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Systematic review of dog bite prevention strategies

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ABSTRACT

Background The prevention of dog bites is an increasingly important public health topic, as the incidence of serious injury continues to rise.

Objectives To evaluate the effectiveness of interventions to prevent dog bites and aggression.

Methods Online databases were searched (PubMed, Cochrane Library, Embase and Google Scholar), using the search terms: *dog/s, canine, canis, kuri, bite/s, bitten, aggression, attack, death, fatal, mortality, injury/ies, prevention, intervention*, for studies between 1960 and 2021. All study designs were considered. Outcomes of interest were the incidence of dog bites or dog aggression. Non-English studies, and those without full-text access were excluded.

Results Forty-three studies met the review criteria, including 15 observational and 27 interventional studies. Fifteen studies investigating dog-control legislation, including leash laws, stray dog control and infringements indicated this can reduce dog bite rates. Breed-specific legislation had less of an effect. Six studies investigating sterilisation, showed while this may reduce dog bites through a reduction in the dog population, the effect on dog aggression was unclear. An alcohol reduction programme showed a significant reduction in dog bite rates in one study. Seven studies assessing educational approaches found that intensive adult-directed education may be effective, with one study showing child-directed education was not effective. Eight studies on dog training (two police-dog related), and six evaluating dog medication or diet were generally low quality and inconclusive.

Conclusions Multiple strategies including effective engagement with indigenous communities and organisations will be required to reduce dog-bites and other incidents involving dog aggression. This review provides some evidence that legislated dog control strategies reduce dog bite rates. Available evidence suggests greater restrictions should be made for all dogs, rather than based on breed alone. Due to a burden of child injury, protection of children should be a focus of legislation and further investigations. Prevention strategies in children require redirection away from a focus on child-directed education and future research should investigate the effectiveness of engineering barriers and reporting strategies.

INTRODUCTION

The prevention of dog bites and other dog-related injuries is an increasingly important public health concern globally and in New Zealand (NZ), as the incidence of these events continues to rise, including during the current COVID-19 pandemic.[1–3] As with other unintentional injuries, dog bites are not 'accidents', but preventable traumatic injuries. Annually in NZ around 10 951 people present to health professionals for a dog bite injury (242 per 100 000 people, 95% CI 240 to 245).[1] Unacceptably high rates disproportionately affect our most vulnerable members of society: Māori (NZ's Indigenous population), and those from low-socioeconomic areas.[1] The prevalence of dog bites is also much greater as many cases do not seek medical attention.[4 5] A 2015 UK cross-sectional survey reported an estimated annual dog bite incidence 1870 dog bites per 100 000 people (95% CI 1100 to 3180), with a quarter of respondents indicating they had been bitten by a dog at least once in their lifetime.[5]

Children and adults are equally as likely to sustain a dog bite that requires medical attention; however, children are more likely to suffer more serious injuries to the face, head or neck region, and have greater rates of hospitalisation than adults.[6] Injuries to the hands are more common in adults and often occur when a person intervenes in a dog fight.[4] Hand injuries can be serious with the potential for a significant loss of function and the sequelae associated with this.[7]

Substantial psychological consequences can follow an incident of dog aggression, with or without physical injury (including non-bite injuries), with several studies highlighting this as a significant traumatic event, with the potential for economic and social costs as well as the development of post-traumatic stress disorder.[8–10] An NZ study of adult dog bite victims found that 87% of respondents described their injury as moderate to severe, with 72% describing psychological effects from the injury.[11]

Risk factors for dog bites include factors involving the dog, the physical environment, the owner or the victim, and occur in a variety of circumstances, within both private and public spaces, and urban and rural areas.[11–13] There is a lack of robust evidence regarding dog factors such as the influence of breed or sex on dog aggression, due to a lack of appropriate studies with control groups, already existing restrictions on certain breeds and inaccuracy of breed identification.[14–16] One recent Finnish study of pure-bred dogs showed differences in owner-reported aggression scores between breeds with Rough Collies, Miniature Poodles and Miniature Schnauzers being most aggressive. This is not reflected in published studies of dog bites or fatalities which depend in part on the proportion of popular breeds owned including a predominance of mixed breeds.[11 17]

Dogs that bite are most commonly owned by a neighbour, friend or relative (23%–83%), or an unknown person (20%–60%), and less commonly by the victim or family they live with (5%–30%).[11–13 18–20] An NZ survey in 2002 of 535 adults who presented for medical attention following a dog bite, found that over one-third (36%) occurred in public places, 21% in the victims' home and 43% in other private property; with 56% occurring in urban areas.[11] Of note, 71% of dog-bite incidents were considered unprovoked. No NZ published data has investigated the geographical location of dog bite incidents among children.

Existing dog-bite interventions can be broadly categorised into education, engineering and enforcement, in line with the WHO's framework for injury prevention,[21] and will likely require input from multiple disciplines. Dog bite prevention in NZ has primarily focused on the 1996 Dog Control Act, which includes a set of national guidelines, directing predominantly locally governed legislation, and focusing on dog control in public spaces.[22] The Act focuses on dog access legislation (leash laws), requirements for registration and microchipping, breed banning and restrictions for dogs considered to be dangerous based on either breed or behaviour. Restrictions for dangerous dogs can include infringements, disqualification of owners, sterilisation (neutering, spaying or chemical) with the perception that it reduces dog aggression, the use of muzzles and leashes in public, improved fencing, separate visitor access, a ban on re-homing from a shelter, signage on private property, owner-licensing, wearing of collars identifying them as high risk, or euthanasia.

Breed specific legislation (BSL) regarding restrictions for owners and dogs based on breed alone has been criticised as being ineffective and unfair for dogs and owners.[23 24] The evidence for and against sterilisation has also been discussed.[25–27]

Improved reporting policies are likely to be an effective strategy, given a large number of bites are not reported to animal management services,[11 13 28 29] and strong evidence suggesting that dogs who bite often have a history of aggression.[11–13 30 31]

Education has traditionally been a focus of dog bite prevention, and can be targeted toward dog-owners, children, parents, the general public or the dogs themselves (dog training). Messages vary broadly but are commonly based on the assumption that dog bites can be prevented by correctly interpreting a dog's behaviour or not provoking a bite with an incorrect approach to a dog.[32] Other educational messages and/or policies focus on the importance of puppy sourcing from appropriate breeders, early socialisation (the process of introducing a puppy to new experiences),[33] or on the importance of exercising a dog, to prevent aggression and other behavioural issues.[34] Dog training programmes also exist in NZ and are at times accompanied by the introduction of medication or a change in diet in dogs with behavioural issues including dog aggression. There are currently no standardised requirements for dog-training or the education of dog owners, children or parents in NZ.

In the home environment, engineering solutions such as baby gates, adequate fencing height, gate locks or separate dog areas are an emerging concept[35] that have not been strongly promoted for the prevention of dog bites, despite their promotion in other areas of child unintentional injury.[36] Neither is the use of home-care visits by well-child providers, which is proven to be an effective strategy for other unintentional trauma in children.[37]

Despite several published review articles that discuss dog bite prevention,[32 35 38 39] no systematic reviews have evaluated the effectiveness of prevention strategies to reduce the incidence of dog bites or aggression. Therefore, the aim of this systematic review is to address this gap.

METHODS

The methods of this systematic review were guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[40] The methods for this review were developed after consultation with clinical and Indigenous leaders with a wide range of experience in the field.

Literature search

Four online databases were searched (PubMed, Cochrane Library, Embase and Google Scholar), using the search terms: "dog OR dogs OR canine OR canis OR kuri" AND "bite OR bites OR bitten OR aggression OR attack OR death OR fatal OR mortality OR injury" AND "prevention OR intervention", for studies published between 1 January 1960 and 10 March 2021. Reference lists of located studies were reviewed for additional relevant studies, and several experts in the field were contacted for recommendations of further studies. The same method was applied to searches of the grey literature.

All study designs were included that investigated a dog-bite prevention strategy, including those that had a broader dog-related focus such as rabies prevention. There were no restrictions on dog-bite prevention interventions or dog environments (ie, free-roaming/stray, contained dogs). Outcomes of interest were the incidence of dog bites or dog aggression, or animal bites if a large proportion were caused by dogs. Non-English studies, and those without full-text access were excluded.

Screening and inclusion

The title and abstract of located studies were screened by a single researcher (ACL) to identify those for potential inclusion. Identified studies were evaluated in more detail by two researchers (ACL, ND-S), and exclusion criteria applied, with any discrepancies discussed and a collaborative decision made.

Analysis

Information from the included studies was extracted and summarised, including authors, title, year of publication, country, study aims, design and length, participant demographics, description of the intervention, relevant outcomes measured, and key results.

The quality of included studies was critiqued by two researchers (ACL, ND-S) using the Critical Appraisal Skills Programme method of evaluating intervention studies.[41] This included an appraisal of validity, reliability and concise reporting of results. Based on an analysis of strengths and limitations, the authors collaboratively assigned a study quality category (high, moderate or low), in line with current Cochrane recommendations.[42]

A meta-analysis was not possible due to the heterogeneity of study designs and outcomes.

RESULTS

There were 20 385 studies identified from the search criteria. Following a review of the title and abstract, the majority of studies (n=19 890) did not meet the inclusion criteria (figure 1). Many of these excluded articles did not study a specific intervention, often describing epidemiology only, or lacked outcomes of interest, including investigating rabies vaccination rates only. Four hundred and sixty-eight were further excluded, with 138 duplicates, 32 non-English, 28 with no full-text access and 270

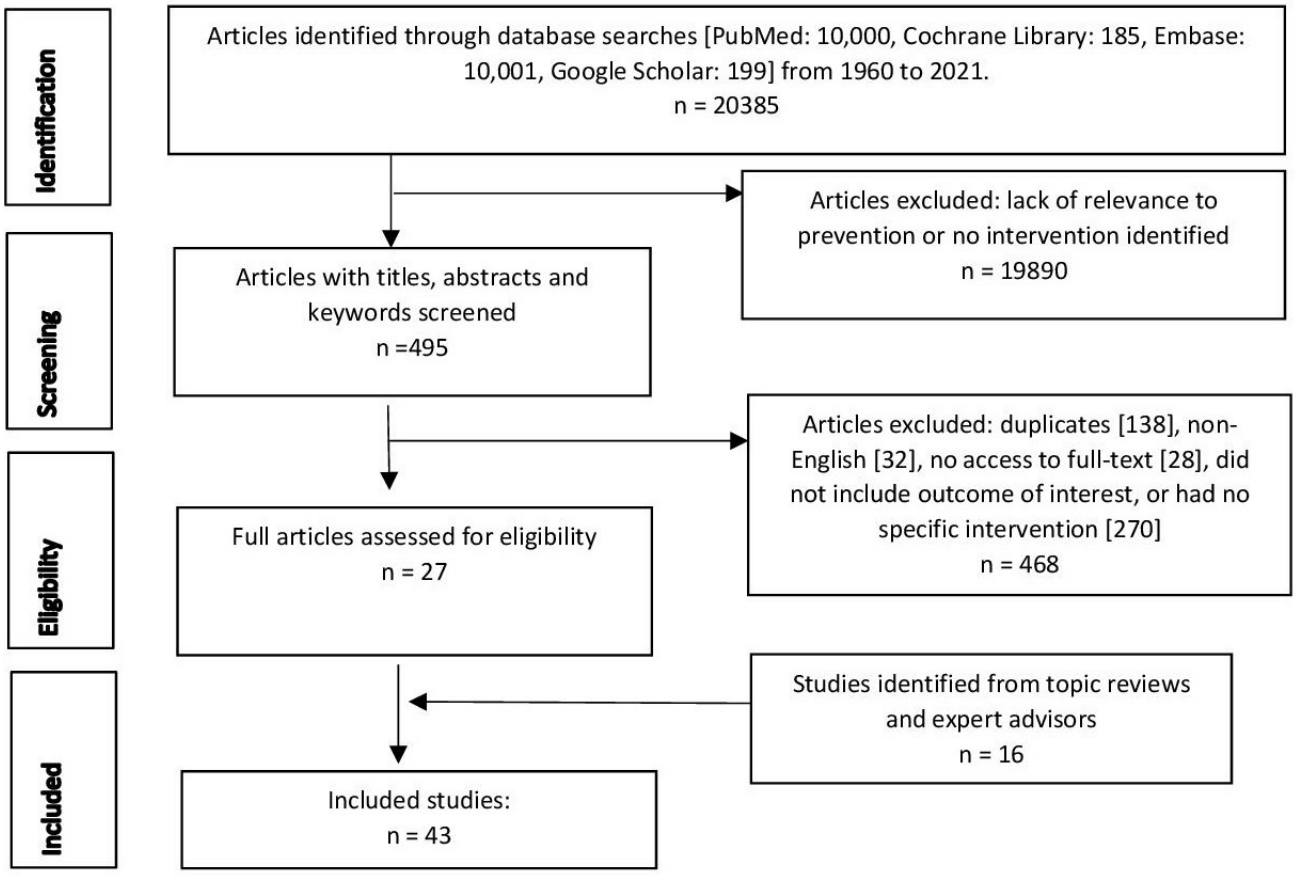

Figure 1 Flow chart describing the process of inclusion and exclusion of studies.

that also did not investigate a specific intervention, or relevant outcomes.

Among the included studies, most were conducted in the Northern Hemisphere, with only three from Australia[43–45] and one from NZ[46] (online supplemental table 1). Study designs included 15 observational cohort studies[46–59] and 27 interventional studies, 18 of which were predesign and postdesign with no control group,[43 45 60–75] five non-randomised studies with a control group,[44 76–79] three cross-over studies,[56 61 80] and one randomised controlled trial (RCT).[81] One study had inadequate information given to determine the study design.[65] Two studies were located from the grey literature.[50 69]

Dog bites were measured in 27 studies, including four studies that reported animal bites (predominantly dog bites),[70 75 77 82] a study reporting all dog attacks (including being rushed at by a dog),[44] a study reporting bite ratio, a measure used by the police force[54] and a study measuring bite attempts.[76] Dog bite incidence as a proportion of the population was calculated in 14 studies.[43–47 50 51 57 62 71 77 79 83 84] Dog bites were measured from a variety of data sources including hospital admissions, emergency department (ED) or primary care presentations, household surveys, or reports to animal management or public health services. Dog aggression was measured in 15 studies.[55 56 59–61 63 66–68 72 73 78 80 81 85]

Interventions identified focused on six main areas: dog-control legislation, sterilisation, alcohol reduction, education of people, dog training programmes, and medication or diet (online supplemental table 1). Fifteen studies investigated the effect of dog-control legislation, with a focus on either general dog control, or breed-specific strategies.[44–52 57 65 74 75 83 84] Six studies investigated sterilisation.[58 59 63 64 81 82] One study investigated a community alcohol reduction programme.[43] Seven studies focused on education; with five on public education,[69–71 77 79] and one each directed at children,[62] and dog owners.[78] Eight studies investigated predominantly dog-training,[53–55 60 72 73 76 85] with a further six studies investigating predominantly medication or diet.[56 61 66–68 80] Some studies investigated multiple interventions. In particular, legislation changes were often accompanied by education,[57 74 75 75 84] and studies on dog training methods often included medication as part of the strategy.[55 60 72] Studies were clustered by the predominant intervention. Five studies specifically mentioned implementing interventions from a One Health framework.[45 57 58 74 77]

Legislation

Eleven studies[44–47 50 52 57 65 74 75 84] investigating the effect of general dog control strategies, were considered moderate to high quality in all but three studies, providing some evidence that this decreases the rates of dog bites (online supplemental table 1).

A study of moderate quality conducted in Calgary, Alberta, showed a substantial (80%) reduction in the incidence of dog bites reported to animal management over a 30-year period from 99 per 100 000 people in 1984 to 20 per 100 000 in 2014.[50] This time period included a change in legislation that focused on strict leash laws (including leash-length, and walking on the correct side of a path), increased ticketing, immediate return of stray dogs to owners, sterilisation of dogs that injure a person, reduced registration rates, restrictions including muzzling/caging requirements, and adjunctive public education about the laws.[50 86]

This was supported by a high-quality study by Clarke and Fraser demonstrating that ticketing for animal control violations and requiring licensing for domestic dogs in areas of Canada was associated with lower incidence of dog bites reported to animal management (p<0.01).[84] However, the study found no association between higher budget or staffing rates, or public education, with reported dog bite incidence. An additional two small low-quality studies of intensive community dog control programmes in small indigenous communities in Canada, showed reduced dog bite rates from 6 to 10 per year to 1–2 per year.[65 74]

Two further similar small low to moderate quality studies conducted with high levels of community engagement within Indigenous communities in rural Australia provided free animal care and introduced dog control strategies.[44 45] The study by Riley *et al* with a focus on animal welfare showed no change in dog bite presentations to healthcare clinics.[45] The study by Ma *et al* focusing on dog control measures, including euthanasia or re-homing of dogs to other areas, had a small reduction in annual Council reported dog attacks (defined as 'rushes at, attacks, bites, harasses or chases any person or animal, whether or not injury has occurred') from 2.5 to 1.5 attacks per 1000 people in the preintervention year to <1 attacks per 1000 people postintervention (p=0.035), with a control community demonstrating an increase over a similar time-period from 4 to 8 attacks per 1000 people.[44]

In Spain, the introduction of dog control legislation in a moderate quality study of a rural/urban region resulted in a 38% significant reduction in dog bite hospitalisations over an 11-year period, from 1.80 per 100 000 (95% CI 1.47 to 2.13) prior to the legislation change, to 1.11 per 100 000 (95% CI 0.87 to 1.36) after it was introduced.[51] Legislation included registrations, restrictions on 'dangerous' dogs by both breed and behaviour (such as a requirement to have a special licence, a psychological aptitude certificate and absence of criminal record of the owner), leash laws, muzzles in public and microchips.

The introduction of the NZ Dog Control Act in 1996, appeared to temporarily reduce dog bite hospitalisations from 7.5 per 100 000 people in 1996 to 5.5 per 100 000 in 1999 in a moderate quality study; however, 2 years later rates increased to 6.8 per 100 000.[46]

A historical study from Guam in the 1960s showed a 75% reduction in animal encounters (predominantly dog bites) from 995 in 1967 to 252 in 1969, after the mass euthanasia of >15 000 stray dogs in an effort to eradicate rabies.[75] A study in Sri Lanka investigated a change from the euthanasia of stray dogs to a more comprehensive 'One-Health' rabies-prevention intervention.[57] This involved the development of dog managed zones in public areas, targeted sterilisation, and the education of children and adults on bite prevention and rabies awareness.[57] This moderate quality study showed a 34% non-significant decrease in the number of dog bites disclosed in household surveys over a 4-year period from 0.216 per person (n=23/1063) in 2007 to 0.0143 per person (n=8/559) in 2010 (p=0.31). The authors also noted a 9% increase in the number of people presenting to the hospital for bites from 131 in 2006 to 160 in 2011, which they postulated could have been due to an increase in reporting, which they were promoting.[57]

Only one study did not show a difference when dog control legislation was introduced.[52] The moderate quality study from Scotland, compared a 3-month period the year dog control legislation was introduced, to a similar period 3 years later, showing number of people with a dog bite presenting to an ED was unchanged at 134.[52] However, the 3-month data collection periods used were likely, not long enough to adequately investigate number of bites.[52]

The five moderate-high quality studies investigating BSL suggest there is possibly a small effect on dog bite rates.[47–49 83 84]

Raghavan *et al*[83] and Clarke and Fraser[84] both investigated dog control legislation by comparing the incidence of dog bites in Canadian jurisdictions with and without BSL policies in place. Clarke and Fraser described no significant difference in rates of dog bites reported to animal management between areas with (170 per 100 000) and areas without BSL (180 per 100 000).[84] However, Raghavan *et al* showed that areas with BSL had 19% significantly less dog bite hospitalisations (2.92 per 100 000) than areas without (3.60 per 100 000, p<0.002). Contradicting this however, there was only a 9.6% non-significant reduction in the rate over time in areas with BSL following the introduction of the legislation.[83]

An Italian study of moderate quality showed an 18% reduction in the number of dog bites from various sources after BSL was introduced, which was stable in the long term (210 pre-BSL, 172 in short term, 174 in long term).[49] Of note, BSL was removed in Italy in 2009, 5 years after the completion of this study. A moderate quality study in Denmark showed a 15% non-significant reduction in the average 6 monthly number of dog bites presenting to EDs over 13 years from 103 pre-BSL (95% CI 98 to 108) to 87 post-BSL (95% CI 82 to 93). There appeared to be a more marked, but again non-significant result, in private spaces with a 19% reduction from 75 (95% CI 71 to 79) to 61 (95% CI 56 to 66) compared with a 7% reduction in public spaces from 28 (95% CI 26 to 31) to 26 (95% CI 56 to 66).[48] A Spanish study of moderate quality described no significant difference in the rates of dog bites reported to public health after BSL was introduced; however, data is missing in the publication to support this statement.[47] This study also reports a non-significant 50% reduction in reported dog bites in highly populated areas, versus only a 2% reduction in low populated areas.

The main limitation of the studies on BSL legislation was that they did not compare dog bite rates in legislated breeds compared with a control group of non-legislated dogs, they often already had a decreasing trend prior to intervention implementation,[49–51] and lacked robust statistical analysis.

Sterilisation

Six studies investigated the effects of sterilisation on either dog bite rates or dog aggression[58 59 63 64 81 82] (online supplemental table 1). One moderate-quality study evaluated the impact of stray dog sterilisation as a single intervention on the number of dog bites.[64] The study undertaken in an Indian city demonstrated the chemical or surgical sterilisation (and then release) of free-roaming dogs in a city with a high rate of dog bites reduced the number of dog bites by 48%, from approximately 11 500 in 2003, to 6000 in 2011, likely due to a 28% decrease in the dog population.[64] The authors suggest this also may in part have been due to female dogs protecting their young, as they noticed an increase in bites occurring 3 months after a peak in pregnancies.

Two further low-quality studies used stray dog sterilisation as a means of dog population control to prevent rabies,[58 82] along with education regarding the importance of vaccination and post-exposure prophylaxis (PEP). One study in India had a nearly threefold increase in dog bites over a 9 year period (853 in 2005/2006 to 3314 in 2012/2013).[58] A similar study in Thailand had an initial 66% increase in reported animal bites from potentially rabid animals (predominantly dogs) over the first 4 years

(1692 in 1996 to 2816 in 2000), and then a drop the following year to preintervention levels.[82] Both studies were limited by their data collection method, from either an unknown method (provided by Department of Health)[58] or from potentially rabid (presumably unvaccinated) animals.[82] Results from these rabies prevention programmes were also confounded by their promotion of presenting for PEP.

A further study on the sterilisation of stray dogs was conducted in Chile in 2016. This high-quality, blinded RCT demonstrated a significant increase in aggressive behaviour in 36 free-roaming dogs who were chemically sterilised, with no difference in 39 dogs who were surgically sterilised, or in 44 control dogs with no intervention.[81] One small (n=57) low-quality study of domestic dogs in California in 1997, found a small percentage of owners (10%–25%) demonstrated a substantial (90%) reduction in aggressive behaviours toward following surgical sterilisation.[63] A further similar study in 23 household dogs in the USA found a 26% reduction in aggression indoors and a 52% reduction outdoors.[59] However, these studies were limited by small sample sizes, lack of a control group and subjective owner-reported measures of aggression which are likely subject to bias.

Alcohol

A 60% absolute reduction (ARR 0.6, 95% CI 0.4 to 0.9, p=0.024) in dog bites during a controversial strict alcohol reduction programme was shown in two Indigenous communities in the outback of Australia, aiming to decrease injury rates (online supplemental table 1).[43] The communities with zero carriage of alcohol had a reduction in dog bites, of 61% in Community A from 12.4 per 1000 people in 2006/2008 to 4.8 in 2009/2011 (IRR 0.4, 95% CI 0.2 to 0.7, p=0.001), and 30% in Community C from 40.0 to 27.9 per 1000 people (IRR 0.7, 95% CI 0.5 to 1.0, p=0.033). The control community with restrictions limited to personal alcohol consumption had a 29% non-significant reduction, from 12.9 to 9.2 per 1000 people (p=0.317). Although there was no randomisation, this was a high-quality study, which measured bite incidence from primary care clinics, used large sample size (n=1684), and included a control group with less alcohol restrictions.

Education

One high quality, large scale, preinterventional and postinterventional study in the Philippines, investigated the impact of educating 5764 school children (5–14 years) on rabies and bite prevention, on the incidence of dog bite presentations among same aged children (online supplemental table 1).[62] There was only a minimal, non-significant reduction in child dog bite incidence captured in either the household surveys from 26.4 per 1000 (n=124/4700) in 2011, to 24.7 per 1000 (n=114/4700) in 2012 (p=0.46), or on hospitalisation rates from 8.6 per 1000 (n=79/9211) in 2011 to 7.5 per 1000 (n=69/9211) in 2012 (p=0.65). They did however report a reduction in the proportion of Category III (deeper) bites, (11% in 2011 to 3% in 2012, p<0.05). While there was no control group in this study, and the authors acknowledge the potential under-representation of children who were not enrolled in the traditional education system but may be at higher risk of dog bite injuries, this was a high-quality study demonstrating the limitations of providing education to children as an intervention strategy.

A small low-quality Canadian study (n=99) targeting dog owners found that giving behavioural advice at their puppy's first veterinarian visit, regarding the importance of early socialisation and positive training techniques, resulted in less aggressive behaviour of the dogs toward unknown people and toward other dogs, compared with a control group, at 1-year follow-up (2% vs 16%, p<0.05).[65] However, this study relied on non-validated owners' interpretation of dog behaviour, with unknown adherence to the intervention, and a small sample size.

Five studies investigated the effects of providing intensive public education on rabies prevention, primarily aimed at local adult leaders (online supplemental table 1).[69–71 77 79]

One high-quality interventional study on rabies prevention from South India, compared three rural villages (n=1735) to three control villages (n=1080), resulting in a 30% significant reduction in animal bites (predominantly dogs) in the intervention villages from 2.7% (n=47/1735) to 1.9% (n=33/1735, p=0.04), and a 13% non-significant decrease in bite cases in the control villages from 2.8% (n=31/1080) to 2.5% (n=27/1080, p=0.55).[77] The study also showed increased presentations of Category III dog bites, and attribute this to increased awareness of the need for medical intervention for more severe bites. This was a comprehensive community-based strategy, with control groups, and outcomes appropriately measured by a randomised household survey. However, it is possible that people may be more motivated to reduce dog bites if education is focused on rabies prevention.

A similar high-quality study in Northern Tanzania found that education on rabies prevention and dog vaccination had a 79% decrease in bites within intervention areas, and a 60% non-significant increase in control areas.[79] However, this study only investigated the incidence of dog bites from potentially rabid (presumably unvaccinated) dogs, and thus has no benefit in estimating the effect on bite rates from all dogs. A further moderate-quality, preinterventional and postinterventional study in Southern Tanzania found that public education on rabies prevention resulted in an initial increase in bite incidence from 1.8 per 100 000 per quarter (n=1600), to 2.8 per 100 000 (n=2700) the following year, then a general decline to zero in the final quarter of 2016.[71] However, this study had likely high variability in the data collection method, using dog bites reported to researchers by livestock field officers and healthcare workers. Likewise, a low-quality study on intensive adult directed rabies prevention education in Zanzibar had an unknown data collection method.[69] A low-quality study with a more well-defined data collection method done in Philippines found that rabies prevention community education and dog vaccination resulted in an initial increase in animal bite presentations (83%–89% dogs) to eight animal bite treatment centres in the region, from 2015 in 2011 to a peak of 5908 in 2014, and then a fall to 5520 the following year.[70] However, this was substantially confounded by a potential increase in presentations with increased awareness of the need for rabies PEP.

Dog training

Two studies investigated a change in police dog training methods from a 'bite and hold' method to a new 'bark and hold' method, which trains a dog to circle and bark during an arrest, but only to bite a suspect if the suspect moves or actively resists.[53 54] A moderate-quality, Los Angeles study investigating the impact of the introduction of the 'find and bark' training method in 1992, resulted in a 90% reduction in the number of dog bites to incarcerated patients seen in the ED in 4 years before and 4 years after the policy was introduced from 639 to 66 bites.[53] Patients also had fewer fractures, vascular complications, hospitalisations and multiple bites. In contrast to this, a low-quality Florida study surveying police dog handlers, compared 45 dogs who were

trained using the new 'bark and hold' programme introduced in 2001, with 135 dogs who continued training in the standard 'bite and hold' method.[54] This study found that the bite and hold method had significantly lower mean bites per arrest (bite ratio) than the new method (15.7 vs 22.4). However, this second study had a high (48%) non-response rate and thus small sample size. Both studies had unknown adherence to training and dogs were likely previously trained in the old method before introduction of the new method.

Six studies investigated dog training methods for dogs with a history of behavioural issues, two of which also used concurrent medication.[55 60 72 73 76 85] Tortora in the high quality 1983 study of 36 household dogs with a history of aggression, showed reductions to near zero in a trainer-reported measure of dog aggression (using video footage of sessions with the dogs) over a 2.5-year intensive dog-training programme including the use of electric shock collars ($p<0.001$), with no improvement in the control group ($p>0.05$).[76] Dodman *et al*, in two low-quality studies in the USA, found an 8-week non-confrontational behaviour modification programme reduced owner-reported dog aggression in 9/10 dogs with a history of aggression in one study ($p<0.05$),[85] and 14/20 dogs in another study.[73] A further similar study found that 10/24 dogs in the USA had a greater than 50% improvement in aggressive behaviours with dog training that was combined with sterilisation and progestin treatment.[72] These studies were limited by their very small sample size with no control group. Knol conducted a low-quality study that found that in 133 dogs with behavioural problems in the Netherlands, owner satisfaction with a mixed positive and negative (collar) training programme (in conjunction with medication in only five dogs), was reported as 'good/fair' in 42% of cases, 'moderate' in 11% and 'bad' in 41%.[60] However, this study used an indirect measure of dog aggression, with no control group, also included medications in some dogs, and had an unclear intervention with different methods for different behavioural problems. Likewise, Dinwoodie *et al*, in their low-quality retrospective cohort study of 963 dogs in the USA, where the owner employed one of 21 different behavioural techniques with or without medication, found that 82% of owners felt there was some improvement in aggression.[55] This study was limited by asking owners retrospectively their view of a highly heterogenous group of interventions with no standardised outcome measure or control group for comparison. All located studies on dog-training were potentially influenced by financial gains from dog-behaviouralists undertaking studies of their own interventions.

Medication and diet

Three studies primarily investigated the effect of pharmaceutical intervention, in conjunction with behavioural modification.[67 68 80] A further three studies investigated the use of medication only[56 61 66] and one with diet alone (online supplemental table 1).[56]

The three studies investigating medication alone were low quality, and conclusions could not reliably be made.[56 61 66] They were limited by small sample sizes, subjective and non-standardised owner-reported measures of aggression, and no control group. One used a cross-over design, however, had unreliable results with a sample size of nine.[61] One study had an unknown period of medication given, and multiple medications used simultaneously,[56] and one study used an inappropriate control group of non-aggressive dogs receiving the intervention.[66] One moderate quality study looked at the effect of low or high protein diets, with or without tryptophan using an appropriate cross-over design with a 3-day washout period, exclusion of participants with recent medication use, and a well-defined outcome measure.[56] They found no significant change in behaviour over a 4-week period with any of the groups. However, this study also had a small sample size, relied on owner-reports of aggression, excluded dogs with severe aggression or pregnancy, and appeared to have sponsorship from a pet food company. There did not appear to be sponsorship of studies by medication companies.

The three studies investigating medication in conjunction with behavioural therapy were likewise low-quality studies, with no conclusions able to be drawn.[67 68 80] They were mostly limited by small sample sizes, lack of a control group, owner-reported measures of aggression, and no separation of dogs with or without behavioural therapy, a significant confounding factor.

Furthermore, with all studies on medication or diet, maintaining the recommended diet or dosage of medication would require highly motivated and likely high-income dog owners, and therefore these studies may have been subject to a significant response bias.

DISCUSSION

The aim of this review was to evaluate the efficacy of interventions to prevent dog bites and dog aggression, and used a systematic approach guided by the PRISMA statement.[40]

The strength of this review is that it provides a broad overview of the literature on a range of strategies to address dog bites and dog aggression, using an established public health framework. The wide search strategy predictably resulted in a large number of non-relevant studies, however, this also identified a number of relevant prevention strategies that would otherwise not have been considered. The outcome measure was clear and relevant, and did not rely on assumptions about how it might translate into injury prevention. The inclusion of grey literature reduced publication bias, and studies were systematically evaluated by two researchers, reducing individual biases.

This review should be considered in light of some limitations. Studies had a high degree of heterogeneity in both interventions and outcomes. A large number were excluded as they did not study an intervention or did not measure dog bites or aggression. Half of the studies were considered low-quality by the authors and were of limited value, primarily due to low sample size, the lack of a control group, limited statistical analysis, or bias in the outcome measure used, including subjective and heterogeneous owner-reported measures of dog aggression, dog bites reported to an authority, or hospitalisations which only represent a small proportion of dog bite injuries.[1]

In addition, study findings may not be generalisable between populations with socioeconomic or cultural differences. The authors also acknowledge that acceptability, ethical views or cultural appropriateness of interventions will vary, with this review touching on a number of controversial issues, including euthanasia, aversive dog-training techniques and BSL. A number of studies on rabies prevention (primarily addressed through vaccination and PEP), also employed dog bite prevention strategies.[57 58 62 69–71 75 77 79 82] The main issue with these studies is that dog bite injuries measured through medical presentations may be confounded by an increase in presenting for PEP.

Legislation

This review found moderate to high evidence that dog control strategies decreases dog bite injuries, particularly for those that substantially reduce the dog population through sterilisation,

euthanasia or re-homing. Euthanasia of dogs is controversial with mass culling of dogs, a measure used historically for reducing the dog population,[75] no longer considered acceptable in most countries. Likewise, euthanasia of dogs who pose a risk of serious injury, including those with a history of aggression or those relinquished to a shelter is controversial, with no well validated risk assessment tools available,[87] and devastating health consequences for people when wrong decisions are made. This is of particular concern considering the results of a recent UK study showing the most common reasons for dog relinquishment to a shelter being aggressive behaviour between dogs in the home (20%) or aggression around children (19%).[88] Sterilisation may be a more socially acceptable strategy. However, while there is evidence this decreases injuries through a reduction in the dog population, whether it reduces dog aggression in either contained or roaming dogs is still uncertain. Study findings are consistent with a previous systematic review of this topic in the context of rabies prevention.[26]

Further effective dog control strategies in located studies included dog management in public spaces (through microchipping, registrations, community patrols, property fencing requirements, infringements, establishment of dog shelters or leash laws). The use of leash laws is currently debated in many countries, with public calls for increased leash use as the population of dogs and people grow, with subsequent increased use of public spaces. There is also an increasing trend to establish dog-control methods to address roaming/stray dogs in low-socioeconomic areas with benefits for both the welfare of stray dogs and injury prevention.[57 58 64 65 74 81 82 89] Of note, several included studies specifically adopted a 'One Health' approach.[45 57 58 74 77] This multi-sectoral framework recognises the increasing interactions between humans and animals as the population of both grow, as a root cause for the spread of zoonoses (ie, rabies) or increasing injuries, and promotes prevention of these through humane dog control strategies, education and animal welfare. It is predominantly used within low socioeconomic regions, or indigenous cultures, however, can be applied to any group. Four included studies were conducted in small rural indigenous populations living within colonised countries (Canada and Australia), with high levels of community engagement.[44 45 65 74] Of note, interventions within communities that employed dog control strategies[65 74 89] had more impact than those focusing on dog health alone.[45] One study also described that while these strategies can be effective, they require a high level of resource and can be difficult to implement with changes in community leadership or priorities over time.[74]

Restrictions on dogs by breed are also controversial worldwide. While there is a call to change this approach from the perspective of both dog-advocacy and injury prevention, an evaluation of the currently available evidence in this review has shown a small decrease in BSL. To address this, it seems a sensible approach to promote the widening of humane dog-control restrictions to be placed on all dogs, rather than limiting these to certain breeds. This is supported by studies showing that the most common breeds to bite are those that are the most popularly owned.[11 24 90 91] An NZ study found the majority of dog bites (66%) were caused by mixed, undefined or unknown breeds, with bites from known breeds ranging from only 2% (Bull Terrier) to 8% (German Shepherd).[11] A study in Ireland also found a lack of perceived threat from legislated versus non-legislated breeds, which were also less likely to be reported (27% vs 55%); a considerable concern, as people may underestimate the risk of the most popular non-legislated breeds.[90]

Legislative measures to reduce injury may also include promotion of reporting of issues either by members of the public or professional bodies. Internationally, while there are regional policies within the UK and USA, only Switzerland has a national legal requirement for the mandatory reporting of dog bites by health professionals or veterinarians for the purposes of dog-bite prevention, with a high rate of reporting after this strategy was introduced, and a 31% reduction in insurance claims for dog bites from approximately 3600 in 2005 to 2500 in 2007.[92 93]

Alcohol reduction as a general injury prevention strategy is an area of focus in NZ[94] and globally, and may be linked through either decreased ability of victims to defend themselves or difficulties in providing adequate care for a dog. It has also been noted that fatal dog attacks have occurred in victims who are vulnerable such as those with disabilities, dementia or seizures, those with drug or alcohol compromise, the elderly, young children or infants.[14]

Education

Among the seven studies included in this review that explored the impact of education on dog bite rates, five found intensive community based adult education reduced dog bite rates.[69–71 77 79] A study conducted in the Philippines among children showed no significant change in dog bite rates.[62] A recent low-quality Austrian study investigating an intensive child and parent-directed education programme on dog safety likewise showed no reduction in hospital presentations, with mean hospitalisation rates not reported.[95] This is unsurprising, given child-directed education is not advocated for or commonly used in other areas of unintentional trauma in young children,[36 96] and is consistent with research showing that dog bites in children and adults are frequently unprovoked, or occur with a minor interaction such as patting a dog.[11 13 97] While there are a large number of studies investigating the effect of children's education programmes on children's knowledge of dog safety, including two systematic reviews,[98 99] these did not investigate the impact of these programmes on either injuries or incidents involving dog aggression, and this should be considered in any future research on this topic.

The current review found no studies investigating the effect of educating caregivers on the importance of supervision of children on dog bite rates, despite this being a common educational message. Promoting this may not reduce injury, given supervision of children is a highly complex task that involves an understanding of a child's developmental ability, along with an assessment of multiple hazards within different environments. Constant supervision is also simply not always possible, and depends on the ratio of children and adults, the environment they are in, socioeconomic factors, and the capability of the supervisor who may not be a parent.[100]

Given the predominance of attacks by dogs who are not owned by the victim or their immediate family, and dogs natural tendencies for resource guarding, territorial or predatory aggression,[31] redirection toward owner-directed safety information is likely required. Non-aversive dog training is a strategy promoted by dog-advocates, and is further supported by studies demonstrating the negative impact of aversive training techniques on dog welfare.[101] All studies located in the current review using positive behavioural techniques to reduce dog aggression were low-quality and inconclusive. Bias may also exist in studies undertaken by dog behaviouralists who have a financial interest in their own interventions. Furthermore, intensive dog training programmes are likely to be more effective for the highly

motivated, higher-income owner. An example of this is given in a study that demonstrated low adherence to both internet-based or face-to-face dog training programmes in low socioeconomic groups, even when provided at no cost.[102]

Police dogs are a sub-population of dogs that are trained, and are often not considered in research on dog bites. A change in training strategy to 'bark and hold' in police dogs[53] reduced the number of bites within a US prison, although the consequences to police or the public of not using the bite and hold method were not investigated. In NZ police dog bites make up less than 2% of bites presenting for medical attention,[1] are highly regulated and used only in extreme situations.[103]

One study included owner-directed education regarding the importance of early socialisation,[78] and no studies investigated education on dog walking to reduce dog aggressiveness. These may not be as important in reducing dog aggression as previously thought, as a recent large prospective cohort study in Finland comparing risk factors in 1791 aggressive to 7479 non-aggressive dogs, showed no differences in either early socialisation or number of hours walked between the groups.[104]

Medication and diet

Results from studies on the effect of medication on dog behaviour were inconclusive, and require larger RCTs to investigate this.

Engineering strategies (to modify the physical environment)

No studies were located that considered the effectiveness of dog-person barriers such as baby gates, adequate fencing height, gate locks, separate dog areas or the use of leashes as a single intervention, which are likely important given the role of physical barriers in other areas of unintentional injury in children.[36] In-home barriers reduce the need for constant supervision of children, and do not rely on behaviour change in either dogs or people. Physical barriers such as pool fences, stair gates, playground safety standards, child-resistant packaging and restrictive window latches have been effective in other areas of unintentional child injury prevention.[36] Likewise, no studies were located on the effect of home safety visits, with or without equipment provision, either at an early stage of dog-rearing, or following a dog bite, shown to be effective in other areas of unintentional injury in children.[105] The implementation of fencing as a strategy may also be challenged by socioeconomic circumstances. For example, one article highlights the inability to modify shared or rented accommodation, as a barrier to improving child safety in more deprived areas.[106]

Future research

Future studies should employ interventional rather than observational study designs with an appropriate control group, ideally as RCTs, using adequate sample sizes and statistical analysis, and investigating specific well-defined interventions. Studies should also use the incidence of dog bites and other dog-related injuries as primary outcomes of interest (per 100 000 people), and use broad methods of data collection, including non-bite incidents of dog aggression from household surveys or presentations to primary care clinics, rather than more limited methods such as bites that are reported to animal management, or hospitalisation rates. Using standardised measures of owner-reported dog-aggression such as C-BARQ[107] would aid in comparison between studies, despite the challenges with the inherent subjectivity that exists in these measures. Rigorous studies are specifically required for the use of positive dog training techniques, reporting strategies, and implementation of engineering barriers (fencing, baby gates, separate dog spaces or leashes) to protect children. Future research should also investigate macro-level strategies such as the distribution of funding provision of dog-control strategies, or access to services. Strong engagement with indigenous cultures should be prioritised in all future research on this issue, including exploration of indigenous approaches to dog control/safety.

CONCLUSION

Multiple strategies including effective engagement with indigenous communities and organisations will be required to reduce dog-bites and other incidents involving dog aggression. This review provides some evidence that legislated dog control strategies reduce dog bite rates. Available evidence suggests greater restrictions should be made for all dogs, rather than based on breed alone. Due to the burden of child injury, protection of children should be a focus of legislation and further investigations. Prevention strategies in children require redirection away from a focus on child-directed education and future research should investigate the effectiveness of engineering barriers and reporting strategies.

What is already known on the subject

⇒ Injury by dogs is an increasing and serious public health issue.

What this study adds

⇒ Dog control legislation, such as leash laws, stray dog control, infringements and restrictions or euthanasia of dogs with a history of aggression likely reduces dog bites, with less of an effect for breed specific legislation.
⇒ Sterilisation (spaying, orchidectomy or chemical) may reduce dog bites through a reduction in the dog population.
⇒ There is currently no evidence to support child education as a dog bite reduction strategy.

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Table 1 (Supplementary): Included studies investigating dog bite prevention strategies

Study, Design, Aims	Participants, Intervention	Outcomes measured	Findings	Quality
LEGISLATION				
Häsler, B., 2014 [57] **Design:** Observational retrospective cohort study **Aim:** Investigate the economic value and effect on animal and human welfare of a rabies intervention programme	**Participants:** 47 sub-districts in Colombo city, Sri Lanka (n=650,000) 2007 – 2011 **Intervention:** One Health approach: • Stopped mass culling roaming dogs • Public area dog control • Targeted sterilisation • Education public • Public education • Mass vaccination	4-year study period • Incidence dog bites from randomised household surveys in 2007 and 2011 • Monthly number of hospital presentations for a dog bite	Dog bites: • Household Surveys (n=31/1,622): 34% non-significant reduction from 0.0216 per person (23/1,063) in 2007 to 0.0143 per person (8/559) in 2010 (p=0.31) • Presentations to hospital (n=291): Increase from 131 (11%) in 2006 to 160 (12%) in 2011	**Study Quality:** Moderate **Strengths**: • Use of hospital records and household survey • Incidence rates reported for survey • Comprehensive intervention **Limitations:** • Small sample size • Statistical analysis and method of incidence calculation not reported for hospital data • Unknown if increase in hospital presentations due to improved treatment seeking or an increase in dog bite injuries • Response bias in house-hold survey • Introduction of new intervention concurrently with ending mass culling stray dogs. • No control group • Did not study level of enforcement
Dhillon, J., et al, 2016 [65] **Design:** No specific information given on study design **Aim:** Investigate how a dog control program can be introduced into a small indigenous community	**Participants**: Indigenous community in Canada, 2009-2013 (sample size not reported) **Intervention**: • Dog control officer visited every school, community group and household. • Addressed dog welfare • Built a shelter	5-year study period • Dog bites reported (did not specify who to) • Dog population data (not defined how they gained this)	Dog Bites (n=19) • Number of reported dog bites decreased from 6-10 per year to 1 per year for three years • Dog population reduced by 50%, and roaming dog population reduced by 90% • Elders and children reported feeling safer • Increase in dog population after termination of programme	**Study Quality:** Low **Strengths:** • Programme implemented in a small indigenous community • Used feelings of safety as an outcome • Reported effects of stopping intervention **Limitations**: • Unknown population size, small sample size • No control group • Unknown method of data collection

	• Ticketing or euthanasia for stray dogs • Sterilisation • Community patrols • Encouraged reporting of stray dogs			
Schurer, J.M., 2015 [74] **Design:** Pre-post interventional study **Aim:** To investigate the effect of a community based dog control programme on dog welfare and dog bites	**Participants**: Two rural indigenous communities in Saskatchewan, Canada (n=1,050) **Intervention:** One Health approach: • Dog control (including 32%, n=124/382 dogs re-homed outside the community) • Community discussions • Dog welfare (including de-worming and vaccination) • Free sterilisation clinics	1-year study period • Dog bites presenting to medical attention	Dog Bites (n=11): • Nine dog bites in 2012 and two in 2013 • Home-owners noticed children felt safer playing outside or walking to school.	**Study Quality:** Low **Strengths:** • Programme implemented in small indigenous communities • Culturally sensitive with strong community engagement • Also noted feelings of safety as outcome **Limitations**: • Small sample size • No control group • Substantial reduction in dogs during study
Riley, T., et al 2020 [45] **Design:** Pre-post interventional study **Aim:** To investigate the effect of a community animal welfare intervention on dog bite rates	**Participants:** Remote Indigenous community in Wadeye, Northern Australia (n=approx. 2,280) **Intervention:** One Health approach: Free Vet visits (259): • Sterilisation • Medication • Vaccination • Owner directed education on animal health (with translations)	4-year study period • Quarterly incidence of dog bites presenting to health clinics	Dog-bites: • No change in quarterly incidence of dog bites from 4.7 per 1,000 people in 2016 to 4.2 per 1,000 people in 2019 • Small reduction in dog population (598-532)	**Study Quality:** Low **Strengths:** • Appropriate statistical analysis • Appropriate study period • Indigenous engagement **Limitations:** • Small sample size • No control group
Ma 2020 [44] **Design:** Non-random interventional study	**Participants:** Remote Indigenous communities in Northern Australia (n=approx. 4,000)	7-year study period • Council reported dog attacks (rushes at, attacks, bites, harasses or chases any person or	Dog-attacks: • 33-66% reduction in reported dog attacks from 2.5 per 1,000, 1.5 per 1,000 and 1.5 per 1,000 in the pre-intervention year of each community, to	**Study Quality:** Moderate **Strengths:** • Tailored interventions to indigenous communities with strong engagement

Aim: Investigate effect of community intervention on dog bite rates	**Intervention:** Free: • Sterilisation • Registration/Microchips • Vet visits (assistance w transport) • Unwanted dogs euthanized or rehomed • Education at local schools on dog safety/hygiene	animal, whether or not injury has occurred)	<1 per 1000 for all three communities in 2018/19 (p=0.035) • No change in control community (4 per 1,000 in 2015/16 and 8.1 per 1,000 in 2018/19)	• Control group • Appropriate statistical analysis **Limitations:** • Small sample size • Many communities had unreported results • Dog population change not reported • Definition of dog attacks is likely to have greater variation than dog bites alone
Marsh, L., et al, 2004 [46] **Design:** Observational retrospective cohort study **Aim:** Describe the extent of dog bite injuries in New Zealand	**Participants**: NZ population (n=3.7 million) 1989 - 2001 **Intervention:** Dog Control Act, 1996: • Ticketing • Registrations • Leash laws • Muzzling • Sterilisation • Prohibited owners • Euthanasia • Breed Specific Legislation (BSL)	12-year study period • Incidence dog bite hospitalisations	Dog Bites (n=3119) • Rising incidence prior to legislation (from graph) from 4 per 100,000 per year in 1989 to 7.5 per 100,000 in 1996 • Rates dropped to 5.5 per 100,000 in 1999 after introduction of legislation • Rates returned to 6.8 per 100,000 in 2001	**Study Quality:** Moderate **Strengths:** • Study length • Reliable data source • Use of incidence rates • Use of hospitalisation data • Large sample size **Limitations:** • Changes to coding may have over-estimated rates before legislation was introduced • No statistical analysis • No control group • Did not study level of enforcement
The City of Calgary Animal & Bylaw Services, 2006 [50,86] **Design:** Observational retrospective cohort study **Aim:** Investigate the effect of dog control legislation on the incidence of dog bites	**Participants:** Calgary, Canada population (n=1,195,000) 1984 - 2014 **Intervention:** Pet Ownership bylaw 2006: • Strict leash laws • Directly returning strays • Reduced registration rates • Increased ticketing, muzzling, caging and sterilisation of dogs causing an injury to a person or animal • Education on the laws	30-year study period • Incidence dog bites reported to Animal Management	Dog Bites (n=4193) • 80% reduction in reported bite incidence from 99 per 100,000 per year in 1984 to 20 per 100,000 in 2014	**Study Quality:** Moderate **Strengths:** • Study length • Use of incidence rates • Large sample size **Limitations:** • Reported bites likely an underestimation • Changes to reporting guidelines within study period • No statistical analysis • No control group

	• No BSL			• Rates declining prior to legislation being introduced • Did not study level of enforcement
Clarke, N.M., et al, 2013 [84] **Design:** Observational retrospective cohort study **Aim:** Investigate the effect of dog control strategies on rates of reported dog bites	**Participants:** 36 jurisdictions in British Columbia Canada (n=10.1 million) 2003 – 2005 **Interventions:** • Ticketing • Licensing • Education • BSL • Financial investment into animal control	3-year study period • Incidence dog bites reported to animal management in different jurisdictions (per 100,000 people per year)	Dog Bites (n=not reported) Lower dog bite rates in areas with: • High ticketing rates (p<0.01) • High licencing rates (p<0.10) No difference in dog bite rates in areas with: • Higher budget allocation for dog control • Higher staffing allocation for dog control • More public education • BSL (170 vs 180 in Non-BSL areas)	**Study Quality:** High **Strengths:** • Excellent statistical analysis. Incidence rates used. • Described that dog ownership rates (per person) not substantially different by area • Assesses legislative strategies separately • Large sample size likely • Control groups • Accounts for the impact of ticketing and licensing on likelihood of reporting • Investigated levels of enforcement of legislation **Limitations:** • Reported bites likely an underestimation • Confounding bias: Likely other differences in policy, dogs, owners, victim or environment • Reporting bias (response rate 22/36 areas)
Glosser, J., et al, 1970 [75] **Design:** Pre-post interventional study **Aim:** Investigate the effect of a national dog control strategy, implemented as a response to a rabies epizootic	**Participants:** Guam population (n=95,000) **Intervention:** Mass poisoning of stray dogs and cats (>15,000), the introduction of leash laws, and adult education	3-year study period • Number of animal encounters (predominantly dog bites or contact with saliva)	Animal encounters • 75% reduction in encounters from 995 in 1967 to 252 in 1969	**Study Quality:** Moderate **Strengths:** • Large sample size • Clear intervention: reduction in stray dog population **Limitations:** • Unclear method of data collection • Included all animals, not just dogs • No statistical analysis done • No incidence rates calculation • Unacceptable intervention in some societies
Villalbí, J.R., et al, 2010 [51]	**Population:** Catalonia, Spain population (n=7.2 million) 1997-2008	11-year study period • Incidence dog bite hospitalisations	Dog Bites (n=1103) • 38% reduction from 1.80 per 100,000 (n=332, 95% CI 0.87, 1.36) in 1997-99, to	**Study Quality:** Moderate **Strengths:**

Design: Observational retrospective cohort study **Aim:** Investigate the effect of dog control legislation on dog bite injuries	**Intervention:** Dangerous Animals Act 1999 & 2002 • Restrictions for dangerous dogs (breed, behaviour, size and other physical characteristics) • Leash laws • Microchips • Owner licencing		1.11 per 100,000 (n=241, 95% CI 0.87, 1.36) in 2006-08	• Long study period • Large sample size • Incidence rates used **Limitations:** • No control group • No statistical analysis • Hospitalisation data only • Rates declining prior to intervention • Did not study level of enforcement
Klaassen, B., et al, 1996 [52] **Design:** Observational retrospective cohort study **Aim:** Investigate the effect of the Dangerous Dogs Act 1991 on dog bite injuries	**Participants:** Aberdeen, Scotland population (n=200,000) 1991-1994 **Intervention:** Dangerous Dogs Act 1991 • Ticketing • Registrations • Stray dog control • Leash laws • Restrictions for dangerous dogs (breed/behaviour)	4-year study period • Emergency department (ED) presentations of dog bite injuries over 3 months	Dog Bites (n=268) • No difference in dog bite presentations to ED pre and post legislation (134 in 1991 and 134 in 1994)	**Study Quality:** Moderate **Strengths:** • Allowed enough time (2 years) to see impact • Broad outcome measure (ED presentations) **Limitations:** • No incidence rate or statistical analysis reported • No control group • Moderate sample size • Does not show seasonal term effects • Did not study level of enforcement
Raghavan, M., et al, 2013 [83] **Design:** Observational retrospective cohort study **Aim:** Investigate the effect of banning pit-bull breeds on dog bite injuries	**Population:** 19 jurisdictions in Manitoba, Canada (n= 26 million), 1984-2006 **Intervention:** Banning of Pit-bull breeds	23-year study period • Incidence of hospitalisations for dog bite injuries	Dog Bites (n=838) • Areas with BSL had 19% significantly less dog bite hospitalisations (2.92 per 100,000, 95% CI 2.66, 3.19) than non-BSL areas (3.62 per 100,000, 95% CI 3.25, 3.99, p=0.002) • Areas with BSL had a 9.6% non-significant reduction over time. 3.14 per 100,000 pre-BSL (n=144, 95% CI 2.65, 3.69), to 2.84 per 100,000 post-BSL (n=331, 95% CI 2.53, 3.15), p=0.319	**Study Quality**: Moderate **Strengths:** • Long study period • Includes controls without legislation • Uses incidence rates and statistical analysis • Focused intervention **Limitations**: • Likely many confounding factors • Hospitalisation data only • Did not study level of enforcement • Unclear outcomes: all areas versus two cities • Control areas had other forms of pit-bull legislation

				• Unclear time-periods compared between exposure and control • Non-BSL areas not studied over time • Two cities compared instead of all areas • Did not account for differences in dog-ownership rates between areas
Mariti, C., et al 2015 [49] **Design:** Observational retrospective cohort study **Aim:** Investigate the effects of breed-specific legislation on the trend of dog bites	**Participants:** Florence, Italy population (n= 355,000) **Intervention:** Breed Specific Legislation (banning 92 breeds) 2003-04	4-year study period • Aggregate of dog bites from three sources including ED presentations, reports to canine registry and observational reports for prophylaxis in Florence: -Pre-BSL: 2002-03 -Short term: 2003-04 -Long term: 2004-05	Dog Bites (n=556) • 17-18% reduction from 210 pre-BSL to 172 in short term, and 174 in long term	**Study Quality:** Moderate **Strengths:** • Focused intervention • Long study period • Large sample size • Broad outcome measure **Limitations:** • Three different data-sources used • Decreasing trend prior to study period (1986-2001) • No incidence or statistical analysis • Did not report increased rate of decline post-BSL • No control group • Moderate sample size
Nilson, F et al, 2018 [48] **Design:** Observational retrospective cohort study **Aim:** Investigate the effect of breed-specific legislation on the number of dog bite injuries	**Participants:** Odense, Denmark population (n=188,000) **Intervention:** Breed Specific Legislation 2010 (11 breeds banned and euthanised)	13-year study period • Average 6-monthly number of dog bites presenting to an ED: -Pre-BSL: 2002-10 -Post-BSL: 2010-15	Dog Bites (n=2622) • Non-significant 15% reduction pre-BSL: 103 per six months (n=1748, 95% CI 98, 108) to 87 per six months post-BSL (n=874, 95% CI 82, 93) • Non-significant 14% reduction pre-post BSL, in private spaces: 75 per six months (n=1269, 95% CI 71, 79) to 61 per six months (n=610, 95% CI 56, 66), or 7% reduction in public spaces: 28 per six months (n=480, 95% CI 26, 31) to 26 per six months (n=264, 95% CI, 56, 66)	**Study Quality:** Moderate **Strengths:** • Investigated private and public spaces separately • Long study period • Large sample size • Statistical analysis appropriate • Broad outcome measure (ED presentations) **Limitations:** • Decreasing trend prior to intervention • 6-monthly rates do not account for seasonal variation • No control group • No incidence calculated

				• Two breeds already banned in 1991
Rosado, B. et al, 2007 [47] **Design:** Observational retrospective cohort study **Aim:** Investigate the effect of the Dangerous Animals Act on the incidence of dog bites	**Participants:** Aragón, Spain population (n=1,204,215) **Intervention:** Dangerous Animals Act 1999 (non-BSL) and BSL 2002	9-year study period • Mean incidence of dog bites recorded in Public Health Department: -Pre non-BSL: 1995-99 -Post non-BSL: 2000-01 -Post BSL: 2003-04	Dog Bites (n=4186) • No difference in dog bite incidence pre-post BSL (total rates not reported) • Low-populated area: 1.7% significant increase: 71.8 per 100,000 (SE 3.8) before and 73.0 per 100,000 (SE 3.3) after • High-populated area: 50% significant reduction: 18.6 per 100,000 (SE 3.9) before and 9.3 per 100,000 (SE 3.0)	**Study Quality:** Moderate **Strengths:** • Investigates low-populated vs high-populated areas separately • Long study period • Large sample size • Incidence calculated **Limitations:** • Reported bites likely an underestimation • Limited statistical analysis • Confounding likely • No control group
STERILISATION				
Byrnes, H., et al, 2017[58] **Study design:** Observational retrospective cohort study **Aim:** Investigate the effect of a One health rabies prevention programme	**Participants:** Sikkim, India population (n=610,000) **Intervention:** SARAH (One Health) rabies prevention programme 2006: • Stray dog sterilisation, medical care, and return to owners if known • Animal welfare education	13-year study period • Number of bites provided by Dept of Health. Unknown method data collection	Dog Bites • Increased from 853 in 2005/06 to 3,315 in 2012/13 • Bi-annual increases during breeding seasons	**Study Quality:** Low **Strengths:** • Long study period • Large sample size • Culturally sensitive interventions **Limitations:** • Unknown data collection, missing data • No statistical analysis • Multiple interventions • No control group • Primarily rabies prevention • Intervention aimed to increase presentations of animal bites to medical care
Kamoltham, T., et al, 2003 [82] **Design:** Pre-post interventional study **Aim:** Investigate the effect of sterilisation as part of a	**Participants:** Phetchabun, Thailand population (n=1.04 million) **Intervention:** Rabies prevention: • Public education for rabies prevention	5-year study period • Number of Animal bites from potentially rabid animals reported to Health Office	Animal Bites (93% dog bites): • 66% increase in presentations of bites in intervention years, from 1,692 in 1996 to 2,816 in 2000, with a drop to pre-intervention levels of 1,693 in 2001 • Increase in total dog population from 91,190 in 1996 to 105,272 in 2001	**Study Quality:** Low **Strengths:** • Long study period • Large sample size **Limitations:**

rabies prevention programme	• Sterilisation of dogs, particularly targeting strays around temples or schools 1997-2001			• Intervention aimed to increase presentations of animal bites to medical care • Bites only included if potentially from rabid animal, and only if reported to public health • No control group • No statistical analysis • Large annual variability in rate – percentage rate change over time not reported • Primarily rabies prevention
Reece, J.F., et al, 2013 [64] **Design:** Pre-post Interventional study **Aim:** Determine if a relationship exists between canine reproductive behaviour and human dog bites, through sterilisation of stray dogs	**Participants:** Jaipur, India population (n=3 million) **Intervention:** Surgical sterilisation and release of stray dogs from 2003 – 2011	8-year study period • Annual number of dog bite injuries presenting to the dog bite unit of the city hospital	Dog Bites (n=167,000, approx) • 48% reduction in dog bites injuries from 11,500 in 2003 to 6,000 in 2011 • Increase in bites 3 months after a peak in canine pregnancies in January, possibly due to protecting young	**Study Quality:** Moderate **Strengths:** • Broad outcome measure (unit presentations) • Large sample size • Long study period • Investigated seasonal variation **Limitations:** • No control group • Likely confounding • No incidence rates or statistical analysis
Garde, E., et al, 2016 [81] **Design:** Randomised Controlled Trial **Aim:** Investigate changes in behaviour following sterilization in a free-roaming male dog population	**Participants:** Free roaming dogs in Chile (n = 119) **Intervention**: Randomly assigned to either surgical (n=39) or chemical sterilisation (n=36) or control (no treatment, n=44)	6-month study period: • Independent scale of aggression from videos of dogs in a session	Dog aggression: • An increase in aggressive behaviour in chemically sterilised dogs (p = 0.001) • No change in aggressive behaviour in dogs that were surgically sterilised or control group.	**Study Quality:** High **Strengths**: • Mostly randomised (3 dogs changed groups) • Adequate sample size • Control group • Independent blinded aggression scores • Well defined and described aggression scores **Limitations:** • 14% loss to follow up (17/119) • Aggression testing done in different seasons • Does not report dog bites • Behaviours had varying degrees of aggressiveness • Limited to free-roaming dogs only.
Neilson, J.C., et al, 1997 [63]	**Participants:** Male household dogs in	Unknown study period	Dog Aggression:	**Study Quality:** Low

Design: Pre-post interventional study **Aim:** Determine whether surgical sterilisation can reduce problem behaviours in adult male dogs	California, USA, aged 2-7yrs with a behavioural issue (n = 57) **Intervention:** Surgical sterilisation	• Percentage improvement in dog behaviours based on report by owners (aggressive or non-aggressive)	• 20-25% of dogs showing aggression toward other dogs or family members had a 90% improvement • 10-15% of dogs who showed aggressive behaviours toward unfamiliar dogs or human intruders had a 90% improvement	**Strengths:** • Follow up questions to owner made by a Vet • Some statistical analysis **Limitations:** • Small sample size • No control group • Young dogs and females not included • Confounding likely • Owner reported aggression scores • Non-validated measures of behaviour problems • Likely more motivated dog owners in study
Maarschalkerweerd, R.J., 1997 [59] **Design:** Observational **r**etrospective cohort study **Aim:** Investigate the effect of orchiectomy on dog behaviour	**Participants:** 23 male dogs with aggression problems, castrated 6-12 months prior to study, Netherlands **Intervention:** Surgical sterilisation	12-month study period • Percentage of owners reporting an improvement in dog aggression	Dog aggression: • 26% (6/23) dogs decreased aggressive behaviour inside the house, and 52% (12/23) outside the house	**Study Quality:** Low **Strengths:** • Dogs with a number of behavioural issues **Limitations:** • Small sample size • No control group • Owner reported aggression improvement • Non-specific measures aggression • No appropriate statistical analysis • Likely motivated dog owners in study
ALCOHOL REDUCTION				
West, C., et al, 2019 [43] **Design:** Pre-post interventional study **Aim:** Investigate the effect of alcohol restrictions on the incidence of dog bites and other types of injury	**Participants:** Three remote indigenous communities in Far North Queensland, Australia, 2006-2011 (n=2,262) **Intervention:** Community Alcohol Management Plans: • Community A (n = 1,063) and C (n = 621) strict alcohol zero carriage restrictions	5-year study period • Incidence of dog bites presenting to primary care clinics	Dog-bites (n=229): • Community A: 61% significant reduction from 12.4 per 1,000 people in 2006/08 to 4.8 per 1,000 in 2009/11 (IRR 0.4, 95% CI 0.2, 0.7, p=0.001) • Community C: 30% significant reduction in community C from 40.0 per 1,000 to 27.9 per 1,000 (IRR 0.7, 95% CI 0.5, 1.0, p=0.033) • Community B: 29% non-significant reduction, from 12.90 per 1,000 to 9.20 per 1,000 (p = 0.317)	**Study Quality**: High **Strengths:** • Good sample size • Control group with partial intervention • Community based intervention • Broad outcome measure (primary care) • Incidence rates calculated • Appropriate statistical analyses • Other injury outcomes also measured • Strategy directed towards an indigenous population

	• Community B (n = 578) restricted to limited personal alcohol consumption		All communities: 0.6 times (60%) less likely to occur in 2011 (95% CI 0.4, 0.9, p=0.024) compared with 2006	**Limitations:** • Unknown relationship between alcohol and dog-bites • Controversial intervention, with potentially poor long-term engagement
GENERAL PUBLIC EDUCATION				
Masthi, R.N.R., et al, 2014 [77] **Design:** Non-random interventional study **Aim:** Estimate the incidence of rabies and animal bites, investigate the efficacy of a rabies prevention programme, and assess the safety of vaccination	**Participants:** 6 rural villages in South India (n=16,243): • 3 received intervention (n=10,220) • 3 controls (n=6,023) **Intervention**: One Health approach: • Intensive Public Adult Education on rabies prevention, including responsible pet ownership and how to avoid animal and dog bites	2-year study period: • Incidence of dog bites measured through random survey of 20% of the village populations, at the start of the study, and at one year	Animal Bites (n=138/1735): • 30% reduction in animal bites in intervention villages from 2.7% (47/1,735, all dogs) to 1.9% (33/1,735: 27 dogs and 6 cows), p = 0.0398 • No significant change in all animal bites in control villages, from 2.8% (31/1,080) to 2.5% (27/1,080, p=0.5501). Proportion caused by dogs not reported	**Study Quality**: High **Strengths:** • Comprehensive and culturally sensitive community-based education • Control group • Statistical analysis • Broad outcome measure (Household Survey) **Limitations:** • Small sample size • Education may increase reporting of bites • In context of rabies prevention • Proportion of animal bites caused by dogs not reported for the control group
Cleaveland, S., et al, 2003 [79] **Design:** Non-random interventional study **Aim:** Investigate the effect of a rabies prevention programme on number of dog bites from potentially rabid dogs	**Participants:** Rural Tanzanian Communities. Intervention: Serengeti District. Control: Two Neighbouring Districts (n=unknown) **Intervention:** Public education on rabies prevention and dog-vaccination 1996 – 2001	5-year study period • Annual incidence of dog bites from potentially rabid dogs, presenting to district hospitals	Dog-bite incidence: • 79% significant decrease in bites within intervention areas, from 28.8 per 100,000 people per year (95% CI 20.7, 39.1) pre-intervention, to 6.02 per 100,000 post-intervention (p<0.001) • 60% non-significant increase in bites within control areas from 11.7 per 100,0000 people per year (95% CI 8.6, 15.5) pre-intervention period to 29.4 per 100,000 (95% CI not reported) post-intervention period (p=0.06)	**Study Quality:** High **Strengths:** • Rural communities studied • Long study period • Monthly incidence calculated • Excellent statistical analysis • Appropriate control group • Demographics compared between intervention and control areas through random household sampling, including number of household dogs and people **Limitations:** • Used bites from potentially rabid dogs (uncertain if only non-vaccinated) • Rabies prevention and vaccination dogs

Mpolya, E.A., et al, 2017 [71] **Design:** Pre-post interventional study **Aim:** Investigate the effect of a rabies prevention programme on dog bite incidence	**Participants:** Southern Tanzania population (n=unknown) **Intervention:** Public education on rabies prevention and dog vaccination from 2010 to 2015	5-year study period • Incidence of dog bites reported to researchers by livestock field officers and health care workers	Dog-bite incidence • An initial increase in bite incidence from 1.8 per 100,000 per quarter (n=1,600) in 2011 to 2.8 per 100,000 (n=2,700) in 2012. Then, with monthly fluctuations there was a general decline to zero by 2016.	**Study Quality:** Moderate **Strengths:** • Monthly and annual incidence calculated • Broad data collection method **Limitations:** • No control group • High variability in data collection method • No statistical analysis • Did not investigate pre-intervention rates • In context of rabies prevention
Mudoga, E., et al, 2014 [69] **Design:** Pre-post interventional study **Aim:** Investigate the effect of a rabies prevention programme on dog bites	**Participants:** Unguja, Zanzibar population (n=900,000) **Intervention:** Rabies prevention 2009 to 2013: • Intensive adult education, including vets, local leaders and dog-owners	5-year study period • Dog bites presenting for medical attention (unknown data collection method)	Number dog-bites: • Reduced by almost 65% from 2009 to 2013	Study Quality: Low **Strengths:** • Developing country, not often studied • Appropriate outcome measure • Large sample size **Limitations:** • No control group • Data collection methods limited in Zanzibar • No statistical analysis, numbers not reported • Did not investigate pre-intervention rates • In context of rabies prevention
Valenzuela, L.M., et al, 2017 [70] **Design:** Pre-post interventional study **Aim:** Investigate the effect of a rabies prevention programme on dog bites	**Participants:** Ilocos Norte, Philippines (n=593,081) **Intervention:** Rabies prevention 2012 to 2016: • Community education to adults and children • Vaccination of dogs	8-year study period • Animal bite consultations from eight animal bite treatment centres	Number of Animal bites: • Animal bite consultations (83-89% by dogs) increased from 2,015 in 2011 (pre-intervention) to a peak of 5,908 in 2014 (post-intervention), then fell to 5,520 in 2015	Study Quality: Low **Strengths:** • Broad data collection method • Large sample size **Limitations:** • No control group • No statistical analysis • Numbers were increasing pre-intervention • In context of rabies
EDUCATION OF CHILDREN				
Deray, R., et al, 2018 [62]	**Participants**: Children aged 5-14 years (n = 5,764) in 27	2-year study period	Dog bites to children aged 5-14yrs:	**Study Quality:** High

Design: Pre-post interventional study **Aim:** Evaluate the impact and economics of education and pre-exposure prophylaxis on rabies and animal bite incidence in school children	Public Elementary schools in El Nido, Philippines **Intervention**: Rabies prevention: • Education on dog-bite prevention 2012-2013	• Incidence of dog bites in children aged 5-14 years: • Follow up interviews every 3 months over 18 months (per 1,000) • Presentations to bite centre at local hospital	• Interviews: No significant difference from 26.4 per 1,000 (124/4,700) in 2011 to 24.7 per 1,000 (114/4,700) in 2012 (p=0.46) • Hospital Presentations: No significant difference in presentations to hospital from 8.6 per 1,000 (79/9,211) in 2011 to 7.5 per 1,000 (69/9,211) in 2012 (p=0.65) • Decrease in the proportion of Category III bites, (11% of bites in 2011 to 3% in 2012 (p<0.05)	**Strengths**: • Single intervention - education children • Dog bite rates measured in the same population • Broad outcome measure (interviews and hospitalisations) • Recall bias reduced by surveying at regular intervals • Large sample size • Statistical analysis appropriate • Investigated wound depth • Appropriate study length • Low loss to follow up (3.5%) **Limitations:** • No control group • Lower response rate for urban areas • Children at-risk not included in study (37% of children are not enrolled in a school)
EDUCATION OF DOG OWNERS				
Gazzano, A., et al, 2008 [78] **Design:** Non-random interventional study **Aim:** Assess the effect of educating owners early in puppy management for the prevention of undesirable behaviours in adult dogs	**Participants:** Puppy owners, Pisa, Italy (n=89) **Intervention:** Advice on the importance of early socialisation, and positive behavioural techniques, from a veterinary behaviourist during first vet visit Non-randomly assigned: • 46 received intervention • 43 control	1-year follow up: • Owner reported dog behaviour	Dog Aggression: • Dogs in the intervention group were significantly less likely than controls to show aggressive behaviour toward unknown people and dogs (2% vs 16%, p<0.05), with a non-significant difference in aggression toward known people (0% vs 9%, p=0.051)	**Study Quality**: Low **Strengths:** • Appropriate follow up time • Control group • Balanced characteristics of owners and dogs **Limitations:** • Small sample size • Owner reported aggression scores • Non-validated and unclear measures of undesirable behaviour • Degree to which advice was implemented unknown • Loss to follow-up not reported • Aggression may not occur until a later age
DOG TRAINING				

Hutson, H.R., et al, 1997 [53] **Design:** Observational retrospective cohort study **Aim:** Investigate how a change in K9 police training method influences police dog bites	**Participants:** Police dogs in Los Angeles from 1988-1995 (n=unknown) **Intervention:** Dog training method, changed in 1992 from "Bite and Hold" to "Find and Bark"	8-year study period: • Number of dog bites (and severity) to incarcerated patients in the jail ward ED (≥16 years age) -Pre: 1988-91 -Post: 1992-95	Dog bites (n=705) • 90% decrease in number of bites from 639 'Pre' to 66 'Post' (no p-value) Bite severity: • Decrease in people with ≥3 bites (Pre:58.4% to Post:45.5%; OR 1.68, 95% CI 0.98, 2.89, p=0.04) • Decrease in fractures (Pre:2.4% to Post:0%), vascular complications (Pre:7.5% to Post:1.6%), hospitalizations (Pre:52.0% to Post:33.8%) • No difference in overall complication rate (Pre:19.7% vs Post:15.6%; OR 1.32, 95% CI 0.64, 2.99, p=0.4)	**Study Quality:** Moderate **Strengths**: • Investigates severity of bites • Long study period • Relevant training methods **Limitations:** • Size of police dog population unknown • No incidence rate (proportion of prison population) • No statistical analysis on primary outcome • Dogs likely already trained in old method prior to new method implemented • No control group • Potential bias of referrals of injured inmates to ED • Unknown adherence to training • Police dogs not representative of general dog population • Loss to follow-up (10.8%)
Mesloh, C., 2006 [54] **Design:** Observational retrospective cohort study **Aim:** Investigate the impact of a new police dog training method on police dog bites (2001)	**Participants:** Police dogs in Florida, USA (n = 181) **Intervention:** New 'bark and hold' method • 45 received intervention • 135 control (standard 'bite and hold' method)	1-year study period • 'Bite ratio' (% of arrests where a bite was involved), measured by a survey (2002) to police dog handlers	Bite-Ratio: • New method had higher mean bite ratios than the standard method (22.4% vs 15.7%, no p-value)	**Study Quality:** Low **Strengths:** • Adequate sample size • Control group • Relevant training methods **Limitations:** • Inadequate statistical analysis reported • No allocation to each group, retrospective study • Dogs likely already trained in old method prior to new method implemented • Dog trainers (white males) and police dogs not representative of general population • Unknown adherence to training • Response bias (48% did not return survey)

				• Short study period
Tortora, D.F., 1983 [76] **Design:** Non-random interventional study **Aim:** Investigate behavioural characteristics and efficacy of treatment of avoidance aggression in dogs	**Participants:** Household dogs in New Jersey, USA, referred to a vet with signs of aggression (n = 36) **Intervention:** Dog training programme (over 2.5 years) reinforced with an electric dog collar. Non-random assignment: • 36 received intervention • Controls (waiting list, n=not specified)	4.5-year study period: • Trainer reported measure: frequency of biting attempts within sessions	Bite Attempts: • Significant decrease in bite attempts with training (p<0.001), remaining at zero at a two-year follow-up • No change for controls (p>0.05)	**Study Quality:** High **Strengths:** • Variety of dog breeds included • Control group • Two people independently measuring outcome • Good follow up period (2.5 years) • Statistical analysis • Focused outcome • Detailed description of intervention **Limitations:** • Intervention requires high-input/cost • Electric dog collars are considered to be unethical by some • Did not report size of control group, or if loss to follow-up • Follow-up data collected via survey/owner videos
Dodman, N.H., et al, 1996 [85] **Design:** Pre-post interventional study **Aim:** Investigate the effect of positive training methods to treat dogs with dominance aggression	**Participants:** House-hold dogs with a history of owner-directed aggression (n = 10), Massachusetts, USA **Intervention:** A 1.5hr behavioural consultation followed by an individualised 8-week non-confrontational behaviour modification programme	8-week study period: • Owner reported dog aggression	Dog aggression: • 9/10 aggressive dogs experienced a decrease in aggressive responses (p<0.05)	**Study Quality**: Low **Strengths:** • Use of non-aversive technique an acceptable strategy to many people **Limitations:** • Very small sample size • No control group • Short study period, no further follow-up • Measures of aggression not validated • Inconsistent intervention (altered for individual dogs) • Owner reported aggression scores • Intervention requires high-input/cost • Unknown adherence to training
Knol, B.W., 1987 [60]	**Participants:** House-hold dogs with behavioural	Study period unknown	Dog aggression:	**Study Design:** Low

Design: Pre-post interventional study **Aim:** Summarise information on behavioural problems and the efficacy of treatment options	problems (n = 133), Netherlands **Intervention:** Owner-implemented successive approximation training (mixed rewards and leash/collar punishment system)	• Owner satisfaction with the programme in changing dog behaviour (aggressive and non-aggressive): Good, Fair, Moderate, Bad	• Owner reported satisfaction with the programme to change dog behaviour as 'good' or 'fair' in 42% of cases, moderate in 11% and bad in 41%	**Strengths:** • Adequate sample size **Limitations:** • 5 dogs also received medications (methyl-progesterone and methyl-testosterone) • No control group • Different strategies for different behavioural problems • Mixed aversive and non-aversive training • Unknown time-period of intervention / follow-up • Owner satisfaction a proxy measure of dog behavioural change • Intervention requires high-input/cost • Unknown adherence to training • No statistical analysis on outcome
Dinwoodie, I.R., et al, 2021 [55] **Design:** Observational retrospective cohort study **Aim:** To investigate the proportion of dog owners seeking help for behavioural issues, who they sought help from, which treatment plan worked best (behavioural or medication strategies), and the effect of treatments	**Participants:** House-hold dogs with at least one form of aggressive behaviour (n = 963), Connecticut USA **Intervention**: Owner-implemented behavioural modification (19 different types) or medication	Study period up to 2yrs • Owner-reported improvements in aggression	Interventions accessed: • 98% (943) engaged in behaviour training • 56% (542) sought help from professional trainer • 21% (202) received at least one of 11 kinds of medication Dog Aggression: • 82% (790/963) of owners reported an improvement in aggression • 25% (245/963) reported an improvement of at least 75% • No medication or alternative treatment improved aggression • Behavioural techniques associated with improvements were: communication technique, habituation, relaxation, and the use of short, frequent training sessions	**Study Quality:** Low **Strengths:** • Variety of dog breeds included • Statistical analysis **Limitations:** • Low sample size medication groups • No control groups • 91% of dogs were neutered • Owners asked retrospectively • Owners initiated a heterogenous group of interventions • Owner-reported improvements, and non-validated measures • Interventions likely require motivated owners, were not standardised or well defined, and were of unknown duration • Unknown adherence to interventions
Line S, et al 1986 [72] **Design:** Pre-post interventional study	**Participants:** House-hold dogs with owner directed aggression (n=24), USA	Study period: 12 months	Dog aggression: 4/24 had >90% improvement 6/24 had 70-90% improvement 5/24 had 50-70% improvement	**Study Quality:** Low **Strengths:**

Aim: To investigate the effect of strategies to treat dog aggression	**Intervention**: Behavioural techniques, progestin, and surgical or chemical sterilisation	• Owner-reported improvements in aggression	4/19 had <50% improvement 2/19 euthanised due to aggression, 2/19 died of other causes and 5 were lost to follow-up	• House hold dogs with aggression **Limitations:** • Low sample size • No control group • Multiple different interventions • Owner-reported improvements • Interventions likely require motivated owners • Unknown adherence to behavioural interventions • No intention to treat analysis • High loss to follow-up
Uchida Y, et al, 1997 [73] **Design:** Pre-post interventional study **Aim:** Investigate the effect of a behavioural modification programme on dogs with dominance aggression	**Participants:** House-hold dogs with dominance aggression, presenting to a behaviour clinic (n=20), USA **Intervention:** Non-confrontational behaviour management advice	8-week study period: • Owner-reported response to treatment	Dog aggression: • 20% (n=4) 'cured' • 35% (n=7) marked or moderate improvement • 15% (n=3) slight improvement • 30% (n=6) no improvement	**Study Quality:** Low **Strengths:** • House hold dogs with aggression • Non-aversive training techniques • No concurrent medication use **Limitations:** • Low sample size • No control group • Owner-reported improvements • Interventions likely require motivated owners • Unknown adherence to behavioural interventions
MEDICATION AND DIET				
Chutter, M., et al, 2019 [67] **Design:** Pre-post interventional study **Aim:** Assess the effect of fluoxetine and behavioural modification therapy in the treatment of canine behavioural disorders	**Participants**: House-hold dogs with behavioural issues including aggression, presenting to a behaviour clinic (n=88), USA **Intervention:** Fluoxetine with a behaviour modification plan at some point in a 4-year period	4-year study period: • Owner-reported response to treatment (positive, neutral, or negative)	Dog aggression: • Response to treatment: 55%, 32% neutral, 13% negative	**Study Quality:** Low **Strengths:** • Range of doses used **Limitations:** • Small sample size • No control • Other medications also prescribed • Duration of treatment not reported • Intervention likely requires motivated owners • Owner-reported improvements

				• High loss to follow up (n=41/134). Potentially treatment failure/non-compliance
Virga, V., et al, 2001 [80] **Design:** Cross-over interventional study **Aim:** Investigate the effect of amitriptyline to assist behavioural modification in the management of aggressive behaviours in dogs	**Participants:** House-hold dogs with chronic aggression, USA (n=39) **Intervention:** Amitriptyline with behaviour modification plan • 12 randomly assigned (prospectively) to either: -4wks drug then 4wks none -4wks none then 4wks drug • 27 had drug for 4 weeks (retrospectively)	8-week study period: • Owner-reported improvement in dog aggression	Dog aggression: • No difference in owner-reported improvement between weeks of receiving amitriptyline: 83% (95% CI 51, 97), and weeks receiving Placebo: 75% (95% CI: 44, 94, p=1.0) • No difference in owner-reported improvement between dogs receiving Amitriptyline in retrospective phase 70% (95% CI 50, 86), and weeks when prospectively treated dogs were receiving placebo 75% (95% CI 44, 94) (p=1.0)	**Study Quality:** Low **Strengths:** • Double blinded, placebo control, cross-over • Statistical analysis **Limitations:** • Small sample size • 12/24 prospective participants excluded • Unknown compliance with medication or behaviour modification plan • Unknown effect of behaviour techniques • No washout period • Owner-reported measures of improvement
Odore, R., et al, 2020 [68] **Design:** Pre-post interventional study **Aim:** Investigate the behavioural effects of Fluoxetine in dogs affected by dominance aggression	**Participants:** Dogs referred due to owner-directed aggression (n = 8), Italy **Intervention:** Fluoxetine and positive behavioural techniques for 6 months	6-month study period • Owner-reported dog-aggression scale	Dog aggression: • Aggressive behaviour decreased from pre-intervention to 6 months	**Study Quality**: Low **Strengths**: • Valid treatment • Focused outcome **Limitations:** • Very small sample size • No control group • Unknown compliance with medication or behaviour modification plan • Unknown effect of behaviour techniques • Owner-reported measure of aggression
Dodman, N.H., et al, 1996 [61] **Design:** Cross-over interventional study **Aim:** Investigate the use of fluoxetine for the treatment of dominance aggression in dogs	**Participants:** House-hold dogs with owner-directed dominance aggression (n = 9), USA **Intervention:** Fluoxetine: 1 week of placebo, followed by 4 weeks of medication	5-week study period: • Owner-reported aggression score: (growling, lip curling, snapping, biting)	Dog aggression: • Significant reduction in aggression score (p = 0.01), but not in any specific behaviour • 8/9 owners reported some level of improvement	**Study Quality:** Low **Strengths:** • Cross over design • Partial blinding (week of placebo unknown to owners) • Use of an aggression score • Compliance to medication was checked **Limitations:**

				• Very small sample size • Owner-reported measure aggression • Non-validated measure aggression • Uses continuation of medication as a measure of success • Post-study analysis uncertain accuracy
Rosado, B., et al, 2010 [66] **Design:** Pre-post interventional study **Aim:** Investigate the effect of fluoxetine on aggressive behaviour and biochemical markers	**Participants**: House-hold dogs with behavioural aggression, Valencia, Spain (n = 22) **Intervention:** Fluoxetine for 30 days • 22 received intervention • 9 non-aggressive dogs also received intervention	30-day study period • Owner-reported aggressive behaviour	Dog aggression • All owners reported an improvement in aggressive episodes (authors did not specify by how much, or which group)	**Study Quality:** Low **Strengths:** • Also investigates biochemical markers **Limitations:** • Small sample size • No appropriate control group • Owner-reported measure of aggression • Non-validated measure of aggression • Main objective of study was to measure biochemical markers
DeNapoli, J.S., et al, 2000 [56] **Design:** Crossover interventional study **Aim:** Investigate the effect of protein or tryptophan diet on dog aggression and biochemical markers	**Participants:** House-hold dogs with aggression, Boston, USA (n=33). Grouped by aggression type: dominance, territorial, hyperactivity **Intervention:** Four diets: high or low protein, with or without tryptophan. Random allocation to 1 week of each	4-week study period • Owner-reported aggression (average score)	Dog aggression: • No significant improvement in behaviour with any groups for any diet • Dogs with dominance aggression fed a high-protein + Tryptophan diet had higher aggression scores	**Study Quality:** Moderate **Strengths:** • 3-day washout period between diets • Exclusion of recent medications • Randomisation and blinding of diet weeks • Well defined measure of aggression • Appropriate statistical analysis **Limitations:** • Potential conflict of interest with Pet-Food company sponsorship • Exclusion of pregnancy or severe aggression • Small sample size • 5 dogs lost to follow-up • Owner-reported aggression score • Further analysis done on whole sample (no crossover/randomisation)