46. Avner JR, Baker MD. Dog bites in urban children. *Pediatrics* 1991;88:55–57.

47. Lauer EA, White WC, Lauer BA. Dog bites: a neglected problem in accident prevention. *Am J Dis Child* 1982;136:202–204.

48. Wright JC. Severe attacks by dogs: characteristics of the dogs, the victims, and the attack settings. *Public Health Rep* 1985;100:55–61.

49. Fleisher GR, Boenning DA. The treatment of animal bites in humans. *Compend Contin Educ Pract Vet* 1981;3:366–373.

50. Sacks JL, Sattin RW, Bonzo SE. Dog bite-related fatalities from 1979 through 1988. *JAMA* 1989;262:1489–1492.

51. Beck AM, Jones BA. Unreported dog bites in children. *Public Health Rep* 1985;100:315–321.

52. Sokol RR, Rolf FJ. *Biometry*. San Francisco: WH Freeman and Co, 1981;690, 847–848.

53. Borchelt PL, Lockwood R, Beck AM, et al. Attacks by packs of dogs involving predation on human beings. *Public Health Rep* 1983;98:59–68.

54. Thomas PR, Buntine JA. Man's best friend?: a review of the Austin Hospital's experience with dog bites. *Med J Aust* 1987;147:536–540.

55. Daniels TJ. A study of dog bites on the Navajo reservation. *Public Health Rep* 1986;101:50–59.

56. Pinckney LE, Kennedy LA. Traumatic deaths from dog attacks in the United States. *Pediatrics* 1982;69:193–196.

57. Wright JC. Reported dog bites: are owned and stray dogs different? *Anthrozöos* 1990;4:113–119.

58. Castelein C, Klouda J, Hirsch H. The bite case scenario—it is not what you think. In: *WFHS newsletter*. Madison, Wis: Wisconsin Humane Society, 1996;Sep:12–14.

59. Chun Y-T, Berkelhamer JE, Herold TE. Dog bites in children less than 4 years old. *Pediatrics* 1982;69:119–120.

60. Langley J. The incidence of dog bites in New Zealand. *N Z Med J* 1992;105:33–35.

61. Rubin HD, Beck AM. Ecological behavior of free-ranging urban pet dogs. *Appl Anim Ethol* 1982;8:161–168.

62. Jones BA, Beck AM. Unreported dog bites and attitudes towards dogs. In: Anderson RK, Hart BL, Hart LA, eds. *The pet connection: its influence on our health and quality of life*. Minneapolis: University of Minnesota Press, 1984;355–363.

63. Moss SP, Wright JC. The effects of dog ownership on judgements of dog bite likelihood. *Anthrozöos* 1987;1:95–99.

64. Smith WJ. Message, meaning, and context in ethology. *Am Nat* 1965;99:405–409.

65. Smith WJ. *The behavior of communicating: an ethological approach*. Cambridge, Mass: Harvard University Press, 1977.

66. Wiseman NE, Chochinov H, Fraser V. Major dog attack injuries in children. *J Pediatr Surg* 1983;18:533–536.

67. Hopkins SG, Schubert TA, Hart BL. Castration of adult male dogs: effects on roaming, aggression, urine marking, and mounting. *J Am Vet Med Assoc* 1976;168:1108–1110.

68. Borchelt PL. Aggressive behavior of dogs kept as companion animals: classification and influence of sex, reproductive status and breed. *Appl Anim Ethol* 1983;10:45–61.

69. Wright JC, Nesselrote MS. Classification of behavior problems in dogs: distribution of age, breed, sex, and reproductive status. *Appl Anim Behav Sci* 1987;19:169–178.

70. Voith VL. Profile of 100 animal behavior cases. *Mod Vet Pract* 1981;62:394–396.

71. Overall KL. *Clinical behavioral medicine for small animals*. St Louis: Mosby Year Book Inc, 1997.

72. Borchelt PL, Voith VL. Dominance aggression in dogs. *Compend Contin Educ Pract Vet* 1986;8:36–44.

73. Overall KL. Sex and aggression. *Canine Pract* 1995;20(2):16–18.

74. Overall KL, Beebe AD. Dominance aggression in young female dogs: what does this suggest about the heterogeneity of the disorder, in *Proceedings*. 1st Int Confer Vet Behav Med 1997;1: 58–63.

75. Clutton-Brock J. *A natural history of domesticated animals*. Cambridge, Mass: Cambridge University Press, 1987.

76. Serpell JA. The influence of inheritance and environment on canine behavior—myth and fact. *J Small Anim Pract* 1987;28:949–956.

77. Wayne RK. Molecular evolution of the dog family. *Trends Genet* 1993;9:216–224.

78. Anonymous. Aggressive behavior revisited. *J Am Vet Med Assoc* 1999;214:1449–1450.

79. Spiegel I. *The BARK dog bite prevention program workbook*. Washington, DC: HSUS, 1987.

80. White N. *Why do dogs do that?* New York: Scholastic Inc, 1995.

81. Agan EM, Burnette JE. *Fido! Friend or foe? Activity book*. Bloomington, Ill: State Farm Fire and Casualty Company, 1997.

82. Willis MB. *Genetics of the dog*. New York: Howell Book House, 1989.

83. Burns M, Fraser MN. *Genetics of the dog: the basis of successful breeding*. Edinburgh, Scotland: Oliver and Boyd, 1966.

84. Van der Velden NA, De Weerdt CJ, Brooymans-Schallenberg JHC, et al. An abnormal behavioural trait in Bernese Mountain Dogs (Berner Seennenhund): a preliminary report. *Tijdschrift Diergeneesk* 1976;101:403–407.

85. Murphree OD. Inheritance of human aversion and inactivity in two strains of pointer dogs. *Biol Psychiatry* 1973;7:23–29.

86. Murphree OD, Angel C, DeLuca DC, et al. Longitudinal studies of genetically nervous dogs. *Biol Psychiatry* 1977;12:573–576.

87. MacKenzie SA, Oltenacu EAB, Leighton E. Heritability estimates for temperament scores in German Shepherd Dogs and its genetic correlate with hip dysplasia. *Behav Genet* 1985;14:475–482.

88. MacKenzie SA, Otenacu E, Houpt KA. Canine behavioral genetics—a review. *Appl Anim Behav Sci* 1986;15:365–392.

89. Reinhard DW. Aggressive behavior associated with hypothyroidism. *Canine Pract* 1978;5(6):69–70.

90. Reisner IR. The pathophysiologic basis of behavior problems. *Vet Clin North Am* 1991;21:207–224.

91. Immelman K, Beer C. *A dictionary of ethology*. Cambridge, Mass: Harvard University Press, 1989.

92. Reisner IR, Erb HN, Houpt KA. Risk factors for behavior-related euthanasia among dominant-aggressive dogs: 110 cases (1989–1992). *J Am Vet Med Assoc* 1994;205:855–863.

93. Lockwood R, Rindy K. Are "Pit Bulls" different? An analysis of the Pit Bull Terrier controversy. *Anthrozöos* 1987;1:2–8.

94. Felthous AR, Kellert SR. Childhood cruelty to animals and later aggression against people: a review. *Am J Psychol* 1987;144:710–717.

95. Tapia F. Children who are cruel to animals. *Child Psych Hum Dev* 1971;2:70–77.

96. Rigdon JD, Tapia F. Children who are cruel to animals—a follow-up study. *J Operational Psych* 1997;8:27–36.

97. Olson PN. *Recognizing and reporting animal abuse: a veterinarian's guide*. Englewood, Colo: American Humane Association, 1998.

98. Riegger MH, Guntzelman J. Prevention and amelioration of stress and consequences of interaction between children and dogs. *J Am Vet Med Assoc* 1990;196:1781–1785.

99. Cornwell MJ. *Animal safety is fun: be a tree, act like a log* (videotape). Columbus, Ohio: Glencoe Animal Hospital, 1992.

100. Spiegel IA. The BARK program: the evaluation of an elementary school-based dog bite prevention program. *Public Health Rep* 2001;in review.

101. Connelly KP. Advising families about pets. *Contemp Pediatr* 1997;Feb:71–86.