

Human-directed dog aggression;

A systematic review

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By

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DECLARATION

I declare that, other than where otherwise acknowledged, this thesis and the work it entailed is of my own composition, it has not been submitted for any other degree or professional qualification.

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June 2012

Abstract

Human-directed dog aggression is a worldwide issue with major public health and animal welfare implications. Consequences for the target of aggression range from fear and minor injury, to life threatening injury and death, and for the dog impaired freedoms, restricted interactions and ultimately euthanasia.

The systematic review undertaken here aimed to identify and assimilate all robust evidence regarding factors that affect the risk of human-directed dog aggression. Such information is vital for the development of sound preventive strategies.

Multiple electronic literature databases were interrogated in order to identify all evidence for risk factors of human-directed dog aggression. The search strategy was designed to minimise the risk of publication and language biases, specificity was sacrificed for sensitivity.

The threshold for acceptance of evidence was predetermined at a moderate level; any study that provided evidence with a low risk of confounding and bias and a moderate probability that any relationship identified was causal would reach the final review. Appraisal examined methodological quality, study design, selection process, measurement of outcome and exposures, and type and quality of analysis. All stages of appraisal were undertaken blind to the study findings.

On assimilating the evidence identified, no robust evidence for any risk factors of human-directed dog aggression was identified. Eight studies provided a moderate level of somewhat conflicting evidence. Amongst those studies appraised as failing to reach the moderate level of acceptable evidence, the majority were excluded as a result of multiple limitations.

It is vital that future research is undertaken to a high methodological standard in order that it provides robust evidence for the effect of any risk factor identified.

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Chapter One

Introduction & Literature review

1. Introduction

Human-directed dog aggression is a worldwide issue, with major public health and animal welfare implications. In order for preventative measures to be identified, be they legislative, behavioural, genetic or social, the factors which make dog aggression directed towards people more likely to occur need to be identified in a reliable manner. The systematic review described in this thesis sought to identify all available robust evidence of factors which affect the risk of human-directed dog aggression.

This thesis will outline: man's association with the dog, the issue of human-directed dog aggression, the methodology and findings of the systematic review undertaken and will evaluate common limitations of studies investigating human-directed dog aggression. Hence, the principal aim of the work presented in this thesis is to systematically identify and review the current robust evidence base of risk factors for human-directed dog aggression, highlighting the areas where further research is a priority and areas where improvements in research methodology might be focused in the future.

1.1. Dog-human relationships

1.1.1. Domestication of the dog

There is little dispute that the closest relative of today's domestic dog (*Canis familiaris*) is the grey wolf (*Canis lupis*), with no other canid sharing closer genetic lineage.¹⁻³ The archaeological record suggests that man's domestication of the dog can be dated to 10,000-17,000 years ago^{1,4-8} and possibly as far as 30,000 years.⁹ The former coincides with a key stage within human development, with man beginning the transition from hunter gatherer to more settled agriculture, a time associated with the domestication of many species.^{10,11}

1.1.1.1. Archaeological evidence

One of the earliest identified remains of a tamed canid in Europe was of a five month old puppy, unearthed at the Mesolithic Star Carr site in Yorkshire, England. These remains have been carbon dated to approximately 10,000 years ago.¹² Remains of very similar size and morphology, found close to various coastal sites near historical shipping routes and carbon dated to the same period, suggest that at that time the genetic diversity amongst these early European domesticated canids was minimal, with perhaps one litter being distributed around Europe and further afield by sailors.¹⁰

A notable finding from this time was of elderly human and juvenile canid remains buried together at Ein Mallaha, an Eastern Mediterranean hunter-gatherer settlement.¹² This puppy has been identified as likely to be a

domesticated Arabian Wolf, the manner of burial suggested the wolf's significance to the human and his kin.¹²

1.1.1.2. Genetic evidence

Vila et al. examined the mitochondrial DNA (mtDNA) of modern day wolves and dogs representing 67 modern breeds.² The molecular distance found by Vila suggested that the point of divergence of the dog and wolf from their common ancestor was nearer 100,000 years ago, far earlier than the archaeological record suggests. This work also suggested that divergence occurred in multiple geographical sites and was not, as previously suggested, a single point divergence.

More recently similar studies have suggested that divergence occurred approximately 16,000 years ago from a small group of founders.¹³ Genomic methods of estimation of the time of divergence suggest that this may have occurred as recently as 10,000 years ago.⁸ However this estimate does not take account of the continued backcrossing occurring between the early dog and wolves. Backcrossing will lead to significant underestimation using both mtDNA and genomic methods for estimation of the time of divergence.^{8,14} Taking this into account the work above estimated that even a small amount of continued back crossing could move the time of divergence nearer 30,000 years ago.⁸

Whilst the limited number of lineages identified by mtDNA evidence suggests that domestication resulted from a relatively small number of discrete domestication events,^{2,10,13} the diversity within the modern day *Canis*

familiaris suggests a large number of ancestors are likely to have been involved.¹⁴ This supports the theory that backcrossing contributed significantly to the development of the modern day dog, and its phenotypically diverse breeds.^{8,14}

1.1.1.3. The process of domestication

Vigne describes the process of domestication as involving a number of stages; with an intensification of the relationship between animals and humans, commensalism, human control of the wild animal, followed by control and extensive breeding of the now captive animal.¹¹ Intensive breeding, with man artificially exerting selection pressure for desired characteristics, then results in the development of a domesticated species.

Vigne's theory supports Coppinger's suggestion that domestication of the wolf began by those least afraid of humans having a shorter "flight distance" and thus being able to live more closely to human camps, and thereby benefit from their food waste and shelter.¹⁵

Lindsay proposed that early in the process of domestication wolves existed in a mutualistic relationship with groups of human hunter-gatherers, living in a niche close to settlements but not within them.¹⁶ This mutualism developed an environment in which further co-evolution could occur, selecting for those phenotypic features which conferred an advantage to dogs whilst living closely with humans.^{16,17}

The archaeological and genetic evidence appears contradictory, with estimates of the date of divergence and domestication spanning 100

millennia. However, it is likely this is a reflection of the process of evolution of the dog, from a common canid ancestor, and its subsequent speciation and domestication. Selection pressure exerted by the protodog's developing relationship with man resulted in the morphological changes seen in archaeological remains and ultimately today's breeds of dog.

1.1.1.4. The dog in modern society

Dogs fulfil numerous roles within the human community. To early man, the main purpose for owning dogs is thought to have been their hunting prowess and the protection they conferred against other predators.¹² To twenty-first century humans, dogs continue to fulfil these roles for some, and in addition are companions, confidants, and a member of the family, to others the dog is a work partner, an assistant, a status symbol, perhaps even a weapon.¹⁸⁻²² These diverse, human-appeasing, roles fulfilled by dogs engender differing expectations, attitudes and husbandry.

Although related to the wolf by a common ancestor, dogs have evolved over the past millennia to depend to varying extents on their relationship with man. For the dog, the human-canine relationship routinely provides the biological essentials of shelter, nourishment and warmth. In addition humans offer companionship and stimulation, something these family animals require in order to thrive.

1.1.2. Health benefits of dog ownership

The impact of dog, and other companion animal, ownership upon human health has been the subject of considerable research since the 1980s. There

have been conflicting reports of benefit to human health via various outcomes,²³⁻³⁹ and of consequent reduced consumption of health care resources.⁴⁰⁻⁴²

Before the question of the affect of pet dog ownership on human health can be understood, we must first consider that health is far more than the absence of disease. The World Health Organisation (WHO) defines health as “a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity.”⁴³ With this in mind, it can be foreseen that any affect of ownership on an isolated disease outcome may not be reflected in the overall effect on health, and likewise that any positive effect on health may reflect the interaction of psychosocial factors with somatic disease. These interactions create a complex situation for analysis with many potential confounders.

1.1.2.1. Dog ownership and exercise

Cross-sectional studies have suggested that dog owners tend to be more physically active than non-owners,²³⁻²⁵ and that this relationship persists when socio-demographic, socio-environmental and physical factors are controlled for.²⁷ Prospective work by Cutt et al. found that acquiring a dog was associated with an increase in recreational walking greater than in those who did not acquire a dog ($p < 0.05$), however this work also identified a number of lifestyle factors and changes which were associated with acquiring a dog and may act as confounders to the relationship with walking.²⁶

Although the effect of acquisition was reduced when socio-demographic variables were controlled for, it remained statistically significant ($p < 0.01$).

Whilst studies have repeatedly found an association between a moderate increase in walking and dog ownership,²³⁻²⁶ others have found that a significant proportion of owners do not walk their dogs.²⁸ It has been suggested that owners who do not identify that their dog has a social support role are less likely to walk with their dog.⁴⁴

1.1.2.2. Pet ownership and cardiovascular health

Work carried out in the mid 1970s by Friedmann et al., reported to be the first study of its kind, found that one year survival following myocardial infarction was significantly higher in patients who reported owning a pet at the time of their initial admission, as compared to those who did not.²⁹ The authors of this study considered that the exertional capacity required in order to own a dog may have confounded this relationship. However, when the 80% of the pet owners who were dog owners were removed from the analysis the significance of the relationship persisted. The authors concluded that the effect on mortality was likely to reflect personality and social differences in those choosing to own pets, rather than an increase in exercise or a direct effect of ownership.²⁹

Whilst much of the work in this area examines the effect of pet ownership on health, without distinguishing between species owned; work undertaken in a randomly selected subset of the study population of the Cardiac Arrhythmia Suppression Trial (CAST) examined the effect of cat and dog ownership, in addition to psychosocial factors, on 1 year survival post myocardial infarction.³⁹ Friedmann and Thomas found that dog ownership was associated with an 8 fold reduction in first year mortality rate ($p < 0.05$) whilst

cat ownership was associated with an increase in mortality at one year ($p=0.03$).³⁹ Further analysis however revealed that social support confounded this relationship and the negative effect of cat ownership was ameliorated when this was taken into account, whilst the beneficial association with dog ownership persisted independently.³⁹ These findings, in common with others, identify that there are differences in the psychosocial and physiological impacts of dog ownership as compared to ownership of other companion animals.^{39,45-47}

1.1.2.3. Dog ownership and psychosocial health

Dogs are commonly considered friends or members of the family,⁴⁸⁻⁵⁰ with the owner-pet relationship fitting the evolutionary attachment system of the parent-child bond.⁵¹ Dogs impart security and well being, providing companionship and social support, pleasure in recreation and relaxation.^{18,22,47-50}

During childhood especially, it is thought that the perceived unconditional love and non-judgemental affection, derived from the pet-human bond, is particularly beneficial to psychological well being.^{52,53}

An owner's relationship with their pet dog may mirror some aspects of human relationships known to have positive benefits to health.⁵⁴ Ownership of a pet, and especially a dog, appears to attenuate the physiological and psychological effects of stress.^{37,42,55} This stress attenuating effect has also been found to be present in individuals exposed to an unknown dog.^{56,57}

Levinson is noted as the first to document the beneficial effect of the presence of a dog on child communication, and their beneficial influence on building rapport in the psychotherapy setting.⁵⁸ Attachment to a pet during childhood and early adolescence has been noted to be associated with positive emotional functioning⁵⁹ and improved self esteem,^{59,60} both important aspects of socio-emotional development.⁶¹

At the other extreme of life, a longitudinal study of non-institutionalised older adults, found that the ability to perform activities of daily living of pet owners deteriorated at a slower rate than in those not owning a pet, after controlling for other factors.⁶²

1.1.2.4. Early dog ownership and atopy

There is contention over the affect of dog ownership during early childhood on the incidence of later atopy and asthma. A number of studies have found a, possibly exposure-dose dependent,^{32,35} reduction in the incidence of both childhood atopy and asthma in those exposed to pets during infancy.³²⁻³⁵

With ownership of a single dog or cat associated with a slight increase in atopy whilst ownership of two or more dogs is associated with a significant reduction in atopy.^{32,35} It has been suggested that this effect may be confounded by selection for pet ownership,^{33,35,63} likewise this may explain the finding of an inverse relationship between current pet ownership, sensitisation and symptoms of hay fever, with families where children have become sensitised no longer owning pets.³⁴ This may also have a role in the finding that the negative association was only present in those without a family history of atopy.³⁶

1.1.2.5. Assistance dogs

Increasingly the role of canine companions in improving the quality of life for those with physical or mental impairment is recognised and actively nurtured. Wartime Germany, 1916-17, saw what are thought to be the first guide dogs for the blind, with dogs being taught to lead soldiers blinded in the trenches. News of this spread to Switzerland and thence the United States where The Seeing Eye organisation was established in 1928.⁶⁴ In the United Kingdom, the Guide Dogs for the Blind Association was established in 1934.⁶⁵ Over the intervening decades dogs have also been trained to assist those with a diverse range of physical impairments, including hearing loss,⁶⁶ epilepsy⁶⁷ and diabetes mellitus.⁶⁸

In common with dogs kept as pets, in addition to fulfilling their role in reducing the physical impact of their owner's impairment and thus reducing the consequent physical disability; assistance dogs confer both companionship and confidence, reducing social handicap and reliance on others for personal care, whilst increasing community integration and independence.^{38,66,69-71} Although a recent systematic review found sound scientific evidence of these effects to be sparse,⁷² as a result of recognition of this aspect of the role of assistance dogs the past two decades have seen the broadening of assistance dog programs to include provision of psychiatric assistance dogs, and in the development of animal assisted therapy.^{73,74}

1.1.2.6. Security

Dogs are utilised in a number of military and law enforcement roles; protection, detection and reassurance, maintenance of public order, assistance of armed officers with non lethal apprehension and restraint of assailants, searching for persons, property and contraband substances.⁷⁵⁻⁷⁸

1.1.3. Motivation for dog ownership

Humans can be considered to be intrinsically or extrinsically motivated.⁷⁹

Intrinsic aspirations are described as those relating to meaningful relationships, personal growth and community contributions, and external aspirations as relating to the acquisition of wealth and self image.^{79,80}

Intrinsically motivated individuals have been described as gaining from the journey towards their goals whilst extrinsically motivated individuals focus on the attainment of the goal.⁸¹ These motivations are found in all aspects of life including our relationships with companion animals.²⁰

1.1.3.1. Dogs as a status symbol

Where motivation for dog ownership is driven by external reward, such as acclaim from others or alteration in personal identity within a community, this is often at the expense of acknowledgement of the dog's innate personality and needs as a canid.²⁰ Reward from these relationships is measured in terms of gain for the human, owner control of the animal, its conformation to the role imposed upon it and its affect on the status of the owner within their community.²⁰ These dogs are in effect, although perhaps not consciously, considered material objects.

Extrinsic motivations applied to dog ownership result in a diverse range of expectations of the dog, in part dictated by the cultural environment to which the owner relates. Dogs fulfilling these extrinsic expectations range from the track greyhound, through those dogs sought for their appearance and conformation to breed standard, to the small dog carried everywhere and treated as a toy.

For the dog, the restriction of activities and limitations of normal canine behaviour and expression imposed by the role that they are placed into may be considerably detrimental to their mental and physical health and welfare.^{20,21,82} This is in contrast to the intrinsically motivated owner who values their dog for its innate personality, nurtures their freedom and values a bidirectional relationship with the animal.²⁰

1.1.3.1.1. The “Status Dog”

Within some cultural environments, a dog’s physically dominating appearance is considered to add to the owner’s status,^{83,84} and in this context dogs are usually seen as representing socially undesirable sub-cultures.^{21,84} This issue is commonly perceived within inner city, socially deprived, urban environments,^{22,81} the “pariah status” of certain types of dog is thought to encourage their ownership within this social environment.⁸⁴ “Status dog” as a term is today used by some parties interchangeably with “Weapon dog.” These dogs are felt to be used to intimidate others and in some cases as weapons. Whether these dogs are in fact at greater risk of biting is not known; even in the absence of physical injury, the fear they engender within some communities is harmful. For their owners however

these dogs may provide not only a symbol of status within their community but companionship.²¹

Kasser et al^{79-81,85} suggested that early deprivation and uninvolved parenting are associated with external motivation and the latter with dissatisfaction and mental health problems.^{81-83,87} These descriptions were originally related to a study of the life aspirations of college students, however can be extrapolated to the dog owner's motivations.²⁰ This theory is in keeping with the opinion expressed by Grant regarding the problem of "status dogs" within UK cities as a consequence of a greater societal problem,^{86,87} and also reflects the findings of the Marmot Report.⁸⁸

1.2. Risks associated with the human-canine relationship

Whilst there are undoubted mutual benefits, the human-canine relationship introduces risks to both parties. These include some factors (such as those related to a deprived socio-cultural environment) where both humans and their canine companions are exposed to the same suboptimal conditions. Other risks are less specific to the shared environment.

Living within a human dominated environment results in a range of risks for the dog, from restricted liberties, inappropriately altered diet and interactions,⁸² through neglect and other forms of abuse and injury towards the dog.²¹ Misunderstanding of the needs and behaviours of a dog may result in further compromise of their environment and welfare.⁸²

From a human perspective, the risks associated with canine-human interaction primarily relate to aggressive behaviour exhibited by the dog,

although other risks are also posed including accidental injury through tripping over the dog or its belongings,⁸⁹ and zoonotic risks.^{90,91} The latter also frequently transmitted by bite injuries. Aggressive canine-human interactions can result in injury, fear and even death. This issue is further explored below.

1.3. Human-directed dog aggression

Aggression forms a normal component of every animal's repertoire of behaviours;⁸² however, for the dog living within a human environment, human-directed dog aggression has major public health and animal welfare implications; as a consequence aggression is considered by most to be unacceptable in this context.

Expressed aggression is usually the end stage of the dog's attempts to express discomfort at a situation.^{82,92,93} The expression of emotions which may culminate in a dog expressing overt aggression and biting have been described hierarchically, this sequence of escalation is illustrated in Shepherd's Ladder of Aggression⁹⁴ (Figure 1).

There are instances where the escalation illustrated by Shepherd's Ladder of Aggression is not seen, notably where a bite is the result of predatory behaviour, when the emotions and behaviour of the dog differ to those seen in fearful or stressful situations.⁹⁵

It is those behaviours at the peak of Shepherd's hierarchy that are generally considered acts of aggression.^{92,93} This can range in severity from a raised lip, growl, snap or snarl directed towards a person, to an aggressive act

resulting in injury of the target, usually by biting, and in extreme cases life threatening bite injuries.



Figure 1: Ladder of Aggression by Kendal Shepherd, Reproduced with permission from the BSAVA Manual of Canine and Feline Behavioural Medicine. © BSAVA⁹⁴

There are various methods used to describe aggression.⁹⁶ Historically man attempted to infer motivation to the aggressive dog, defining the dog as dominantly aggressive when he was aggressive in situations interpreted as a challenge to the pack hierarchy or territorially aggressive when faced with a threat to the dog’s domain.^{97,98} However, as the field of ethology has grown, so has the understanding of the dog, and indeed the wolf, as a family animal.⁹⁹ This, in addition to a growing awareness of our limited knowledge of what motivates an individual dog, has led to the increasing use of the target or circumstances of aggression as a descriptor, and not the inferred motivation.^{92,95,100} Thus we have for example; intra- and inter-specific

aggression, owner-directed and stranger-directed aggression. The relationship between instigator and target being key to the likely factors leading to aggression and potentially the manner in which it developed and can be managed.¹⁰⁰

1.3.1. The impact of human-directed dog aggression on people

Human-directed dog aggression is *directly* responsible for considerable worldwide morbidity and a small annual mortality rate. The number of people injured by dogs annually is difficult to quantify, with many incidents going unreported, even where this is obligatory,¹⁰¹⁻¹⁰⁴ and multiple potential biases affecting which bites are reported to authorities or presented for medical treatment.^{88,104-106}

In addition to the public health issues, human-directed dog aggression carries implications to the welfare of dogs.¹⁰⁷ For all of these reasons many parties are keen to reduce the occurrence and consequences of aggressive acts.

1.3.1.1. Fatalities

Fatalities as a *direct* result of acts of human-directed dog aggression are rare occurrences. Across England and Wales, during the decade to 2008 there was an average of 2.2 registered deaths per annum attributed to dog bites or strikes.¹⁰⁸ However, as the Office of National Statistics acknowledge, these figures are not entirely accurate, with for example only one of those four deaths registered in 2008 occurring during that year.¹⁰⁹ Children are disproportionately represented amongst those fatally injured by dogs.^{108,110}

Indirect deaths, as a result of human-directed dog aggression, result largely from the infective consequences of bite injuries. The most common pathogens implicated in bite wound infections include *Pasteurella spp.*, *Streptococcal spp.* and *Staphylococcal spp.*¹¹¹

Whilst not currently present in the United Kingdom, rabies virus is a notable potential pathogen responsible for considerable additional indirect mortality worldwide. The World Health Organisation (WHO) estimates that 55,000 people die as a result of rabies virus infection each year,¹¹² the vast majority of these deaths occur in Asia and Africa where transmission of the rabies virus from a dog is thought to be the almost exclusive source of infection.¹¹² Dog-human transmission of rabies virus is extremely rare outwith these areas,¹¹¹ with most rabies deaths in the United States, Europe and Australasia resulting from infection via other vectors.^{111,112}

Incidents of human-directed dog aggression resulting in the loss of life are of great public and political concern. Identifying modifiable factors which will enable their rate of occurrence to be reduced is a priority. However these incidents are by far outnumbered by non life-threatening bite injuries and deaths from other causes across all age groups. For example compared to the annual average of 2.2 deaths attributable to dog bites or strikes; 30 people drowned in the bath in England and Wales during 2005³¹ and, despite a falling trend, road traffic collisions accounted for 2946 deaths in Great Britain during 2007; 646 of these were pedestrians.¹¹³

It is not clear whether factors which predispose to increased risk of a minor bite are the same as those which predispose to increased risk of a life threatening bite injury.

1.3.1.2. Bites

Whether or not a dog has bitten would intuitively seem indisputable; however this is not as well differentiated as at first appears with definitions and perceptions of bite varying. Guy et al. defined a bite as “the upper or lower teeth making contact with the victim’s skin with sufficient pressure to cause a visible injury such as an indentation, welt, scrape or bruise, puncture or tear in the skin. A dog mouthing a person’s skin without applying sudden pressure is not considered a bite.”¹¹⁴ This definition does not however implicitly identify the act as aggressive. A puppy in play for example may perform an act which would meet these criteria for bite, without any aggressive intent.¹¹⁵

Within the scope of bite injury fall both the limb threatening, disfiguring, wounds with extensive tissue loss and the minor abrasion with no skin penetration. The injury imparted by a given dog in a given situation is dependent on factors intrinsic both to the dog and the target of aggression. Physics alone would suggest that a large muscular dog is able to generate a greater bite force than a small dog,^{116,117} this is likely to at least in part underlie the finding that owners are more likely to tolerate aggression in a small dog as compared to larger dogs.^{106,118}

The rate of bite injuries as a result of human-directed dog aggression is unknown; many do not result in presentation to any medical or law enforcement authority.^{102,105,119,120} For the UK, we are able to crudely estimate the number of injuries requiring hospital admission, and to a lesser degree of certainty Emergency Department attendance, from data collected by the NHS and made available as Hospital Episode Statistics (HES).¹²¹

Annual admissions for NHS care in England attributed to being bitten or struck by a dog, coded as W54 using the 10th edition of International Classification of Disease (ICD10), have risen over the past decade. The most recent figures, for the year ending April 2011, indicate that there were 5,409 emergency admissions and a total of 10,690 occupied bed days attributed to these injuries.¹²¹

An estimated 1 in 5 dog bites to adults and 1 in 4 dog bites to children result in attendance for medical treatment in the United States.^{122,123} Owing to the interaction of socially disparate health care seeking behaviour,⁸⁸ perception of risk and other psychosocial factors,^{124,125} those attending for treatment are not likely to be representative of all bite injuries.^{88,104,105,119} As a result, even if Emergency Department and Minor Injury Unit attendances were accurately recorded, this data would not be definitive in determining who is at greatest risk of being bitten.

Amongst those receiving medical attention for dog bite injuries, as in the case of fatalities as a result of dog bite injuries,¹¹⁰ children are over represented.^{119,126} However, studies which attempt to capture all bites, and not just those attending for treatment, do not tend to find an increased

incidence in children,^{105,122} nor do they find an increased severity of injury in children, although more injuries were to the head.¹⁰⁵ Amongst reported bites, those to children are more likely to have resulted in no injury than those to adults.¹⁰⁵ These findings, and the differences in distribution of bites identified in the hospital attending as compared to general populations,^{105,119,122,126} support the hypothesis that bitten children are more likely to be presented to hospital or reported to authorities than bitten adults, regardless of their degree of injury.^{105,106}

1.3.1.3. Aggression where no physical injury occurs

Aggression does not inevitably involve physical injury. The dog has a repertoire of expressions of aggression, from the raising of a lip, snarl and growl to a snap and ultimately a bite.⁹² This escalation provides the potential for de-escalation and thereby reinstatement of the emotional equilibrium and prevention of bite incidents.⁹² The difficulty in this obvious strategy of bite prevention is in the recognition, by both owner and the target of aggression, of the early stages of the escalation.¹²⁷ Recognition of these non-injurious expressions of aggression by all parties is thus potentially crucial in forming strategies to reduce dog bite injuries.¹²⁶

1.3.1.3.1. Cognitive bias in interpretation of behaviour

The incidence of non-injurious aggressive acts is likely impossible to quantify in any meaningful manner. There is, in addition, inherent difficulty in establishing whether what has been perceived by the target, or an observer, was in reality aggression or an alternative behaviour misinterpreted.^{95,126,128} This issue compounds the challenges of legislative control, given that those

perceiving a non-aggressive act as aggressive are likely to be similarly affected emotionally as where the act truly was aggressive. This is recognised for example in the United Kingdom legislation; where section 3 of the Dangerous Dogs Act 1991 legislates for a dog causing “reasonable apprehension” that it may injure a person.¹²⁹

Perception of the purpose for which a dog was acquired, and subsequently owned, is likely to have a bearing on an individual’s interpretation of the risk a given dog poses, and further the human reaction to the behaviour exhibited by that dog.¹³⁰ Observer perception of the circumstances of any situation will be the consequence of interplay between perceived and real motivation, emotional state, behaviour, knowledge and the environment, both physical and cultural.^{131,132} An act of aggression by a dog perceived to be friendly and playful is for instance less likely to be reported to authorities than the same act by a dog perceived to be kept for intimidation or guarding.¹³⁰

These issues have the potential to introduce considerable cognitive bias into studies designed to identify the existence of a relationship between factors such as the use, breed and size of dog and the risk it poses for human-directed dog aggression.

1.3.1.4. Psychological implications

Even where no physical injury has occurred, the psychological morbidity resulting from dog aggression, and perceived threat,⁸⁴ can be profound and long lived. Receipt of a dog bite may be associated with the development of

anticipatory fear of dogs, transmission of phobias to dependents and in some cases the development of post-traumatic stress related symptoms.¹³³⁻¹³⁵

1.3.1.5. Financial implications

The physical and psychological cost of human-directed dog aggression is mirrored by monetary and societal costs. At the tip of the iceberg are those bites attending for emergency medical attention; Weiss estimated this cost to be US \$102.4 million within the United States in 1998,¹¹⁹ this excluded follow up care and indirect costs. In England, the Department for the Environment Food and Rural Affairs (Defra) estimated the cost to the National Health Service of dog attacks on people was £3.3 million in 2009.¹³⁶

Non-medical costs include household liability claims, which in the United States cost on average \$26,166 per claim and \$413 million in total in 2010.¹³⁷ Professional liability claims in the United States have been estimated to be in the region of \$10 million per annum and ancillary costs, including damage to belongings and lost income at \$25 million.¹³⁸

1.3.2. The impact of human-directed dog aggression on dogs

Whilst the more evident direct consequences of human-directed dog aggression are to the human recipient of the aggression, there are also considerable implications to the dog. These range from the relatively minor, such as restriction to lead, to more extreme restrictions to the dog's activities resulting from impoundment, through to euthanasia.^{107,120} Aggression itself may be a consequence of impaired welfare standards.^{86,139}

1.3.2.1. Euthanasia

Human-directed aggression, especially where it results in serious injury, may lead to owners choosing, or being compelled, to euthanise their dog.^{95,97,118}

A level of aggression which would lead one owner to euthanise may be tolerated by others. How large the risk and how incompatible that risk is with family life is likely to be determined by many factors, some relating to the dog and the perceived predictability of the aggression and others to the owner's home situation and ability to adapt and respond to their dog's behavioural changes and needs.¹¹⁸

1.3.2.2. Restricted activities

Where a dog is considered aggressive the owner may voluntarily restrict its activities to avoid the potential for aggressive interactions. Whilst this may reduce the risk of subsequent incidents it also restricts the dog's interactions with others, which may be detrimental to the welfare of the dog,¹⁴⁰ and prove counterproductive by increasing the social conflict and fear experienced by the dog.^{82,107}

Where a dog has bitten and is subject to court proceedings their activities are likely to be restricted by kennelling with limited interactions, exercise and ability to express themselves. Kennelling poses significant challenges to the psychological and physiological health of the dog, with the potential to compromise welfare.^{141,142} If a dog is returned to its owner following court proceedings, the court judgement will often continue to restrict activity and interactions with restrictions to lead and muzzling.¹²⁹

1.3.2.3. Relinquishment

Aggression is frequently cited as a reason for owners relinquishing dogs to welfare and rescue organisations¹⁴³⁻¹⁴⁵ and also for the failure of adoptions from such organisations.^{146,147}

Dogs considered aggressive are less likely to be offered for adoption within rehoming facilities¹⁴⁸ more likely to spend a prolonged period waiting to be adopted,¹⁴⁹ more likely to be returned following adoption¹⁴⁷ and are frequently euthanised.^{148,150}

1.3.2.4. Emotional state causing aggression

In addition to the consequences of aggressive behaviour, the factors that result in a dog becoming aggressive may have welfare implications for the dog themselves.^{86,107} For example a dog that is fearful and continues to be exposed to the stimulus causing that fear, or is subjected to aversive handling in response to its exhibited fear.⁹²

1.4. Strategies to prevent the consequences of aggression

1.4.1. Education

There is an increasing trend to educate children in an attempt to develop awareness and understanding of canine behaviour, with the prime intention being to reduce the incidence of bite related injuries.¹²⁰ A number of projects exist attempting to teach children how to approach a dog safely and how to interpret canine behaviour.^{151,152} From those that have been evaluated, these programmes do achieve some success, improving awareness of the dog's

body language and behaviour in the short term,^{126,153-156} however the impact on receipt of bite injuries has not been established.

The other focus for educational intervention is in educating owners regarding interpretation of canine behaviour and the management of their dogs. This type of intervention assists owners in recognising the escalation of arousal and factors which may be leading to it,^{157,158} thereby enabling timely action and removal of the stimulus before the dog has reached a level of arousal which may lead to harm.

1.4.2. Behavioural

The nature of appropriate behavioural approaches for both the prevention and management of aggression is a subject of some debate.^{82,95,100,158} This in part originates from the partisan nature of animal behaviour science.

One approach, recommended by some clinical behaviourists, requires that the emotions underlying aggressive behaviour are identified and addressed before effective management of the consequent exhibition of aggression is likely to be effective.⁹⁵

1.4.3. Physical

Restraint of a dog by use of a lead, and physical limitation on the location and nature of its interactions is one manner of attempting to prevent aggressive interactions. Most dogs are walked on the lead a proportion of the time,¹⁵⁹ however when this limits all interactions it may be detrimental to the mental health and well being of the dog.⁸²

Dogs may be muzzled in order to attempt to prevent biting.¹⁰⁰ Whilst it provides a physical barrier; muzzling does not address the emotions underlying the aggressive behaviour nor the expression of aggression in other ways, which may be equally psychologically, if not physically, damaging to the target of aggression and the dog themselves.

1.4.4. Legislative

A range of legislative strategies have been used in attempts to reduce the occurrence and consequences of human-directed dog aggression.

Legislation generally targets dogs and their owners in one of three ways:

- I. All dogs within the jurisdiction.
- II. A designated subset of dogs considered to pose greatest risk, as a result of their breed or type, irrespective of the individual dog's behaviour.
- III. Those dogs that individually are considered to pose a heightened risk.

1.4.4.1. Legislation affecting all dogs within a jurisdiction

1.4.4.1.1. Control of free-roaming dogs

Regulations aimed at the control of free roaming dogs provide the powers to remove dogs found without an owner in a public place. Whilst the majority of bite incidents occur on private property,^{104,105} and are caused by owned dogs,^{104,160-163} control of dogs in public places has the potential to significantly reduce the incidence of bites occurring there.

In the United Kingdom environmental protection legislation¹⁶⁴ regulates the seizure and disposal of stray dogs, unclaimed dogs are held for a minimum of seven days prior to being euthanised or where possible rehomed. In other jurisdictions this period is shorter still, with for example the Republic of Ireland holding dogs for five days¹⁶⁵ and some States in the United States for three days.¹²⁰ In some jurisdictions stray dogs may be shot on sight in an attempt to control rabies outbreaks.¹⁶⁶

1.4.4.1.2. Restraint of dogs

In order to control dogs in public places, and facilitate the removal of unrestrained dogs, many jurisdictions have regulations governing the control of all dogs, regardless of their behaviour, in public places. In England and Wales these powers are conferred by Dog Control Orders Regulations^{167,168} which form part of the Clean Neighbourhoods and Environment Act 2005,¹⁶⁹ and provide local authorities with the ability to enforce restriction of dogs to lead, exclude dogs, or limit the number that may be walked together, in specific areas.

1.4.4.1.3. Licensing and Identification

Where licensing or registration of dogs is compulsory the primary benefit is in identification of lost or straying dogs and as a means of revenue generation, in effect a tax on dog ownership, offsetting the costs of enforcing control of the dog population within a jurisdiction.¹²⁰ Regardless of local dog licensing legislation, owned dogs in most jurisdictions must be identified, usually by means of a collar and identity tag.

Currently within the United Kingdom, only Northern Ireland has dog licensing legislation¹⁷⁰ with a compulsory annual fee and requirement for display of identifying disc on the dog's collar, similarly in the Republic of Ireland all dogs must be licensed.¹⁶⁵ In the remainder of the United Kingdom all dogs must wear a collar and identifying tag.¹⁷¹

Other jurisdictions utilise licensing to ensure vaccination status of dogs, especially against rabies virus. This acts to encourage both individual and herd immunity to rabies, and enables rapid tracing of a dog's ownership and vaccination status in the event that it bites.¹²⁰

1.4.4.1.4. Training

In Switzerland legislation passed in 2008 requires all prospective dog owners to undergo training in the theoretical aspects of responsible dog ownership, and in addition all dog owners to undergo practical training with their dog during the first year of ownership.¹⁵⁷ This legislation is aimed at improving animal welfare, with the compulsory training covering the fundamental needs of the dog, in addition to interpretation of canine behaviour, and also reducing injury by encouraging responsible ownership, training and socialisation of the dog.

1.4.4.2. Breed Specific Legislation

Breed specific legislation attempts to identify and regulate those dogs posing greatest risk to public health. This type of legislation targets dogs of a specified type or breed regardless of the behavioural history of the individual dog.

There are many critics of this form of legislation,^{120,172} including a joint lobbying group of 19 welfare and veterinary organisations, trade unions and regulatory bodies formed by the British Veterinary Association (BVA)¹⁷³ the American Society for the Prevention of Cruelty to Animals (ASPCA)¹⁷⁴ and the Humane Society of the United States.¹⁷⁵ In response to the Consultation on Dangerous Dogs, undertaken by the United Kingdom Department for Environment Food and Rural Affairs during spring 2010, 12% of respondents considered the current legislation protected the public from dangerous dogs.¹⁷⁶

One of the major issues with enforcement of breed specific legislation is in the identification of those dogs to which it applies.¹²⁰ This is compounded in several jurisdictions by the inclusion of dogs which are either not recognised as a breed or represent cross breeds, for example the Pit Bull Terrier and Ban Dog in the British¹⁷⁷ and Irish¹⁷⁸ legislation respectively.

1.4.4.2.1. Prohibition of specific breeds or types of dog

In the United Kingdom, Section 1 of the Dangerous Dogs Act 1991 (DDA 1991) is targeted at the prohibition of dogs considered to be fighting type; specifically the Pit Bull Terrier, Japanese Tosa, Dogo Argentina and the Fila Brasileiro.¹²⁹

Ownership of all four types of dog has been prohibited since November 1991, unless the dog is registered via the exemption scheme. Dogs were initially permitted exemption provided their owners complied with restrictions including their neutering, permanent identification by tattoo and microchip,

their owners maintained adequate third party insurance, and a fee was paid for entry onto the Index of Exempted Dogs.¹²⁹ The Dangerous Dogs (Amendment) Act 1997 gave courts discretion on sentencing, and re-opened the Index of Exempted Dogs for those prohibited dogs which the courts considered would not pose a risk to the public.¹⁷⁷ Only courts can direct that a dog can be placed on the list of exempted dogs.

At the time that the DDA was enacted in 1991, it was estimated that there were around 10,000 Pit Bull Terriers in the UK and less than half a dozen of the other banned types.¹⁷⁹ It is widely believed that the numbers of these dogs present in the United Kingdom today are considerably greater than at the time that the DDA was enacted. During the year to December 2011 the Metropolitan Police Status Dogs Unit seized 579 dogs for Section 1 offences, i.e. they were thought to belong to a banned type, and a further 71 dogs for Section 3 offences that were also thought to be Pit Bull Terriers.¹⁸⁰

1.4.4.2.2. Management restrictions of specific breeds

In addition to regulations governing control of all dogs, some jurisdictions impose more stringent controls on specific groups of dogs, identifying them as dangerous whilst not prohibiting their ownership.

The current Irish legislation for example, the Irish Control of Dogs Regulations 1998,¹⁷⁸ imposes lead and muzzle restrictions on 10 cited breeds and their crosses, and the “Ban Dog,” a cross breed. These breeds are cited as dangerous within the legislation, the same legislation imposes a

limitation on the number of Greyhounds that may be walked together by one person and restricts them to a lead in public places.

1.4.4.2.3. Behaviour testing of specified breeds

Dutch legislation prohibiting specific breeds (Regeling Agressieve Dieren (RAD) 1993) was repealed in 2008, in part as a result of an evaluation of the legislation and dog bite incidents by Cornelissen and Hopster.¹⁰⁵ The current legislation requires that previously prohibited Pit Bull Terriers, Pit Bull cross breeds and Rottweilers undergo a temperament test. Dogs found to be aggressive by this test are now euthanised.¹⁸¹ The repealed legislation, enacted in 1993, was similar to the UK DDA 1991 and required that these dogs were euthanised regardless of their behaviour.

There are difficulties with behaviour testing in order to determine the danger posed by a dog. Van der Borg et al. found that the Socially Acceptable Behaviour test used in the Netherlands was likely to be unable to detect aggression where it was not associated with fear, and recommended alterations to the manner in which the test findings were applied.¹⁸¹

Similar legislation has been enacted in several other jurisdictions, in Lower Saxony, Germany, for example, ownership, management and breeding of 14 breeds was restricted in 2000.¹⁸² Exemption from these restrictions was possible if dogs were able to demonstrate that they displayed no exceptional or inappropriate aggression during a standardised behaviour test. This legislation was repealed in 2008, in part following studies which found no

significant difference between breeds restricted by the legislation and Golden Retrievers,^{183,184} which were not restricted.^{183,184}

1.4.4.3. Legislation affecting individual dogs considered to pose heightened risk.

Many jurisdictions have laws which may be enforced if an individual dog is considered dangerous. In the United Kingdom, Section 3 of the Dangerous Dogs Act 1991 provides powers to deal with any dog considered dangerous.¹²⁹ This Act created a new offence of a dog being dangerously out of control in a public place (Section 3(1) DDA 1991) or private place where it is not permitted to be (Section 3(3) DDA 1991). The Act does not require a dog to have caused injury to be considered dangerously out of control; it regards this to have occurred if there were “grounds for reasonable apprehension that it would injure any person.”

Whilst the DDA 1991 is criminal law and therefore requires a level of proof beyond all reasonable doubt, section 3(5) of the Act also clarifies the application of the civil law. The Dogs Act 1871 applies on both public and private property, including the private home of the dog and by virtue of it being civil law requires a lower standard of proof.¹⁸⁵ The application of these laws is intended to encourage the safe control of all dogs.

In Scotland the Control of Dogs (Scotland) Act 2010 aimed to move away from breed specific legislation and focus on the responsibilities of dog ownership.¹⁸⁶ The Act was designed to enable early intervention where dogs are out of control, allowing remedial measures to be taken to improve owner

and dog behaviour before a dog becomes dangerous. The Act introduced a new strategy whereby a Dog Control Notice can be issued by an authorised officer, these notices are able to impose a range of conditions including; restriction to lead, muzzling, neutering and completion of training by both the owner and dog.

The Control of Dogs (Scotland) Act 2010 also extended criminal liability of Section 3 of the Dangerous Dogs Act 1991,¹²⁹ to include all locations including private property where the dog is allowed to be.¹⁸⁶ A similar extension to legislation in England was one of the key matters on which public and professional opinions were sought during consultations held by the Department for Environment Food and Rural Affairs in the spring of 2010 and 2012.^{176,187} Other proposals discussed during these consultations included; extension or abolition of the list of breeds prohibited by section 1 of the DDA 1991,¹⁷⁶ the introduction of compulsory micro chipping of puppies^{176,187} and third party insurance for all dog owners.¹⁷⁶

1.5. Risk factors for aggression

Many factors conspire to make establishing which dogs are most at risk of biting, and conversely which people are most at risk of being bitten, a complex task. Much of the data on which statements of risk and legislation are based is derived from case series of the recipients of bite injuries or bite related fatalities or cases referred to behaviourists. By virtue of their design these studies are not capable of determining a causal association as they are not longitudinal and lack an appropriate denominator group.^{105,120}

Before it is possible to devise effective preventative strategies aimed at reducing the incidence and impact of human-directed dog aggression, it is crucial to identify reliably which factors are associated with an increase, or decrease, in the risk of aggressive acts occurring.

Many studies are cited in the lay and professional literature suggesting factors which are either protective or increase the risk of a dog biting, or of an individual receiving a bite injury. However, the majority of these cited studies are descriptive and as such provide little evidence of the sequence of causality nor, as they lack an appropriate denominator or comparator group, do they provide evidence for a specific factor's role in the escalation of risk in an individual dog or human.

The interaction between individuals, relationships and their environment is complex. Several individual and combined relationships may interplay in the formulation of a high risk situation for acts of human-directed dog aggression. The simplest situation to unravel is perhaps where a dog bites its owner within their own home with no other individuals present. Even in this situation however there are factors outwith the two individuals and their relationship to consider.

1.6. Factors which affect the consequences of aggression

There are a number of factors, which do not affect the likelihood of an aggressive act occurring but may have significant affect on the consequences of that act. These include the manner and effectiveness of restraint of the dog, via interaction between the dog and handler and physical

restraint. The owner's response to aggression has the potential to alter the risks of injury, be it psychological or physical, and potentially to alter the risk of escalation of aggression.

1.6.1. Anatomical conformation of dog

There are clear differences in the mechanics involved in the bite of a small dog, the toy breeds for example, as compared to one from a large breed such as a Greyhound or Neapolitan Mastiff. The jaw size and musculature of these contrasting breeds confers the potential for increased risk of tissue damage from the larger dog.^{116,117}

Within two dogs of comparable size the jaw musculature may have a profound effect on the potential to generate force.

1.6.2. Bite inhibition

Dogs are generally considered to bite in an attempt to stop the actions of their target, to remove the source of their distress or in defence. Once the perceived threat ceases, the majority of dogs will stop their attack and withdraw.¹⁸⁸ However in some cases biting continues despite cessation of the activity which precipitated the attack.

Historically, dogs bred for hunting live prey or fighting were selected for their tenacity and ability to continue fighting despite injury. This trait has been suggested to be reflected in modern terrier breeds which share a similar tenacity and persistence in biting.¹⁸⁸ This prolonged post-exposure arousal period, disproportionate to any stimulus, has the potential to cause greater injury.

Chapter Two

Introduction - The Systematic Review

2. The Systematic review

The systematic review is considered the gold standard for establishing the current robust evidence base.¹⁸⁹⁻¹⁹⁴ The systematic review process seeks to objectively answer a specific research question, whilst minimising bias by identifying all available relevant evidence, critically appraising that evidence and identifying those studies which both answer the research question and are of a robust methodological standard.^{192,195}

Whilst a traditional literature review provides an overview of empirical work, its construction has the potential to introduce a high level of bias, with the subjective opinion of the author determining what is included and excluded. A systematic review involves an objective, reproducible process, utilising explicit methodology, whilst evaluating all available evidence regarding the subject under investigation.^{192,195}

In addition to the minimisation of bias via the use of explicit methodology; systematic reviews have a number of advantages to the researcher, clinician, policy maker and consumer.¹⁹⁴ The systematic review provides a readily accessible and digestible summary of the current evidence base.^{192,194,195}

The systematic review is increasingly used within, and forms the cornerstone of, evidence based health care, forming the foundation for example of the National Institute of Clinical Excellence¹⁹⁶ (NICE) and Scottish Intercollegiate Guidelines Network¹⁸⁹ (SIGN) treatment guidelines. Although it is secondary evidence, the systematic review is considered to be at the peak of the hierarchy of research evidence.^{191,192,194,195,197}

The term meta-analysis is often used interchangeably with systematic review,¹⁹⁵ however, strictly meta-analysis is a statistical technique for quantitatively combining the findings of equivalent studies, and thus to be reliable needs to be preceded by a sound systematic review.¹⁹⁷

The systematic review process aims to reduce the effect of inclusion and publication bias by identifying all available literature.^{195,197} The process requires impartiality and objectivity. Objectivity is ensured by the appraisal process focusing on methodology and analysis, with the results of studies being considered only after a decision on inclusion, based on the strength of the evidence provided, has been reached.¹⁹⁷

In order to further safeguard objectivity it is recommended that a systematic review is undertaken by researchers with sufficient distance from the subject matter so as to retain objectivity. This avoids preconceptions of the “correct” findings introducing bias, reducing the objectivity of the review, and thus reliability of the systematic review.¹⁹⁸⁻²⁰⁰

2.1. Identifying an acceptable standard of evidence

The systematic review process seeks to objectively appraise the quality of studies and so requires that a threshold level of evidence is pre-determined.^{192,195} Typically this is set very high, including only high quality randomised controlled trials (RCTs).¹⁹¹ However, when studying risk factors and especially studies of human-animal interaction, for logistical and ethical reasons, the vast majority of research consists of observational studies.

2.1.1. Evaluation of published standards

Whilst there is general consensus on the broad nature of the hierarchy of evidence, there are a range of published systems for grading the quality of evidence. These grading systems have been published by researchers in an effort to clearly and reproducibly convey the quality of evidence provided by a range of designs of scientific investigation. Evidence grading systems have, in general, been developed with a specific purpose in mind, developing treatment guidelines for example. They provide a relative measure of the trust we can place in a given study design.

There are three aspects to be considered in the development of evidence based guidelines; effectiveness of the intervention, appropriateness, practical and financial feasibility.²⁰¹ The importance of each of these to the body designing the hierarchical evidence grading system will influence the importance given to various aspects of study design. For example the findings of a focus group may have a role and provide a fair level of evidence when evaluating the appropriateness and feasibility of an intervention but not when evaluating its effectiveness.²⁰¹

The Canadian Taskforce on the Periodic Health Examination was one of the earliest bodies to publish an evidence grading system, in 1979 (Table 1).²⁰² This system provided little ability to distinguish between different qualities of design within a study type. This over simplified the situation, with for example a poorly designed randomised controlled trial being graded above a robust longitudinal study.

Table 1: Canadian Task Force on the Periodic Health Examination: Levels of evidence

Level	Description of evidence
I	Evidence obtained from at least one properly randomized controlled trial.
II-1	Evidence obtained from well designed cohort or case-control analytic studies, preferably from more than one centre or research group.
II-2	Evidence obtained from comparisons between times or places with or without the intervention. Dramatic results in uncontrolled experiments (such as the results of the introduction of penicillin in the 1940s) could also be regarded as this type of evidence.
III	Opinions of respected authorities, based on clinical experience, descriptive studies or reports of expert committees.

The US Preventive Services Taskforce adopted and amended the Canadian Taskforce grading system, creating a system that allowed broad distinction between quality of design within a study type.²⁰³ This system was designed as part of a review process in which evidence for primary care in the United States healthcare setting was evaluated (Table 2).

Where evidence is required for other purposes, for example establishing the efficacy of diagnostic or preventive strategies or the natural history of a disease, an evidence grading system designed for these purposes is required.

Table 2: United States Preventive Services Taskforce, levels of evidence

Level	Description
I	Properly powered and conducted randomized controlled trial (RCT) Well-conducted systematic review or meta-analysis of homogeneous RCTs
II-1	Well-designed controlled trial with randomization
II-2	Well-designed controlled trial without randomization
II-3	Multiple time series with or without the intervention; dramatic results from uncontrolled experiments
III	Opinions of respected authorities, based on clinical experience; descriptive studies or case reports; reports of expert committees

The Oxford Centre for Evidence Based Medicine (CEBM) developed a hierarchical grading system which attempts to account for the different needs of various types of research question (Table 3).¹⁹⁰ This system works well across a range of research questions. However, whilst the CEBM grading system addresses the various types of research question; concerning prevention, prognosis, diagnosis, prevalence and economics, it is complex and considered by some researchers to have too many categories whilst omitting a number of discriminators.²⁰⁴

Table 3: Oxford Centre for Evidence Based Medicine; Levels of Evidence, more detail and a glossary of terms used is provided at <http://www.cebm.net/>

Level	Therapy / Prevention, Aetiology / Harm	Prognosis	Diagnosis	Differential diagnosis / symptom prevalence study	Economic and decision analyses
1a	SR (with homogeneity) of RCTs	SR (with homogeneity) of inception cohort studies; CDR validated in different populations	SR (with homogeneity) of Level 1 diagnostic studies; CDR with 1b studies from different clinical centres	SR (with homogeneity) of prospective cohort studies	SR (with homogeneity) of Level 1 economic studies
1b	Individual RCT (with narrow Confidence Interval)	Individual inception cohort study with > 80% follow-up; CDR validated in a single population	Validating cohort study with good reference standards; or CDR tested within one clinical centre	Prospective cohort study with good follow-up	Analysis based on clinically sensible costs or alternatives; systematic review(s) of the evidence; and including multi-way sensitivity analyses
1c	All or none	All or none case-series	Absolute "SpPins" and "SnNouts"	All or none case-series	Absolute better-value or worse-value analyses
2a	SR (with homogeneity) of cohort studies	SR (with homogeneity*) of either retrospective cohort studies or untreated control groups in RCTs	SR (with homogeneity) of Level >2 diagnostic studies	SR (with homogeneity) of 2b and better studies	SR (with homogeneity) of Level >2 economic studies
2b	Individual cohort study (including low quality RCT; e.g., <80% follow-up)	Retrospective cohort study or follow-up of untreated control patients in an RCT; Derivation of CDR" or validated on split-sample only	Exploratory cohort study with good reference standards; CDR after derivation, or validated only on split-sample or databases	Retrospective cohort study, or poor follow-up	Analysis based on clinically sensible costs or alternatives; limited review(s) of the evidence, or single studies; and including multi-way sensitivity analyses
2c	"Outcomes" Research; Ecological studies	"Outcomes" Research		Ecological studies	Audit or outcomes research
3a	SR (with homogeneity) of case-control studies		SR (with homogeneity) of 3b and better studies	SR (with homogeneity) of 3b and better studies	SR (with homogeneity) of 3b and better studies
3b	Individual Case-Control Study		Non-consecutive study; or without consistently applied reference standards	Non-consecutive cohort study, or very limited population	Analysis based on limited alternatives or costs, poor quality estimates of data, but including sensitivity analyses incorporating clinically sensible variations.
4	Case-series (and poor quality cohort and case-control studies)	Case-series (and poor quality prognostic cohort studies)	Case-control study, poor or non-independent reference standard	Case-series or superseded reference standards	Analysis with no sensitivity analysis
5	Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles"	Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles"	Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles"	Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles"	Expert opinion without explicit critical appraisal, or based on economic theory or "first principles"

The system for grading levels of evidence published by the Scottish Intercollegiate Guidelines Network (Table 4), in their handbook for development of evidence based clinical practice guidelines,²⁰⁵ provides distinction between the evidential quality of different study designs and assignment of value to individual studies within these design groups.

Table 4: Scottish Intercollegiate Guidelines Network (SIGN) Levels of evidence

Level	Description
1++	High quality meta-analyses, systematic reviews of RCTs, or RCTs with a very low risk of bias
1+	Well-conducted meta-analyses, systematic reviews, or RCTs with a low risk of bias
1-	Meta-analyses, systematic reviews, or RCTs with a high risk of bias
2++	High quality systematic reviews of case control or cohort or studies High quality case control or cohort studies with a very low risk of confounding or bias and a high probability that the relationship is causal
2+	Well-conducted case control or cohort studies with a low risk of confounding or bias and a moderate probability that the relationship is causal
2-	Case control or cohort studies with a high risk of confounding or bias and a significant risk that the relationship is not causal
3	Non-analytic studies, e.g. case reports, case series
4	Expert opinion

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) working group, an informal collaboration, was formed in 2000 in an attempt to address limitations in the currently available systems of grading evidence in the field of human health care. The working group aimed to develop a unified sensible approach to the grading of evidence and recommendations.²⁰⁶

2.1.2. Identification of evidence

In order to attempt to avoid selection and publication bias, the systematic review requires identification of all available evidence. This requires the development of a sensitive search strategy.¹⁹¹

The search strategy used for a systematic review should have few restrictions thereby ensuring an inclusive, unbiased, retrieval of evidence. High recall and sensitivity is the focus of the search, with unavoidable compromise of specificity, i.e. the search will be effective at detecting the evidence sought, but much of what is identified will not be relevant.¹⁹¹

2.1.2.1. Language and location bias

Papers published in the English language are more likely to reach publication than those in other languages.²⁰⁷ Further, English language publications appear more likely to be subject to publication bias, with regard to the preferential publication of positive findings.²⁰⁸ Consequently, if a systematic review was restricted to English language publications, there is a high risk that its conclusions would be skewed.²⁰⁹

In addition, whilst many European language journals are indexed within Medline, this does not hold true for journals published in developing countries.²¹⁰ Notably poorly represented within the major citation indices are studies from researchers based in Asia and Africa, even where these are published in the English language.²¹¹ The characteristics of studies published in indexed journals are likely to differ from those published in non-

indexed sources.²¹⁰ Systematic review search strategies should therefore not be restricted by language or geography.²¹²

2.1.2.2. Database selection

There is a host of searchable electronic databases of published research available to investigators. If a systematic review is undertaken and studies which met the inclusion criteria fail to be identified this risks the introduction of bias. No matter how appropriate the search equation utilised, if it is restricted to a single database there is significant risk of introducing bias in this manner.²¹³ Thus databases should be selected based on knowledge of the subject area with both broad and specialised citation indices being interrogated.

In order to avoid the language and location biases described above, these databases should ideally include those that index journals published in non-European languages and those published in the developing world.

2.1.2.3. Publication bias

The phenomenon of publication bias is well recognised,^{214,215} with investigators less likely to submit, and editors or reviewers less likely to accept, research with findings of no or negative association.²¹⁶⁻²¹⁸ One method of assessing the affect of publication bias is to compare abstracts presented at conference to those reaching peer reviewed publication, using this method between 50 and 80% of conference presentations fail to reach publication.²¹⁹⁻²²⁴

As a result of publication bias, if only published literature were retrieved during the systematic review process there would be significant risk of skewing the findings. It is therefore imperative to attempt to identify and access work which is unpublished, in addition to that reaching publication.¹⁹¹

2.1.3. Appraisal of evidence

Once all relevant research has been identified an objective appraisal process is undertaken. This process aims to identify the quality of evidence provided by individual studies, and in so doing determine whether they meet the predetermined standards of required evidence.¹⁹¹

The appraisal process evaluates the design, methodology and analysis of a study, with each being compared to predefined standards. At this stage the results of studies are not examined. In this manner objectivity is retained and those studies meeting the predefined inclusion criteria are identified without reference to their findings.

2.1.4. Compilation of findings.

Once all identified studies, published and unpublished, have been identified and appraised, the findings of those reaching the inclusion criteria are examined. These findings constitute the current evidence base reaching the predetermined standard of the review.¹⁹¹

In some cases a systematic review will identify studies addressing the given research question, however on appraising these studies none meet the inclusion criteria, or occasionally that no research has been undertaken; the Cochrane Collaboration noted that identifying the absence of high quality

evidence is a key asset of the systematic review.¹⁹¹ Indeed the systematic review may be used to drive an improvement in the quality of research and its reporting.²²⁵

2.2. Time scale for systematic review

The time taken to undertake a systematic review will be dependent on the nature and scope of the review and the volume of research previously undertaken in the field, in addition to the size and quality of review and support services available.^{191,226}

An analysis of 37 systematic reviews carried out by MetaWorks, a private company undertaking systematic reviews and meta analyses, found that the average time taken by their company to complete a review was 1139 working hours, equivalent to approximately 33 working weeks, with a median of 1110 hours and a range of 216-2518 hours.²²⁶

On examining this dataset of 37 reviews, Allen and Olkin found that the preparatory work required for a review accounted for on average 721 hours, approximately 21 working weeks, (95 % CI 478-964 hours) regardless of the number of citations retrieved, even reviews retrieving no evidence required this initial ground work.²²⁶

Allen and Olkin identified a correlation between the number of citations retrieved and the time taken to complete a systematic review or meta analysis. Having taken into account the time required to initiate a review, the following expression was generated from their dataset:

$$\text{Total time required} = 721 + 0.243x - 0.0000123x^2$$

(Where x is the number of citations retrieved)

It was suggested that this expression could be used to estimate the time likely to be required for completion of a systematic review, based on the number of citations retrieved by initial searches. As the authors noted that this expression was less reliable where less than 1000 citations were retrieved by initial searches, and the dataset from which the expression was derived consisted of meta analyses with a maximum initial citation retrieval of approximately 9000; it is not expected to be a reliable predictor outwith this range.

In the studies examined by Allen and Olkin, the work required for completion reached a plateau around 1900 working hours, approximately 54 working weeks.²²⁶ These figures illustrate that, even where the work is undertaken by a dedicated and experienced company, the time commitment required for completion of any systematic review is considerable.

2.3. Systematic reviews and observational studies

Much evidence concerning the elucidation of risk factors is derived by necessity from observational studies.¹⁹³ These studies are particularly at risk of hidden biases, introduced for example by selective recall.²²⁷ Observational epidemiology has also been criticised for its vulnerability to confounding, measurement and selection bias and difficulty in establishing the direction of causality.²²⁸ These limitations are particularly pronounced where risks are small and the causal web complex.²²⁹

In order to identify the current evidence base the findings of multiple observational studies must be synthesized.²³⁰ A prerequisite to facilitate this is clear and explicit reporting of the methods and findings of individual studies.^{231,232} In turn the findings of systematic reviews of observational studies must be reported in such a way as to ensure their usefulness to all interested parties.^{230,233}

2.4. Systematic reviews and animals

When compared with human medicine, behaviour and veterinary medicine has seen a slower uptake of the systematic review as a tool for establishing the existing evidence base. As a result, fewer systematic reviews have been undertaken in these fields. However, as with the development of veterinary epidemiology, the systematic review is increasingly utilised in these fields.

Searching the PubMed database using the term (systematic review[Title]) AND ((canine[Title]) or (dog*[Title])) identifies only 20 systematic reviews, in addition to the study described in this thesis; 9 of these reviews were published in the past 2 years and all were published since the year 2000.

Whilst acknowledging that this basic single-database search will not have identified all systematic reviews concerning dogs, it does provide an indication of the growing application of this method of objectively summarising the evidence base in canine medicine.

2.4.1. Systematic reviews and human-directed dog aggression

The systematic review described in this thesis explores the evidence base regarding risk factors for human-directed dog aggression. A review with this

aim has not previously been undertaken. However, two related reviews were identified within the Cochrane Collaboration Library.^{153,234}

Medeiros and Saconato examined randomised controlled trials of the use of prophylactic antibiotics following dog, cat and human bites.²³⁴ Nine studies were identified, and eight included in the review, six of these studied humans with dog bites. Following meta analysis the authors found no evidence of benefit for prophylactic antibiotic use following dog bites. The only finding of significant effect in this meta analysis was for antibiotic use where bites were to the hand (for all three species of aggressor combined) with an overall odds ratios of subsequent infection of 0.1 (95% CI 0.01, 0.86). The authors concluded that further research was required.²³⁴

Duperrex et al. investigated the effectiveness of educational interventions in the prevention of dog bites to under twenty year olds.¹⁵³ The aims of this review were two fold; to determine the effectiveness of educational programmes for children and adolescents in preventing dog bite injuries and in changing the behaviour of those targeted. The review protocol was registered in 2004 and findings first published in 2008, of 1598 articles retrieved by searches, 20 were fully evaluated and 2 included in the final review,^{154,155} a further study, The Blue Dog Project¹⁵¹ was still under consideration when the review was last updated in 2009.

The two studies meeting inclusion criteria examined the effect of an education program on behaviour in the presence of a dog¹⁵⁴ and on interpretation of dog behaviour or body language.¹⁵¹ Duperrex et al concluded that educational interventions in a school setting could change the

knowledge, attitude and observed behaviour of children under 10 years old.¹⁵³ As neither study examined the effect of the intervention on dog bite rates, children over ten years of age or living outside of Australia, further conclusions could not be drawn.

Chapter Three

Methodology of human-directed dog aggression systematic review

3. Systematic review methodology

The systematic review provides high level evidence and is at the cornerstone of evidence based practice, commonly utilised in the formulation of health care guidelines and policy.¹⁸⁹⁻¹⁹⁴ The systematic review objectively appraises all available evidence in answer to a research question; thereby identifying current high quality evidence and areas where such evidence is lacking.^{191,195}

The systematic review described in the following pages was designed to identify the current evidence base for risk factors of human-directed dog aggression.

3.1. Identifying research questions

A systematic review requires the identification of a specific research question, which the review is then designed to answer. A typical review would focus on the effect of a single factor on a single outcome in a narrowly defined population. In contrast, the systematic review described in this thesis is broadly focussed in order to capture aggression across its spectrum of severity and targets, worldwide.

Several individual and combined relationships interplay in the formulation of the circumstances in which acts of human-directed dog aggression occur.¹²⁰

The interaction between individuals, relationships and their environment, both physical and social, is complex. The simplest situation to unravel is perhaps where a dog bites its owner within their own home with no other individuals present. The situation becomes more complex when there is a

third individual involved in an aggressive act, for instance a visitor to the home of the dog. Even where these minimal individuals are involved, the social setting, cultural norms and pressures, education level and type of the owner, dog and target of aggression, to name but a few, may also play a role in determining level of risk.

In order to attempt to untangle the complex web of interactions and identify potential risk factors, a conceptual matrix of interactions between parties, risk factors and outcome was developed (Figure 2). Using this framework it was possible to examine the interactions, outcomes and potential risk factors involved in aggressive acts. Risk factors can be stratified by the outcome which they may affect, by their ability to be modified, and by the interactions between parties or the environment.

On examining the potential risk factors and interactions within the theoretical causal webs, it became clear that focusing on a single possible risk factor would potentially be to the detriment of identifying other equally influential factors. Similarly, in examining outcomes it was feasible that factors affecting the risk of a dog exhibiting non-injurious aggression may be different from those affecting risk of bite injury and life threatening injury. Although there is a progression in severity of outcome, this may not represent a sequential progression in the degree of aggression exhibited by the dog. Thus, whilst identifying sub-questions to be answered, a broad research question was retained; “what robust evidence is there for risk factors affecting human-directed dog aggression?”

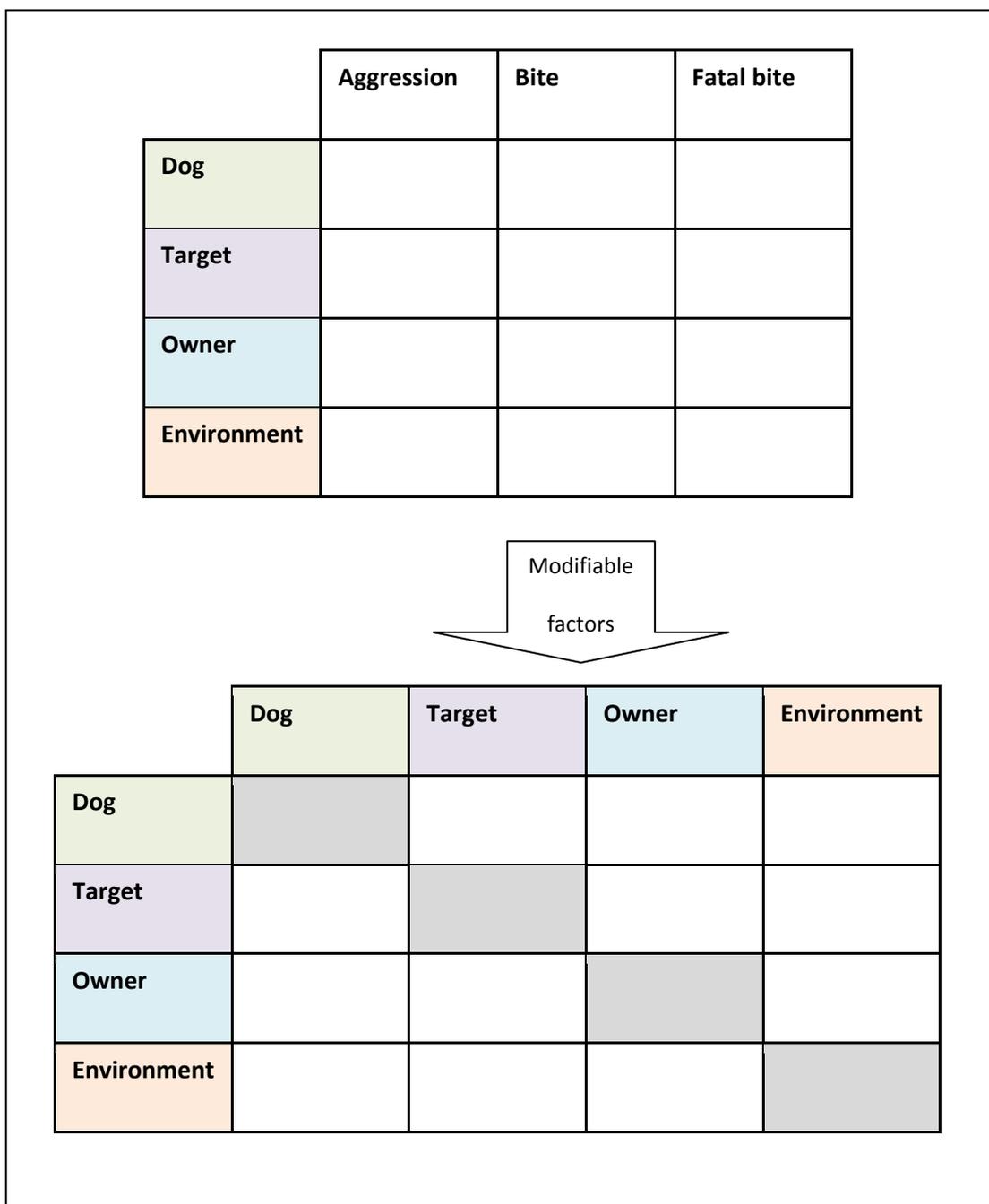


Figure 2: Conceptual framework for examining the interactions between parties and risk factors generated. Factors relating to the dog, target of aggression, owner and the environment in which the three meet can be identified and postulated to affect one or more of the three broad outcomes of aggression. These factors can be divided into those that are modifiable, and so may be potentially targets for preventive strategies, and those that are non-modifiable. The desired time scale of modification will dictate which factors fall into each group. To have prevented an incident on the day it occurred those factors that could have been modified on that day would be considered modifiable. The interactions involved in the generation of potential risk factors can then be examined. This is oversimplified by the two-dimensional matrix as interactions may be in three or more directions.

3.1.1. Evidence grading system utilised in systematic review

For the purposes of this systematic review, the system of grading evidence needed to be designed to evaluate the quality of evidence of risk or prevention. It was essential that the grading system was unambiguous and provided clear distinction between studies which were of an acceptable standard and those falling below this. Further, the review needed to be readily accessible to researchers, behaviourists and policy makers alike.

The CEBM hierarchy may have been appropriately utilised for the purposes of this systematic review.¹⁹⁰ However owing to its complexity, considerable overlap and lack of explicit descriptions of the studies falling into a given level, it was not thought to be ideal.

The SIGN levels of evidence,¹⁸⁹ widely utilised within the human healthcare field, were amended with the addition of cross-sectional studies to level 2 (Table 5). This provided a suitable system for both evaluating and presenting the evidence likely to be identified by this study.

Recognising that a large proportion of evidence in this area was likely to be observational in nature, a pragmatic approach was adopted in an attempt to identify all high quality evidence. The inclusion criteria thus included any study where there was a low risk of confounding or bias and at least a moderate probability that relationships identified were causal. This equated to levels 1++, 1+, 2++ and 2+ on the amended SIGN levels of evidence.

Table 5: The hierarchy of evidence utilised in this systematic review, amended from SIGN

Level	Description of studies meeting this level
1++	High quality meta-analyses, systematic reviews of RCTs, or RCTs with a very low risk of bias
1+	Well-conducted meta-analyses, systematic reviews, or RCTs with a low risk of bias
1-	Meta-analyses, systematic reviews, or RCTs with a high risk of bias
2++	High quality systematic reviews of case control, cohort or analytical cross-sectional studies. High quality case control, cohort and cross-sectional studies with a very low risk of confounding or bias and a high probability that the relationship is causal
2+	Well-conducted case control, cohort or analytical cross-sectional studies with a low risk of confounding or bias and a moderate probability that the relationship is causal
2-	Case control, cohort or analytical cross-sectional studies with a high risk of confounding or bias and a significant risk that the relationship is not causal
3	Non-analytic studies, e.g. case reports, case series, descriptive cross-sectional studies
4	Expert opinion

The threshold for accepting research as providing evidence of sufficient quality was thus set relatively low and a wide range of study designs were included. The intention of this compromise was to avoid the common criticism of systematic reviews; that they are merely a paper exercise, setting such a high level that a wealth of useful research is discarded.^{235,236} Any research of a moderate quality had the potential to be accepted by this review.

3.2. Search strategy

3.2.1. Search equation

The search strategy used for a systematic review should have few restrictions thereby ensuring an inclusive, unbiased, retrieval of evidence. High recall and sensitivity is the focus of the search, with unavoidable compromise of specificity,^{191,195} i.e. the search will be effective at detecting the evidence sought, but much of what is identified will not be relevant. Having evaluated a range of search terms, with input from experts in the behavioural field via an expert panel and behavioural medicine conference,²³⁷ the search equation for this systematic review was:

(dog or dogs or canine or canis)

AND

(bite or bites or bitten or aggress* or attack* or death* or fatal*)

This search equation was designed to identify any article relating to dogs and biting or aggression. It was anticipated in developing this equation that a large number of articles relating to other topics such as dentistry and causes of mortality in dogs would be retrieved, however the priority was sensitivity and not specificity.

3.2.2. Database selection

As human-directed dog aggression and its consequences are of multidisciplinary concern, literature was sought from a wide range of disciplines with no restriction on language, country of origin or publication

status. This approach aimed to minimise the risk of publication, language or location bias affecting findings, whilst identifying all available information.

Searches were limited to 1960 onwards and included publications to the 31st December 2010.

To this end the search equation was used in a range of electronic literature databases. Databases were selected primarily on the basis of their scope and apparent reliability in retrieving publications. A number of databases were found to be unpredictable in their use of Boolean terms or unable to retrieve data reliably and so were not utilised.

Where two databases had similar scope and coverage, Scopus and Web of Science for example, preference was given to the database with the interface that best facilitated the purposes of the systematic review. International theses databases and institutional repositories were also searched.

Table 6: Electronic citation databases utilised in identifying published work

Database	URL	Description
Scopus	http://www.scopus.com/home.url	Multidisciplinary abstract and citation database. Covers 18,500 titles, across over 5000 publishers. Includes conference proceedings and trade journals.
PubMed	http://www.ncbi.nlm.nih.gov/pubmed	Biomedical literature citation index hosted by the National Library of Medicine.
Science Direct	http://www.sciencedirect.com	Database of core scientific publications.
ISI Web of Knowledge	http://apps.webofknowledge.com	Multidisciplinary academic citation index covering the sciences, social sciences and humanities. Due to overlap with the contents of Scopus search of this database was limited to the Social Sciences Citation Index and conference proceedings.
Index medicus for South East Asia	http://imsear.hellis.org	Database of articles published within selected journals in the World Health Organisation South-East Asia Region.
Airiti	http://www.airiti.com	Database of Chinese and Taiwanese academic journals and theses.
African journals online	www.ajol.info	An index of published research of African-based academics.
Educational Research Information Centre	www.eric.ed.gov	A digital library of educational literature.
Cochrane Library	http://www.cochrane.org	Library of healthcare research including the database of Cochrane (systematic) reviews.

3.2.3. Unpublished work

Publication bias is a well-recognised phenomenon,^{214,215} studies with statistically significant positive results are more likely to be submitted and accepted for publication than those with negative findings.²¹⁶⁻²¹⁸ This is

particularly problematic when conducting a systematic review, where identification of all available literature is key. In order to minimise this risk several steps were taken to identify relevant unpublished work.

A summary of the research project was presented at a behavioural conference of 300 delegates²³⁷ and via poster at a veterinary epidemiology conference,²³⁸ with a request for information from anyone aware of unpublished work, a letter to the same effect was published in a veterinary journal²³⁹ and magazine,²⁴⁰ conference proceeding and these databases were searched and authors who had published work in the field within the past decade were contacted by email.

3.3. Appraisal

3.3.1. Initial appraisal

All identified literature was imported into a spread sheet program (Excel 2007, Microsoft Corporation, Redmond, WA) to facilitate appraisal. All titles were reviewed and each item was coded; where the title of retrieved studies clearly signified that they related to subjects other than human-directed aggression these were assigned as “irrelevant”, studies which could not be excluded at this stage were assigned as “possibly relevant”. Where the title provided insufficient information to determine the subject of an article, the key words and abstract were also evaluated. Assignment was undertaken with article author(s) obscured.

3.3.2. Translation

Where articles were indexed in a language other than English their title was translated using Google Translate (<http://translate.google.com/#>) to enable ascertainment of relevance. Where necessary, for these and other non-English publications, further translation was then undertaken using the same software and native speakers of the article language.

3.3.3. Initial appraisal of relevant literature

All retrieved articles on the subject of human-directed dog aggression underwent an initial appraisal. At this stage articles were excluded where they were not primary research or they related to aspects of human-directed dog aggression other than risk factor analysis; this included those articles concerning the infective consequences of bite injuries, wound management and behaviour management.

Where articles were primary research of human-directed dog aggression, they were evaluated for the presence of a comparator group, this being essential for reliable risk factor analysis. Those articles without a potentially appropriate comparator group for risk factor analysis were excluded from further appraisal. This was again undertaken with authorship obscured.

3.4. Formal appraisal

Articles that had not been excluded by the above process were then fully appraised. Appraisal aimed to identify whether the study was appropriately included in addition to assessing the quality of the study with regard the following criteria;

- I Study design,
- II Selection process,
- III Measurement of outcome and exposure to risk factors,
- IV Control of confounding,
- V Analysis.

This appraisal process was undertaken by four main reviewers and an arbiter. Three of the reviewers were Diplomats of the European College of Veterinary Public Health in the sub-specialty Population Medicine, the fourth was the author of this thesis. Each study was reviewed independently by at least two reviewers, the author appraised every paper. Where reviewers disagreed in their conclusion, a third independent appraisal was undertaken by the fifth member of the team.

3.4.1. Round table discussion

Following this process, any study that had not been rejected by both reviewers was re-examined, using the same criteria, during “round table” discussions involving the author and at least two further members of the research team. Ultimately a consensus was reached on the grade of each study, using the amended SIGN grading system. In this manner it was established whether each study had a sufficiently low risk of bias and confounding, and a moderate probability that any relationships identified were causal, and thus whether they were of sufficiently robust quality to reach the final review.

3.5. Assimilation of robust evidence base

Following appraisal those studies considered to reach the required standard for inclusion in the final review were examined and their results interrogated.

As appraisal is based solely on methodological and analytical quality this was the first time study findings were examined. The findings of these studies were assimilated and utilised to answer a series of research sub-questions concerning risk for human-directed dog aggression.

Chapter Four

Results of human-directed dog aggression systematic review

4. Results

4.1.1. Publications retrieved

The electronic searches retrieved 27,565 publications, this included duplicates which were not removed as inconsistent referencing across databases and the sheer volume of references rendered this process unreliable and risked removing non-duplicates in error. The Scopus database returned the greatest number of articles, retrieving 14,697 (53% of all articles identified): and contained 122 of the 164 studies reaching final appraisal (74%) It is therefore estimated that there were 19,754 unique articles retrieved (72%).

Initial sorting identified that 84% (n= 23,154) of the articles could be excluded from further appraisal as they concerned an unrelated subject. Of the remaining 4411 publications, 28% (n=1235) which were broadly related to human-directed dog aggression were removed because they primarily related to rabies, predominantly vaccination development and use, with a further 12% (n=529) concerning other infective consequences of dog bite injuries. Another 10% (n= 430) were removed because they concerned bite injury management, 3% (n=124) as they concerned management of aggressive behaviour and 11% (n=481) were opinion based articles. A further 12% (n=536) were removed for a range of reasons, this included for example examinations of biomarkers, forensic investigations and the development of temperament tests. This left 24% (n=1076) of the relevant publications that were primary research potentially providing evidence of risk factors for human-directed dog aggression.

4.1.2. Unpublished work

Eighty-seven authors, identified via their recent publications, were emailed requesting information regarding unpublished work and potential data sources that they may be aware of. Of these, thirteen emails failed to send (address failed or spam blocked) and these authors were subsequently contacted by post at their last published address. Twelve authors replied but were not aware of additional unpublished work, nine authors replied with information concerning projects or datasets. Of these nine, six described work which was not currently available, two provided information on available data sets; CBARQ,^{241,242} developed by the University of Pennsylvania School of Veterinary Medicine, whose authors would be keen to collaborate with future researchers, and European surveillance data identified by Lakestani.¹²⁶ One author provided additional authors who may have had further information and a further two authors, that the team are aware of, forwarded the email to colleagues, however no further data was made available as a result.

In addition, 29 authors were contacted with specific questions regarding their studies, of these four responded but had no further useful information.

In total 98 authors were directly contacted as some of those contacted specifically had published prior to the last decade and so were not initially included. Four individuals contacted the study team directly with information regarding their work having learned of this research via publications,^{239,240} presentations^{237,238} or the study website.²⁴³

4.1.3. Formal appraisal

The subset of primary research consisting 1076 papers, identified as potentially providing evidence of risk factors for human-directed dog aggression was further examined with reference to the levels of acceptable evidence.

Case reports and series of bite injuries or aggressive dogs were removed as they did not contain a comparator group. Cross-sectional studies of hospital attendances or referrals to behaviourists were removed as they had a high risk of selection bias and were, in general, designed to investigate prevalence rather than risk.

This left a subset of studies with a potentially appropriate design and comparator group for risk factor analysis. These 164 studies underwent formal appraisal (see Appendix).

In addition, 28 studies that had been rejected during the sorting process underwent appraisal in order to confirm correct assignment; appraisers were blind to whether or not a paper had been previously rejected. 192 studies were formally appraised.

If a study could not be excluded on the available evidence at the time of screening or initial appraisal it was included to the next stage of appraisal. As a result of this “fail-safe” approach, a number of articles reaching formal appraisal provided no evidence of risk factors for human-directed dog aggression by virtue of their design, for example those that had yet to be

translated and those that were designed for other purposes but could not be excluded prior to full appraisal.

In keeping with the recommendations of the Preferred Reporting Items for Systematic reviews and Meta Analyses (PRISMA)²⁴⁴ figure 3 summarises the screening and appraisal process.

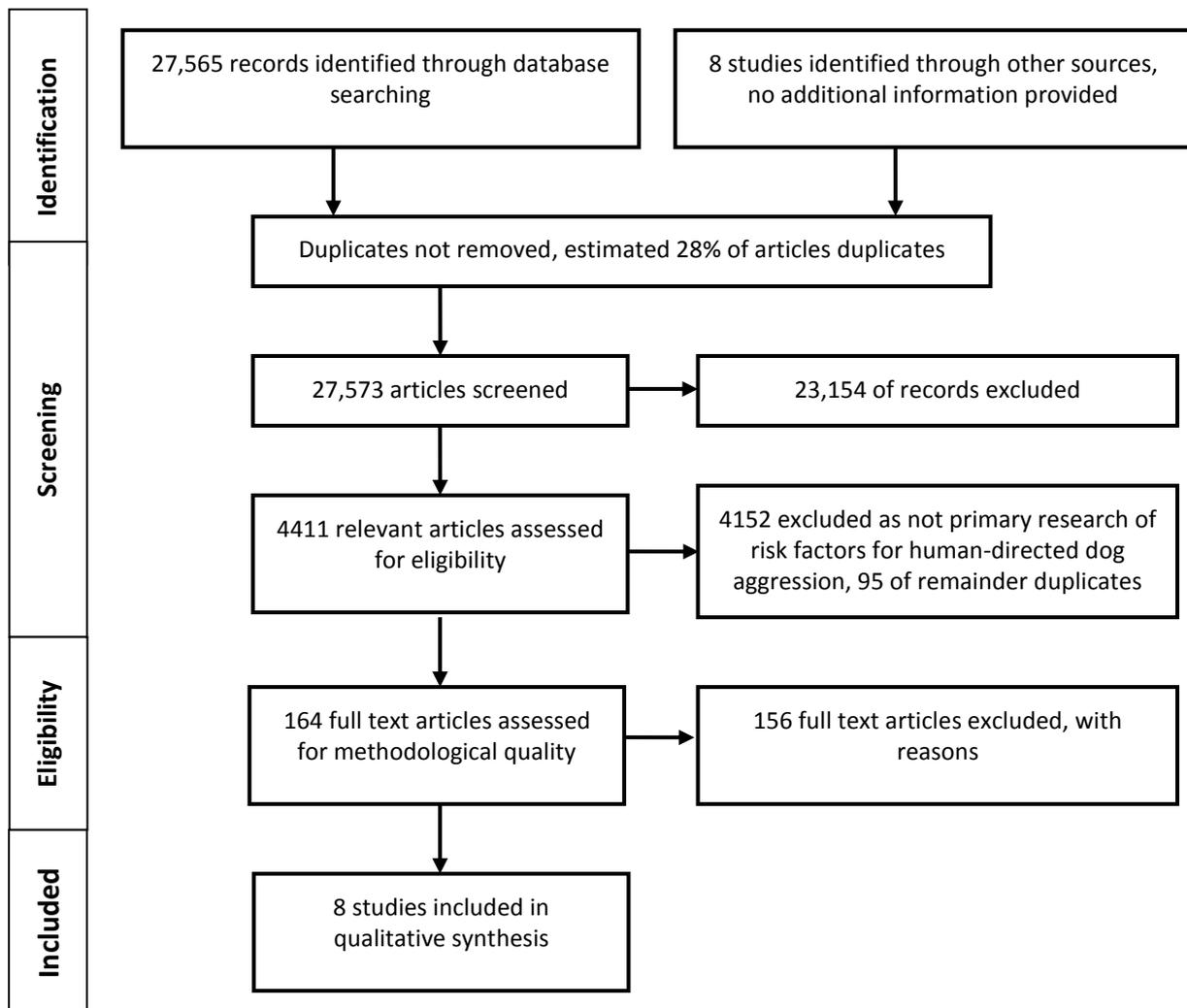


Figure 3: PRISMA diagram summarising the screening and appraisal process

4.1.4. Risk factors investigated

Over one hundred factors have been investigated by authors attempting to identify those factors which affect risk of human-directed dog aggression.

These are summarised in tables 7-11 below. **These tables do not represent risk factors for human-directed dog aggression, but factors which have been investigated.** As a result of reporting bias and summarising during the reporting process, this list is unlikely to be exhaustive. In some instances factors may have been measured as potential confounders rather than risk factors, however as such they were still considered to potentially influence risk.

The majority of investigated factors can be categorised as primarily related to the dog (Table 7), the owner (Table 8), the target of aggression (Table 10), interactions between these parties (Tables 9, 10,11) or the circumstances surrounding the event (Table 11). Whilst these categories are somewhat artificial, with some factors falling across several categories and others not fitting discretely into a category – neutering for example is integral to the dog whilst resulting from a decision made by current or previous owner, they are potentially useful when exploring mechanisms for reducing aggressive dog-human interactions.¹

1. References included in tables 7-11 refer to studies in which the identified factor was measured.

4.1.4.1. Factors relating to the dog

Table 7: Investigated factors primarily related to the dog

Signalment	Behaviour history ^{101,114,241,245-248}	Medical history ^{114,246,248-252}	Ownership status ^{160,162,253}	Heritable factors
Sex ^{101,102,114,160,241,246,247,249-281}	Stress related ^{250,268}	Sensory impairment ²⁷⁰	(Owned vs stray)	Coat colour ^{246,248,251,252,255,266,272}
Reproductive status	Fear related ¹¹⁴	Pruritic skin disease ^{114,317}		Genetic polymorphisms ³¹⁹⁻³²²
<ul style="list-style-type: none"> Neuter status^{101,102,114,241,245,246,250-252,254-257,260,264,265,268,270,271,276,277,280,282-286} Age at neutering^{287,288} Parity (own/dam)^{245,261} 	House training ²⁶⁵	Seizures ^{246,318}		Heritability ^{263,272,323-329}
Age ^{101,102,114,160,241,245-247,249-252,254,255,257-262,264,265,269,271,274,275,278,289-292}	Obedience ^{241,250,268,316}	Pain ²⁴⁹		Parental behaviour ³³⁰
Breed ^{101,105,114,160,184,241,247,249-252,257,258,260-263,265,269-271,273,276,278,279,290,293-312}	Dog-dog aggression ²⁴⁶	Vaccination status ¹⁰¹		Pedigree ²⁴⁶
<ul style="list-style-type: none"> Type (show/field)²⁴⁶ Breed group^{102,105,251,252,257,278} Pure breed status^{101,102,160,247,251,252,256,257,264,278} “Dangerous breed”^{135,184,271,301} 	Perceived risk ²⁴⁹	Serious illness ¹¹⁴		
Size ^{101,114,160,251,252,256,265,270,274,278,300,313-315}	Previous aggression ^{101,114,246,249}	Treatment ¹¹⁴		
		<ul style="list-style-type: none"> Interventions²⁴⁹ Glucocorticoids³¹⁷ 		

4.1.4.2. Factors related to the owner

Table 8: Investigated factors primarily related to the owner

Socio-demographics	Ownership	Psychosocial factors	Husbandry ^{268,270,280,313,314}
Gender ^{102,241,247,248,251,252,261,270,331}	Duration of ownership ²⁶⁵	Advice ¹¹⁴	Sleep location ^{114,247,248,250,261,270,333,337}
Age ^{241,248,251,252,256,257,259,261,270,331}	Purpose of ownership ^{241,246,248,251,252,256,270,333}	<ul style="list-style-type: none"> • Source²⁶¹ • Behaviourist²⁶¹ 	Allowed on furniture ^{115,319}
Household composition ^{162,241,245,250-252}	Previous experience ^{241,251,252,256,257,261,268,333}	Personality ^{334,335}	Time spent outdoors ^{115,123}
<ul style="list-style-type: none"> • Number of dogs^{101,241,245,256,257,259,261} • Other pets^{248,251,252} • Children^{101,114,256,257,270} • Teenagers¹¹⁴ 	Registration status ^{101,102,105}	Relationship ^{250-252,268}	Confinement ^{101,114,270,339,340}
Housing ^{254,270,332}		<ul style="list-style-type: none"> • Attachment^{248,250,336} • Anthropomorphism³³⁷ • Attitude²⁶⁵ • Spoiling^{251,252,337} 	Grooming ²⁴⁸
<ul style="list-style-type: none"> • Presence of garden²⁶¹ • Type^{241,248} • Location^{122,241,279} 		Criminality ³³⁸	Feeding ^{246,248-250,319,322}
Education level ^{102,241,251,252,261}			<ul style="list-style-type: none"> • Relative feeding time³³³ • Dietary protein^{341,342} • Dietary tryptophan³⁴²
Household income ¹⁰²			
Ethnic Origin ¹⁰²			

4.1.4.3. Factors related to owner-dog interaction

Table 9: Investigated factors related to owner-dog relationship and interaction

Companionship ^{268,313}	Play ^{247,250}	Training ^{241,246,248,250-252,264,265,270,313,332,337,343}	Experiences	Exercise ^{248,250-252,332}
Time spent together ^{247,251,252}	Play style ^{114,333,344}	Duration ²⁴⁷	Previous handling ²⁶⁸	Use of lead ^{279,351}
Time spent interacting ²⁴⁷¹	Play initiation ³³²	Attendance ¹⁰¹	Participation in sport ²⁶⁸	
Primary attachment ²⁴⁶	Play frequency ³³²	Type ^{101,257}	Experience in working role ^{268,347}	
	Toys ²⁶¹	Methods ^{257,316,345}	Early life experiences ²⁶¹	
		Formality ¹⁰¹	<ul style="list-style-type: none"> • Socialisation^{257,348-350} • Urban environment²⁸⁹ • Maternal environment^{289,325} • Litter environment^{270,325} 	
		Use of shock collar ^{290,346}	Previous home	
		Discipline style ^{101,241,251,252,316,332}	<ul style="list-style-type: none"> • Reason for relinquishment²⁷⁷ • Age at relinquishment²⁷⁷ • Age at acquisition^{241,245,248,255-257,261} • Source of acquisition^{101,246,248,254-257,261,263,264,270} 	

4.1.4.4. Factors related to the target of aggression

Table 10: Investigated factors related to the target of aggression

Socio-demographics	Relation to dogs
Educational level ^{122,249}	Relationship to dog ^{102,104,105,160,268,275,276,278,300,304,315}
Household income ^{122,249,352,353}	Dog ownership ^{104,105,122,276,279,300,306,315,352}
Marital status ^{249,300}	Preferred animal ¹⁰⁴
Weight ³⁵²	History of being bitten ^{249,354,357}
Gender ^{102,104,105,122,160,249,258,276,278,279,281,293,300,304,306,315,352-357}	Understanding of behaviour ²⁴⁹
Height ³⁵²	Attitudes towards dogs ^{249,352}
Ethnic origin ^{122,249,353}	Precautions taken ²⁴⁹
Age ^{102,104,105,122,160,249,258,276,278,279,293,300,304,306,315,352-357}	
Occupation ³⁰⁰	
<ul style="list-style-type: none"> Occupational experience^{249,352,354,356-358} Occupational exposure^{249,354,356-359} 	

4.1.4.5. Factors related to the circumstances of the aggressive event

Table 11: Investigated factors related to the circumstances of the event

Location ^{102,122,162,253,258,264,276,293,300,304,306,352,353}	Time	Legislation	Circumstance ^{276,304,315}
Relative to dog's home ¹⁰⁵ Relative to target's home ¹⁰⁵ Urbanicity ^{261,276,353,354,360} Population density ^{102,160,301}	Time of day ^{293,304} Time of year ^{102,160,278,293,331} Lunar cycle ³⁶¹	Enactment ^{301,362}	Interactions ^{105,160,246} Preceding events ²⁹³ Activity of dog ^{105,270} Activity of target ²⁴⁹ Persons present ²⁷⁰ Number of dogs in group ^{253,293} Supervision ¹³⁵

4.1.5. Studies meeting inclusion criteria

Eight studies^{101,114,246,324,325,341,342,354} were identified as being of sufficiently high methodological quality to consider the evidence they provided at low risk of bias and confounding (i.e. SIGN levels 2+, 2++, 1+ or 1++). These studies fell into three broad categories (Figure 4); four were non-specific observational studies,^{101,114,246,354} two studies of heritability^{324,325} and two studies of the effect of diet on aggression.^{341,342}

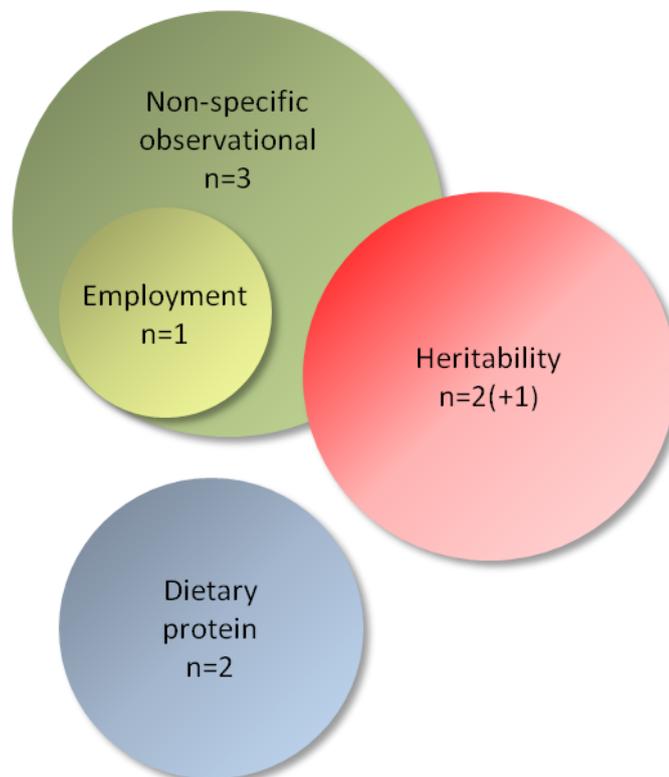


Figure 4: Studies of sufficient methodological quality to reach final systematic review. The area of each circle is proportional to the number of studies in that category.

4.1.5.1. Non-specific observational studies

4.1.5.1.1. An epidemiological study of dog bites among postmen in central Taiwan.³⁵⁴

This cross-sectional survey utilised a structured questionnaire and trained interviewer during annual occupational medical examinations. The survey explored factors predisposing postal workers to being bitten by a dog during the course of their working day. The study population consisted of 193 postal workers, 183 of them male. Multivariable analysis was undertaken allowing the authors to elucidate the effect of independent factors on risk of having been bitten.

The major limitation of this study was its narrow study population and resultant limited external validity; factors affecting the risk to postal workers in Taiwan may not be the same as those affecting postal workers elsewhere, or the general population.

4.1.5.1.2. Which dogs bite? A case control study.¹⁰¹

Gershman et al. undertook a case control study utilising a structured telephone interview with the owners of 178 pairs of dogs. Cases were licensed dogs that had been reported to Denver Animal Control for a bite to a non-household member requiring hospital attendance, any dog that had bitten a non-household member prior to the index incident was excluded. Controls were identified using random telephone dialling and were matched to a case by geographic area. Multivariable analysis allowed the identification of independent risk factors.

Major limitations of this study resulted from the authors' definition and analysis of breed, and the recruitment of cases which excluded a large number of the reported bites within the jurisdiction.

4.1.5.1.3. Risk factors for dog bites to owners in the general veterinary caseload.¹¹⁴

Guy et al. undertook a case-control study within the Canadian general veterinary caseload. Cases were identified from a previous cross-sectional survey of the same population and consisted of dogs that had bitten a household member or frequent visitor. Controls were dogs that had not bitten and were matched by their veterinary clinic. Cases and controls undertook a structured telephone interview. Strengths of this work included the use of an explicit definition of a bite and multivariable analysis.

Limitations of this study were acknowledged by the authors. The population was drawn from the veterinary caseload; this is thought not representative of the general dog population, as a result external validity may be somewhat limited. Further it was necessary to exclude recent behaviour from the multivariable analysis, due to multiple interactions and difficulty establishing the direction of causal relationship; this may have excluded factors affecting risk. However, recognition of these interactions and limitations brings strength to the study's reported findings.

Additional, unpublished, information was identified within the thesis describing this work.¹¹⁵

4.1.5.1.4. National survey of owner directed aggression in English Springer Spaniels.²⁴⁶

This cross-sectional survey of American Kennel Club registered English Springer Spaniels utilised a postal questionnaire to examine factors affecting risk of owner-directed aggression and biting. There was also limited study of the pedigree of the 1053 recruited dogs.

The major limitation to this study was its external validity as a result of only registered members of a single breed being included, however this also served to control for some confounders.

4.1.5.2. Studies of heritability

4.1.5.2.1. The genetic contribution to canine personality.³²⁴

This cross-sectional pedigree analysis of German Shepherd dogs and Rottweilers who had undertaken the Dog Mentality Assessment (DMA) test of the Swedish Working Dog Association between 1989 and 2001. The authors sought to establish the amount of variation in a number of behaviour traits that could be attributed to genetics, whilst controlling for environmental variables.

The major limitation of this study was its external validity, as with all pedigree analyses, heritability estimates only apply to the study population.

4.1.5.2.2. Direct genetic, maternal and litter effects on behaviour in German Shepherd dogs in Sweden.³²⁵

This cross-sectional pedigree analysis utilised the same German Shepherd dog population that had undergone the DMA between 1989 and 2001 as Saetre et al.³²⁴ above. The effect of the litter and mother on heredity of identified behaviour traits was analysed, in addition to heritability of behaviour traits.

As in Saetre et al.³²⁴ limitations resulted from the unavoidably restricted external validity. In addition the authors identified a significant tester effect on the DMA results.

4.1.5.3. Studies of the effect of diet on aggression

4.1.5.3.1. Effect of dietary protein content and tryptophan supplementation on dominance aggression, territorial aggression, and hyperactivity in dogs.³⁴²

This randomised trial with cross-over design recruited 38 privately owned neutered dogs and examined the effect of four diets, fed in a random order, on hyperactivity and aggression. Behaviour was scored daily by the dogs' owners using a defined scale; the study outcome was a change in the aggression or hyperactivity score.

The main limitations of this study resulted from its small sample size and the short duration of both the trial and feeding periods.

4.1.5.3.2. Effect of dietary protein content on behaviour in dogs.³⁴¹

This randomised trial with cross-over design recruited 50 privately owned dogs, with diagnoses of dominance aggression (towards owner) hyperactivity, or territorial aggression (towards visitor to property) and healthy controls. The dogs were fed three diets of differing protein content for 2 weeks each in random order. Aggression was scored daily by the dogs' owner using a defined scale. Outcome was a change in aggression score.

Major limitations to this study as with DeNapoli et al.³⁴² resulted from the small sample size and short duration of the study.

4.2. Narrative systematic Review

4.2.1. Summary of findings

Tables 12 and 13 provide a summary of the eight studies which met the inclusion criteria for the systematic review. Of note is the propensity of these studies to have a well defined but narrow population, where aggression towards or biting a specific target, for example a household member, had been investigated. The adoption of a restricted study population provides a means to control for confounding due to the restricted factor;¹⁹⁷ and will also control for effect modification due to this factor, which may arise, for example, where the affect of risk factors for aggression toward a stranger may be different to that toward a household member. Hence, this approach has some methodological advantages, although to the detriment of the external validity (i.e. generalisability) of the study's findings.

Many studies presented both univariable and multivariable analytical results. Where appropriate, only the findings of the multivariable modelling process have been accepted by this review. Multivariable analysis attempts to control for confounding by creating a model with many predictor variables, thus presenting findings for a variable of interest after adjustment for the effects of other important variables.¹⁹⁷

In examining the findings of studies reaching the final systematic review, attempts were made to extract information regarding variables that were tested in the multivariable model, but were not included in the final model due to lack of statistical significance or effect on other variables. Failure to identify a statistically significant effect cannot be assumed to mean that no such effect exists, merely that one was not identified; failure to detect a significant effect may result from a type II error (where a true effect is not identified) the probability of this occurring increases as the statistical power decreases. Very few studies stated the expected statistical power, but many had a relatively small sample size and so the power may be expected to be low.

Table 12: General observational studies reaching the inclusion standard of systematic review

General observational studies				
Paper name	An epidemiologic study of dog bites among postmen in central Taiwan. ³⁵⁴	Which Dogs Bite? A case-control study of risk-factors. ¹⁰¹	Risk factors for dog bites to owners in a general veterinary caseload. ^{114,115}	National survey of owner-directed aggression in English Springer Spaniels. ²⁴⁶
Study type	Cross-sectional	Case-control	Case-control	Cross-sectional
Level	2+	2+	2+	2+
Study population size	192 postal workers.	178 geographically matched pairs of dogs.	227 cases, 126 controls.	1053 dogs.
Study location	Taiwan	United States	Canada	United States
Population characteristics	Postal workers.	Registered dogs reported for biting a non-household member and geographically matched controls.	General veterinary caseload in Canada.	Adult, AKC registered, English Springer Spaniels.
Outcome measures	Bite during course of work.	Bite to non-household member requiring hospital attendance.	Bite to household member.	Owner-directed aggression and bite.
Main factors studied	Socio demographics. Experience. Location.	Signalment. Size. Acquisition. Husbandry. Behaviour history. Discipline.	Signalment. Weight. Home environment. Medical history. Behaviour history. Husbandry.	Signalment. Breeding. Acquisition. Behaviour history.
Risk factors identified	Working in rural area.	Male dog, entire, living with children, chained in yard.	Interaction between weight and sex - small female dogs at greatest risk. Teenage children in home. History of skin disorder. Behaviour history.	Male dogs. Neutered females. Specific kennel in pedigree. Source of acquisition. Aggression towards other targets.

Table 13: Studies of diet and heritability reaching the inclusion standard of systematic review

	Studies of dietary effect		Studies of heritability	
Paper name	Effect of dietary protein content and tryptophan supplementation on dominance aggression, territorial aggression, and hyperactivity in dogs. ³⁴²	Effect of dietary protein content on behavior in dogs. ³⁴¹	The genetic contribution to canine personality. ³²⁴	Direct genetic, maternal and litter effects on behaviour in German shepherd dogs in Sweden. ³²⁵
Study type	Randomised trial	Randomised trial	Cross-sectional	Cross-sectional
Level	1+	1+	2+	2+
Study population size	38 Privately owned dogs.	50 Privately owned dogs.	5694 German Shepherd dogs, 4589 Rottweilers	5959 German Shepherd dogs
Study location	United States	United Kingdom	Sweden	Sweden
Population characteristics	Privately owned dogs.	Privately owned dogs.	Dogs who underwent the Dog Mentality Assessment by the Swedish Working Dog Association between 1989 & 2001.	
Outcome measures	Change in aggression score.	Change in aggression score.	Finding of aggressive trait during the Swedish DMA.	
Main factors studied	Protein and tryptophan content of diet	Protein content in diet	Heritability of an aggressive behaviour trait.	Heritability of an aggressive behaviour trait. Maternal and litter environment.
Risk factors identified	High protein associated with highest dominance aggression. Low protein, tryptophan supplemented, associated with lowest territorial aggression	No overall effect. Reduced protein content reduced only fear related territorial aggression.	Evidence of heritability.	Evidence of heritability. Greater environmental effect than genetic.

4.3. Evidence regarding dog related factors

4.3.1. Does the size of dog affect the risk of it exhibiting human-directed dog aggression?

There is clearly an inextricable link between the breed of dog and its size or weight. Thus any study looking at weight or height as a putative risk factor for human-directed dog aggression would need to take into account the confounder of breed and also age if growing dogs are included in the study population. This is further complicated by the association between the size of a dog and potential to damage as a result of the crude mechanics of greater muscle power and larger jaw, which would potentially result in the bites of larger dogs being more likely to present to Emergency Departments and to be reported in statistics.

In their 2001 case-control study of dog bites received by owners, Guy et al. found that the mean weight of biting dogs was lower than that of non biting dogs, 19.5Kg (range 1.8-58.5Kg) as compared to 22.4Kg (3.6-58.5Kg) respectively ($p < 0.05$).¹¹⁴ This association was especially true of female dogs. However, in their multivariable model, the authors found that there was a complex relationship between the weight and sex of a dog, with smaller female dogs being more likely to bite.¹¹⁴

This study¹¹⁴ and others^{313,314} have found that the size of a dog affects the way in which it is managed and the freedoms that it has within the home, for example, small dogs are more likely to be allowed onto furniture.^{114,314} As a result it is difficult to interpret the effects of size of the dog without detailed information about the management and general behaviour of the dog, and vice versa.

Guy et al. utilised a population previously recruited from the general veterinary caseload in provincial Canada.^{114,115,265} This had many merits, avoiding the limitations of those studies utilising behaviour referrals or reported bite incidents for example. However it is recognised that vet visiting dogs within a population are not likely to be representative of the general dog or owner population. A recent study in the United Kingdom found that 77% (95% CI 62-92%) of the dog population were registered at a veterinary practice,³⁶³ and 29% (95% CI: 17-43)% of dogs were Kennel Club registered.³⁶³ This study found marked differences in the popularity of breeds within each population studied – with for example the King Charles Spaniel ranking 38th amongst the microchipped dogs, 18th amongst insured dogs and 105th in Kennel Club registrations, similarly the greyhound ranked 18th, 39th and 163rd respectively, despite the study predating the requirement for raced greyhounds to be microchipped.³⁶³

Guy et al. suggest that the detected complex relationship with size may reflect owners of larger aggressive dogs being less likely to present to a veterinarian, or more likely to relinquish their dog because of the greater perceived risk of injury.¹¹⁴

Gershman et al. examined the relationship between a dog's weight and risk of biting and found no evidence of an association with a dog having bitten a non-household member.¹⁰¹ However, in their analysis weight was included as a binary variable (>50lb, (22.7Kg) or not) simultaneously with the variable for breed (German Shepherd, Chow Chow or other). German Shepherd and Chow Chow were the two most numerous breeds in the study and would

likely have been within the >50lb category. Hence, any effect of weight may have been accounted for by the variable “breed”. The authors of this study state that biologically meaningful interaction terms were tested in the multivariable model.¹⁰¹ However it is not explicitly stated which interactions with weight were examined.

Interpretation of evidence: There is limited evidence that smaller female dogs are at greater risk of biting household members; however there are many confounding factors of size and further study is required to elucidate whether this is a true risk factor.

4.3.2. Does the age of a dog affect the risk of it exhibiting human-directed dog aggression?

The relationship of an act or behaviour with age is somewhat complicated by increasing age providing increasing opportunity for an event to have occurred. For example a three year old dog has only had three years in which to bite, whereas a twelve year old dog has potentially had four times the opportunity. This may be attenuated by older dogs representing a “survivor population” as a result of some of those dogs who have bitten being euthanised. Increasing age also raises the likelihood of coexistent illness and age related cognitive and sensory changes which may act as confounders in any apparent relationship.

Studies examining the risk of household¹¹⁴ and non-household member¹⁰¹ directed bites and owner directed aggression²⁴⁶ found no independent association of risk with age of the dog.

Interpretation of findings: There is no evidence for an association of age with risk of aggression or biting.

4.3.3. Do the sex and neuter status of a dog affect risk for human-directed dog aggression?

Sex and neuter status are frequently quoted as risk factors for human-directed dog aggression in both the peer reviewed^{101,255,264,364-366} and lay press.

The causal direction of any identified relationship between neutering and aggression must be scrutinised as many animals are neutered as a result of undesired behaviour in the hope or belief that it will rectify problems,^{246,367} as a result studies may identify the cause and not the consequences of neutering if they are not longitudinal in design. Reisner et al. found that of the 167 neutered males in their study population, 17% had been castrated because of human-directed aggression and 6% because of dog-directed aggression.²⁴⁶ In comparison, only 1% of the neutered females had been neutered in response to human-directed aggression and none as a result of dog-directed aggression.

Guy et al. identified that there was an interaction between the weight of a dog, its sex, and risk of biting a household member, with females being increasingly likely to bite with decreasing weight.¹¹⁴ Neuter status was not found to be significantly associated with reports of biting (OR 0.83 (CI 0.37-1.89, p=0.66). The majority of dogs in this study were neutered, 93% of females and 82% of males, reducing the study's ability to detect an effect.

In their 2005 survey of owner-directed aggression by American Kennel Club registered English Springer Spaniels, Reisner et al. found that male dogs were significantly more likely than females to exhibit aggression towards a household member, with an odds ratio of 1.68 (CI 1.22-2.33 p=0.002).²⁴⁶

Reisner et al. found that, overall, neutered dogs were more likely to be reported to be aggressive towards household member with an odds ratio of 1.73 (CI 1.25-2.39 p<0.001).²⁴⁶ When male and female dogs were analysed independently the association with neutering only persisted in the female dogs, with neutered females having an odds ratio of 1.92 (CI 1.32-2.79 p<0.001) compared to intact females, the odds ratio for neutered male dogs is not available.

Gershman et al. found that male dogs were at greater risk of having been reported for biting a non-household member, with an odds ratio of 6.2 (CI 2.5-15.1).¹⁰¹ In this study sexually intact dogs were found to be at greater risk of biting with an adjusted odds ratio of 2.6 (CI 1.1-6.3). In their subgroup-analysis of those victims below 12 years of age this relationship was no longer statistically significant; OR 2.3 (CI 0.7-7.3).

Interpretation of evidence: There is conflicting evidence for the roles of both sex and neuter status as risk factors for aggression and bite; further study is required. Elucidation of the true effect of neutering on risk of aggression requires prospective study.

4.3.4. Does the breed of a dog affect the risk of it exhibiting human-directed dog aggression?

It is often reported that a given breed is more or less likely to be aggressive towards people, indeed many jurisdictions have enacted breed specific legislation as a result of concerns over the risk posed by some breeds or types of dog.^{129,165,182} However, there is potential for many factors to confound any relationship between breed and aggression. For example, most dogs within a given breed will fall within a relatively narrow range of height and body mass; this may impact on the damage done if a bite should occur, and whether the recipient of a bite attends an Emergency Department. The perceived risk of a specific breed of dog biting may also impact on interpretation of both the dog's behaviour and any injury received.

Further adding to the complexity of identifying whether a breed is at increased risk of exhibiting human-directed aggression, recipients of dog bite injuries (and, indeed, others such as witnesses and even those regularly working with dogs) may not be best placed to identify the breed of dog involved in the incident. A study of American shelter dogs found that even those trained and experienced in breed identification are unreliable identifiers of breed, with the predominant breeds, of dogs with mixed or unknown parentage, proposed by shelter staff not found to be present in the DNA breed analysis of 87.5% of the dogs studied.³⁶⁸ This breed misidentification has significant implications, not only for the reliability of any study including breed as a variable, but also the behavioural interpretations and expectations of prospective owners and others who come into contact with a misidentified dog.

Of those studies which examined the effect of breed on risk, the common difficulty was the relatively small study population and large number of breeds represented, resulting in limited ability to identify breed differences.

In their case-control study of risk factors for dog bites to household members, Guy et al. found no association between breed and dogs having bitten.¹¹⁴ However, as the authors acknowledge, there were 62 different breeds represented amongst the 202 purebred dogs in this study, rendering the number of dogs belonging to each breed very small. Thus power to detect differences is likely to have been insufficient.

The case control study by Gershman et al., examining risk of bites to non-household members, had similar difficulty identifying the effect of breed on risk, in addition to a problematic method of breed identification.¹⁰¹ In this study breed was defined as the predominant breed identified by the owner, as outlined above this may be subject to significant inaccuracies. Gershman et al. identified that dogs considered to be predominantly German Shepherd or Chow Chow breeds were at increased risk of biting, however as a result of the issues associated with breed identification, the method of analysis for breed and the low numbers of other breeds within the study population, these findings are of low quality evidence.

Interpretation of evidence: Despite considerable speculation of a role for breed as a risk factor for human-directed dog aggression, insufficient evidence exists to draw firm conclusions.

4.3.5. Are there genetic determinants of risk for human-directed dog aggression?

It has long been suggested that the temperament of the sire and dam is a significant predictor of the behaviour of their offspring; the key factor to this claimed relationship being their genetic heritage.

Work presented in Strandberg et al³²⁵ and Saetre et al³²⁴ investigated the heritability of a range of behavioural traits in a cohort of 5964 German shepherd dogs and 4589 Rottweilers which had undergone the Swedish Dog Mentality Assessment,^{369,370} a standardised behaviour test. They determined that only aggression appeared to be inherited independent of other traits, with other behaviours falling along a broad spectrum of canine personality previously denoted as the “shyness-boldness dimension.”³⁶⁹ These studies estimated that within the study population, in both breeds, 10% of the aggression shown towards a person who suddenly appeared was controlled by additive genetics and the remainder could be attributed to non-genetic factors ($p \leq 0.01$).^{324,325}

When studying the maternal heritability of behaviour amongst the German Shepherd dogs in their study population Strandberg et al. failed to find an influence from maternal genetics.³²⁵ This aspect of their study suggested that the environmental influence on the litter had a larger influence on behaviour displayed during the standardised test.

In their cross-sectional survey of owner-directed aggression in the English Springer Spaniel, Reisner et al. found that amongst their study population of 1053 adult English Springer Spaniels, the 48.4% of dogs reported to have a

history of aggression were significantly more likely to have one particular breeding kennel within their four generation pedigree (OR 1.6, CI 1.13-2.27, $p=0.009$).²⁴⁶ This kennel was specifically studied because of its noted frequent presence in the pedigrees of dogs being referred for aggression. The kennel was present in 34% of the pedigrees in the study. The authors acknowledge that this finding may reflect non-genetic factors associated with the kennel under study.

Interpretation of evidence: There is evidence for heritability of human-directed aggression; this however requires further investigation across multiple breeds.

4.3.6. Does the behavioural history of the dog affect risk of human-directed aggression?

It is perhaps intuitive that a dog that has bitten once may go on to bite again; however is there any evidence to support this? Are there factors in the behavioural history which may provide forewarning that a dog is at high risk of exhibiting aggression in the future? If such factors could be identified and well described this could provide mechanisms for detection of dogs at greatest risk of human-directed dog aggression.

In their study of risk factors for bites of a household member, Guy et al. found that dogs who were reported to have exhibited aggression over food in the first two months of ownership were more likely to have bitten, with an odds ratio of 3.08 (CI 1.05-9.01, $p=0.040$), compared to those that had not exhibited aggression over food. Those who had scored highly for excitability during the same period were also more likely to have bitten with an odds

ratio of 1.14 (CI 1.02-1.26, $p=0.018$).¹¹⁴ These aspects of behavioural history were only examined in those dogs acquired prior to six months of age. More recent behavioural history was recorded but not included in multivariable models due to the high number of interactions and difficulty in establishing the causal direction of any relationship identified.

Reisner et al. reported that dogs exhibiting owner-directed aggression were more likely to have a history of aggression towards familiar non-household members; with odds ratios of 18.27 (CI 2.41-138.81 $p=0.005$) and 4.02 (CI 1.47-10.95 $p=0.007$) for those with a history of aggression towards a familiar child and adult respectively.²⁴⁶ There was also an association between a dog having a history of aggression towards unfamiliar children within the dog's own territory and exhibiting aggression towards a household member; OR 2.55 (CI 1.06-6.14 $p=0.037$).

Reisner et al. also found an association between having exhibited aggression towards other dogs and risk of aggression towards household members; OR (1.85, CI 1.26-2.7 $p=0.002$).²⁴⁶

Gershman et al. did not identify any association between factors in the behavioural history, including previous bites to household members, and biting a non-household member.¹⁰¹

Interpretation of evidence: There is some evidence that various aspects of a dog's behaviour are associated with their future propensity to both exhibit aggression and bite; in particular, a history indicating past aggressive acts

increases the risk of future aggressive acts. This requires further high quality investigation.

4.3.7. Is the health status of a dog a risk factor for human-directed dog aggression?

It is well recognised that ill health, be it in dog or man, influences behaviour,³⁷¹⁻³⁷⁴ it is also suggested that the converse may be true.^{373,375}

Indeed, illness in an animal is often first recognised by deviation from their usual behaviour pattern.³⁷² This association may be influenced by factors involved in the management of illness, such as separation from owner, removal from usual environment, the impact of medication and pain, and change of normal routines and rules. It is likely that the effects of health, for example reactions to pain, will vary depending on the personality and inclination of individual dogs.

In their case-control study of dogs that had bitten a household member, Guy et al. found that dogs with a history of having a malodorous or pruritic skin condition, that had been treated by a veterinarian, had an odds ratio of 1.87 (CI 1.03-3.38, p=0.039) for biting, compared to those that did not have a history of such conditions.¹¹⁴ There was no association identified between having had a serious illness requiring overnight admission to a veterinary clinic and risk of biting.¹¹⁵

Reisner et al. found no association between a history of seizures and aggression towards a household member in their population of English Springer Spaniels.²⁴⁶

Interpretation of evidence: Whilst there is some evidence for an association between skin conditions and biting, the association of aggression and health requires more extensive study, ideally with a longitudinal design across the general dog population and not restricted to vet-visiting dogs.

4.3.8. Does the diet of a dog alter risk of human-directed dog aggression?

It has been suggested that the behaviour of aggressive dogs may be modified by altering the protein content of their diet. Theories behind the hypothesis that diet may affect behaviour relate to the impact of dietary intake on neurotransmitter and catecholamine levels. Protein for example is thought to increase the cerebrospinal fluid (CSF) catecholamine level, lowering threshold for aggression.³⁴¹ Conversely it is hypothesised that tryptophan, a precursor for 5 hydroxy-tryptophan, also known as serotonin, in the diet leads to raised CSF serotonin levels and that these attenuate aggressive responses.^{376,377} As tryptophan competes with other amino acids for carrier proteins across the blood brain barrier³⁷⁸ the relative proportions of each may be key.

Dodman et al. investigated the effect of altering the protein content of the diet using a randomised trial with a cross-over design and three diets of low, medium and high protein content.³⁴¹ Owners were blinded to their dog's dietary protein content during the two weeks that each diet was fed and asked to report behaviour using defined criteria.

This study found that dietary protein content made no significant difference to the primary problem behaviour of dogs exhibiting owner-directed aggression

($p=0.5$) or hyperactivity ($p =0.13$), nor the control dogs. However in the group whose main reported behavioural issue was aggression towards visitors to their home, termed territorial aggression by the authors, low or medium dietary protein content was associated with a reduction in the reported intensity of the aggression ($p=0.035$) as compared to high dietary protein content. On further evaluating this group, Dodman et al. found that the effect was present in those dogs that scored highly for fearfulness ($p <0.0001$) but narrowly failed to reach statistical significance in the remainder of the group ($p=0.054$), this requires further investigation.³⁴¹

DeNapoli et al. undertook a similar randomised trial with internal cross-over design, examining the effect of dietary protein and tryptophan content on the level of aggression in a population of 38 privately owned dogs, 33 of the dogs completed the study.³⁴² This study found that overall the lowest “territorial” (visitor-directed) aggression scores were recorded whilst being fed a low protein, tryptophan supplemented, diet and that the high protein, unsupplemented, diet was associated with the highest “dominance” (owner-directed) aggression scores.

These two studies, whilst similar in design and undertaken in part by the same research group, analysed their data differently. Dodman et al. only found an effect within individual groups and DeNapoli et al. only when the study population was analysed as a whole. This, in addition to the very small population size, raises questions as to the validity of the findings.

Interpretation of evidence: There is some limited evidence for an effect of dietary protein and tryptophan content on the level of aggression expressed

towards either owners or visitors; however this requires further investigation with a larger population and longer duration of study.

4.4. Factors which primarily relate to the interaction between dog and owner

4.4.1. Does the source of acquisition of a dog affect risk for human-directed dog aggression?

Dogs are acquired from a range of sources. Any risk associated with source of acquisition may be multifactorial and confounded by a range of related factors including husbandry, early life experience, genetic factors and age at acquisition. Breed and pure breed status is also likely to confound any relationship with the source of acquisition.

In their cross-sectional survey of owner-directed aggression in English Springer Spaniels, Reisner et al. found that dogs that were acquired through newspaper advertisements had an odds ratio of 1.53 (CI 1.12-2.09 $p=0.007$) for all dogs, and 2.33 (CI 1.62-3.34 $p<0.001$) for female dogs, of being reported to be aggressive towards a member of their own household, compared to dogs acquired via all other sources.²⁴⁶ The authors did not find this association when male dogs were analysed alone. Of note, the multivariable analyses did not adjust for age of dog at acquisition, which may have been related to the source, if for example dogs were being rehomed via newspaper advertisements rather than litters being advertised.

This study exclusively included purebred dogs of a single breed registered with the American Kennel Club, and thus may have limited external validity. One notable absence from the findings of Reisner et al. is of dogs obtained from rehoming organisations; the proportion of dogs adopted from shelters

was not identified, although 0.9% of the dogs were classified as being acquired from a miscellaneous source and this may represent rehomed dogs. This is a notable absence in terms of determining risk factors in the general dog population.

Neither Gershman et al.¹⁰¹ nor Guy et al.¹¹⁵ found an association between a dog's source of acquisition and the risk that it would subsequently bite.

Interpretation of evidence: There is very limited evidence that source of acquisition may be a risk factor for owner directed aggression, however further work is required in this area with particular attention being paid to the multiple potential confounding factors at play.

4.4.2. Do the environment and experiences in the early life of a dog affect subsequent risk of human-directed dog aggression?

It is understood that there are periods in a dog's early life experience which are developmentally sensitive and help to shape their future behavioural attributes.¹⁵⁸ Experiences gained during these periods are strongly attributed to the breeding environment and the first few weeks at the new home. They will also likely be interlinked with the age and source of acquisition, the dog owning experience of both the owner and the breeder and their behavioural understanding and beliefs, which in turn will be influenced by their socio-demographic and cultural environment.

Guy et al. examined urbanisation and to a limited extent, via training and correction used during first months of ownership, early experiences, for those

dogs acquired prior to six months of age. They found no association with any of these factors.^{114,115}

Strandberg et al. examined the magnitude of the effect of litter and maternal environment via their pedigree analysis in German Shepherd dogs and found that the effect of the litter environment was greatest.³²⁵ However the nature of this study did not permit further investigation of which factors of the litter environment this related to.

Interpretation of evidence: This is a key area for further research given the ability of both the breeder and the owner to influence early life experience. Due to the complexity of gathering such data, this would require studies of longitudinal design with dogs followed from birth.

4.4.3. Does extent and type of training undertaken affect the risk of human-directed dog aggression?

How and when to train a dog is a topic associated with some controversy amongst the public, dog trainers and behaviourists. Some are advocates of 'positive' reward-based training used to increase the frequency of desired behaviour, whilst at the other end of the spectrum is the use of primarily aversive methods to reduce undesirable behaviour, relying heavily on the use of negative reinforcement and positive punishment to create avoidance.³⁷⁹

Reisner et al. found no evidence of an association between training and risk of aggression. However, this study did not appear to distinguish between reward based and aversive training methods, and it is not clear whether they differentiated between attendance at formal training classes and training at

home.²⁴⁶ Amongst their variables, as potential precipitants of aggression, were several actions which could be described as aversive training methods but do not appear to have been analysed as such.

Gershman et al. found no independent association between training and discipline and a dog's risk of being reported for biting a non-household member.¹⁰¹

Interpretation of evidence: No robust evidence of an association between training and risk of aggression has been identified.

4.5. Owner related factors

4.5.1. Do socio-demographic factors of the owner affect risk for human-directed dog aggression?

Socio-demographics may have wide ranging influence on an individual's experiences and available choices, actions and responsibilities. There is potential for many of these factors to influence various aspects of dog ownership; from the breed of dog that is owned, through its early life experiences to ongoing husbandry and training.

The gender and age range of the dog's primary human attachment was examined amongst the variables analysed by Reisner et al. for an association with owner-directed aggression amongst their population of pure bred English Springer Spaniels. No independent association was identified.²⁴⁶

In their study of bites to non-household members requiring medical attention, Gershman et al. found an association between one or more children below

10 years of age sharing the home with the dog and risk of biting non-household members, with an odds ratio of 3.5 (CI 1.6-7.5). Where the recipient of the bite was below the age of 12 years the odds ratio increased to 6.9 (CI 1.8-26.1).¹⁰¹ This may have resulted from increased opportunities for interaction with non-household members, especially children, in households with children of their own.

Guy et al. found no association between children living within the dog's household and risk of biting a household member.^{114,115} However this study did find an association between the risk of a dog biting and the number of teenagers in the dog's home. With each additional teenager the risk of biting increased; OR 2.09 (CI 1.30-3.35 p=0.002).

Interpretation of evidence: There is evidence that sharing a home with children or teenagers may be associated with an increased risk of biting both household and non-household members. This is an area requiring further research.

4.5.2. Does the purpose for which a dog is kept affect risk for human-directed dog aggression?

The reasons for acquiring and keeping a dog are multiple; from companionship through assistance to hunting and protection. The purpose for keeping a dog may influence its source of acquisition, genetic heritage, husbandry, early life experience and training amongst other factors. These all have the potential to confound any relationship between purpose and exhibited aggression.

Reisner et al.,²⁴⁶ Guy et al.¹¹⁵ and Gershman et al.¹⁰¹ all looked for an association between the purpose for which a dog is kept and risk of aggression or biting. None of these studies identified an independent association with the risk of human-directed dog aggression.

Interpretation of evidence: No robust evidence of an association between the purpose for which a dog is kept and its risk of exhibiting human-directed dog aggression has been identified.

4.5.3. Does the husbandry of a dog affect its risk of exhibiting human-directed dog aggression?

Factors affecting the manner in which a dog is managed in its home environment are complex and potentially related to socio-demographic factors, experience and beliefs of the owner, size and breed of the dog, in addition to the purpose for which it is kept. The evidence in this area is particularly problematic to interpret and disentangle cause from effect; dogs thought to have aggressive tendencies may be managed differently to other dogs.

Guy et al.^{114,115} examined many factors related to the manner in which a dog is kept. In their univariable analysis they found several associations between current management and biting, however the authors concluded that these associations could readily be the consequence and not cause of aggression and so they were not further evaluated within their multivariable model.^{114,115}

The multivariable analysis of Guy et al.^{114,115} did include factors relating to husbandry during the first two months of ownership in those dogs acquired prior to six months of age, as the authors concluded that these were less

likely to be consequences of aggressive behaviour. This study found that allowing a dog to sleep on the bed during the first two months of ownership was independently associated with risk of the dog subsequently having bitten a household member (OR 1.93; CI 1.06-3.53, p=0.032), including adjustment for weight. As described previously, this study found a complex relationship between the size of a dog, its sex and risk of biting. The authors acknowledge the potential association between a dog's size and how it is managed.

Reisner et al. found no independent association between a range of factors relating to the husbandry of the dogs within their study population and their risk of owner-directed aggression.²⁴⁶ This included no evidence of an association with allowing the dog to sleep on the owner's bed and the risk of aggression.

Gershman et al. studied a range of factors related to the husbandry of the dogs in their study; they found evidence of an association between dogs being chained whilst in the yard and having bitten a non-household member OR 2.8 (CI 1.0-8.1).¹⁰¹ However, the lower bound of the confidence interval for this relationship was 1, and the relationship was not found in the subgroup analysis of dogs that had bitten a child younger than 12 years of age. The authors of this study acknowledge that the relationship may not be causal.

Interpretation of evidence: There is weak and conflicting evidence of an association between allowing a dog to sleep on the bed and it biting, and

also evidence of an association between chaining a dog whilst in the yard and biting non-household members. These and other areas of the management of a dog require further detailed study in a manner which allows disentanglement of the many potential confounders.

4.6. Factors related to the target of aggression

4.6.1. Do socio-demographic factors related to the target of human-directed dog aggression influence the risk of aggression occurring?

Determining who is at greatest risk of being bitten is complex. Risk taking behaviour, occupation, pet ownership, how an individual perceives risk and health are determined by a combination of past experience, education and culture. Inequalities in health care seeking behaviour, consequent on similar determinants, have the potential to heavily influence findings of studies examining medically attended bite injuries.

In their study of bite injuries received by postal workers in Taiwan, Chen et al. found no evidence of an association with the gender, age, experience nor hours worked and risk of receiving a dog bite injury.³⁵⁴

None of the other studies reaching the final review examined the demographics of the target of aggression against a comparator group.

Interpretation of the evidence: No evidence was identified of an association between socio-demographic factors and the risk of being the target of human-directed aggression.

4.6.2. Is the relationship between the target of aggression and the dog and owner a risk factor for human – directed dog aggression?

Each of the general observational studies which have been appraised as being of an adequate standard examined the risk to a specific target of aggression in relation to the dog; Guy et al. and Reisner et al. investigated aggression towards,²⁴⁶ or bites of,^{114,246} the dog's owner or a household member. Gershman et al. examined risk of bites to a non-household member,¹⁰¹ and Chen et al. bites to a postal worker.³⁵⁴ That these studies were targeted in this way enabled them to more readily control for potential confounding variables relating to different motivations behind a dog's aggression towards humans. However, this systematic review did not identify any methodologically robust studies that compared the risk across different groups.

4.6.3. Is the degree of experience and understanding of dog behaviour a risk factor for human-directed dog aggression?

Understanding of canine behaviour by owners and non-owners varies and is not always as full or reliable as the individual believes,³⁸⁰ there is at times disagreement even between behavioural experts over what emotion a given expressed behaviour represents.³⁸¹ Intuitively we may infer that greater experience and understanding of dog behaviour would be associated with less risk of injury as a result of an aggressive act, however without evidence we cannot reach this conclusion.

Guy et al examined the effect of members of the dog's household having read about or watched information on dog training or attended obedience or puppy classes with a previous dog and found no association with their

current dog biting household members.¹¹⁵ In this study the owning household represented both the owner and target of aggression.

Interpretation of the evidence: No robust evidence of an association between experience and understanding of dog behaviour and risk of human-directed dog aggression was identified.

4.7. Factors which interact with the environment

4.7.1. Does geographic location or degree of urbanisation affect risk of human-directed dog aggression?

Contrasting environments, both physical and cultural, may affect the risk of human-directed dog aggression, there are likely to be many confounders involved in any direct effect of location on risk.²⁷⁰

In their study of dog bites to postal workers across 9 postal districts in Taiwan, Chen et al. found that those working in rural areas were significantly more likely to be bitten, with an incidence of 0.96 dog bites for each person-working year in rural areas, compared to an incidence of 0.45 bites per person for each working year in urban districts.³⁵⁴ This gave an odds ratio for bites to postal workers in rural areas of 2.70 (CI 1.39-5.25), following adjustment via logistic regression, as compared to urban postal workers. The authors examined the demographics of postal workers in rural and urban areas and found no other significant differences.

This evidence of association is restricted to a specific group who by virtue of their work may enter the territory of an unknown dog on a regular basis. It is therefore difficult to extrapolate these findings to the general population.

Further, this finding may be due to uncontrolled confounding, for example the

number of dogs in an urban compared to rural environment and their access to different parts of the home environment, such as gardens and post-boxes. However, this study does highlight that there may be an association which requires further investigation.

Guy et al. looked for an association between degree of urbanisation and the risk of a dog biting a household member, they found no association.¹¹⁵

Interpretation of evidence: Amongst postal workers in Taiwan, there is evidence of an association between working in rural areas and increased risk of receiving bite injuries, the external validity of this evidence is limited. No robust evidence of an association with geographical area was identified in the general population.

4.8. Summary of findings and key areas for future research

This review has highlighted the absence of high quality evidence relating to risk factors for human-directed dog aggression. Even that evidence identified as having a low risk of confounding and bias, summarised in table 14 below, does not provide firm evidence of causal relationships and in a number of cases is contradictory.

As a result of these contradictions and the moderate level of evidence identified, the findings of this review do not provide robust evidence for any factor affecting the risk of human-directed dog aggression. These findings can however be utilised in formulating hypotheses for future research. The conceptual matrix (figure 2) can be utilised to visualise the interactions between parties related to a given factor, this may assist in identifying those

most amenable to change. An appropriate focus for future research should be identified by undertaking a prioritisation exercise involving a multidisciplinary group.

Table 14: Summary of current evidence base for risk factors of human-directed dog aggression

	No association found									
	Association identified									
	Mixed findings	Chen ³⁵⁴	Gershman ¹⁰¹	Guy ^{114,115}	Reisner ²⁴⁶	DeNapoli ³⁴²	Dodman ³⁴¹	Saetre ³²⁴	Strandberg ³²⁵	Current robust evidence
Size										Limited evidence of a complex relationship between sex and size, many confounders.
Age										No evidence for an association across multiple studies.
Sex (male)			↑	↓	↑					Conflicting evidence.
Neuter			↓		↑					Conflicting evidence.
Breed										No evidence.
Genetics										Evidence of heritability in studies of three breeds.
Behaviour history										Limited evidence that aspects of behaviour are associated with their future propensity to aggression.
Physical illness										Some evidence for an association between skin conditions and biting, no evidence for other illness.
Diet										Limited evidence for an affect of dietary protein and tryptophan content on the level of aggression.
Source of acquisition										Very limited evidence, multiple potential confounders.
Early experience										Limited evidence.
Training										No evidence.
Owner socio-demographics										No evidence.
Child/teen in home			↑	↑						Limited evidence of an association between children or teens sharing the home and risk of biting.
Purpose										No evidence.
Husbandry										Limited and conflicting evidence, many confounders.
Target socio-demographics										No evidence.
Target relationship to dog										No evidence.
Experience & knowledge										No evidence.
Geography										Evidence of increased risk to postal workers in rural areas, no evidence out with this group.

Chapter Five

Appraisal of methodological issues

5. Appraisal of methodological issues

A number of common methodological issues were identified within the studies evaluated. Many studies had multiple limitations which were additive in their effect on the level of evidence provided. These are discussed below, the order is not prioritised.

5.1. Study design

5.1.1. Case studies and series

Studies designed to establish risk factors require a control or comparator group.³⁸² Thus, in order to establish which factors affect the risk of a dog exhibiting human-directed aggression, comparisons must be made to dogs who do not exhibit aggressive behaviour.¹¹⁴

As a result of their lack of a comparator group case series and studies do not provide robust evidence for the effect of potential risk factors.

5.1.2. Sample size

Few studies report having undertaken sample size or power calculations in advance. In the absence of these it is difficult to establish the value of findings, especially those of a lack of an association.³⁸² In many cases it was likely that the number of individuals within a study population was insufficient to detect a statistically significant effect. A prime example of this is where studies attempt to determine the effect of breed on risk. With only a handful of dogs from each breed within study populations, detecting an effect of breed was problematic, this limitation was acknowledged by some authors.^{101,114} One method utilised to overcome this is grouping of breeds by

group; hound, working, pastoral etc.^{102,105,251,252,257} This is in itself problematic due to the diversity of dog characteristics within breed groups, the Hound group comprises breeds including the Dachshund, Borzoi and Otterhound for example.³⁸³

5.2. Selection

Study population selection is fundamental to any high quality investigation. Regardless of the quality of subsequent measurement and analysis; if the original selection was potentially biased then all subsequent findings are devalued.

5.2.1. Convenience sampling

Many studies utilised populations selected by convenience, with a high risk of introducing bias.^{241,250,254,256,257,262,264,266,267,270,273,282,316,330,384} All types of convenience sampling in observational studies carries the likelihood that those who are convenient, or more likely to be sampled, are not representative of the overall population under study, by virtue of the factors increasing their likelihood of being sampled.³⁸⁵

A number of methods of convenience sampling were identified within the appraised studies these included:

I Recruitment via advertisements placed in dog related magazines^{250,314,360} where bias is introduced by the select readership of such magazines, in addition to those who choose to participate having read the advertisement.

II Internet based surveys^{105,242,260,320} have a similar propensity to introduce volunteer bias, in addition to bias resulting from the factors making an owner more likely to access internet based information. There is evidence that this method of recruitment may produce populations with characteristics comparable to more traditional methods in some fields of research.³⁸⁶

III Recruitment of dogs being walked in public places.^{251,252,316,319} Studies that recruited in this manner were at risk of not being representative of the general dog population. Sampling in this manner would be most likely to recruit dogs that were walked more frequently, possibly those walked on lead, and during the working day in public areas. Conversely those receiving little, or less formal, exercise, those walked during the quieter times of the day and those walked in more isolated areas would be less likely to be approached. These factors are likely to be related to a host of potential confounders interwoven with the behaviour of dog and owner.

5.2.2. Registries

A number of studies utilised registry-based populations as their comparator group in risk factor analysis.^{102,105,161,298,304} Within these populations only a limited amount of information is known about the individuals, and perhaps more critically information concerning those falling outwith the register is lacking. Without knowledge of the population not represented within the comparator dataset it is impossible to gauge relative risk reliably.

5.2.2.1. Registered dog population

In some studies the signalment (age, breed and sex) of dogs that had bitten was compared to that of licensed dog registrations within the same jurisdiction, usually to establish relative breed risk.^{102,105,161,298,304} This is potentially problematic as even where registration or licensing of dogs is compulsory it will not be complete,^{101,102,105} factors affecting the likelihood of an owner to register or license a dog may confound the relationship with risk of aggression, thus the use of registries in this manner has considerable potential for introducing bias. In Shuler's study of dog bites in Multnomah County, Oregon, 51% of the dogs reported for biting were not licensed.¹⁰² An earlier survey in the same county found that only 43% of dogs were licensed.¹⁰³

5.2.2.2. Reported dog bites

Multiple factors are likely to influence an individual's decision to report a bite incident to authorities, even where it is compulsory to do so. In the study described by Shuler for example the authors acknowledge that, although multiple parties are required to report dog bites in the county, the reported bite rate was 40% below the national estimated rate of bites attending emergency departments,¹⁰² in turn this is known to be only a small proportion of all dog bites.^{119,122} The characteristics of the dogs, owners and recipients involved in unreported bite incidents are not captured if only those reported are examined.

5.2.3. Medically attended bites

Datasets of those attending for medical treatment of bite injuries do not represent all bites occurring^{105,122,123,353} with an estimated 1 in 5 dog bites to adults and 1 in 4 dog bites to children resulting in attendance for medical treatment in the United States,^{122,123} and are liable to considerable biases.^{88,104,105,119}

Whether an injury is considered to require medical treatment will be affected by a number of factors, in addition to the perceived severity of injury and risks posed, which in turn, may be influenced by health beliefs and understanding.^{125,387,388} Inequalities in health care seeking behaviour and access are well recognised and again will influence who attends for treatment.^{88,124} Cognitive biases influencing the perceived risk of a given type of dog causing serious injury may be generated by media flurries and breed bias in reporting of severe bite injuries¹³⁰ and result in the recipients of bites inflicted by dogs of some breeds or types being more likely to attend for treatment.¹⁰¹

Bite injuries resulting in hospital attendance are commonly considered an indicator of injury severity; however this does not necessarily follow.

Although they didn't record injury severity, Beck et al. found that in children the sole factor associated with a bite resulting in attendance for medical care was the ownership category of the dog; with bites inflicted by dogs of unknown ownership more likely to result in attendance followed by those owned by neighbours and in turn dogs belonging to the child's family.¹⁰⁴

In contrast to studies examining hospital attendance records,^{34,119,126} studies which attempt to capture all bites, and not just those attending for treatment, do not tend to find an increased incidence nor severity in children.^{105,122}

Differences in the distribution of bites identified in the hospital attending as compared to general populations,^{34,105,119,122} support the hypothesis that bitten children are more likely to be presented to hospital or reported to authorities than bitten adults, regardless of their degree of injury.¹⁰⁵

5.2.4. Randomisation

Randomisation is fundamental to reducing the risk of introducing selection bias. Within an observational study it is important to consider whether, despite attempts at random selection, some members of the population are disproportionately more likely to be selected. The use of convenience sampling described above, with recruitment via the readership of dog related magazines,^{250,314,360} internet based surveys,^{105,242,260,320} and dogs being exercised in a specific location,^{251,252,316,319} exemplify non-random recruitment to observational studies.

In controlled trials, randomisation is crucial to ensuring those assigned to each group are not fundamentally different in ways other than their exposure to the factor being tested. Amongst the studies evaluated evidence was found of allocation by a supervising individual,³⁸⁹ significant differences in the early life experiences²⁶¹ and in the housing³⁴⁸ of cases and controls.

5.2.5. Control selection

For any meaningful risk factor analysis, comparator populations must be derived from the same population as the cases. For example, in case-control studies where dogs that have bitten are cases and dogs that apparently have not are controls, it is important that should one of the controls be found to have bitten it could become a case. This was exemplified in the case control study by Guy et al.¹¹⁴ where dogs who were initially included as non-biting controls as a result of their owners responses during the cross-sectional study,²⁶⁵ were subsequently found to have bitten and thus became cases. Where this does not occur any association identified may be as a result of the inherent differences between the case and control populations, rather than exposure to the risk factor being investigated. This was a pitfall of a number of studies; Appleby et al. for example acknowledged some of these pitfalls, but in studying the effect of early life experience went on to compare referrals to a behaviour practice for aggression or avoidance to referrals for issues related to control or attention seeking and a third group of vet visiting dogs.²⁸⁹

5.3. Measurement

Robust research requires reliable and reproducible measurement of both the outcome under study and exposure to potential risk factors. This was a shortcoming of many studies.

5.3.1. Outcome definition

In order to measure an outcome reliably, and in so doing accurately classify members of the study population as either having demonstrated that outcome (aggression for example) or not, i.e. whether they are a case or non-case, the outcome being studied must be clearly defined.

Many studies of aggression had a poorly defined outcome.^{255,283,289,389}
^{251,252,260,319,390} Some used direct questions regarding the frequency or presence of specific behaviours,^{246,251,252,313} others derived an aggressive trait from responses to a questionnaire^{241,260,267,319,330,390} or standardised behaviour test.^{184,271,324,325}

Where studies examined factors related to a dog's risk of biting the outcome definition was often equally problematic. Amongst those studies that did provide an explicit definition there was some disagreement as to what constituted a bite:

Guy et al defined a bite as "*the upper or lower teeth making contact with the victim's skin with sufficient pressure to cause a visible injury such as an indentation, welt, scrape or bruise, puncture or tear in the skin. A dog mouthing a person's skin without applying sudden pressure is not considered a bite.*"¹¹⁴ This definition does not however implicitly identify the act as aggressive. A puppy in play for example may perform an act which would meet these criteria for bite, without any aggressive intent.¹¹⁵

Messam et al²⁷⁰ sought to identify non-play bites and, to this end, asked three questions: (1) "*Not during play, in the last two years, did the dog ever*

hold onto or catch a part of any person's body with its teeth and cause a wound?", (2) *"Not during play, in the last two years, did the dog ever hold onto or catch a part of any person's body or clothes with its teeth but not cause a wound?"* and (3) *"During play, in the last two years, did the dog ever hold onto or catch a part of any person's body with its teeth and cause a wound?"* Responding in the affirmative to either of questions 1 and 2 resulted in the dog being classed as a biting dog in this study.

As can be seen from these two definitions the same dog could readily be classified as a biting dog in one study but not the other.

Without a clear definition dogs can readily be misclassified in either direction, generating a fundamentally unreliable study population. The appraisal process sought to identify those studies with an outcome definition that was both objective and reproducible.

Frequently studies used an outcome of bites requiring medical attention^{161,362} or reported to authorities,¹⁰² on some occasions both¹⁰¹ Whilst this provides a clear discriminator, did a bitten person attend hospital or not, it does not provide a guide to severity of the injury received as a host of factors determine whether an individual chooses to attend for medical treatment.^{88,106,125}

Some studies sought to ascribe emotion^{251,252} or intent^{105,270} to aggression or bite incidents, this was problematic and had the potential to introduce subjectivity to their outcome definitions, two dogs acting identically could be classified in opposite groups as a result of observer perceptions.

5.3.2. Outcome measurement

Measurement methods, of both the outcome and exposure to study factors, were often not reproducible or validated. A poor outcome definition frequently compounded this problem.

A number of studies utilised the opinion of veterinarians and other animal care workers in ranking breeds on various behaviours.^{294-297,299,302} Opinion of breed behavioural characteristics, even where expressed by an experienced and knowledgeable body, is low level, potentially biased, evidence. Indeed, such studies are investigating beliefs about breed preponderance to aggression, rather than actual differences between the breeds.

5.3.3. Study factor measurement

If exposure to potential risk factors is not reliably measured it is impossible to quantify their effect.

A key study factor whose measurement was frequently problematic was breed of dog. Breed was assessed in various ways; some studies only classified purebred dogs by breed¹¹⁴ others used owner opinion of the predominant breed where a dog was of mixed breeding.¹⁰¹ Even experienced observers have been found to be unreliable at determining a dog's breed composition.³⁶⁸ Breed determination by the target of aggression, where the breed is not subsequently verified, is further problematic as a result of the effect of cognitive biases, for example those being bitten by an unknown dog may subconsciously misidentify the dog as of a breed that they perceive to be aggressive. Measurement of breed was especially problematic where the

breed of cases was identified by the target of aggression and the breed of controls by the owner.¹⁰⁵

A robust method of measuring outcome or exposure would be objective, validated, reproducible and unbiased, with cases and controls assessed in an identical manner.

5.3.4. Blinding

Whether a study is observational or interventional, blinding reduces the risk of introducing measurement or observer bias.

Bias is potentially introduced by prior knowledge of outcome by the person measuring exposure to a study factor, or conversely of exposure to a potential risk factor when measuring outcome. If for example an interviewer knows that a dog has been reported to have bitten they may interpret the owner's responses differentially to when they know the dog has not bitten, making measurement of exposure to risk factors unreliable.

5.4. Confounding

Confounding occurs where the true relationship between characteristics is distorted by a further factor. Without accounting for confounding false conclusions may be drawn.

Many studies failed to adequately account or control for confounding in both designing their study and analysing findings.^{102,122,248,251,252,264,267,268,274,276,282,287,301,314,315,317,333,337,353,360,367,389,391}

In part this resulted from the lack of a priori identification of potential

confounders. Without this, controlling for confounders is impossible. Other studies appeared to recognise the presence of confounding, but not its importance to their findings.^{263,270}

5.5. Analysis

Multivariable analysis is used to determine the effects of individual factors by controlling for the confounding effect of other measured factors within an analytical model,³⁸² and presenting findings for the effect of a variable after adjustment for confounders.¹⁹⁷ Many studies did not undertake multivariable analysis reporting only univariable findings.^{122,162,247,254,255,262,265,293,315-317,352,353}

Where a study found no effect within the study population as a whole and subsequently looked within a subset of that population or vice versa, without a priori expression of intention to do so, we can be less confident that the findings are not due to chance alone.^{341,342}

Chapter Six

General discussion

6. Discussion

Despite considerable conjecture in both lay and professional publications, there is no robust evidence for any risk factors of human-directed dog aggression. This systematic review has identified a limited number of studies that provide a moderate level of somewhat conflicting evidence. It is imperative that any future investigations of human-directed dog aggression are of sufficiently high methodological standard that evidence provided is able to inform development of preventive strategies and legislation.

6.1. Findings of the review

The most striking finding of this systematic review is that of the absence of any robust evidence for risk factors of human-directed dog aggression. Given the large number of factors investigated and the variety of factors often cited as altering risk, this is perhaps surprising. However the absence of any robust evidence is likely a reflection of the epidemiological dictum that absence of evidence for an effect does not provide evidence for lack of an effect, i.e. the findings of this review *do not* suggest that there are no factors that alter the risk of human-directed dog aggression, but simply that there is no robust evidence of the effect of these factors. To this end the findings of this work provide a baseline on which future research can build.

Where moderate evidence of an effect was identified this may facilitate the formation of hypotheses for future work with a higher methodological standard. Focus should perhaps turn to those factors most amenable to modification.

6.1.1. Neutering and risk

For some factors the moderate quality evidence identified was conflicting. When examining the effect of neutering and sex of the dog, for example, the conclusions from each of the three studies providing a moderate level of evidence differed.^{101,114,246} This discrepancy may in part reflect differences in the outcome examined; perhaps the effect of neutering on aggression towards non-household members is different to that on aggression towards household members.

The effect of neutering is an intricate issue to untangle, with many confounders and problems of recall bias of chronology when studied retrospectively. Adding to the complexity, as Reisner et al. demonstrated, a proportion of dogs are neutered because of pre-existent aggression,²⁴⁶ this has potential to create the impression that neutering increased risk where the causal relationship was (at least in part) in the opposite direction; pre-existent aggression making dogs more likely to be neutered. For these reasons prospective longitudinal studies of a large cohort of dogs would be required to elucidate whether, and in which direction, neutering alters the risk of a dog exhibiting human-directed dog aggression. As neutering is commonly recommended for welfare, behavioural and medical reasons it is important to establish its effect on behaviour.

6.1.2. Youngsters in the home

It is often cited that children are most at risk of being bitten; however no robust evidence was identified to support this. It is possible that children are no more likely to be bitten than adults, but that when they are bitten children

are more likely to be presented for medical attention as a result of complex psychosocial factors underlying decisions to seek medical care.

Two studies reaching the final review investigated the effect of the presence of a child or teenager in the home on the risk of a dog biting. Evidence was identified for an association between the presence of a child in the home and risk of a dog biting a non-household member and the presence of a teenager in the home and risk of a dog biting a household member or frequent visitor.

Whilst awareness and understanding of the risks posed by dogs is important for owners, parents and the child themselves, there are many developmental and social benefits in children having regular contact with dogs, and these risks and benefits need to be balanced.

Further quantifying the risk associated with a youngster and dog sharing a home is unlikely to provide additional benefit to the general population.

Education to ensure appropriate supervision and behaviour of children in the presence of dogs may be more efficacious, without removing the life enhancing benefits of the presence of dogs in a child's life. Studies evaluating the efficacy of educational programs on actual risk of being bitten are lacking, this may be an appropriate focus for future study.

6.1.3. Heritability of aggression

Amongst the conflicting evidence identified in this systematic review one factor stood out with homogeneous findings across three studies - the heritability of aggression. Whilst none of the three cross-sectional studies that performed pedigree analyses suggested that genetics could account for

all of the risk of aggression, there was agreement that a degree of the variation in risk of aggression, estimated at 10% by Saetre, Strandberg et al.^{324,325} could be accounted for by heritable factors. Further study in this area has the potential to yield benefits over future generations of dogs.

Dogs are bred in a range of settings from accidental mating through the hobby breeder to establishments breeding for show or working purposes. It would be unrealistic to expect that all of these settings could be influenced by an elucidation of the mechanism of inheritance of aggressive traits. However if those breeders who selectively choose sires and dams with knowledge of desired conformation and behaviour traits were able to exert selection pressure against an aggressive trait, it might be possible to reduce the prevalence of that trait in future litters.

6.1.4. Husbandry and risk

How a dog is managed by its owners is intertwined with cultural, socio-demographic and experiential factors, in addition to factors integral to the dog; rendering examination of any relationship between husbandry and behaviour complex. Limited and conflicting evidence for an effect of husbandry on the risk of aggression and biting was identified.

The complex web of factors that conspire to influence husbandry practices provides multiple potential opportunities for intervention and reduction of risk. High quality longitudinal study of the husbandry of dogs and their behaviour, allowing for measurement and control of confounders, may elucidate simple measures that owners could be encouraged to take in order to reduce the

risk of their dog biting, without impinging on the beneficial aspects of the owner-dog relationship.

Given the links between emotional stress, welfare and aggression it is possible that such measures may also improve the welfare of some dogs by reducing the stressors within their environment. This should be a key area for future research.

6.2. The systematic review

The systematic review is increasingly utilised as a tool for determining the current robust evidence base in both medical and social sciences, rightly recognised by epidemiologists as forming the pinnacle of quality evidence assimilation. However the systematic review is criticised by some authors as a theoretical exercise, often concluding that little evidence exists and lacking the ability to provide specific guidance on an effective intervention or preventive strategy.^{236,392}

The design of this systematic review addressed these concerns; the utilisation of a relatively low threshold of methodological quality for inclusion of evidence, in particular, should have averted criticism of accepting the cream whilst ignoring other important evidence. Despite this, on the four occasions that this work has been presented to date; two seminar events hosted by the research team, a behavioural conference³⁹³ and an anthrozoology conference,³⁹⁴ it was well received and considered of high methodological quality but there was considerable criticism that the appraisal process was excessively harsh.

In order to thoroughly examine the evidence base for risk factors of human-directed dog aggression, capturing evidence across the spectrum of circumstances, interactions, severity and targets, it was necessary to maintain a broad focus for this systematic review. This permitted studies of all potential risk factors, including any as yet unidentified by the study team, to be included in the review if they met the required methodological standard. This approach recognised that progression in severity of outcome may not represent a sequential progression in the degree of aggression exhibited by the dog, and thus factors altering risk of non-injurious aggression may not also alter risk of life threatening bite injuries.

In recognition of the diverse range of study designs and the abundance of observational studies undertaken in this field, a compromise was reached whereby any study design that utilised a comparator group was appraised with the potential of reaching the narrative systematic review. Typically a systematic review protocol would specify a limited range of study types to be considered, however the approach taken in this systematic review ensured all studies providing at least moderate quality evidence would be included whether observational or interventional in design.

Conversely it could be argued that this systematic review is not epidemiologically pure, the threshold of acceptance was relatively low, the research question remained broad and the findings contained considerable heterogeneity. However in identifying the current evidence base for a host of potential factors and priorities for future research, this was the most pragmatic approach. The alternative would have been to identify a limited

number of factors or interactions for a given aggression-related outcome and to have assimilated evidence for these factors only. As the method utilised permitted examination of all factors, interactions and outcomes; any research that would have been identified by the latter design would also have been identified by the design utilised.

Given this broad focus, low evidential threshold and the multiple methodological reasons for exclusion of the majority of the studies failing to reach this threshold; this review provides a pragmatic and practical assimilation of the current evidence base.

6.3. Minimisation of publication biases

In recognition of the potential for introducing publication bias to the findings of a systematic review, extensive attempts were made to identify unpublished work in this field. It is likely that unpublished work was not exhaustively identified; as is commonly the case when conducting a systematic review, gaining responses from authors proved challenging and much of the work identified in this manner was not suitable or available for inclusion, or had previously been identified via electronic searches.

Language and geographic biases were a concern in undertaking this review. Human-directed dog aggression is an issue of worldwide concern, as culture may influence man's relationship with the dog and husbandry practises it was particularly important to attempt to minimise any affect of language or location on likelihood of a study being identified.

Online translation software (<http://translate.google.com/#>) was utilised extensively in the initial screening and appraisal process, in addition where necessary native speakers were utilised to translate papers reaching the later stages of the review. These steps ensured that any article that was identified by electronic database searches had an equal likelihood of reaching the narrative review, regardless of its geographic origin or language. However as the search equation was in English, regardless of the diversity of search engines interrogated, there is likely to have been a degree of language bias introduced; only those articles with English keywords, abstract or title would have been likely to be identified by the electronic search strategy.

Despite these limitations, a large number of studies published in languages other than English were identified. Amongst the 14,967 articles retrieved by Scopus, the database for which language was most readily analysed, 16% of all studies were published in a language other than English, with at least 31 languages represented including many European languages, Afrikaans, Chinese, Korean, Russian and Ukrainian.

The most effective strategy to capture publications regardless of their language of publication may have been to translate the search equation into every published language; however this would have been impracticable and likely to introduce biases of its own. A trial of this approach with translation into Spanish and Korean did not yield any additional studies to those identified with the English search terms. Thus whilst acknowledging that it is likely that some publications may have not been identified as a result of their

language or journal of publication, reasonable efforts were made to minimise this and it seems unlikely, given the standard and nature of evidence identified, that additional studies would have significantly altered the findings of this systematic review.

6.4. Design priorities in future research

Having established that there is no robust evidence of risk factors for human-directed dog aggression, it is vital that any future work is undertaken to a high methodological standard.

Attention must be paid to study design, utilising an appropriate design for elucidation of risk factors where this is the aim of a study. Given the large numbers of potential confounders of the relationship between a putative risk factor and the outcome of aggression, well conducted longitudinal studies are likely to provide the most robust evidence with the ability to better determine the direction of causal relationships.

Study populations should be recruited at random with all members of a population having the same likelihood of being approached. Any control population must belong to the same population as the cases.

A priori development, examination and critique of putative causal webs should be undertaken, permitting identification, measurement and control of potential confounders.

Sample size and power calculations should be undertaken in order that populations of sufficient size can be recruited to reduce the risk of failing to identify an effect that is present (type II error).

Measurement of both outcomes and exposure to risk factors should be well defined, objective and standardised.

Analysis should permit identification of the effect of individual factors on risk. For observational studies this is likely to require multivariable analysis so that the effect of confounders can be controlled.

6.5. Conclusion

This systematic review aimed to identify the current robust evidence base for risk factors of human-directed dog aggression. The review identified no high quality evidence and very limited evidence of moderate quality. It is vital that future research in this area is of a high methodological standard in order that it is able to add to the currently sparse evidence base.

Appendix

Table 15: Studies reaching formal appraisal and reasons for their exclusion. See p80,Section 4.1.3.

Title	Main reasons for exclusion
A behaviour test on German Shepherd dogs: Heritability of seven different traits ³²⁶	Measurement, selection
A comparison of dog bite injuries in younger and older children treated in a pediatric emergency department ²⁹³	Design, analysis, selection
A comparison of the behavioral profiles of purebred dogs in Japan to profiles of those in the United States and the United Kingdom ³⁰⁵	Measurement
A comprehensive study of dog bites in Spain, 1995-2004 ¹⁶⁰	Comparator group
A cross-cultural comparison of reports by German Shepherd owners in Hungary and the United States of America ³⁹¹	Measurement, selection, control of confounding
A cross-sectional study on injuries in residents at the community level of Zhejiang ³⁹⁵	Design - prevalence study
A friend or an enemy? Dogs' reaction to an unfamiliar person showing behavioural cues of threat and friendliness at different times ²⁷⁵	Design , measurement
A note on canine aggression towards veterinarians ³⁰⁸	Measurement, analysis
Hundebid. En retrospektiv opgørelse ³⁹⁶	Excluded following translation
A study of dog bites on the Navajo reservation ²⁵⁸	Design
A survey of behavioural characteristics of pure-bred dogs in Italy ²⁹⁹	Measurement
A Survey of Dog Bites in Brisbane, Australia. ³⁰⁰	Selection, analysis
A survey of dog ownership in suburban Australia - Conditions and behaviour problems ³³⁹	Design, measurement
A survey of the behavioural characteristics of pure-bred dogs in the United Kingdom ²⁹⁵	Measurement
Agressief gedrag bij Golden Retrievers: Onderzoek naar de omvang van het probleem ³⁹⁷	Design
Aggressive behavior in the English cocker spaniel ²⁵⁵	Selection, analysis, outcome definition
Aggressive behaviour in English cocker spaniels and the personality of their owners ³³⁵	Selection, analysis
An approach to canine behavioural genetics employing guide dogs for the blind ³¹⁹	Measurement
An epidemiologic study of dog bites among postmen in central Taiwan. ³⁵⁴	Included in final review
An epidemiological investigation into the reported incidents of dog biting in the City of Guelph. ³⁰⁴	Comparator group
An investigation into the prevalence of dog bites to primary school children in Trinidad ³¹⁵	Analysis, control of confounding

Title	Main reasons for exclusion
Analyse du comportement des chiens et des chats pendant l'examen physique en cabinet vétérinaire ²⁶²	Analysis, control of confounding, selection
Analysis of dog bites in children who are younger than 17 years ¹⁶¹	Selection, design, comparator group,
Animal bites as an occupational hazard among animal control officers ³⁹⁸	Design, analysis
Arbeitsgerelateerde gezondheidsaandoeningen bij praktiserende dierenartsen in Vlaanderen ³⁹⁹	Design
Assessing efficiency of a Human Familiarisation and Training Programme on fearfulness and aggressiveness of military dogs ³⁴⁸	Selection
Assessing undesired aggression in military working dogs ⁴⁰⁰	Design
Assessment of Canine Temperament in Relation to Breed Groups ³⁰⁷	Selection, measurement, analysis
Association analysis between canine behavioural traits and genetic polymorphisms in the Shiba Inu breed ³²⁰	Selection
Association of dopamine-and serotonin-related genes with canine aggression ³²¹	Selection
Association of pruritus with anxiety or aggression in dogs ³¹⁷	Analysis, control of confounding
Auffällig gewordene hunde in Berlin im vergleich zur hundepopulation - Wege zur reduzierung der gefährlichkeit von hunden ³¹¹	Outcome definition, analysis
Barking mad? Another lunatic hypothesis bites the dust ³⁶¹	Design
Behavior genetics of canine aggression: Behavioral phenotyping of golden retrievers by means of an aggression test ³²⁸	Evaluation of an aggression test, not a study of risk factors
Behavior of dogs entering a veterinary clinic ²⁷⁴	Analysis, control of confounding
Behavioral changes associated with suspected complex partial seizures in Bull Terriers ³¹⁸	Selection, design
Behavioral characteristics of English Cocker Spaniels with owner-defined aggressive behavior ⁴⁰¹	Selection, design
Behavioral evaluation and demographic information in the assessment of aggressiveness in shelter dogs ¹⁴⁸	Design - evaluation of behaviour test not risk factors study
Behavioral profiles of dog breeds ²⁹⁷	Measurement
Behavioral reactivity of jindo dogs socialized at an early age compared with non-socialized dogs ³⁴⁹	Analysis
Behavioral-Effects of Ovariohysterectomy on Bitches. ²⁴⁵	Control of confounding
Behaviour of smaller and larger dogs: Effects of training methods, inconsistency of owner behaviour and level of engagement in activities with the dog ³¹³	Design

Title	Main reasons for exclusion
Behavioural changes and aversive conditioning in hunting dogs by the second-year confrontation with domestic sheep ²⁹⁰	Design, selection,
Behavioural differences of dogs of various ages in Czech households ²⁹¹	Selection
Behavioural modifications of bitches during diestrus and anestrus ³⁸⁴	Selection, measurement, causal sequence, control of confounding
Behavioural reactivity of the Korean native Jindo dog varies with coat colour ²⁶⁶	Selection, analysis
Behavioural traits of four dog breeds in Czech households ³¹²	Selection
Body size and behaviour traits of dogs in Czech households ³¹⁴	Selection, control of confounding
Breed and sex differences in the behavioural attributes of specialist search dogs - A questionnaire survey of trainers and handlers ²⁷³	Selection
Breed differences in canine aggression ²⁶⁰	Selection, control of confounding
Breed-typical behaviour in dogs - Historical remnants or recent constructs? ³⁰³	Control of confounding
Canine aggression: A survey in northern Italy ²⁷⁸	Comparator group, analysis
Canine and human factors related to dog bite injuries ¹⁰²	Control of confounding
Castration of adult male dogs: effects on roaming, aggression, urine marking, and mounting ²⁸⁵	Design, outcome definition
Characteristics of 234 dog bite incidents in Ireland during 2004 and 2005 ⁴⁰²	Design, comparator group
Chronic stress in dogs subjected to social and spatial and restriction: I. Behavioural responses ³⁴⁰	Outcome,
Companion dog temperament traits ²⁶⁴	Selection, design, control of confounding
Demographic and aggressive characteristics of dogs in a general veterinary caseload ²⁶⁵	Analysis, preliminary study identifying areas needing further investigation.
Determination of behavioural traits of pure-bred dogs using factor analysis and cluster analysis; a comparison of studies in the USA and UK ²⁹⁴	Measurement
Direct genetic, maternal and litter effects on behaviour in German shepherd dogs in Sweden ³²⁵	Included in final review
Disease and injury among veterinarians ³⁵⁹	
Dobermannhaltung in Deutschland: Ergebnisse einer befragung. Teil 2: Verhalten der hunde ²⁵⁴	Selection, analysis

Title	Main reasons for exclusion
Does the dangerous dogs act protect against animal attacks: A prospective study of mammalian bites in the accident and emergency department ³⁶²	Selection, analysis, control of confounding
Dog bite and injury prevention--analysis, critical review, and research agenda ²⁷⁹	Analysis
Dog bites among letter carriers in St. Louis ³⁵²	Analysis
Dog bites in The Netherlands: A study of victims, injuries, circumstances and aggressors to support evaluation of breed specific legislation ¹⁰⁵	Analysis, selection, measurement
Dog bites: how big a problem? ³⁵³	Control of confounding, analysis, designed as prevalence study
Dog bites: Still a problem? ¹²²	Design, analysis -control of confounding
Dog training methods: their use, effectiveness and interaction with behaviour and welfare. ³¹⁶	Selection, analysis
Dogs: A continuing and common neighborhood nuisance of New Providence, the Bahamas ⁴⁰³	Outcome nuisance not aggression
Effect of behavioral testing on the prevalence of fear and aggression in the Dutch Rottweiler population ³³⁰	Selection
Effect of dietary protein content and tryptophan supplementation on dominance aggression, territorial aggression, and hyperactivity in dogs ³⁴²	Included in final review
Effect of dietary protein content on behavior in dogs ³⁴¹	Included in final review
Effects of castration on problem behaviors in male dogs with reference to age and duration of behavior ²⁸⁴	Comparator group, measurement,
Effects of ovariectomy on reactivity in German Shepherd dogs ²⁸³	Outcome definition, analysis, measurement
Environmental influences on the expression of aggressive behaviour in English Cocker Spaniels ²⁴⁸	Analysis, control of confounding
Epidemiologic surveys of dog and cat bites in the Lyon area, France ¹⁶²	Design, analysis
Epidemiology of animal bites among American military personnel in central Germany ⁴⁰⁴	Design, measurement
Epidemiology of dog bites: A Belgian experience of canine behaviour and public health concerns ¹³⁵	Review
Epidemiology of dog bites: A community-based study in India ³³¹	Analysis
Ethiopian village dogs: Behavioural responses to a stranger's approach ²⁵³	Selection, design, analysis
Evaluating the temperament in shelter dogs ⁴⁰⁵	Design
Evaluation and prediction of agonistic behaviour in the domestic dog ³⁰⁹	Selection, measurement

Title	Main reasons for exclusion
Evaluation of risk factors for bite wounds inflicted on caregivers by dogs and cats in a veterinary teaching hospital ²⁴⁹	Analysis, external validity
Evaluation of the serotonergic genes htr1A, htr1B, htr2A, and slc6A4 in aggressive behavior of Golden Retriever dogs ³²²	Selection, measurement, analysis
Evaluation of young and adult dogs' reactivity ²⁹²	Design, outcome
Evidence for an association between pet behavior and owner attachment levels ³³⁶	Design, selection, measurement, confounding.
Factors affecting human-directed dog aggression ²⁸⁰	Analysis
Factors associated with aggressive responses in pet dogs ³⁹⁰	Selection
Factors linked to dominance aggression in dogs ²⁵¹	Selection, measurement, analysis, control of confounding
Factors linked to territorial aggression in dogs ²⁵²	Selection, measurement, analysis, control of confounding
Fälle von Hundeangriffen in Deutschland, eine Internetbefragung ³¹⁰	Selection
Genetic variation in aggression-related traits in Golden Retriever dogs ³²³	Selection
Genetics of traits which determine the suitability of dogs as guide-dogs for the blind ²⁶³	Selection, analysis, measurement
Health and behavior problems in dogs and cats one week and one month after adoption from animal shelters ⁴⁰⁶	Design
Heritability of dominant-aggressive behaviour in English Cocker Spaniels ²⁷²	Measurement
Hundebid. En prospektiv undersagelse. ⁴⁰⁷	Excluded following translation
Influence of orchietomy on canine behaviour ²⁸⁶	Comparator group
Influence of owner personality type on expression and treatment outcome of dominance aggression in dogs ³³⁴	Design, selection, control of confounding,
Injury in Australian veterinarians ³⁵⁶	Selection, analysis
Investigations on population genetics of temperament and performance characteristics in working dogs ³²⁹	Selection
Is breed-specific legislation justified? Study of the results of the temperament test of Lower Saxony ¹⁸⁴	Selection, analysis

Title	Main reasons for exclusion
Is there a correlation between puppy socialisation classes and owner-perceived frequency of behaviour problems in dogs? ³⁵⁰	Analysis, control of confounding
Is there a difference? Comparison of golden retrievers and dogs affected by breed-specific legislation regarding aggressive behavior ²⁷¹	Selection, measurement, analysis
Is there a relationship between canine behavior problems and spoiling activities, anthropomorphism, and obedience training? ³³⁷	Selection, measurement, control of confounding
Links between play and dominance and attachment dimensions of dog-human relationships ²⁴⁷	Design, selection, analysis, control of confounding
Long-term outcome of gonadectomy performed at an early age or traditional age in dogs. ²⁸⁷	Control of confounding, measurement, design
Long-term risks and benefits of pediatric neutering in dogs and cats ²⁸⁸	Confounding
Male and female dogs respond differently to men and women ²⁸¹	Measurement
Medical and behavioral surveillance of dogs deployed to the World Trade Center and the Pentagon from October 2001 to June 2002 ³⁴⁷	Selection, external validity
Morbidity and mortality in 928 Dobermans born in the Netherlands between 1993 and 1999 ⁴⁰⁸	Design
National survey of owner-directed aggression in English Springer Spaniels ²⁴⁶	Included in final review
Occupational health risks in veterinary nursing: An exploratory study ⁴⁰⁹	Selection, analysis, design
Opinions of veterinarians regarding aggression in different breeds of dogs ³⁰²	Measurement
Owner characteristics and interactions and the prevalence of canine behaviour problems ³³³	Measurement, analysis, control of confounding
Owner-companion dog interactions: Relationships between demographic variables, potentially problematic behaviours, training engagement and shared activities ²⁵⁶	Selection
Phenotyping of aggressive behavior in golden retriever dogs with a questionnaire. ⁴¹⁰	Design
Playing styles and possible causative factors in dogs' behaviour when playing with humans ³⁴⁴	Measurement, analysis
Preliminary study on owner-reported behaviour changes associated with chronic pain in dogs	Design, lack of comparator group
Prevalence of aggression and fear-related behavioral problems in a sample of Argentine Dogs in Italy ²⁵⁹	Selection, analysis
Prevalence of behavioural problems in American dogs ⁴¹¹	Design

Title	Main reasons for exclusion
Prevalence of behaviour problems reported by owners of dogs purchased from an animal rescue shelter ²⁷⁷	Comparator group, measurement, analysis
Prevalence of dog bites in children: A telephone survey ⁴¹²	Design
Problemas de agresividad canina. Estudio preliminar en las ciudades de Corrientes y Resistencia ²⁶⁷	Selection, analysis, confounding
Profile of animal bite cases in Pune ⁴¹³	Design, analysis, comparator group
Relationship between aggressive and avoidance behaviour by dogs and their experience in the first six months of life ²⁸⁹	Selection, analysis, outcome definition
Relationship between management factors and dog behavior in a sample of Argentine Dogos in Italy ³³²	Selection, measurement, analysis
Reported behaviour problems in pet dogs in Denmark: Age distribution and influence of breed and gender ²⁶⁹	Selection, outcome definition
Risk factors for dog bites to owners in a general veterinary caseload ¹¹⁴	Included in final review
Risk factors for injury among veterinarians ³⁵⁸	Measurement
Risk factors for separation-related distress and feed-related aggression in dogs: Additional findings from a survey of Australian dog owners ²⁵⁰	Selection, analysis
Selecting pet dogs on the basis of cluster analysis of breed behavior profiles and gender. ²⁹⁶	Measurement
Short report: Health risks in travellers to China: The GeoSentinel experience and implications for the 2008 Beijing olympics ³⁵⁵	Design, comparator group
Significant injuries in Australian veterinarians and use of safety precautions ⁴¹⁴	Design
Spanish dangerous animals act: Effect on the epidemiology of dog bites ³⁰¹	Analysis, control of confounding
Survey of the use and outcome of confrontational and non-confrontational training methods in client-owned dogs showing undesired behaviors ³⁴⁵	Selection, comparator group,
Survey of undesirable behaviors displayed by potential guide dogs with puppy walkers ⁴¹⁵	Analysis, design
The behaviour of Labrador retrievers in suburban backyards: The relationships between the backyard environment and dog behaviour ³³⁹	Design, analysis.
The effect of feeding enrichment upon reported working ability and behavior of kennelled working dogs ³⁸⁹	Selection, control of confounding, outcome definition

Title	Main reasons for exclusion
The English Cocker Spaniel: preliminary findings on aggressive behaviour ³⁶⁷	Measurement, analysis, control of confounding
The epidemiology of behavioural problems in dogs and cats: A survey of veterinary practitioners ⁴¹⁶	Design, outcome definition
The etiology and consequences of injuries to veterinary technicians ³⁵⁷	Measurement, analysis
The experience of dog bites: A survey of veterinary science and veterinary nursing students ²⁷⁶	Analysis, control of confounding
The genetic contribution to canine personality ³²⁴	Included in final review
The Greyhound Adoption Program (GAP) in Australia and New Zealand: A survey of owners' experiences with their greyhounds one month after adoption ⁴¹⁷	Design
The human-canine environment: A risk factor for non-play bites? ²⁷⁰	Selection, measurement,
The influence of urbanization on the behaviour of dogs in the Czech Republic ³⁶⁰	Selection, analysis, measurement
The natural history of exercise: A 10-yr follow-up of a cohort of runners ⁴¹⁸	Design
The perception of problematic behavior in dogs: Application of multi-dimensional scaling and hierarchical cluster analysis	Design
The prevention of undesirable behaviors in dogs: effectiveness of veterinary behaviorists' advice given to puppy owners ²⁶¹	Selection
The public health impact of dog attacks in a major Australian city ³⁰⁶	Analysis, comparator population
The quality of the relation between handler and military dogs influences efficiency and welfare of dogs ²⁶⁸	Measurement, control of confounding
The relationship between training methods and the occurrence of behavior problems, as reported by owners, in a population of domestic dogs ²⁵⁷	Selection, control of confounding
The use of a behaviour test for selection of dogs for service and breeding. II. Heritability for tested parameters and effect of selection based on service dog characteristics ³²⁷	Design, outcome
Three different coping styles in police dogs exposed to a short-term challenge ⁴¹⁹	Design
To bite or not to bite: Canine apprehensions in a large, suburban police department ⁴²⁰	Design
Training dogs with help of the shock collar: Short and long term behavioural effects ³⁴⁶	Design - outcomes primarily stress related not aggression
Training engagement and the development of behavior problems in the dog: A longitudinal study ³⁴³	Selection, analysis
Trauma and the veterinarian ⁴²¹	Design, analysis

Title	Main reasons for exclusion
Unreported dog bites in children ¹⁰⁴	Analysis
Untersuchung einer Bullterrier-Zuchtlinie hinsichtlich ihres Verhaltens im Nds. Wesenstest -Vergleich mit sechs von der Gesetzgebung betroffenen Hunderassen und einer Kontrollgruppe von Golden Retrievern ¹⁸³	Selection, measurement, analysis. Identified as duplicate on full appraisal following translation
Verhaltensänderungen von Hunden nach Kastration ²⁸²	Selection, measurement, analysis, control of confounding
Which dogs bite? A case-control study of risk factors ¹⁰¹	Included in final review
Zusammenhänge zwischen Hundeverhalten und unterschiedlicher Einschränkung des Hundes durch die Leine ³⁵¹	Control of confounding

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