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ORIGINAL ARTICLE

The epidemiology of tick infestation in dog breeds in the UK

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Objectives: The purpose of this study is to report the prevalence and risk factors for tick infestation in dogs in the UK based on anonymised electronic patient records.

Materials and Methods: Clinical records of dogs under veterinary care in 2016 at clinics participating in the VetCompass Programme were followed over a 5-year period to identify cases of tick infestation. Risk factor analysis used multivariable logistic regression modelling.

Results: The study included 905,553 dogs. From a random sample, 1903 tick infestation cases were identified. The estimated 5-year (2014 to 2018) period prevalence was 2.03% (95% confidence interval: 2.00 to 2.06). Sixteen breeds showed increased odds compared with non-designer-crossbreed dogs. Breeds with the highest odds included Cairn terrier (odds ratio 2.86, 95% confidence interval 1.64 to 4.98), standard poodle (odds ratio 2.80, 95% confidence interval 1.25 to 6.29) and Goldendoodle (odds ratio 2.63, 95% confidence interval 1.17 to 5.91). Six breeds showed reduced odds, with lowest odds shown by Staffordshire bull terrier (odds ratio 0.35, 95% confidence interval 0.25 to 0.50), Rottweiler (odds ratio 0.35, 95% confidence interval 0.15 to 0.85) and Chihuahua (odds ratio 0.38, 95% confidence interval 0.26 to 0.55). Males had 1.24 (95% confidence interval 1.13 to 1.36) times the odds of females. Compared with non-designer-crossbred dogs, designer-crossbreed dogs had increased odds (odds ratio 1.81, 95% confidence interval 1.52 to 2.15). Compared with breeds with short coats, breeds with medium length coats (odds ratio 2.20, 95% confidence interval 1.96 to 2.48) showed increased odds. Breeds with V-shaped drop and pendulous ear carriage had higher odds compared with breeds with erect ear carriage.

Clinical Significance: These findings provide an evidence base for veterinary professionals to raise awareness of tick infestation as a preventable disorder in dogs in the UK and to support more effective prevention and therapeutic protocols based on targeted approaches.

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INTRODUCTION

Ticks are common external parasites that can vector several infectious diseases between animal hosts and humans (Colwell et al., 2011). Ticks require living animal hosts for blood meals, and the decreasing boundaries over time between humans, animals and ticks increases the likelihood of these infestation opportunities. Major drivers influencing increased host-tick interactions include urbanisation, climate change, human behaviour, global movement and the increased human-wildlife-pet interface (Baneth, 2014; Colwell et al., 2011). The movement of tick hosts promoted by factors such as increased national and international movement of animals, bird migration and pet importation is leading to an expansion of the geographic distribution where ticks now exist (Baneth, 2014; de la Fuente et al., 2023). Moreover, ticks show signs of adapting their questing behaviour in response to the climate, suggesting a potential ability to adapt to climate change (Leicester et al., 2023). Professional caretakers of hunting dogs in the UK have reported finding 5.8 times more embedded ticks on their body than environmental-only control individuals (Toepp et al., 2018), exemplifying increasing risks from tick exposure at the human-dog interface.

In the UK, general practice veterinarians can now expect regularly to encounter dogs that have travelled from outside the UK (Buckley, 2020). Increasing international pet travel has promoted importation of non-native tick species such as *Rhipicephalus sanguineus* to the UK (Hansford et al., 2018). Babesiosis, a non-endemic disease in the UK caused by *Babesia* species and vectored by ticks, was detected in dogs imported into the UK from France, Spain and Japan more than two decades ago (Shaw et al., 2003). More recently, UK cases of canine babesiosis and ehrlichiosis in dogs with no travel history outside the UK have been identified (de Marco et al., 2017; Silvestrini et al., 2023). Although targeted treatment for these vector-borne diseases achieved clinical remission in 84% of these cases in 2023 (Silvestrini et al., 2023), identifying tick type, prevalence and risk factors for infestation are important.

Large-scale tick surveillance programmes have reported *Ixodes ricinus* as the most common tick species (>89%) identified on dogs seen in UK veterinary practices in 2015 (Abdullah et al., 2016; Cull et al., 2020). *Ixodes ricinus* is capable of transmitting over 20 pathogenic parasites, including *Babesia* sp. (babesiosis) and *Borrelia burgdorferi* (Lyme disease) (Sprong et al., 2018). As climate warming continues, the UK environment is becoming increasingly favourable for *I. ricinus*, extending the annual period during which animal hosts are vulnerable to tick attachment (Gilbert et al., 2014). Though several challenges for the prevention of tick-borne disease transmission exist, a better understanding of tick prevalence and distribution, as well as risk factors for infestations, can contribute to more effective mitigation strategies to decrease pathogen transmission for at-risk dogs and humans (Johnson et al., 2022).

Despite the high human and canine health risks from tick infestation, limited studies have explored the frequency and risk factors for tick infestation in dogs in the UK. In a study of tick infestation in dogs recruited from veterinary practices in the UK during April-July 2015, overall tick attachment prevalence was reported at 30%, and >76% (43/53) of dogs travelling outside the UK were reported as infested by one of three species of ticks (Abdullah et al., 2016). Higher odds ratios of tick infestation were reported in dogs aged over 1 year, in intact dogs, and in Kennel Club Pastoral and Gundog breed groups, suggesting specific canine signalments were important risk factors of tick infestation (Abdullah et al., 2016). In a random sample of UK dogs in 2009, the risk of canine tick infestation was reportedly higher in the Gundog, Terrier and Pastoral groups than dogs in the Hound, Toy, Utility and Working groups (Smith et al., 2011). However, an analysis of electronic medical records relating to over 8 million dogs in the USA reported a much lower prevalence of just 52 cases of tick infestation per 10,000 dog consultations, with peak tick prevalence peak in May-July months (Raghavan, 2008). Using multiple regression modelling methods, that study identified younger dogs, male dogs, and intact dogs with increased risk of tick infestation; toy breeds were least likely to be infested, and no linear correlation was identified between tick infestation and dog bodyweight (Raghavan et al., 2007). A tick collection study in Greece over a 1-year period (1996 to 1997) from 249 dogs admitted to veterinary hospitals recorded 1711 total ticks and attachment locations in 239 dogs (Papazahariadou et al., 2003). The ear pinnae, followed by the neck, interdigital skin folds, trunk, head, ventrum and extremities, were the most common body locations for tick attachment on dogs (Papazahariadou et al., 2003). The study did not explore whether ear carriage (*e.g.* erect, semi-erect, V-shaped drop, pendulous) was a risk factor for tick attachment. Regarding hair length, a UK study that included 179 rural and urban veterinary practices reported medium-haired dogs were 2.1 times more likely to carry ticks than short-haired dogs; no significant difference was identified between short-haired and long-haired dogs (Smith et al., 2011). Conversely, short-haired dogs were reported at higher risk of tick infestation than long-haired dogs in tick-infestation studies on privately owned dogs in Italy and Brazil (Maurelli et al., 2018; Silveira et al., 2009). Overall, the evidence on canine signalment or demographic risk factors for tick infestation is very mixed, leaving high uncertainty for owners living in tick endemic areas about risk factors and consequent optimal tick monitoring and mitigation strategies to reduce tick infestation risk.

Successful control of tick infestation and tick-borne diseases depends on access to accurate prevalence and risk factor information (Díaz-Sánchez et al., 2023). Anonymised electronic patient record data from UK primary-care veterinary practices offers access to big data for analysis and can avoid issues related to inherent biases in questionnaire study designs (O'Neill et al., 2014). Exploration of veterinary electronic health records (EHR) shared by primary-care veterinary practices has previously been reported as a useful data resource for epidemiological studies of tick infestation in dogs (Tulloch et al., 2017). Given currently limited published information on tick infestation in the UK dog population, the current study aimed to explore the VetCompass database of primary-care EHRs to report the prevalence and risk factors for tick infestation in dogs under primary veterinary care in the UK (VetCompass, 2023). Special focus was placed on phenotypic (ear carriage, haircoat, skull shape, adult bodyweight, bodyweight relative to breed-sex mean, spaniel-type and poodle-type) and demographic criteria (breed, breed purity, Kennel Club-recognised breed, Kennel Club breed group, age, sex, neuter and insurance) as risk factors. Based on some prior work (Maurelli et al., 2018, Silveira et al., 2009), the current study hypothesised that short-haired dogs have 0.75 times the odds of tick infestation compared with either medium-haired or long-haired dogs. These results could fill current data gaps and provide owners, breeders and veterinarians with a stronger evidence-base to better understand why certain types of dogs are more likely to become tick infested. The findings could also support improved public awareness, enable earlier detection and removal of ticks from dogs, and reduce vector-borne transmission disease in dogs.

METHODS

The study population included dogs under primary veterinary care at clinics participating in the VetCompass Programme during 2016. Dogs under veterinary care were defined as those with either (2) ≥1 electronic patient record (EHR) (free-text clinical note, treatment or bodyweight) recorded during 2016 or (2) ≥1 EHR recorded during both 2015 and 2017. VetCompass collates de-identified EHR data from primary-care veterinary practices in the UK for epidemiological research (VetCompass, 2023). Data fields available to VetCompass researchers include a unique animal identifier along with species, breed, date of birth, sex, neuter status, insurance and bodyweight, and also clinical information from free-form text clinical notes, and treatment with relevant dates.

A cohort study design was used to estimate period prevalence values for tick infestation and to explore risk factors. Assuming a study population that included twice as many short-haired dogs as either medium-haired or long-haired dogs and assuming a tick infestation prevalence of 0.68% in the medium-haired or long-haired dogs, power calculations estimated that at least 49,539 short-haired dogs and 24,770 medium-haired or long-haired dogs were needed to identify an odds ratio of 0.75 or less short-haired dogs compared to either medium-haired or long-haired dogs, with power of 80% and a false positive rate of 0.05 (Dean et al., 2022; O'Neill, James, et al., 2021a). Ethics approval was obtained from the VetCompass Ethics and Welfare Committee (reference SR2018-1652).

A tick infestation case required recorded evidence in the EHR that a veterinary professional or the owner/caregiver of the dog had seen at least one tick attached anywhere on the dog's body during the relevant date range. Dogs were excluded as cases if the clinical records showed veterinary opinion that the owner/caregiver had mistakenly identified a tick. Results were reported for three date ranges centred on 2016: a broad 5-year date range (January 1, 2014 to December 31, 2018), a 3-year date range (January 1, 2015 to December 31, 2017) and a 1-year period (January 1, 2016 to December 31, 2016). Case-finding involved initial screening of all 905,554 study dogs for candidate tick infestation cases by searching the clinical notes and treatment data fields from January 1, 2014 to December 31, 2018 using the search terms: live tick*, ixode*, rhipic*, found tick*, dermace*, tick granul*, tick*bite*, tick*borne*, tick*found*, tcik*found*, O'tom, otom, tick*hook*, tick*remov* and tick*screen*. The clinical notes of a randomly selected subset of candidate animals were manually reviewed to evaluate for case inclusion. Additional information was extracted for each confirmed tick infestation case to describe the count of tick infestation events for each dog and the date of the tick infestation event.

Breed descriptive information entered by the participating practices was cleaned and mapped to a VetCompass breed list derived and extended from the VeNom Coding breed list that included both recognised purebred breeds and also designer crossbreed terms (The VeNom Coding Group, 2023). A *breed purity* variable categorised dogs from breeds recognised by various kennel clubs as "purebred," dogs with contrived names generated from two or more purebred breed terms as designer-crossbreed (purposely bred crossbreeds) and dogs recorded as mixes of breeds but without a contrived name as non-designer-crossbreed (Burnett et al., 2022; The Kennel Club, 2023). A *breed* variable included individual pure breeds and designer-crossbreed hybrids represented by ≥5000 dogs in the overall study population or with ≥5 tick infestation 5-year cases, along with groupings of all remaining breeds and also general non-designer-crossbred dogs. This approach was taken to facilitate statistical power for the individual breed analyses (Scott et al., 2012). Breeds were characterised by ear carriage based on pinnal phenotypes typically described for each breed (American Kennel Club, 2023; Coren, 2012; The Kennel Club, 2023). The categories of ear carriage included erect (also known as prick or upright, *e.g.* German Shepherd Dog), semi-erect (also known as cocked or semi-pricked, *e.g.* Rough Collie), V-shaped drop (also known as folded, *e.g.* Hungarian Vizsla), pendulous (also known as drop or pendant, *e.g.* Basset Hound) and unspecified (O'Neill, Lee, et al., 2021b). Breeds were also characterised by haircoat (short, medium, long, uncategorised), skull shape (dolichocephalic, mesocephalic, brachycephalic, uncategorised), spaniel (spaniel, non-spaniel, uncategorised) and poodle (poodle, non-poodle, uncategorised) status for analysis. Ear carriage and haircoat were not assigned for designer-crossbreed and non-designer-crossbreed dogs. A *Kennel Club breed group* variable classified breeds recognised by the UK Kennel Club into their relevant breed groups (Gundog, Hound, Pastoral, Terrier, Toy, Utility and Working) and all remaining types were classified as non-Kennel Club recognised (The Kennel Club, 2023).

Neuter and insurance status were defined by the final available EHR value. Adult bodyweight was defined as the mean of all bodyweight (kg) values recorded for each dog after reaching 18 months old and was categorised as: <10.0, 10.0 to <15.0, 15.0 to <20.0, 20.0 to <25.0, 25.0 to <30.0, 30.0 to <40.0 and ≥40.0. Mean adult bodyweight was generated for all breed/sex combinations with adult bodyweight available for at least 100 dogs in the overall study population and used to categorise individual dogs as "at or above the breed/sex mean," "below the breed/sex mean" and "unspecified." Age (years) was defined based on the first date for diagnosis of tick infestation in the available clinical records for cases and on December 31, 2016 (the final date in 2016 that these dogs were not a case) for non-cases. Age (years) was categorised as: ≤1.0, 1.0 to <2.0, 2.0 to <4.0, 4.0 to <6.0, 6.0 to <8.0, 8.0 to <10.0, 10.0 to <12.0 and ≥12.0.

Following internal validity checking and data cleaning in Excel (Microsoft Office Excel 2013, Microsoft Corp.), analyses were conducted using Stata Version 16 (Stata Corporation). Period prevalence with 95% confidence intervals (CI) described the probability of tick infestation at any point during the specified periods (5 years 2014 to 2018, 3 years 2015 to 2017, 1 year 2016). Because the sampling design involved verification of a subset of candidate cases, the predicted total case count was calculated using the Stata *survey* function. The CI estimates were derived from standard errors, based on approximation to the binomial distribution (Kirkwood & Sterne, 2003). Risk factor analysis used binary logistic regression modelling to evaluate univariable associations between risk factors (*breed*, *ear carriage*, *haircoat*, *skull shape*, *spaniel*, *poodle*, *breed purity*, *Kennel Club recognised breed*, *Kennel Club breed group*, *adult bodyweight*, *bodyweight relative to breed-sex mean*, *age*, *sex*, *neuter* and *insurance*) and tick infestation. Because breed was a factor of primary interest for the study, variables that were derived from the breed information and therefore correlate highly with breed (*ear carriage*, *haircoat*, *skull shape*, *spaniel*, *poodle*, *breed purity*, *Kennel Club-recognised breed* and *Kennel Club breed group*) were excluded from initial breed multivariable modelling. Instead, each of these variables individually replaced the *breed* variable in the main breed-focused model to evaluate their effects after taking account of the other variables. *Adult bodyweight* (a defining characteristic of individual breeds) replaced breed and *bodyweight relative to breed/sex mean* in the final breed-focused model. Risk factors with liberal associations in univariable modelling (P<0.2) were taken forward for multivariable evaluation. Model development used manual backwards stepwise elimination. Pair-wise interaction effects were evaluated for the final model variables (Dohoo et al., 2009). The area under the receiver operating characteristic (ROC) curve and the Hosmer-Lemeshow test were used to evaluate the quality of the model fit and discrimination in the final breed multivariable model (Dohoo et al., 2009; Hosmer et al., 2013). Statistical significance was set at P<0.05.

RESULTS

Prevalence

Text searches of an overall study population of 905,553 dogs under veterinary care in 2016 at 887 veterinary clinics yielded 63,025 (6.96%) candidate tick infestation cases. Manual checking of a random subset of 6512 (10.33%) candidate cases identified 1903 tick infestation cases across 5 years from 2014 to 2018, with subsets of 1375 cases across 3 years from 2015 to 2017 and 623 cases across a single year (2016) (Fig 1). After accounting for the subsampling protocol, the estimated 5-year (2014 to 2018) period prevalence for tick infestation in dogs overall was 2.03% (95% CI: 2.00 to 2.06), the estimated 3-year (2015 to 2017) period prevalence for tick infestation in dogs overall was 1.47% (95% CI: 1.44 to 1.50) and the estimated 1-year (2016) period prevalence for tick infestation in dogs overall was 0.67% (95% CI: 0.65 to 0.68). The remainder of this paper will report on the prevalence and risk factors relating to the 5-year risk of tick infestation. Across the 1903 events over the 5-year period, monthly proportional tick infestation peaked in June (n=421, 22.12%) (Fig 2).

Breeds with the highest 5-year prevalence of tick infestation were Cavapoo (5.19%, 95% CI 3.28 to 7.75), Goldendoodle (5.14%, 95% CI 1.90 to 10.83), standard poodle (5.14%, 95% CI 1.90 to 10.83), Cairn terrier (5.09%, 2.74 to 8.56), Cockapoo (4.79%, 3.87 to 5.84), Miniature schnauzer (4.38%,

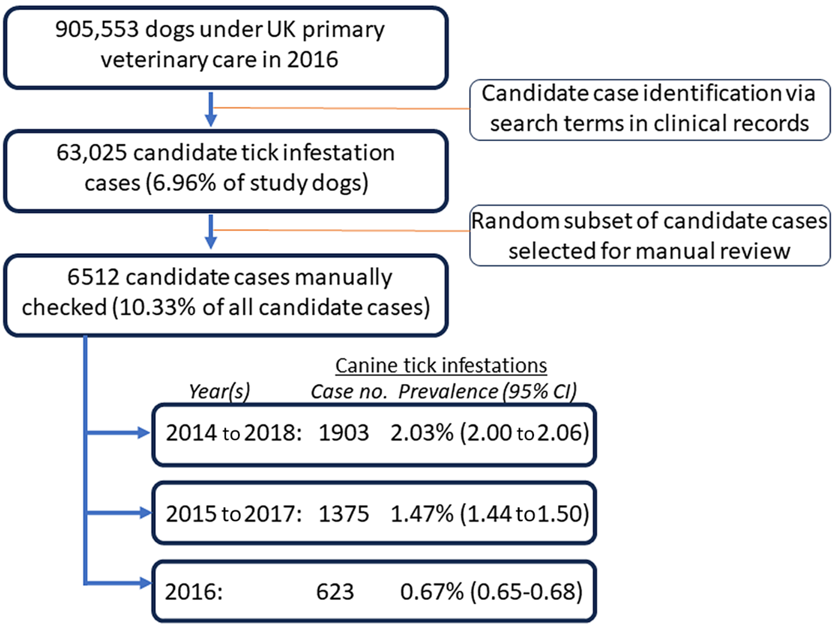

FIG 1. Flow chart of study design including data set, case identification, and subset definition of candidate cohort selected for manual analysis. Numbers of canine tick infestations identified in the subset candidate dogs receiving primary care during 2016 are defined over a single-year (2016), 3-year (2015 to 2017) and 5-year period (2014 to 2018). Annual prevalence of canine tick infestations in dogs under primary veterinary care during 2016 in the VetCompass Programme in the UK are defined

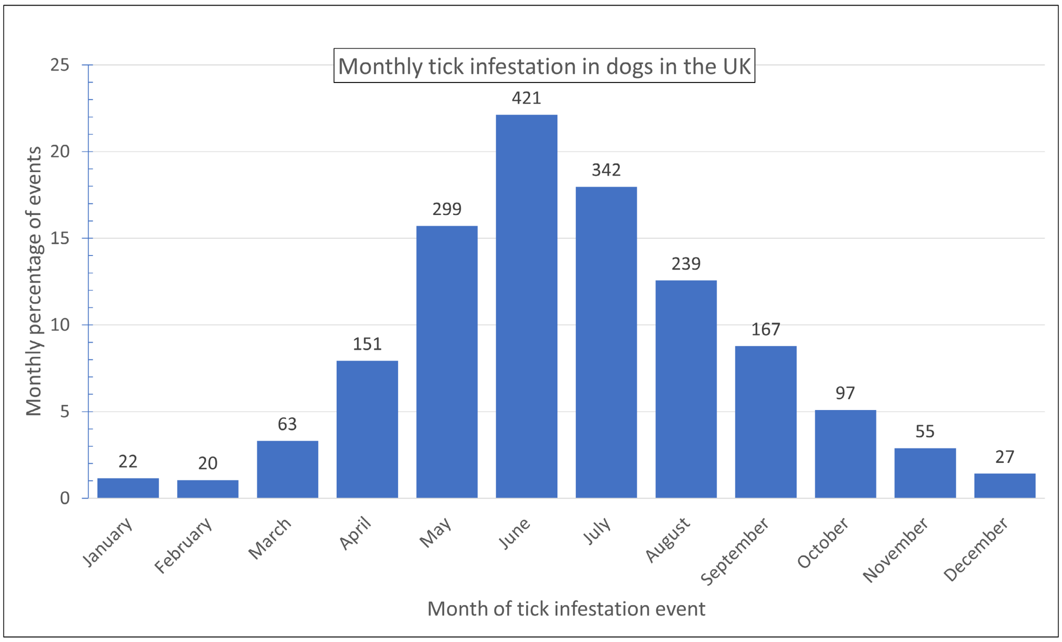

FIG 2. Monthly proportional tick infestation estimated over a 5-year period from 2014 to 2018 in dogs under primary veterinary care during 2016 in the VetCompass Programme in the UK. The monthly count of events is shown above each bar. n=1903

3.12 to 5.96) and Cavachon (4.29%, 2.47 to 6.87) (Fig 3). Among the tick infestation cases, the most common breeds were non-designer-crossbreed (n=387, 20.34%), Labrador retriever (132, 6.94%), English cocker spaniel (127, 6.67%), Cockapoo (91, 4.78%) and Border Collie (87, 4.57%) (Table 1). Dogs with tick infestation had a median adult bodyweight of 13.93 kg [interquartile range (IQR): 9.00 to 24.00, range 1.81 to 73.90] and median age was 4.03 years (IQR: 2.20 to 7.18, range 0.16 to 19.79). Among the non-case dogs, the most common breeds were non-designer-crossbreed (n=182,956, 21.60%), Labrador retriever (55,206, 6.52%), Staffordshire bull terrier (51,270, 6.05%), Jack Russell terrier (46,169, 5.45%) and Chihuahua (35,867, 4.23%) (Table 1). The median adult bodyweight for non-cases was 13.85 kg (IQR: 8.10 to 25.00, range 0.72 to 97.20) and the median age was 4.41 years (IQR: 1.83 to 8.10, range 0.00 to 20.97).

Risk factors

All study variables were liberally associated with tick infestation in univariable logistic regression modelling and were evaluated using multivariable logistic regression modelling (Tables 1-3). The final breed-focused multivariable model retained six risk factors: *breed*, *bodyweight relative to breed-sex mean*, *age*, *sex*, *neuter* and *insurance* (Table 4). No biologically significant interactions were identified. The final model showed acceptable model-fit (Hosmer-Lemeshow test statistic: P=0.230) and acceptable discrimination (area under the ROC curve: 0.689).

After accounting for the effects of the other variables evaluated, 16 breeds showed increased odds of tick infestation compared with non-designer-crossbreed dogs. Breeds with the highest odds included Cairn Terrier [odds ratio (OR) 2.86, 95% CI 1.64 to 4.98], Standard poodle (OR 2.80, 95% CI 1.25 to 6.29), Goldendoodle (OR 2.63, 95% CI 1.17 to 5.91), Cavapoo (OR 2.50, 95% CI 1.62 to 3.86), and Cockapoo (OR 2.42, 95% CI 1.92 to 3.05). Six breeds showed reduced odds of tick infestation compared with non-designer-crossbreed. Older age groups showed reducing odds of tick infestation. Males had 1.24 (95% CI 1.13 to 1.36) times the odds compared with females and neutered animals had 1.13 (95% CI 1.02 to 1.24) times the odds compared with entire animals. Insured animals had 1.54 (95% CI 1.37 to 1.72) times the odds compared with uninsured animals (Table 4).

As described in the methods, breed-derived variables were introduced individually to replace *breed* in the final breed-focused model. Compared with non-designer-crossbred dogs, designer-crossbreed dogs had increased odds (OR 1.81, 95% CI 1.52 to 2.15) of tick infestation. All Kennel Club breed groups showed higher odds compared to breeds that were not recognised by the Kennel Club. Compared with breeds with short coats, breeds with medium length coats (OR 2.20, 95% CI 1.96 to 2.48) showed increased odds of tick infestation. Compared with breeds with mesocephalic skull conformation, breeds with brachycephalic and dolichocephalic skull conformation showed decreased odds of tick infestation. Both purebred and designer-crossbreed types of Spaniels showed increased odds compared to non-designer-crossbreed dogs. Designer poodle types but not purebred Poodles showed increased odds compared to non-designer-crossbreed dogs. Breeds with V-shaped drop and pendulous ear carriage had higher odds of tick infestation compared with breeds with erect ear carriage. Dogs with adult bodyweight from 10 to 25 kg had increased odds compared with dogs weighing under 10 kg (Table 5).

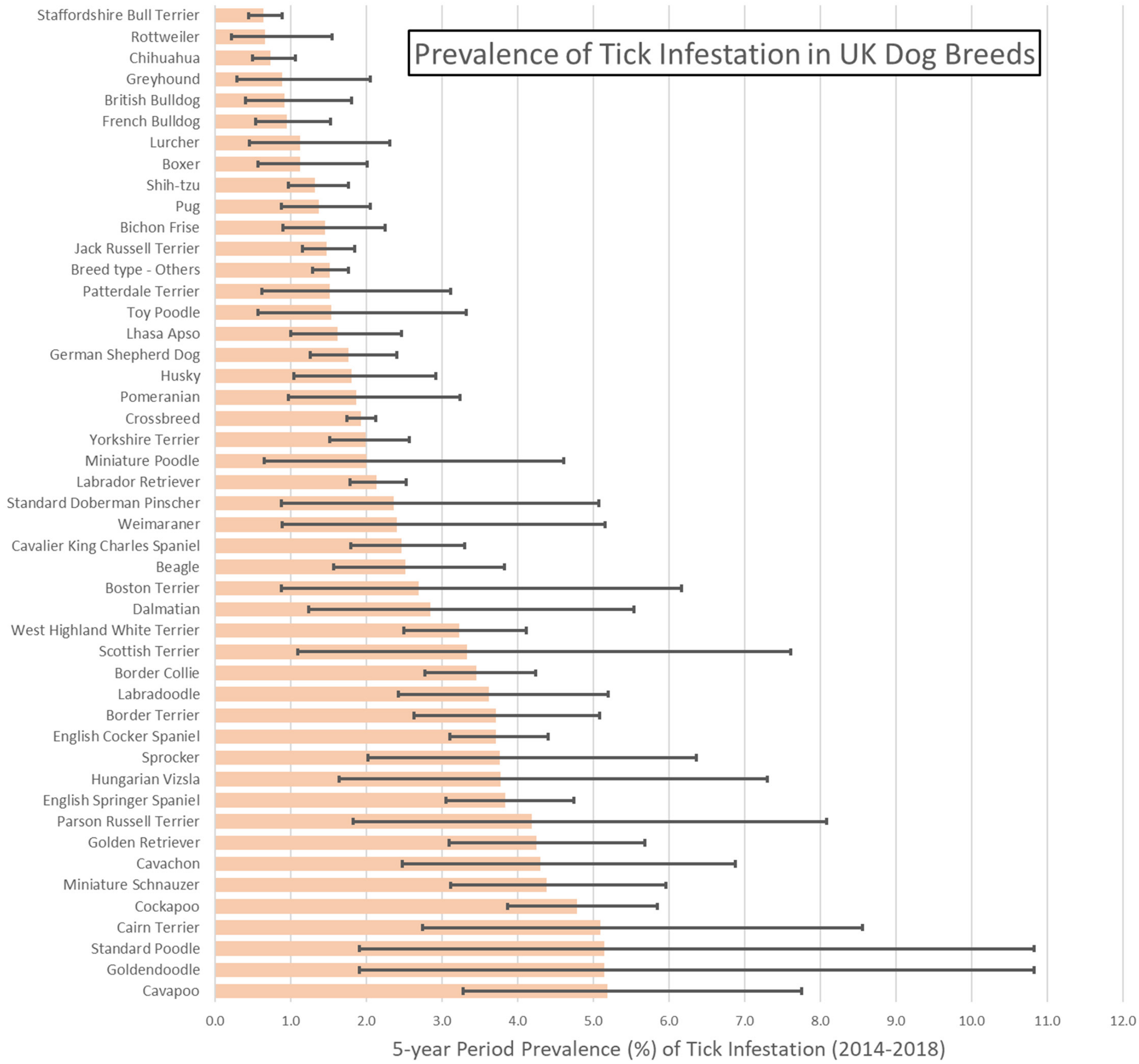

FIG 3. Five-year (2014 to 2018) period prevalence (percentage) of tick infestation in dog breeds under primary veterinary care during 2016 in the VetCompass Programme in the UK. A black line overlaid on each breed horizontal bar represents the 95% confidence intervals

DISCUSSION

The current study examined clinical records from a large population of dogs under primary veterinary care to determine the prevalence and risk factors of tick infestation in the UK. In exploring records from over 900,000 dogs presenting to primary-care veterinary practice, the current study is arguably the largest tick infestation analysis to date and avoids many of the sampling biases often associated with questionnaire-based studies (O'Neill et al., 2014).

The current study reported that in a 1-year period (2016), 0.67% of dogs had tick infestation. The prevalence for a 3-year period (2015 to 2017) was 1.47% and for a 5-year period (2014 to 2018) was 2.03%. These prevalence values are consistent with earlier VetCompass work that explored prevalence among a list of common disorders in a smaller sample of study dogs and reported a 1-year period prevalence of 0.68% for tick infestation (O'Neill, James, et al., 2021a). Previously reported tick infestation prevalence values have varied widely in line with differing study designs. In a UK study with 1094 veterinary practices recruited to monitor tick attachment to dogs from April–July 2015, a prevalence of 30.7% was reported (Abdullah et al., 2016). However, the authors of that study suggested those results may have been an overestimate because of methodological issues whereby some practices misunderstood their instructions and only submitted information on dogs that were positive for ticks. Those authors also suggested there may have been selection biases towards practices in known high-risk areas for ticks and for practitioners with specific interest in tick disorders. Another study that followed a similar study design recruited 173 UK veterinary practices to monitor tick attachment to dogs between March and October 2009 (Smith et al., 2011). Based on five

Table 1. Descriptive and univariable logistic regression results for breed as a risk factor for tick infestation over a 5-year period (2014 to 2018) in dogs under primary veterinary care during 2016 in the VetCompass Programme in the UK

Breed	Case (%)	Non-case (%)	Odds ratio	95% CI	P-value
Non-designer-crossbreed	387 (20.34)	182,956 (21.60)	Base	~	~
Golden doodle	6 (0.32)	979 (0.12)	2.90	1.29 to 6.51	0.010
Cavapoo	22 (1.16)	3665 (0.43)	2.84	1.84 to 4.37	<0.001
Cairn terrier	13 (0.68)	2214 (0.26)	2.78	1.59 to 4.83	<0.001
Standard poodle	6 (0.32)	1050 (0.12)	2.70	1.2 to 6.06	0.016
Cockapoo	91 (4.78)	16,111 (1.90)	2.67	2.12 to 3.36	<0.001
Miniature schnauzer	38 (2.00)	7421 (0.88)	2.42	1.73 to 3.38	<0.001
Golden retriever	43 (2.26)	8696 (1.03)	2.34	1.7 to 3.21	<0.001
Cavachon	16 (0.84)	3324 (0.39)	2.28	1.38 to 3.76	0.001
Parson Russell terrier	8 (0.42)	1710 (0.20)	2.21	1.1 to 4.46	0.027
English springer spaniel	80 (4.20)	18,105 (2.14)	2.09	1.64 to 2.66	<0.001
English cocker spaniel	127 (6.67)	29,183 (3.44)	2.06	1.68 to 2.51	<0.001
Sprocker	13 (0.68)	2984 (0.35)	2.06	1.18 to 3.58	0.011
Hungarian Vizsla	8 (0.42)	1844 (0.22)	2.05	1.02 to 4.14	0.045
Border terrier	37 (1.94)	8663 (1.02)	2.02	1.44 to 2.83	<0.001
Labradoodle	28 (1.47)	6570 (0.78)	2.01	1.37 to 2.96	<0.001
Border Collie	87 (4.57)	22,422 (2.65)	1.83	1.45 to 2.32	<0.001
Scottish terrier	5 (0.26)	1334 (0.16)	1.77	0.73 to 4.29	0.205
West Highland white terrier	63 (3.31)	17,121 (2.02)	1.74	1.33 to 2.27	<0.001
Dalmatian	8 (0.42)	2567 (0.30)	1.47	0.73 to 2.97	0.279
Boston terrier	5 (0.26)	1711 (0.20)	1.38	0.57 to 3.34	0.473
Beagle	21 (1.10)	7433 (0.88)	1.34	0.86 to 2.07	0.197
Cavalier King Charles spaniel	44 (2.31)	15,944 (1.88)	1.30	0.95 to 1.78	0.095
Weimaraner	6 (0.32)	2251 (0.27)	1.26	0.56 to 2.83	0.575
Standard Dobermann Pinscher	6 (0.32)	2332 (0.28)	1.22	0.54 to 2.73	0.634
Labrador retriever	132 (6.94)	55,206 (6.52)	1.13	0.93 to 1.38	0.225
Miniature poodle	5 (0.26)	2276 (0.27)	1.04	0.43 to 2.51	0.933
Yorkshire terrier	58 (3.05)	26,746 (3.16)	1.03	0.78 to 1.35	0.860
Pomeranian	12 (0.63)	5964 (0.70)	0.95	0.54 to 1.69	0.865
Husky	16 (0.84)	8086 (0.95)	0.94	0.57 to 1.54	0.794
German shepherd dog	39 (2.05)	20,156 (2.38)	0.91	0.66 to 1.27	0.596
Lhasa apso	21 (1.10)	11,747 (1.39)	0.85	0.54 to 1.31	0.453
Breed type – others	162 (8.51)	96,946 (11.44)	0.79	0.66 to 0.95	0.012
Patterdale terrier	7 (0.37)	4176 (0.49)	0.79	0.38 to 1.67	0.542
Toy poodle	6 (0.32)	3592 (0.42)	0.79	0.35 to 1.77	0.566
Bichon frise	20 (1.05)	12,516 (1.48)	0.76	0.48 to 1.18	0.222
Jack Russell terrier	74 (3.89)	46,169 (5.45)	0.76	0.59 to 0.97	0.029
Pug	23 (1.21)	15,630 (1.85)	0.70	0.46 to 1.06	0.091
Shih-tzu	45 (2.36)	31,171 (3.68)	0.68	0.5 to 0.93	0.015
Boxer	11 (0.58)	8960 (1.06)	0.58	0.32 to 1.06	0.075
Lurcher	7 (0.37)	5717 (0.67)	0.58	0.27 to 1.22	0.152
French bulldog	16 (0.84)	15,953 (1.88)	0.47	0.29 to 0.78	0.003
English bulldog	8 (0.42)	8144 (0.96)	0.46	0.23 to 0.94	0.032
Greyhound	5 (0.26)	5228 (0.62)	0.45	0.19 to 1.09	0.078
Chihuahua	28 (1.47)	35,867 (4.23)	0.37	0.25 to 0.54	<0.001
Rottweiler	5 (0.26)	7017 (0.83)	0.34	0.14 to 0.81	0.016
Staffordshire bull terrier	35 (1.84)	51,270 (6.05)	0.32	0.23 to 0.46	<0.001

CI Confidence interval
Column percentages shown in parentheses

randomly selected dogs examined for ticks each week, the study reported a 14.9% prevalence of tick infestation over the 3-month period. The authors again suggested that some practices may have misunderstood the instructions and instead submitted only information on tick-positive cases that might have led to over-estimation of the tick prevalence. However, even assuming some level of over-estimation of tick prevalence in these two other UK studies where tick infestation was actively sought out during veterinary consultations, those results are much higher than in the current study. This suggests that many true cases of tick infestation may be being missed under routine primary veterinary care in the UK. If correct, this would have some important implications for potential transmission of tick-borne disease in both dogs and their owners who often share the same habitat during walks (Baneth, 2014). Analysis of veterinary consultation data from 192 UK veterinary clinics from 2014 to 2016 identified that dogs had 0.73 times the risk of presenting for veterinary care with a tick compared to cats (Tulloch et al., 2017).

The current study identified breed as an important risk factor associated with tick infestation, with 16 breeds showing increased odds of tick infestation compared with non-designer-crossbreed dogs and six breeds showing reduced odds. Breeds with the highest odds included Cairn Terrier (OR 2.86), Standard poodle (OR 2.80), Goldendoodle (OR 2.63), Cavapoo (OR 2.50) and Cockapoo (OR 2.42). Breeds with the lowest odds were Staffordshire bull terrier (OR 0.35), Rottweiler (OR 0.35) and Chihuahua (OR 0.38). Some other studies have elected to explore breed effects by grouping breeds

Table 2. Descriptive and univariable logistic regression results for breed-derived risk factors for tick infestation over a 5-year period (2014 to 2018) in dogs under primary veterinary care during 2016 in the VetCompass Programme in the UK

Variable	Category	Case no. (%)	Non-case No. (%)	Odds ratio	95% CI	Category P-value	Variable P-value
Breed purity	Non-designer-crossbreed	387 (20.37)	182,956 (21.68)	Base			<0.001
	Designer-crossbreed	196 (10.32)	47,549 (5.63)	1.94	1.64 to 2.31	<0.001	
	Purebred	1317 (69.32)	613,526 (72.69)	1.01	0.91 to 1.14	0.799	
Kennel Club-recognised breed	Not recognised	599 (31.53)	244,838 (29.01)	Base			0.017
	Recognised	1301 (68.47)	599,193 (70.99)	0.89	0.81 to 0.98	0.016	
Kennel Club breed group	Not Kennel Club-recognised breed	599 (31.53)	244,838 (29.01)	Base			<0.001
	Terrier	261 (13.74)	137,662 (16.31)	0.77	0.67 to 0.90	0.001	
	Gundog	422 (22.21)	122,503 (14.51)	1.41	1.24 to 1.60	<0.001	
	Working	50 (2.63)	37,261 (4.41)	0.55	0.41 to 0.73	<0.001	
	Pastoral	148 (7.79)	49,161 (5.82)	1.23	1.03 to 1.47	0.024	
	Utility	177 (9.32)	97,072 (11.50)	0.75	0.63 to 0.88	0.001	
	Hound	49 (2.58)	29,539 (3.50)	0.68	0.51 to 0.91	0.009	
	Toy	194 (10.21)	125,995 (14.93)	0.63	0.54 to 0.74	<0.001	
Haircoat length	Short	508 (26.69)	321,994 (38.01)	Base			<0.001
	Medium	628 (33.00)	174,388 (20.59)	2.28	2.03 to 2.57	<0.001	
	Long	153 (8.04)	86,850 (10.25)	1.12	0.93 to 1.34	0.232	
	Uncategorised	614 (32.26)	263,895 (31.15)	1.47	1.31 to 1.66	<0.001	
Skull conformation	Mesocephalic	989 (51.97)	387,530 (45.75)	Base			<0.001
	Brachycephalic	208 (10.93)	160,163 (18.91)	0.51	0.44 to 0.59	<0.001	
	Dolichocephalic	120 (6.31)	65,833 (7.77)	0.71	0.59 to 0.86	0.001	
	Uncategorised	586 (30.79)	233,601 (27.58)	0.98	0.89 to 1.09	0.742	
Spaniel	Non-designer-crossbreed	390 (20.49)	186,052 (21.96)	Base			<0.001
	Spaniel purebred	265 (13.93)	69,147 (8.16)	1.83	1.56 to 2.14	<0.001	
	Spaniel designer breed	144 (7.57)	26,672 (3.15)	2.58	2.13 to 3.12	<0.001	
	Non-spaniel purebred	1052 (55.28)	544,379 (64.26)	0.92	0.82 to 1.04	0.171	
	Non-spaniel designer breed	52 (2.73)	20,877 (2.46)	1.19	0.89 to 1.59	0.243	
Poodle	Non-designer-crossbreed	390 (20.49)	186,052 (21.96)	Base			<0.001
	Poodle purebred	17 (0.89)	7934 (0.94)	1.02	0.63 to 1.66	0.930	
	Poodle designer breed	153 (8.04)	30,429 (3.59)	2.40	1.99 to 2.89	<0.001	
	Non-poodle purebred	1300 (68.31)	605,592 (71.49)	1.02	0.91 to 1.15	0.681	
	Non-poodle designer breed	43 (2.26)	17,120 (2.02)	1.20	0.87 to 1.64	0.261	
Ear carriage	Erect	289 (15.19)	154,705 (18.26)	Base			<0.001
	Semi-erect	322 (16.92)	186,780 (22.05)	0.92	0.79 to 1.08	0.322	
	V-shaped drop	278 (14.61)	114,063 (13.46)	1.30	1.11 to 1.54	0.002	
	Pendulous	425 (22.33)	157,096 (18.54)	1.45	1.25 to 1.68	<0.001	
	Uncategorised	589 (30.95)	234,483 (27.68)	1.34	1.17 to 1.55	<0.001	

CI Confidence interval
Column percentages shown in parentheses

within the groups used by the UK Kennel Club, perhaps to increase the statistical power but which then precluded elicitation of breed-specific information (Abdullah et al., 2016; Jennett et al., 2013; Smith et al., 2011). It is possible that the breed predispositions and protections identified in the current study may reflect coat types more so than other attributes of the specific breeds themselves.

In the current study, compared to non-designer-crossbred dogs, the Cairn terrier had the highest odds and is a breed with a medium haircoat length (The Kennel Club, 2023). This finding was consistent with a multivariable analysis of haircoat length in the current study which showed medium-haired dogs had 2.1 times higher odds than short-haired dogs and was also in line with the findings of a previous UK study (Smith et al., 2011). However, a study of dogs walked in a recreational park in the south-east of England reported short-haired dogs as significantly more likely to be in the highest infestation category than long-haired dogs (Jennett et al., 2013). Those authors proposed that higher apparent tick infestation in short-haired dogs might simply reflect greater detection rates by owners because ticks might be more easily visualised; those authors conversely proposed that long hair may provide a barrier effect that protects dogs against tick infestation. However, some other studies have reported that long-haired dogs were more likely to get ticks (Maurelli et al., 2018; Silveira et al., 2009). It is possible that some

Table 3. Descriptive and univariable logistic regression results for non-breed-related demographic risk factors evaluated for tick infestation over a 5-year period (2014 to 2018) in dogs under primary veterinary care during 2016 in the VetCompass Programme in the UK

Variable	Category	Case no. (%)	Non-case no. (%)	Odds ratio	95% CI	Category P-value	Variable P-value
Adult (>18 months) bodyweight (kg)	<10.0	482 (25.33)	198,494 (23.43)	Base			<0.001
	10.0 to <15.0	339 (17.81)	89,015 (10.51)	1.57	1.36 to 1.80	<0.001	
	15.0 to <20.0	191 (10.04)	62,874 (7.42)	1.25	1.06 to 1.48	0.009	
	20.0 to <25.0	167 (8.78)	58,795 (6.94)	1.17	0.98 to 1.40	0.081	
	25.0 to <30.0	131 (6.88)	49,355 (5.83)	1.09	0.90 to 1.33	0.367	
	30.0 to <40.0	168 (8.83)	63,853 (7.54)	1.08	0.91 to 1.29	0.371	
	≥40.0	49 (2.57)	24,394 (2.88)	0.83	0.62 to 1.11	0.206	
	Uncategorised	376 (19.76)	300,347 (35.45)	0.52	0.45 to 0.59	<0.001	
Bodyweight relative to breed mean	Equal/Higher	668 (35.10)	252,798 (29.84)	Base			
	Lower	856 (44.98)	291,967 (34.47)	1.11	1.00 to 1.23	0.044	<0.001
	Uncategorised	379 (19.92)	302,362 (35.69)	0.47	0.42 to 0.54	<0.001	
Age (years)	<1.0	168 (8.83)	99,579 (11.75)	Base			<0.001
	1.0 to <2.0	260 (13.66)	123,562 (14.59)	1.25	1.03 to 1.51	0.026	
	2.0 to <4.0	513 (26.96)	165,573 (19.55)	1.84	1.54 to 2.19	<0.001	
	4.0 to <6.0	335 (17.60)	129,292 (15.26)	1.54	1.28 to 1.85	<0.001	
	6.0 to <8.0	253 (13.29)	104,409 (12.33)	1.44	1.18 to 1.75	<0.001	
	8.0 to <10.0	178 (9.35)	84,257 (9.95)	1.25	1.01 to 1.55	0.037	
	10.0 to <12.0	114 (5.99)	61,686 (7.30)	1.09	0.86 to 1.39	0.468	
	≥12.0	78 (4.10)	66,583 (7.86)	0.69	0.53 to 0.91	0.008	
	Uncategorised	4 (0.21)	12,004 (1.42)	0.20	0.07 to 0.53	0.001	
Sex	Female	800 (42.04)	405,792 (47.90)	Base			<0.001
	Male	1099 (57.75)	437,245 (51.62)	1.27	1.16 to 1.40	<0.001	
	Uncategorised	4 (0.21)	4090 (0.48)	0.50	0.19 to 1.33	0.162	
Neuter	Entire	922 (48.45)	468,371 (55.29)	Base			<0.001
	Neutered	977 (51.34)	374,668 (44.23)	1.32	1.21 to 1.45	<0.001	
	Uncategorised	4 (0.21)	4088 (0.48)	0.50	0.19 to 1.33	0.163	
Insurance	Non-insured	1515 (79.61)	744,202 (87.85)	Base			<0.001
	Insured	388 (20.39)	102,925 (12.15)	1.85	1.66 to 2.07	<0.001	

CI Confidence interval
Column percentages shown in parentheses

of the variability of results on haircoat as a risk factor may be due to inconsistency and subjectivity on how haircoat length is classified across the breeds. In the absence of a universally accepted list of haircoat lengths for all breeds in dogs, the current study developed a classification of haircoat length from information available from various kennel clubs worldwide and from viewing online images of dog breeds, but it is possible that another research team may have chosen to classify hair-coat in some of these breeds differently. Indeed, some discordance was noted for some breeds in the haircoat length reported between the UK and American kennel club databases. Based on the current results, owners of UK dogs with medium-length haircoats should be alerted to possibly increased risk of tick infestation in their dogs and, where possible, recommended to maintain a shortened haircoat during summer and autumn seasons in the UK to reduce tick infestation risk (Smith et al., 2011). It is noteworthy that the current study carried out a power calculation to ensure the analysis was adequately powered to estimate the effects from haircoat. The assumed one-year prevalence of 0.68% in the medium-haired or long-haired dog used in the power calculation was close to the actual result of 0.67% overall in the current paper. The assumption of twice as many short-haired dogs as either medium-haired or long-haired dogs was also close to the actual result in the data of 1.8 times as many short-haired dogs as the medium-haired dogs while being some way off the 3.7 times as many short-haired dogs as the long-haired dogs. Overall, the assumptions made in the power calculation for the regression analysis were largely met, supporting the current study as being adequately powered to evaluate the hypothesis about haircoat length as a risk factor.

The odds of tick infestation decreased with increasing age in the current study, which is consistent with the findings from a previous study in the USA (Raghavan et al., 2007). One possible explanation is that younger dogs are more active and therefore might have greater exposure to ticks from outdoor activities than older dogs (Lee et al., 2022). However, the findings on age as a risk factor for tick infestation are inconsistent across all studies, with one UK study suggesting older dogs as more likely to have ticks than dogs aged 1 year or younger (Abdullah et al., 2016). Therefore, age alone does not seem to be a reliable predictor of tick infestation risk and other co-occurring factors such as indoor *versus* outdoor and urban *versus* rural environments may play important interacting roles (Maurelli et al., 2018).

The current study reported some differences between the sex-neuter status of dogs and their risk of tick infestation. Male entire dogs had higher odds than female entire dogs, and neutered dogs had higher odds than entire dogs. However, previous studies reported that sex was not associated with tick infestation and that neutered dogs had lower risk of tick infestation than entire dogs (Abdullah et al., 2016; Raghavan et al., 2007; Smith et al., 2011). These previous studies used alternative study designs such as questionnaires compared to the current study, and therefore some level of selection bias may have accounted

Table 4. Multivariable logistic regression results that *includes breed* for demographic risk factors evaluated for tick infestation over a 5-year period (2014 to 2018) in dogs under primary veterinary care during 2016 in the VetCompass Programme in the UK. P-values under 0.05 are shown in bold

Variable	Category	Odds ratio	95% CI	Category P-value	Variable P-value
Breed	Non-designer-crossbreed	Base			<0.001
	Cairn terrier	2.86	1.64 to 4.98	**<0.001**	
	Standard poodle	2.80	1.25 to 6.29	**0.013**	
	Goldendoodle	2.63	1.17 to 5.91	**0.019**	
	Cavapoo	2.50	1.62 to 3.86	**<0.001**	
	Cockapoo	2.42	1.92 to 3.05	**<0.001**	
	Parson Russell terrier	2.31	1.15 to 4.67	**0.019**	
	Golden retriever	2.30	1.67 to 3.15	**<0.001**	
	Miniature schnauzer	2.25	1.61 to 3.15	**<0.001**	
	English springer spaniel	2.08	1.63 to 2.65	**<0.001**	
	Cavachon	2.03	1.23 to 3.36	**0.006**	
	Border terrier	1.98	1.41 to 2.78	**<0.001**	
	English cocker spaniel	1.96	1.60 to 2.39	**<0.001**	
	Sprocker	1.94	1.11 to 3.37	**0.020**	
	Hungarian Vizsla	1.92	0.95 to 3.88	0.069	
	Border Collie	1.92	1.52 to 2.42	**<0.001**	
	West Highland white terrier	1.83	1.40 to 2.39	**<0.001**	
	Scottish terrier	1.82	0.75 to 4.41	0.185	
	Labradoodle	1.79	1.22 to 2.64	**0.003**	
	Dalmatian	1.46	0.72 to 2.95	0.289	
	Boston terrier	1.33	0.55 to 3.21	0.531	
	Cavalier King Charles spaniel	1.24	0.91 to 1.70	0.171	
	Beagle	1.22	0.79 to 1.90	0.366	
	Weimaraner	1.22	0.54 to 2.73	0.632	
	Standard Dobermann Pinscher	1.16	0.52 to 2.61	0.716	
	Labrador retriever	1.10	0.90 to 1.34	0.361	
	Yorkshire terrier	1.08	0.82 to 1.42	0.584	
	Miniature poodle	1.04	0.43 to 2.52	0.930	
	Pomeranian	0.97	0.55 to 1.73	0.923	
	German shepherd dog	0.95	0.68 to 1.32	0.751	
	Husky	0.94	0.57 to 1.55	0.801	
	Lhasa Apso	0.83	0.53 to 1.29	0.407	
	Patterdale terrier	0.81	0.38 to 1.72	0.587	
	Jack Russell terrier	0.81	0.63 to 1.04	0.093	
	Breed type – others	0.80	0.67 to 0.97	**0.020**	
	Toy poodle	0.80	0.35 to 1.78	0.579	
	Bichon Frise	0.71	0.46 to 1.12	0.143	
	Pug	0.68	0.44 to 1.03	0.070	
	Shih-tzu	0.67	0.49 to 0.91	**0.011**	
	Lurcher	0.60	0.28 to 1.26	0.178	
	Boxer	0.56	0.31 to 1.03	0.061	
	French bulldog	0.51	0.31 to 0.84	**0.008**	
	Greyhound	0.47	0.20 to 1.15	0.097	
	English bulldog	0.47	0.23 to 0.95	**0.035**	
	Chihuahua	0.38	0.26 to 0.55	**<0.001**	
	Rottweiler	0.35	0.15 to 0.85	**0.020**	
	Staffordshire bull terrier	0.35	0.25 to 0.50	**<0.001**	
Bodyweight relative to breed mean	Equal/Higher	Base			<0.001
	Lower	1.09	0.98 to 1.20	0.113	
	Uncategorised	0.51	0.44 to 0.59	**<0.001**	
Age (years)	<1.0	Base			<0.001
	1.0 to <2.0	1.02	0.84 to 1.24	0.832	
	2.0 to <4.0	1.19	0.98 to 1.44	0.072	
	4.0 to <6.0	0.95	0.78 to 1.17	0.648	
	6.0 to <8.0	0.89	0.71 to 1.10	0.266	
	8.0 to <10.0	0.76	0.60 to 0.95	**0.019**	
	10.0 to <12.0	0.65	0.51 to 0.84	**0.001**	
	≥12.0	0.43	0.32 to 0.57	**<0.001**	
	Uncategorised	0.28	0.10 to 0.75	**0.012**	
Sex	Female	Base			<0.001
	Male	1.24	1.13 to 1.36	**<0.001**	
	Uncategorised	~	~	0.991	
Neuter	Entire	Base			<0.001
	Neutered	1.13	1.02 to 1.24	**0.018**	
	Uncategorised	~	~	0.991	
Insurance	Non-insured	Base			<0.001
	Insured	1.54	1.37 to 1.72	**<0.001**	

CI Confidence interval, ~ count data too low to calculate

Table 5. Multivariable logistic regression results for variables that replaced *breed* in risk factor analysis for tick infestation over a 5-year period (2014 to 2018) in dogs under primary veterinary care during 2016 in the VetCompass Programme in the UK. P-values under 0.05 are shown in bold

Variable	Category	Odds ratio	95% CI	Category P-value	Variable P-value
Breed purity	Non-designer-crossbreed	Base			<0.001
	Designer-crossbreed	1.81	1.52 to 2.15	**<0.001**	
	Purebred	1.03	0.92 to 1.15	0.657	
Kennel Club-recognised breed	Not recognised	Base			0.161
	Recognised	0.91	0.82 to 1.00	0.055	
Kennel Club breed group	Not Kennel Club recognised breed	Base			<0.001
	Terrier	0.84	0.72 to 0.97	**0.020**	
	Gundog	1.38	1.22 to 1.57	**<0.001**	
	Working	0.56	0.42 to 0.75	**<0.001**	
	Pastoral	1.31	1.09 to 1.56	**0.004**	
	Utility	0.76	0.64 to 0.90	**0.001**	
	Hound	0.67	0.50 to 0.89	**0.006**	
	Toy	0.64	0.55 to 0.75	**<0.001**	
Haircoat length	Short	Base			<0.001
	Medium	2.20	1.96 to 2.48	**<0.001**	
	Long	1.10	0.92 to 1.32	0.300	
	Uncategorised	1.44	1.27 to 1.62	**<0.001**	
Skull conformation	Mesocephalic	Base			<0.001
	Brachycephalic	0.50	0.43 to 0.59	**<0.001**	
	Dolichocephalic	0.71	0.59 to 0.86	**<0.001**	
	Uncategorised	0.95	0.86 to 1.06	0.368	
Spaniel	Non-designer-crossbreed	Base			<0.001
	Spaniel purebred	1.74	1.49 to 2.04	**<0.001**	
	Spaniel designer breed	2.33	1.92 to 2.83	**<0.001**	
	Non-spaniel purebred	0.93	0.83 to 1.04	0.216	
	Non-spaniel designer breed	1.12	0.84 to 1.50	0.448	
Poodle	Non-designer-crossbreed	Base			
	Poodle purebred	1.04	0.64 to 1.69	0.876	
	Poodle designer breed	2.16	1.78 to 2.61	**<0.001**	
	Non-poodle purebred	1.03	0.91 to 1.15	0.673	
	Non-poodle designer breed	1.15	0.84 to 1.57	0.392	
Ear carriage	Erect	Base			<0.001
	Semi-erect	0.93	0.79 to 1.09	0.376	
	V-shaped drop	1.23	1.04 to 1.45	**0.016**	
	Pendulous	1.35	1.16 to 1.57	**<0.001**	
	Uncategorised	1.28	1.11 to 1.47	**0.001**	
Adult (>18 months) bodyweight (kg)	<10.0	Base			<0.001
	10.0 to <15.0	1.51	1.32 to 1.74	**<0.001**	
	15.0 to <20.0	1.26	1.07 to 1.49	**0.007**	
	20.0 to <25.0	1.20	1.00 to 1.43	**0.045**	
	25.0 to <30.0	1.10	0.91 to 1.34	0.336	
	30.0 to <40.0	1.06	0.89 to 1.27	0.516	
	≥40.0	0.78	0.58 to 1.05	0.099	
	Uncategorised	0.52	0.45 to 0.61	**<0.001**	

CI Confidence interval
Adult bodyweight replaced both breed and relative bodyweight

for these differences. Although the current study design should ensure a more representative sample of UK dogs, further work is still needed before drawing firm conclusions about the roles of sex and neuter in relation to tick infestation.

Designer-crossbreed dogs had higher odds of tick infestation than non-designer-crossbreed dogs in the current study. However, much of this effect may have been driven more by the most common breeds used in designer-crossbreed breeding than by any actual phenomenon of being a designer crossbreed per se. Designer-crossbreed poodles (*i.e.* non-purebred poodles) showed increased odds compared to general non-designer-crossbreed dogs. And both designer-crossbreed spaniels and purebred spaniels had higher odds compared to non-designer-crossbreed dogs. These results suggest that the breed components within designer-crossbreeds may play a major role in breed risks for designer-crossbred breeds and that designer-crossbreeds derived from poodle or spaniel progenitor breeds may specifically have higher risk of tick infestation. This information could be used by owners and veterinarians to better manage disease risk in high tick prevalence areas by considering carefully what component breeds to select for designer crosses and also to be more vigilant for ticks in higher-risk designer-crossbreed types.

Although some studies have noted the pinnae as one of the most common body locations for ticks to attach on dogs (DeWinter et al., 2023; Wright et al., 2018), there has been very limited previous research on the effects of ear carriage on tick infestation. In the current study, breeds with V-shaped drop and pendulous ear carriage showed higher odds of ticks compared with breeds with erect ear carriage. One explanation for such increased risk might be greater proximity of folded and pendulous ears to the ground when dogs sniff or dig that could facilitate transfer of ticks from vegetation. Folded or pendulous ear carriage may also make it more difficult for owners to detect ticks attached to the inner side of the ear or for the dogs themselves to self-remove these ticks. However, it should also be noted that the current study only explored associations between the infestation risk of the overall dogs and their ear carriage, and it may not actually be the ears specifically that are the main sites of attachment in these higher risk dogs. For example, folded or pendulous ears may reflect linked phenotypic or breed effects linked with ear carriage such as spaniel or haircoat effects discussed above. More work needs to be done to elucidate the precise causal pathways for the associations identified here for ear carriage but for now, owners of dogs with folded or pendulous ear carriage should be advised to check their dogs vigilantly for ticks after walks and when travelling in high-prevalence tick areas.

The current study had some limitations. Because the current study adapted veterinary clinical data for secondary use as a research resource (O'Neill et al., 2014), there was potential for misclassification of disorder and risk factor status. As discussed above, studies that prospectively set out to elicit tick-infestation status have tended to report much higher prevalence values that the current study (Abdullah et al., 2016) and therefore it is possible that many true tick-infestation cases are missed under primary veterinary care such that the prevalence values reported in the current study may be a substantial underestimate. This also suggests that greater veterinary vigilance for the presence of attached ticks could result in many more cases being identified and treated, especially in high-risk canine phenotypes and demographics. Either way, any noise introduced to the current study data from misclassification could reduce the certainty of the results reported here (Hariri et al., 2019) although assuming non-directional misclassification with similar levels and directions for both cases and non-cases may avoid substantially biased outputs for the risk factor results reported here (Elwood, 2007). The current study did not capture dogs as cases from the underlying population of true tick infestation where veterinary care was not sought. The ear carriage analysis assumed a consistently assigned ear carriage for all dogs within each breed even though some variation in ear carriage is likely within many breeds. The current study focused on epidemiological exploration of demographic risk factors for tick infestation and did not aim to report on clinical aspects relating to primary veterinary care such as the body locations of tick attachment or the clinical management strategies that were used. These latter aspects would form a good topic for a future publication.

During veterinary consultations, it is important for veterinary teams to raise awareness to owners of tick vector existence and the risk of diseases these ticks may harbour and transmit to dogs. The current tick prevalence can assist to guide data-driven discussions between veterinary teams and owners. Almost half (47.0%) of owners are reportedly unaware of tick-borne disease risks in dogs (MSD Animal Health, 2023). Limited awareness of tick-borne infection risks might result in underappreciation by owners of the importance of effective tick surveillance and removal. In the USA, a survey of owners reported that only 62% of owners recalled veterinarians recommending flea and tick prevention (Lavan et al., 2017). Even where an acaricide has been prescribed by a veterinarian, incomplete compliance with correct and timely administration can limit the effectiveness. A survey of dog and cat owners in Lisbon identified that only 28.4% of dogs were continuously protected against ectoparasites (Matos et al., 2015). To achieve high levels of understanding in owners of disease risk posed by ticks and to promote higher compliance with prophylactic and therapeutic interventions, veterinary professionals may need to assign more time with owners during initial consultations or undertake greater use of written or electronic sources of information that could be further supported by routine reminders.

This large study of dogs under primary veterinary care reported high and clinically relevant levels of tick infestation in the UK, with a 5-year (2014 to 2018) period prevalence of 2.03%, a 3-year (2015 to 2017) period prevalence of 1.47% and a 1-year (2016) period of 0.67%. Sixteen breeds showed increased odds of tick infestation, while six breeds showed reduced odds. Breeds with medium length coats showed 2.20 times the odds of tick infestation compared with breeds with short coats. Designer-crossbreed dogs had 1.81 times increased odds of tick infestation compared with non-designer-crossbred dogs. These findings provide a broad evidence base for veterinary professionals to raise awareness of the existence of tick infestation as an important and preventable disorder in dogs in the UK and can support the development of more effective prevention and therapeutic protocols based on targeted approaches underpinned by robust epidemiological data.

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Author contributions

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investigation (supporting); methodology (supporting); supervision (supporting); writing – original draft (supporting). **David C. Brodbelt:** Conceptualization (supporting); funding acquisition (lead); methodology (supporting); project administration (supporting); resources (supporting); writing – original draft (supporting); writing – review and editing (supporting).

Conflict of interest

The authors have no conflicts of interest to declare.

Data availability statement

The datasets generated analysed during the study available at 10.6084/m9.figshare.25197074.

Abbreviations

CI	confidence interval
EHR	electronic health record
IQR	interquartile range
KC	The Kennel Club
OR	odds ratio
ROC	receiver operating characteristic

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