University of Veterinary Medicine Budapest

Department of Microbiology and Infectious Diseases

A cross-sectional study of dog owners' awareness and perceived risk of leptospirosis and leptospirosis vaccination in the United Kingdom based on survey data in the period of November 2022-June 2023.

- *Egy keresztmetszeti tanulmány a kutyatulajdonosok leptospirózissal és leptospirózis elleni védőoltással kapcsolatos tudatosságáról és észlelt kockázatáról az Egyesült Királyságban, felmérési adatok alapján a 2022. november és 2023. június közötti időszakban.* -

Author: Louise Skinner

Supervisor: Dr. Fodor László,

Professor at the Department of Microbiology and Infectious Diseases

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Abstract:

Leptospirosis is an important zoonotic disease found globally, in 2014 due to the launch of a new tetravalent vaccination and vaccine related reactions believed to be associated, it reached the public domain as a topic of debate. Not much is known about the current uptake of vaccinations and dog owner understanding of the disease and its vaccinations within the United Kingdom (UK) dog owning population.

The study aimed to analyse UK dog owner awareness and perceived risk of leptospirosis based on an online survey. 259 valid respondents were obtained. Results showed that awareness of leptospirosis correlated positively with high rainfall areas, multi-dog households, owners who obtain their dogs from abroad and those who visit the veterinarian twice yearly. Statistically significant findings were that discussion with veterinary staff increased owner awareness, increased visitations improved owner's opinion of veterinarian influentiality in relation to leptospirosis vaccinations and owners feeding raw food diets were less likely to vaccinate their dogs against leptospirosis. The findings highlight areas where the veterinary profession can enhance owner education, such as the causative agent, transmission route, possible hosts and causative pathologies. As well as areas of improvement, the findings suggest that owners feeding raw diets may require more education on the subject, and that increased visitations such as those in package schemes may enhance the owner-veterinarian relationship.

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1.0. Introduction

2.0. Literature Review

2.1. Global situation

Leptospirosis is an important zoonotic disease seen worldwide [1]. Although in the United Kingdom (UK) the disease is considered rare [2] it still poses a risk, with significant morbidity and mortality documented worldwide [3]. Severe disease can result from infection [4]. Human infections of leptospirosis were estimated in 2015 as over one million, with 58,900 deaths globally [5], and 55 confirmed cases reported in the UK alone in 2021 [6]. The disease is caused by free-living Gram-negative, aerobic, spiral, highly motile bacteria, with unique morphology. The bacteria is classified within the class Spirochaetia, order *Leptospirales*, family *Leptospiraceae*, genus *Leptospira* [7] and was originally divided into two species, "*Leptospira interrogans sensu lato*", involving the pathogenic strains and "*Leptospira biflexa sensu lato*", relating to the non-pathogenic saprophytic strains. However, these were superseded by the recognition of twenty-one species as of 2023, of which nine are recognised as pathogenic. In addition to this, there are 24 recognised serogroups and more than 250 serovars based on serological and antigenic similarities [8]. The serovar classification system of Leptospira is complex with some serovars spanning multiple species due to lipopolysaccharide similarities [8]. Knowledge of which serovars are in circulation plays a key role in vaccine development, low cross protection is documented with whole-cell inactivated vaccines (bacterins) or membrane preparations which are typically used commercially, however there appears to be a greater potential of protection with the advancement of a live attenuated vaccine [9]. As there is a distinct lack of knowledge of specific geographical occurrences of individual serovars due to the fastidious nature of the *Leptospira* genus, the subject of vaccine strain choice is increasingly important. Although few animal species are capable of acting as an efficient disease reservoir capable of harbouring renal colonisation, most mammals are susceptible to Leptospira infection [10]. Serovars and serogroups with relevance in Europe are detailed below (Table 1), highlighting serovars with increased importance in canines and humans (highlighted in blue). Serovars are further separated by their hosts which are discussed in section 2.2 "disease characteristics" below.

Table 1. Common circulating Leptospira strains in Europe and their hosts

Serogroup	**Serovars**	**Maintenance host**	**Secondary host**	**Reference**
Australis	**Bratislava,** Lora, Jalna, Muenchen	Su., Eq., Ca., Hedgehog	Ca., Ho., Bo., Eq.	UK, France, Switzerland, Germany [11–15]
Autumnalis	Autumnalis, Bim	Mouse	Ca., Ho., Bo.	Switzerland [7, 14]
Ballum	Ballum	Rodents	Rodents, Ho.	UK [11]
Canicola	**Canicola**	Ca.	Su., Rodents, Ca., Fe., Ho., Bo., Eq.	UK [16]
Grippotyphosa	**Grippotyphosa**	Rodents	Bo., Ov., Cap., Su., Eq., Ca.	UK, France, Germany [13, 15, 16]
Hardjo	Hardjobovis, Hardjoprajitno	Bo.	Ca., Ho., Su., Eq., Ov.	Italy [17]
Icterohaemorrhagiae	**Copenhageni, Icterohaemorrhagiae**	Rat	Ca., Fe., Ho., Bo., Eq., Su., Rodents	UK, France [11, 13, 16]
Kirshneri	**Grippotyphosa**	Rodents	Ca. Fe., Ho., Bo., Su., Ov., Cap., Rodents	Germany [18]
Pomona	Mozdok, Pomona	Small Rodents, Bo., Ov., Su.	Bo., Ov., Eq., Ca., Rodents	UK, France, Germany [11, 13, 15]
Pyrogenes	Pyrogenes	Rodents		UK [7]
Sejroe	Hardjo, Saxkoebing, Sejroe	Mouse	Bo., Ov., Rodents,	UK [11]

Abbreviations: (Bo.) Bovine, (Ca.) Canine, (Cap.) Caprine, (Eq.) Equine, (Fe.) Feline, (Ho.) Human, (Su.) Swine. (blue highlighted rows indicate current UK vaccine serovars and serogroups).

Although studies have highlighted eight important Leptospira serovars circulating Europe with increased risk to canines and humans, the World Organisation for Animal Health (WOAH) categorises disease caused by *L.interrogans* as "non-listed", with voluntary annual reports from members. Reporting does not include disease caused by *L.kirshneri,* due to this, knowledge of the exact circulating strains are not continuously updated, therefore risk cannot be fully characterised [19].

2.2. Disease characteristics

Zoonotic transmission from pathogenic *Leptospira* species have the potential to form a wide clinical disease spectrum in humans, including severe pulmonary haemorrhage, high mortality, and bleeding manifestations referred to as Weil's syndrome [20]. The bacteria is transmitted mainly by direct or indirect contact with the urine of infected animals via abrasions or mucous membranes, therefore occupational and recreational risks with infected animals and natural water sources exacerbate disease transmission likelihood [21]. Although urine is the main bodily fluid responsible for disease transmission, the bacterium also passes horizontally through milk, placental fluids, and venereal fluids as well as vertically via the transplacental route [22]. Leptospira's high invasivity is demonstrated by its ability to survive the host immune system, specifically serum complement killing, facilitating movement through tissues without any inflammatory influence, allowing them to reach select organs within one hour of infection [3]. Two types of host species exist for leptospirosis, these are the maintaining primary hosts and secondary hosts. Secondary hosts will be affected directly by the bacteria causing subclinical or clinical infection with a brief period of shedding prior to death or bacterial elimination, whereas primary hosts are not clinically affected but carry persistent Leptospira stores in their proximal renal tubules allowing for life-long shedding. Urinary shedding from asymptomatic dog populations has been shown to be as high as 7% in Ireland when detected with PCR [23]. Typical systemic consequences of the disease in their respected hosts are hepatic and renal insufficiency, endothelial cell damage, pulmonary disease, pyrexia, reproductive failure resulting in abortion and uveitis [22].

The host immune system generally responds to the bacterial invasion after a few days in order to eliminate the pathogen, however leptospiras have a multitude of immune system evasion tactics, including the degradation of IgG, complement, subsequent reduction of opsonophagocytosis and the obstruction of fibrin clot formation, resulting in increased dissemination of the bacteria [24]. Out of typical pathological lesions found with Leptospira infection, pulmonary lesions are deemed to be the most prominent necropsy finding in relation to increased mortality[25].

Diagnostics for leptospirosis focuses on the epidemiological situation, clinical signs, and laboratory testing. Laboratory test methods are not reliant on basic light microscopy or culturing due to Leptospira's fastidious nature, currently in the UK the methods used are Polymerase Chain Reaction (PCR), used to detect the leptospira agent, and Microscopic Agglutination Test (MAT) and Leptospirosis SNAP in clinic Enzyme Linked Immunosorbent Assay (ELISA) anti-LipL32 tests which are used for antibody detection [26]. MAT is restricted to a maximum of eight serovars for detection and represents a high-cost method resulting in false positive results due to vaccination, it may therefore not be appropriate for detection of newly emerging serovars despite its reputation as the gold standard. Although not affected by vaccination status, PCR may also result in false negative results due to a short bacteraemia phase and intermittent shedding in the urine, it is recommended that PCR should be used in correlation with clinical signs only [27]. Quick patient-side SNAP tests are commercially available, providing good accuracy in high MAT titre animals, and are useful with early treatment use pending external reference laboratory results, although it may take up to two weeks for antibodies to form, making it difficult to prescribe antibiotics at the appropriate time if this test is used alone in the early stages of infection [26].

Treatment of leptospirosis in dogs focusses on the combination of antimicrobial and supportive therapy with symptoms determining urgency in relation to acting prior to confirmed diagnosis. Recommended first-line antibiotics used are oral doxycycline or intravenous penicillin derivatives, with macrolides, tetracyclines, and aminoglycosides also documented for use as a second-line treatment. Fluoroquinolones are not recommended for use due to their inability to clear leptospiras [27]. In severe cases haemodialysis may be indicated, costing owners an estimated £2000-£4000 in 2023 for the initial three treatments required [28].

Increased risk of zoonotic transmission has been seen in males in rural areas due to contact with livestock and potential flooding implications [21],[29], [30]. Similar links were previously believed to exist in dogs [31], however this trend failed to be replicated in further studies [32], although a strong correlation was seen with disease incidence in rural clinics when compared to urban [33]. It is therefore important to apply preventative strategies especially within rural areas.

Prevention strategies for transmission largely relies on the application of vaccines, and avoidance of increased risk activities, for example swimming in open waters. As well as the aforementioned methods, alteration of the gastrointestinal microbiome has been shown in mice to reverse some pathological consequences of Leptospira, resulting in decreased infectivity, suggestive of future preventative applications parallel with the current strategies [34].

2.3. Vaccinations

The current World Small Animal Veterinary Association (WSAVA) guidelines categorises the leptospirosis vaccine as non-core [32]. The WSAVA recommendations are guidelines, created so that individual countries could choose their own recommendations based on disease likelihood. Contrary to the WSAVA, the British Small Animal Veterinary Association (BSAVA) classifies the vaccine as a core vaccine [35]; therefore recommending all UK dogs to receive the vaccine regardless of specific geographical location or circumstance. Due to the ability of the bacteria to cause acute, often fatal disease in dogs, zoonotic risk, and case occurrences there is a justified need for vaccination in the general population of UK dogs.

As of 2023 in the UK there are 20 authorised vaccines, most containing either two (L2) or four (L4) strains of Leptospira [36], with the exception of Eurican L multi® (Boehringer Ingelheim Animal Health UK Ltd). The vaccines currently on the market are shown in Table 2 below.

Table 2. Canine leptospirosis vaccines available in the U.K. and their components adapted from [25].

Species	*L.interrogans*							*L. kirschneri*
	Canicola		Icterohaemorrhagiae		Grippotyphosa		Australis	Grippotyphosa
Serovar	Canicola	Portland-vere	Icterohaemorrhagiae	Copenhageni	Grippotyphosa	Dadas	Bratislava	Grippotyphosa
Vaccine: Canigen Lepto 2		■		■				
Canixin DHPPi/L	■		■					
Canixin L	■		■					
Canixin Pi/L	■		■					
Duramune DAPPi & LC	■		■					
Duramune PI & LC	■		■					
Eurican L	■		■					
Nobivac Lepto2		■		■				
Virbagen L	■		■					
Vanguard 7	■		■					
Vanguard CPV-L	■		■					
Vanguard Lepto ci	■		■					
Canigen Lepto 4		■		■		■	■	
Nobivac L4		■		■		■	■	
Versican Plus DHPPi/L4	■		■				■	■
Veriscan Plus L4	■		■				■	■
Versican Plus Pi/L4	■		■				■	■
Versican Plus DHPPi/L4R	■		■				■	■
Versican Plus Pi/L4R	■		■				■	■
Eurican L Multi	■		■		■			

Although the vaccine strains used are largely reflective of the strains found in Europe (Table 1.), L2 vaccines reflect only the two previously most common isolates from diseased dogs in the European Union, focussing on L. Icterohaemorrhagiae and L. Canicola. A 25.5% reduction in clinical disease with artificially challenged dogs who received L2 vaccination showed a partial protective function of the vaccines [37].

Absence of L. Hardjo serovar as well as clear shortcomings of the L2 vaccines are apparent. Natural infection of wild virulent Leptospira may therefore occur, especially with the increased incidence of dogs travelling throughout Europe [38]. The Leptospira strains encountered may have few to none of the common epitopes used in the vaccination strains, therefore it is plausible that a dog may be affected by leptospirosis despite previous vaccination as there are no protective antibodies present, especially due to minimal cross protection and when an L2 vaccine is used. A higher protection against clinical disease and renal carrier status was documented (84% and 88% respectively) in a meta-analysis reviewing the L4 vaccine [39]. Although anecdotally providing appropriate protection, L4 vaccine failure has still been reported in Italy [40], showing that protection still cannot be guaranteed against natural challenge. Despite this, the superiority protection-wise of the L4 vaccine when compared to the L2 vaccine is evident.

As well as efficacy, there are current public concerns to safety in relation to the newer L4 vaccination [41].

The majority of public speculation occurred following the launch of the L4 vaccine by MSD Animal Health in 2014 “Nobivac L4 ®”, however, there were concerns prior to its launch in relation to owner-reported adverse events of the L2 vaccine, which was found to not have a significant increase in hypersensitivity reactions compared to other vaccines

although a slight increase in the incidence rate of owner reporting was seen [42], suggestive of owner distrust.

The Committee for Medicinal Products for Veterinary Use (CMPV) deemed the benefit risk balance of Nobivac L4 ® favourable [43]. Media back-lash in the UK questioned the safety of the vaccine following reported adverse events [44]. The UK Veterinary Medicines Directorate (VMD), who manage adverse event reports from veterinary surgeons, owners, and marketing authorisations, responded to the claims with a statement in 2017, reassuring veterinarians and the public that the amount of adverse events were rare [45]. Veterinary Voices UK further reflect this opinion [46].

As of 2020 suspected adverse events were still considered rare with less than six events reported per 10,000 doses of the L4 vaccine and two per 10,000 doses of the L2 vaccine. It is recognised that there may be significant under-reporting of vaccine adverse events, however, even with this in mind, the risk of infection is deemed to be greater [35], it is therefore recommended by the VMD and BSAVA (British Small Animal Veterinary Association) that UK dogs should receive the Leptospirosis vaccination following careful consideration between owners and their veterinarians of the individual risk factors [41].

Although leptospirosis is considered a core vaccination in the UK, utilisation of the vaccine is variable. In 2013 60% uptake of the vaccine was recorded [47], this differs from the 49% documented in 2016 [48], and 96% in 2017 [49], although the latter study only included animals attending the same clinic for two years minimum leading to a potential bias towards more responsible pet owning populations, and the prior 60% resulted from a survey study with a low response rate of 19%. Specific information on actual Leptospira vaccine uptake in the UK is therefore variable. Young dogs less than one year-old were found to be ten times more likely to be vaccinated than dogs over eight. As well as an age related bias, lower leptospirosis vaccine uptake was seen in bull breed dogs, uninsured dogs and in dogs kept in the south of England [48].

Lower socio-economic backgrounds are believed to impact owner choices, especially the implementation of the newer L4 vaccine, potentially due to the financial consideration of an additional vaccination required when changing from L2 to L4 [48]. Within the UK, Wales represented a region with a higher uptake of L4 than L2 and the East midlands recorded more L2 than L4. Overall lower uptake of any form of leptospirosis vaccine was

seen in the south of England and Ireland [48]. Vaccine uptake in different UK regions from 2016 is illustrated in Figure 1. Below.

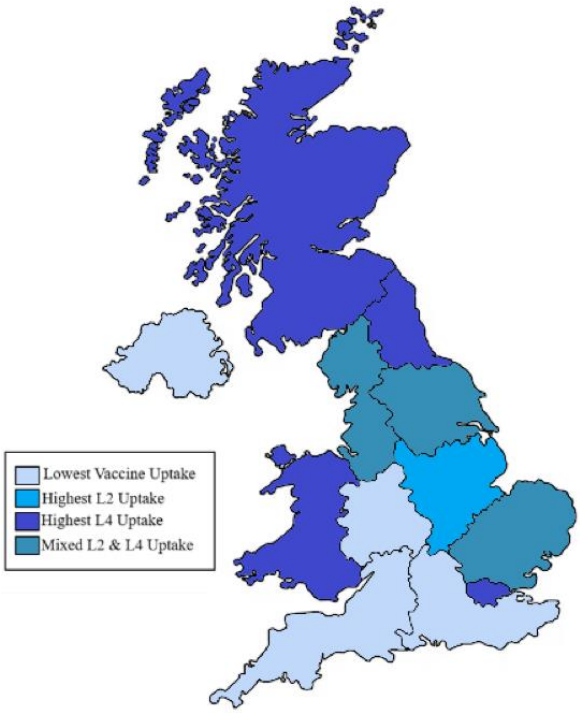

Figure 1. Uptake of leptospirosis vaccines in the UK in 2016 (adapted from [44])

Higher uptake of the vaccine, in particular the L4 vaccine was seen in largely more rural regions of the UK such as Wales and Scotland, reflecting the increased risk seen in these areas, it is not clear however if this is due to owner or veterinarian awareness and education [48].

Since the updated communications from the VMD regarding the safety of the L4 vaccine, there have been no studies determining the impact on the UK dog owning community and L4 vaccine use. Other confounding effects believed to play a role includes the effect of England's exit of the European Union and the COVID-19 pandemic experienced since 2019. Lower uptake of vaccination described as "vaccine fatigue", is believed to be a cause of increased unnecessary disease risk due to decreased population immunity and seen during the COVID-19 pandemic, this phenomenon is also believed to have spilled-out into veterinary field [50].

The Peoples Dispensary for Sick Animals (PDSA), a leading animal welfare charity in the UK, described a steady state of vaccination use throughout the past few years,

although still low when compared to the ideal. PDSA documented the top reasons for lack of vaccine uptake based on their surveillance these are described in the figure 2. below.

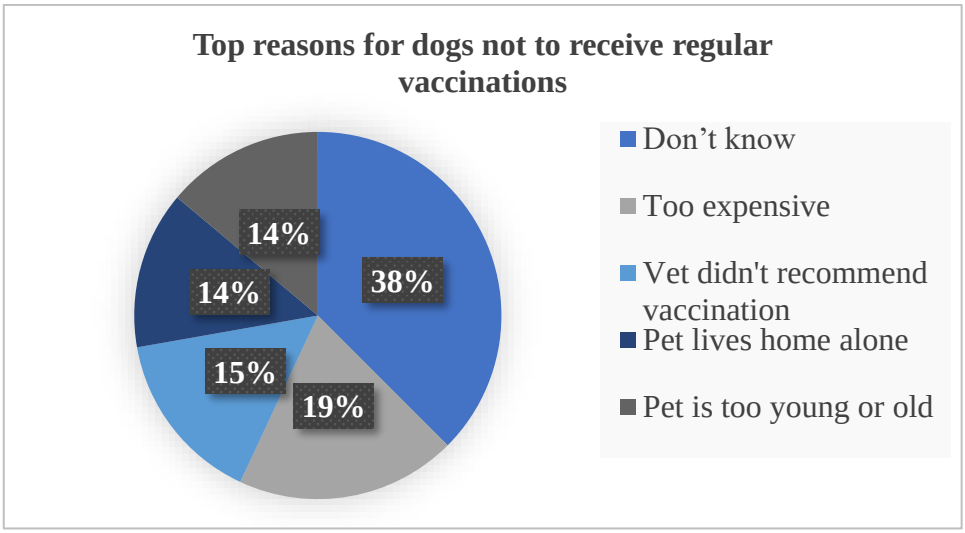

Figure 2. Top reasons for dogs not to receive regular vaccinations in the UK (adapted from[51])

These findings highlight prominent issues in relation to the vaccination. Socio-economic factors were already a known influential factor, explaining its role as the second highest answer given by owners. The lack of veterinarian recommendation is concerning due to the fact that both the WSAVA and BSAVA stipulates that the veterinarian must discuss vaccination choice with the owners as well as the fact that it is a core vaccination in the UK. As well as these, dogs age and housing status also highlights a lack of owner understanding of the epidemiology of the common diseases of dogs which are vaccinated against. In conclusion of the PDSA 2022 report it can be proposed that owner education and veterinary educating roles need to be vastly improved in order to help promote responsible vaccination strategies.

A previous study in 2021, determined that owners see veterinarians, social media, and the world wide web to be the most important influencing factors with regards to pet vaccination decision making. However, the study focussed on overall vaccination decisions, not detailing specific diseases and was not limited to the UK dog owning population [52]. There is an absence in understanding of UK dog owner influencing factors with regards to their specific decisions on Leptospirosis vaccinations despite its important clinical and zoonotic role.

3.0. Objectives/ questions

The primary aim of this study was to determine UK dog owners' current awareness and knowledge of leptospirosis and its associated vaccines. A secondary aim was to determine owner opinions of importance in relation to human and dog health. Thirdly, determination of whether there was a relationship between owner opinion, awareness or knowledge when compared to demographic characteristics and dog feeding preference.

During the author's time in clinical practice a higher-than-expected number of owners were wary of the L4 vaccine, requesting their dogs receive the L2 vaccine instead. When asked verbally for their reasoning owners claimed their concerns originated from their breeder's advice, therefore a final aim was to determine how influential veterinarians and other sources were in owner decision making for this vaccination when compared to other potential sources.

4.0. Materials and methods

4.1. Population of interest

The target population was all dog owners in the UK. The survey could be accessed by people globally, however only responses from the UK were included in the analyses reported in this study.

4.2. Survey structure

An anonymous web-based survey was developed to identify pet owner opinions and understanding of leptospirosis and its vaccination, and to characterise the most influential factors for their opinions. The questionnaire contained twenty-one questions (mostly closed, with some open other responses as shown in Table 3).

Section one established owner demographics, detailing owner: age, gender, education level, number of dogs in current household, location, profession, current feeding practices, where they obtained their dogs from, current vaccination status of their dogs and against what they are vaccinated. Correspondents who responded that they did not vaccinate their dogs were filtered to a free-text box additional question as to why they chose not to vaccinate, prior to entering section two.

Section two determined owner awareness and knowledge of leptospirosis, focussing on owner awareness of the existence of leptospirosis, understanding of the causative agent, methods of transmission, possible hosts, and clinical pathologies of the disease.

Section three investigated owner opinion of importance of the disease for dog and human health and whether they have had a conversation with veterinary staff in relation to leptospirosis and its vaccinations within the last nine years.

Section four used a Linkert scale to determine the level of influence certain factors had on owner's decision making with regards to their vaccination choices. The section asks how frequently they consult with various influential people and how influential they deem different sources to be regarding their choice of vaccination.

Survey correspondents were unable to be filtered throughout the survey due to software restrictions, however during the analysis of the data appropriate data sets could be made.

Incomplete responses were excluded from analysis as well as those from respondents not living in the UK.

4.3. Survey development and distribution

The survey was developed online using Crowdsignal® (Automatic Inc.; https://crowdsignal.com/) software. Questions were developed based on study objectives and similar investigations [52]. Respondents were presented with an introduction and GDPR statement, they were able to opt into the survey by clicking to proceed and opt out at any time by closing the survey. Distribution was through an anonymous single-use link. A pilot study was conducted with ten dog owners of variable ages and involvement in the veterinary industry to ensure the questions were clear, appropriate and that the survey could be completed within the suggested timeframe.

Post-pilot definitive version of the survey was launched on 01.11.2022, questions as shown in Table 3 below and distributed via various methods (Table 4.), including permission for re-distribution and sharing. The survey remained open until 1st of June 2023.

Table 3. Finalised questionnaire questions post-pilot

No.	Question	Answers
1	Which age category do you fit within?*	18-28, 29-39, 40-50, 51-61, 62+
2	Which gender do you associate with?*	Female, Male, prefer not to disclose, Other**
3	What is the highest level of education you have completed?*	Bachelor's degree, GCSE/ N5/ Highers/ O-Level, A Level/ International Bachelorette/ Advanced Higher/ BTEC, master's degree, Foundation degree Associate degree (HND equivalent), PhD, Other**
4	How many dogs are in your current household?*	1, 2, 3, 4+
5	Which region of the UK do you live in (more than 6 months a year)?*	Southeast (England), Southwest (England), East Midlands (England), Northwest (England), Wales, East of England, Scotland, Yorkshire and The Humber, London, West Midlands (England), Northeast (England), Northern Ireland, Other**
6	Have you previously/ are you currently working or studying within the veterinary or human medicine field? If so, please explain.*	Yes, No. Open answer**
7	Which of the following apply best to your chosen dog feeding method (more than one may be chosen)*	Commercial dry, Commercial wet (cooked), Commercial wet (raw), Homemade with meat (cooked),

		Homemade without meat (cooked), Homemade raw, Veterinary specialised diet
8	Where did you obtain your dog(s) from? (More than one option may be chosen) (Kennel club registered breeder refers to any register of breeder, not specific to an assurance scheme)*	Kennel club registered breeder, Rescue UK, Home bred (on purpose) , Unofficial breeder, Rescue abroad, Home bred (accidental), Local accidental breeding, Other**
9	Have you ever heard of leptospirosis?*	Yes, No
10	Are your dog(s) vaccinated?*	Yes (all of my dogs are vaccinated), No (none of my dogs are vaccinated, Some of my dogs are vaccinated (if so, please comment below your reasonings). Open answer **.
11	If your dog(s) are vaccinated what are they vaccinated for? (Select all that apply)	Parvovirus, Distemper, Hepatitis, Leptospirosis, Kenne cough, Parainfluenza, Rabies, I do not know
12	What do you believe leptospirosis is caused by?*	Bacteria, Parasites, Viruses, Fungi, It has an undiscovered cause, I do not know, Other**
13	How do you believe leptospirosis can be transmitted? (Select all that you believe may apply)*	Drinking contaminated water, Contact with urine, Contact with contaminated soil, Contact with saliva, Contact with blood, Ingestion of faeces, Contact with semen, Ingestion of slugs, Bite wounds, Airborne infection, Insect bites, I do not know, None of the above
14	Do you believe leptospirosis is an important disease for dog health?*	Yes, No

15	Do you believe leptospirosis is an important disease for human health?*	Yes, No	
16.	Who do you believe can contract leptospirosis? (Select all that apply)*	Dogs, Humans, Rodents, Cats, Horses	
17.	Which of the following do you believe to be an effect of leptospirosis? (Select all that apply)*	Kidney disease (Nephropathy), Liver disease (Hepatopathy), Fever (Pyrexia), Vomiting (Emesis), Heart inflammation (Myocarditis), Brain inflammation (Meningitis), Eye inflammation (Uveitis), Lung bleeding, Blood clots (Thrombosis), Intense itching (Pruritis), Hair loss (Alopecia), I do not know	
18.	Has your veterinary surgeon or nurse discussed the different forms of leptospirosis vaccines available in the past 9 years?*	Yes, No	
19.	Are your dog/s currently given the L2 or L4 form of the leptospirosis vaccine?*	L4, L2, My dogs are not vaccinated against leptospirosis, I do not know which, but they are vaccinated against leptospirosis, I do not know what my dog is vaccinated against	
20.	How frequently do you consult with the following persons relating to general advice on your dog's health?*	Veterinary surgeon	More than twice a year, Twice a year, Yearly, Rarely/ only when sick, Never
		Veterinary nurse	
		Pharmacist	
		Veterinary paraprofessionals (groomer/ hydro therapist/ physiotherapist)	
		Breeder	
21		Veterinary surgeon	Very influential, Somewhat
		Veterinary nurse	

	Please select how influential you believe each source is in your decision on the leptospirosis vaccine.*	Pharmacist	influential, Slightly influential, Neutral, Not influential
		Veterinary paraprofessionals (groomer/ hydro therapist/ physiotherapist)	
		Breeder	
		Friends and family (non-veterinary)	
		Peer-reviewed journals	
		Popular magazines (E.g., Dogs today)	

* = Mandatory questions, ** = Open answer options, free text.

Table 4. Platforms used for survey dissemination.

Platform	Specifics
Facebook*	Friends Family Canine cognitive decline Staplehurst helping page. Wycombe Dog owners Dog Friendly UK Veterinary Student questionnaire distributing Vet Partners
Email*	Women's institute Vet Partners Ltd
Physical survey acquisition	Local parks of Kent

*Where eligible participants recruit others

4.4. Data management and analysis

Responses were analysed and downloaded from Crowdsignal® (Automatic Inc.; https://crowdsignal.com/) into Microsoft Excel Version 2306 for data management. Responses were excluded if they were from respondents outside of the UK, were incomplete, or respondents did not tick that they had any dogs and were therefore not in the target population of the survey. Owners who have previously or are currently working or studying within the veterinary or human medicine field were excluded from section three and four analyses as there was a bias towards veterinary influence, however their section two knowledge responses were included for data analysis purposes.

Free-text responses detailing reasons for not vaccinating, were extracted into a separate spreadsheet in Microsoft Excel. Responses were read and categorised dependent on whether their influential factors.

Section 2 knowledge responses were graded based on the quantity of correctly chosen answers. The possible correct answers are shown below in Table 4

Table 5. Knowledge question correct answers.

Knowledge question	**Correct answers**
12. What do you believe leptospirosis is caused by?	Bacteria
13. How do you believe leptospirosis can be transmitted? (Select all that you believe may apply)	Drinking contaminated water Contact with urine. Contact with contaminated soil. Contact with saliva. Contact with blood. Ingestion of faeces Contact with semen
16. Who do you believe can contract leptospirosis? (Select all that apply)	Dogs Humans Rodents Cats Horses

17. Which of the following do you believe to be an effect of leptospirosis? (Select all that apply)	Kidney disease (Nephropathy) Liver disease (Hepatopathy) Fever (Pyrexia) Vomiting (Emesis) Heart inflammation (Myocarditis) Brain inflammation (Meningitis) Eye inflammation (Uveitis) Lung bleeding Blood clots (Thrombosis)

Further statistical analysis to assess significance was conducted using social statistical online software. ANOVA tests were available using: https://www.socscistatistics.com/tests/anova/default2.aspx and T tests were available using: https://www.statskingdom.com/150MeanT2uneq.html respectively.

5.0. Results

364 respondents were recorded, 104 were incomplete, n = 259.

5.1. Section one: Demographics

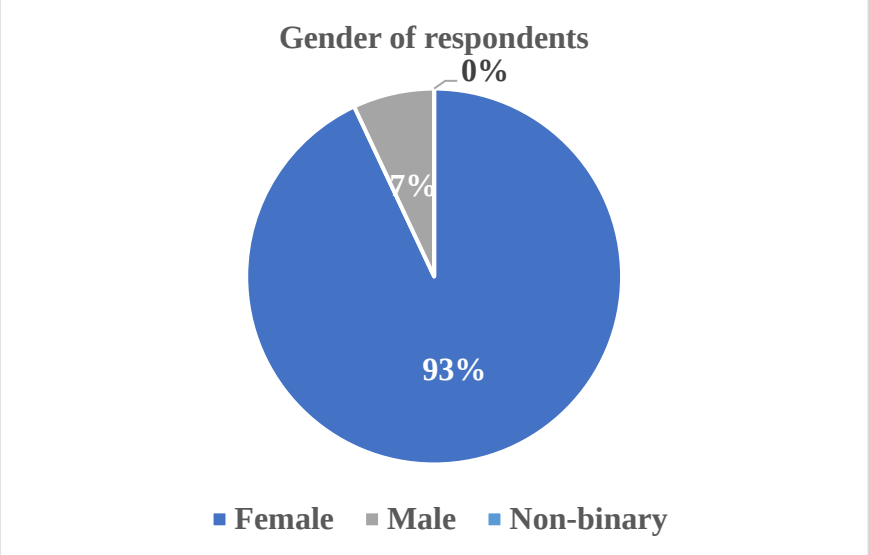

Chart 1. Gender demographics

Chart 1 demonstrates gender demographics of respondents with 93% female respondents recorded.

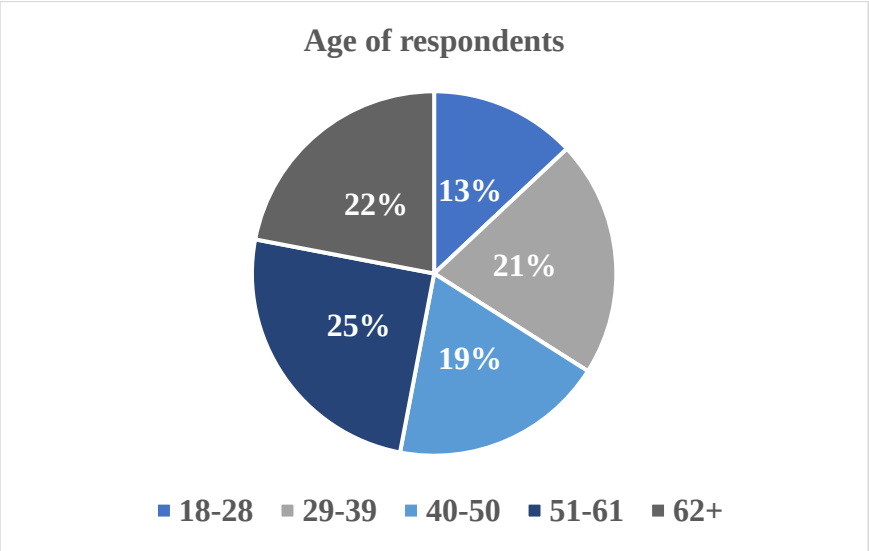

Chart 2. Age demographics

Chart 2 demonstrates age demographics of respondents, with the 25% representing 51-61-year-olds.

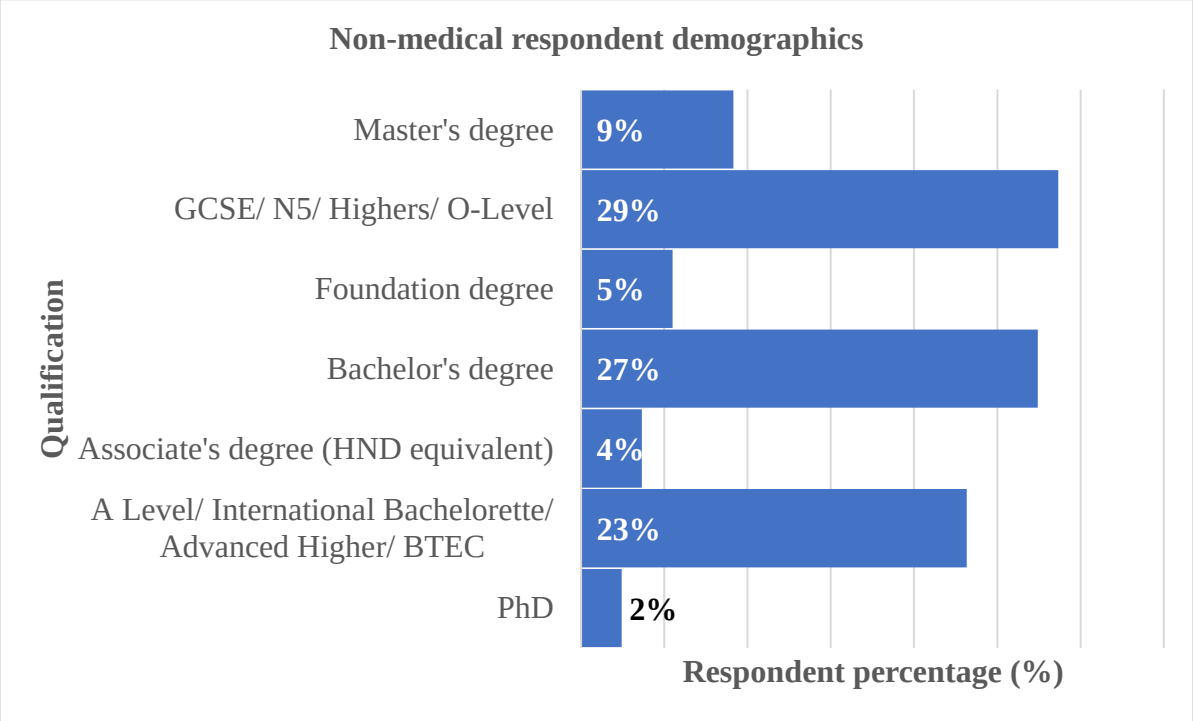

Chart 3. Education demographics

Chart 3 demonstrates that the most common highest level of qualification is GCSE/N5/Highers/O-levels representing 29%.

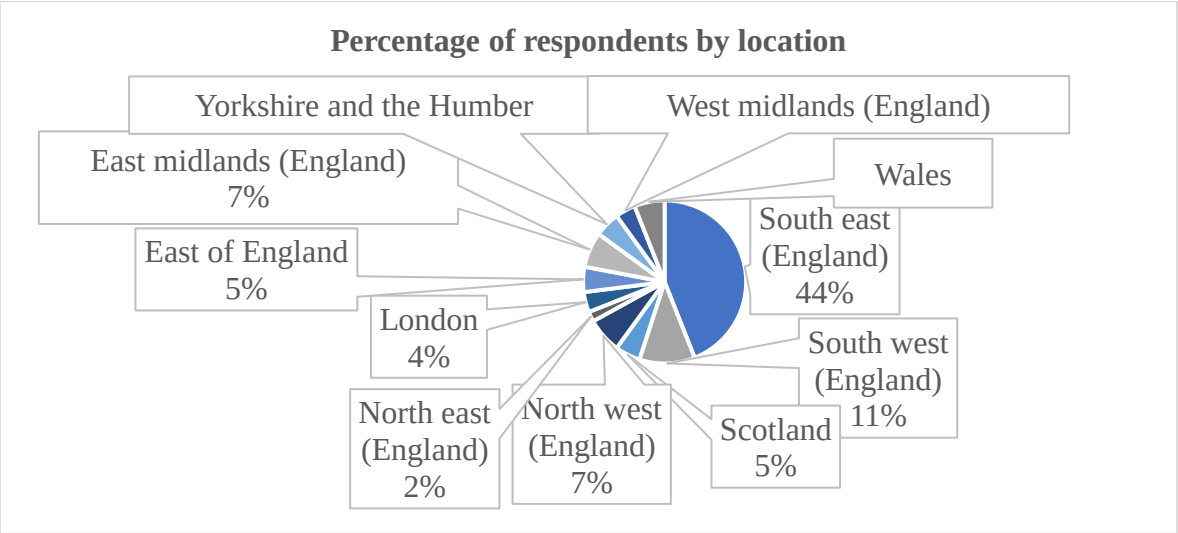

Chart 4.Regional residency demographics

Chart 4 demonstrates the largest proportion of respondents originating from the southeast of England (44%).

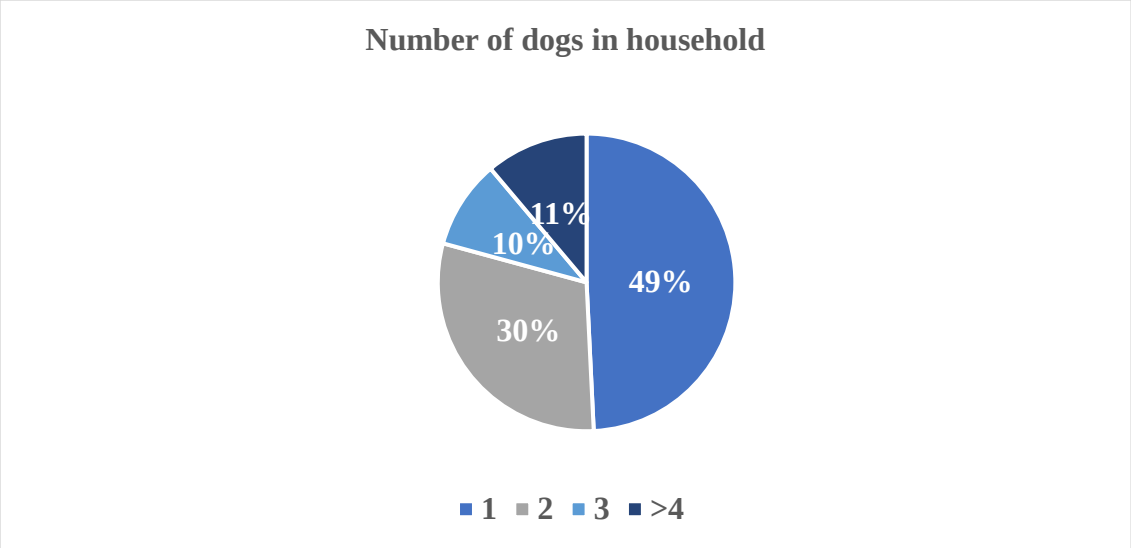

Chart 5. Dog number demographics

Chart 5 demonstrates that the majority of respondents have one dog households (49%).

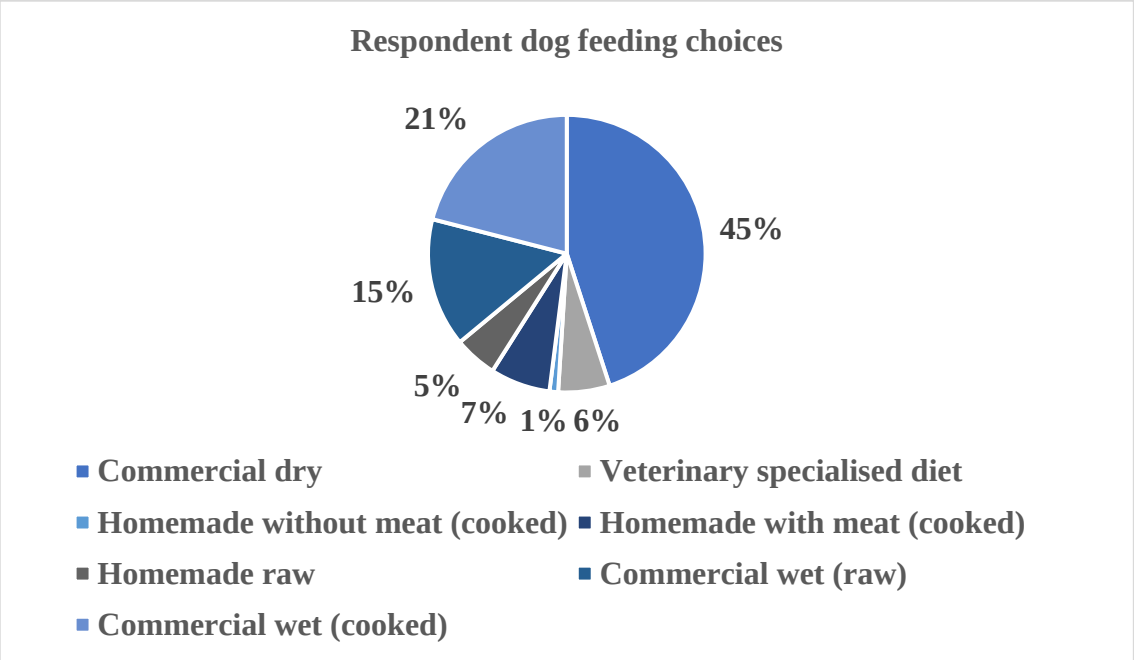

Chart 6. Dog feeding preference demographics.

Chart 6 demonstrates that the majority of respondents feed commercial dry dog food (45%).

5.2. Section two: Awareness and Knowledge

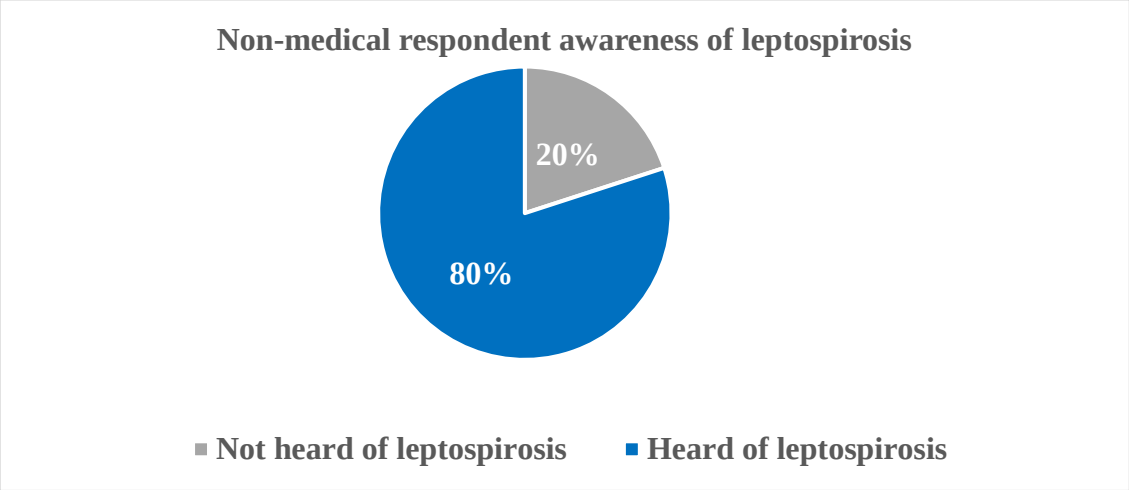

Chart 7. Non-medical respondent awareness of leptospirosis

Chart 7 demonstrates 80% of non-medically trained respondents have heard about leptospirosis.

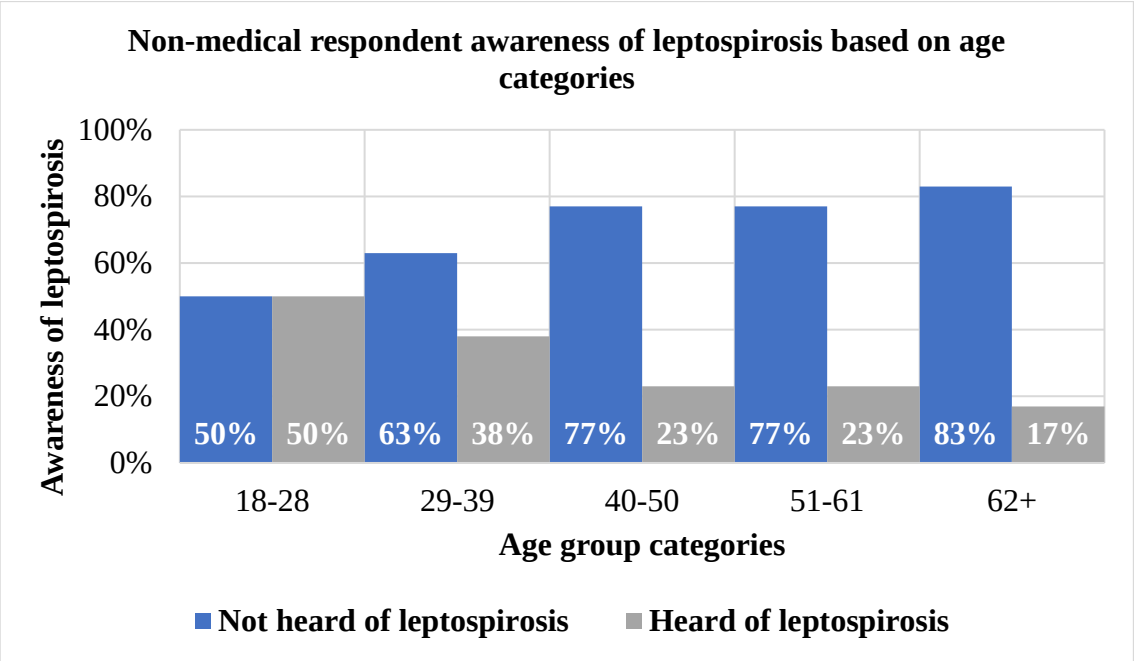

Chart 8. Non-medical respondent awareness of leptospirosis based on age.

Chart 8 demonstrates that the highest awareness of leptospirosis is seen in respondents who are 18-28 years old (50%).

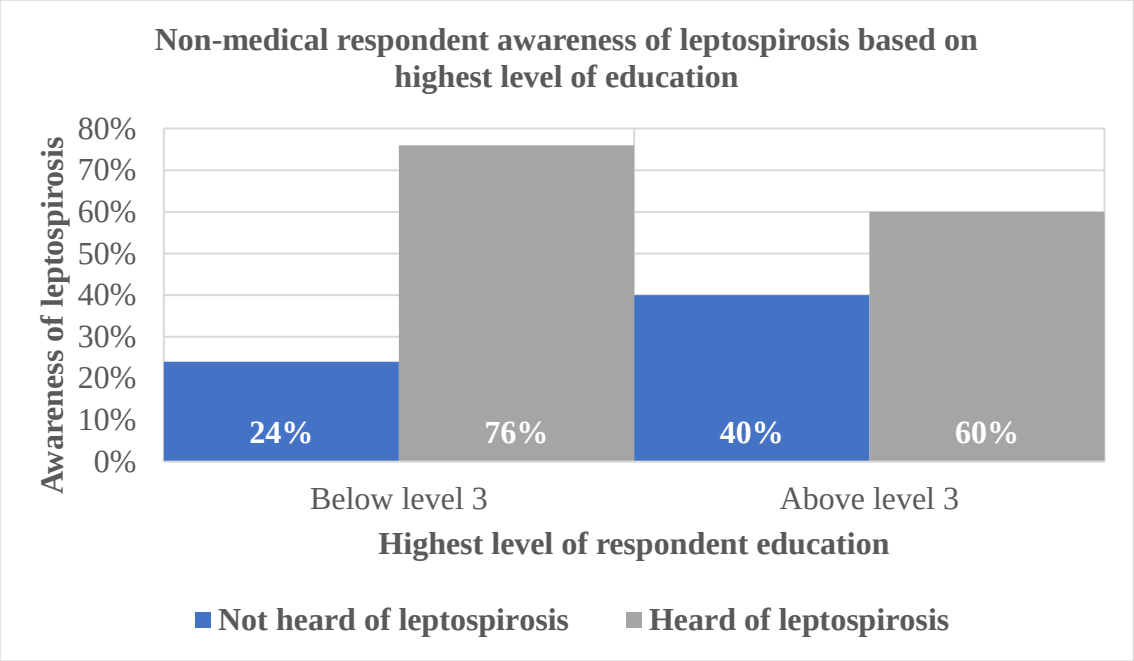

Chart 9. Non-medical respondent awareness of leptospirosis based on education.

Chart 9 illustrates lower levels of awareness in those with education level above level three 60%.

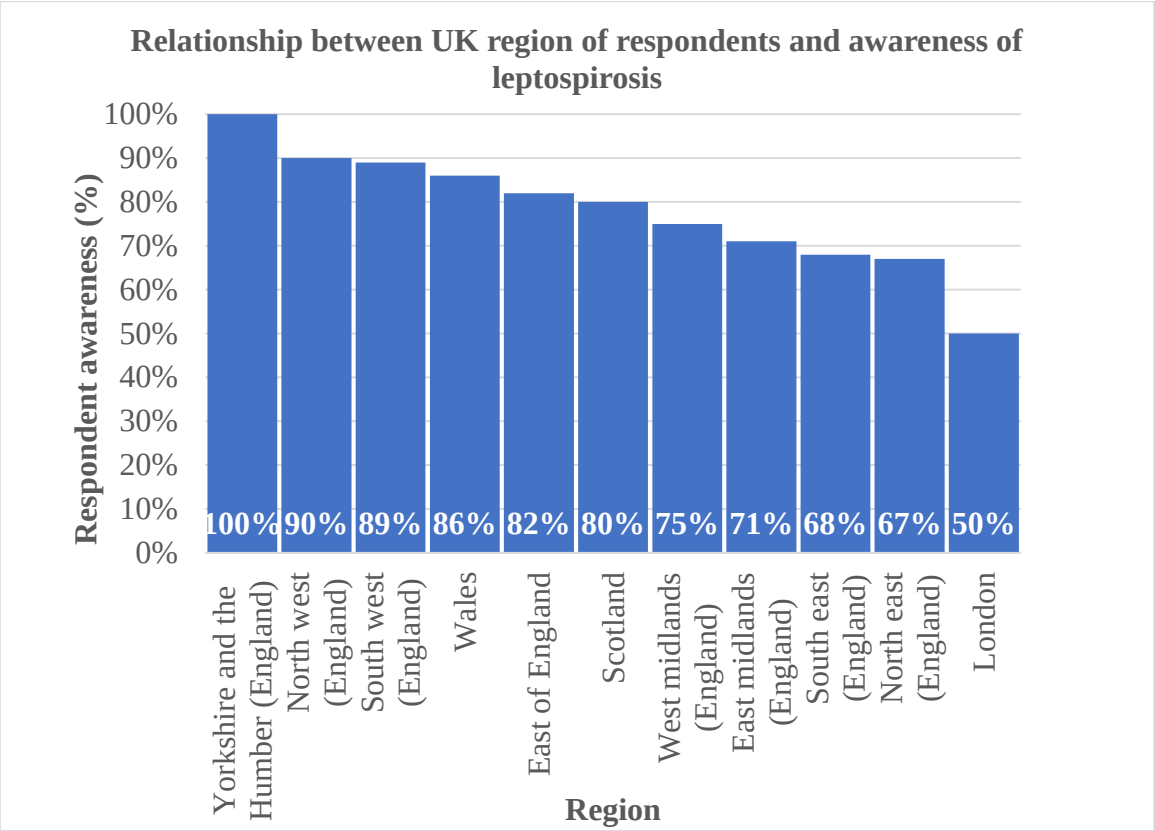

Chart 10. Non-medical respondent awareness of leptospirosis based on region.

Chart 10 demonstrates that the highest level of awareness (100%) was seen in respondents from Yorkshire and the Humber (England), and lowest from London (50%).

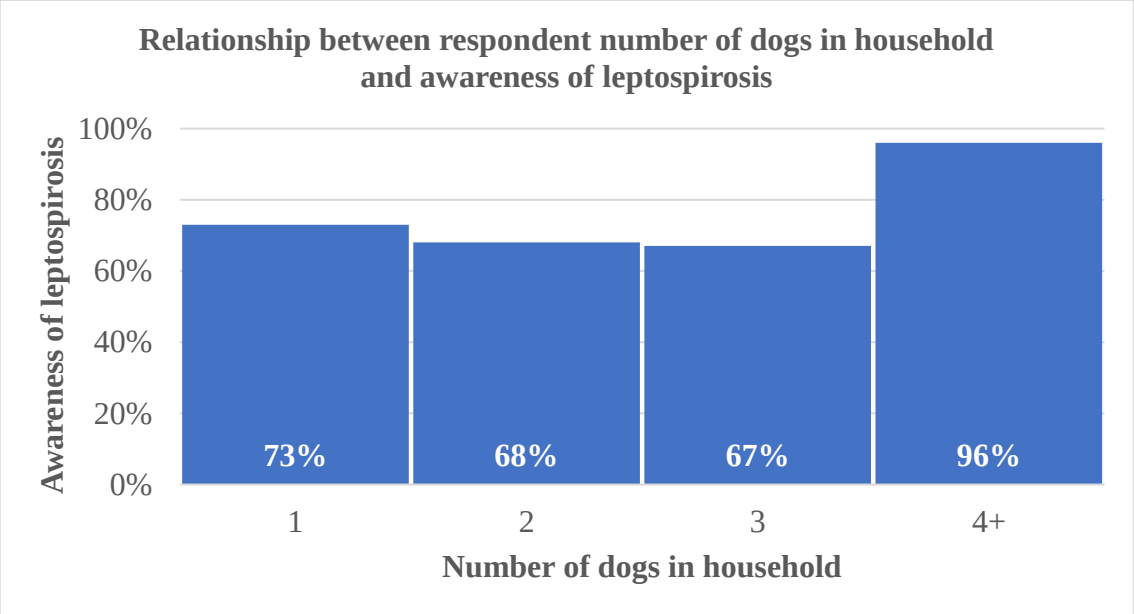

Chart 11. Non-medical respondent awareness of leptospirosis based on number of dogs.

Chart 11 demonstrates a higher level of awareness in respondents with more than four dogs per household (96%).

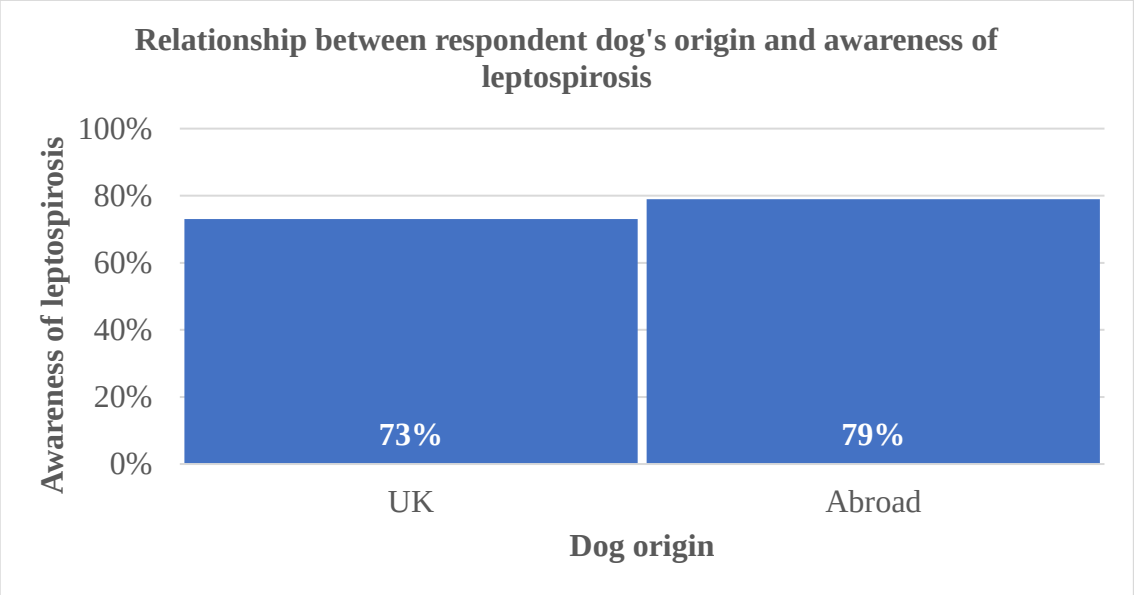

Chart 12. Non-medical respondent awareness of leptospirosis based on dog origin.

Chart 12 shows an increased awareness in respondents with dogs originating from abroad (79%).

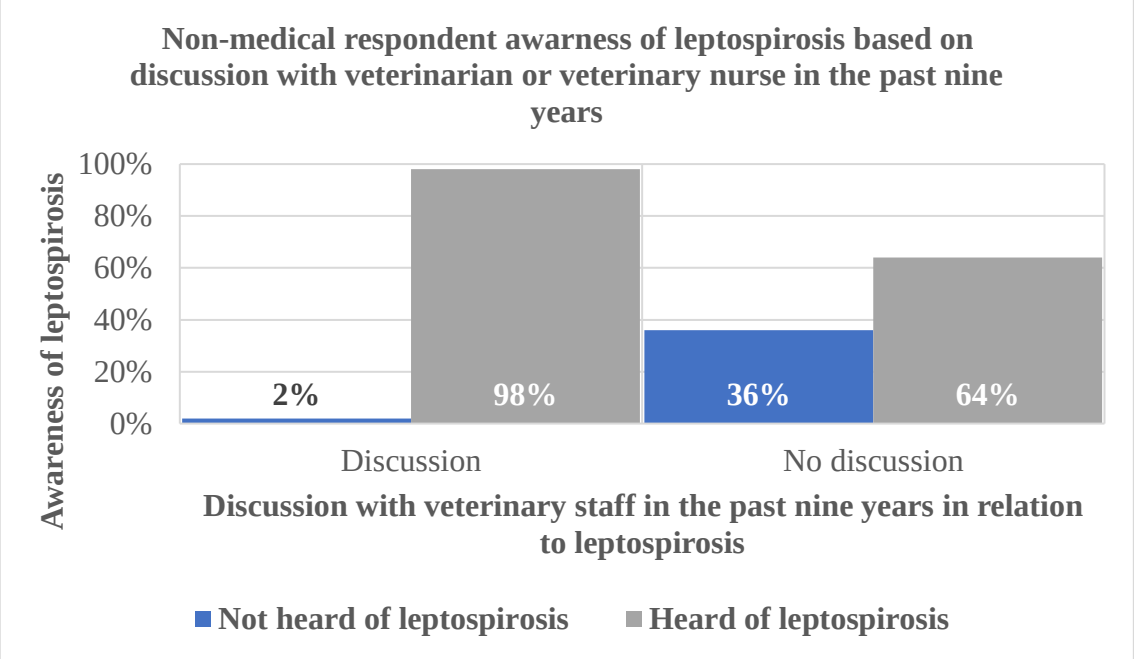

Chart 13. Non-medical respondent awareness of leptospirosis based on discussion with veterinary staff.

Chart 13 illustrates that owners who have discussed leptospirosis in the past nine months have higher awareness of the disease (98%) compared to those without (64%). This relationship was investigated using an un-paired T-test, finding it to be statistically significant (P=< 0.0001) as shown in table 6.

Table 6. Unpaired T-test assessing leptospirosis awareness and discussion with veterinary staff in the past nine years.

	Discussion with veterinary staff in the past nine years relating to leptospirosis and awareness of leptospirosis	
	Discussion	**No discussion**
Sample average ($\bar{x}$)	0.16	0.62
Sample size (n)	56	127
Sample standard deviation (SD)	0.37	0.48
P-value	**<0.0001 (0.01%)**	
T-value	**6.38**	

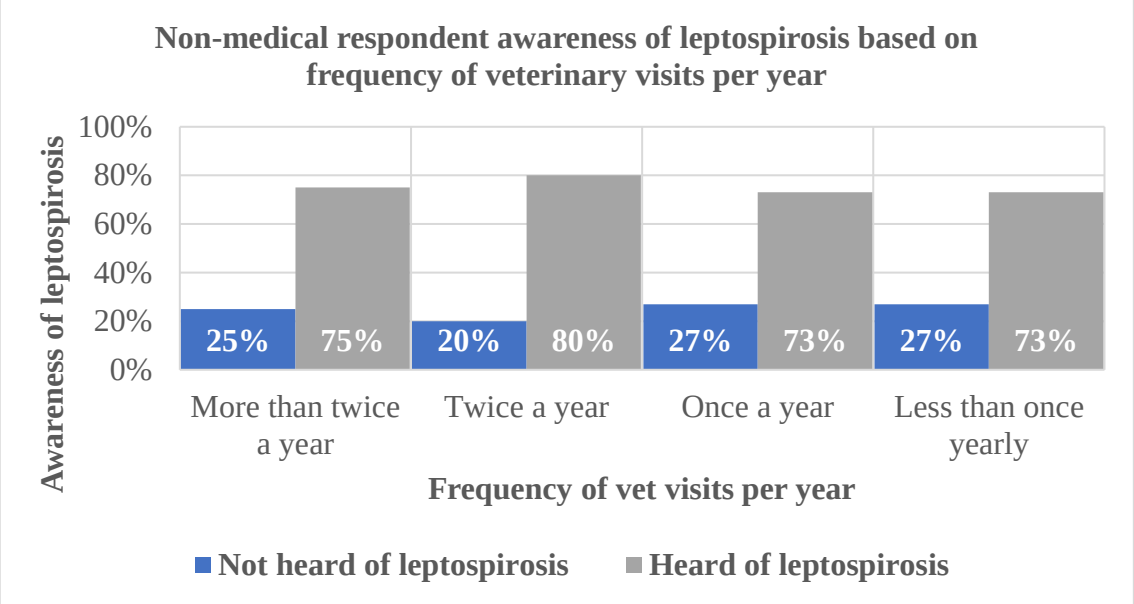

Chart 14. Non-medical respondent awareness of leptospirosis based on vet visit frequency.

Chart 14 demonstrates a positive correlation between veterinary visits and respondents having heard of leptospirosis (80% twice yearly as opposed to only 73% less than once yearly).

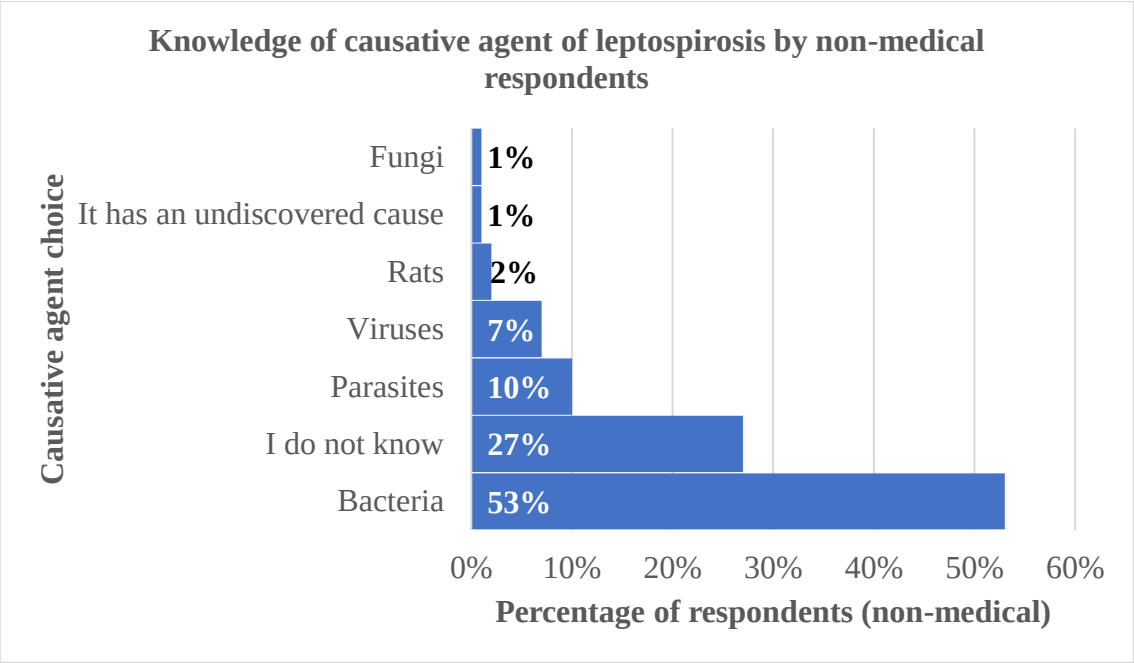

Chart 15. Non-medical respondent causative agent identification

Chart 15 demonstrates that only 53% of non-medical respondents identified bacteria as the causative agent of leptospirosis. with 27% admitting they do not know.

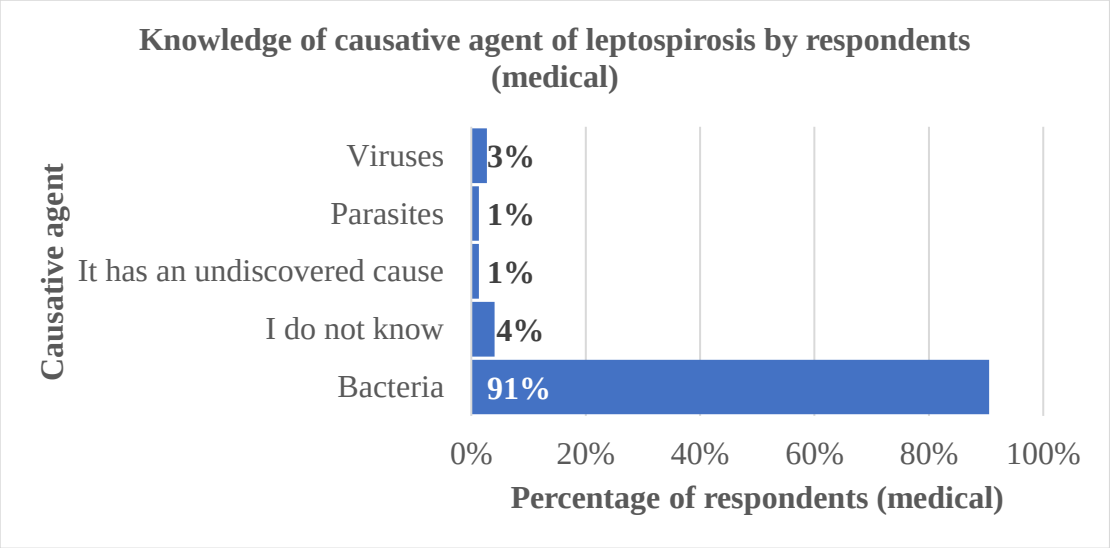

Chart 16. Medical respondent causative agent identification

Chart 16 demonstrates that 91% of medically trained respondents identified bacteria as the causative agent of leptospirosis with 4% admitting they did not know.

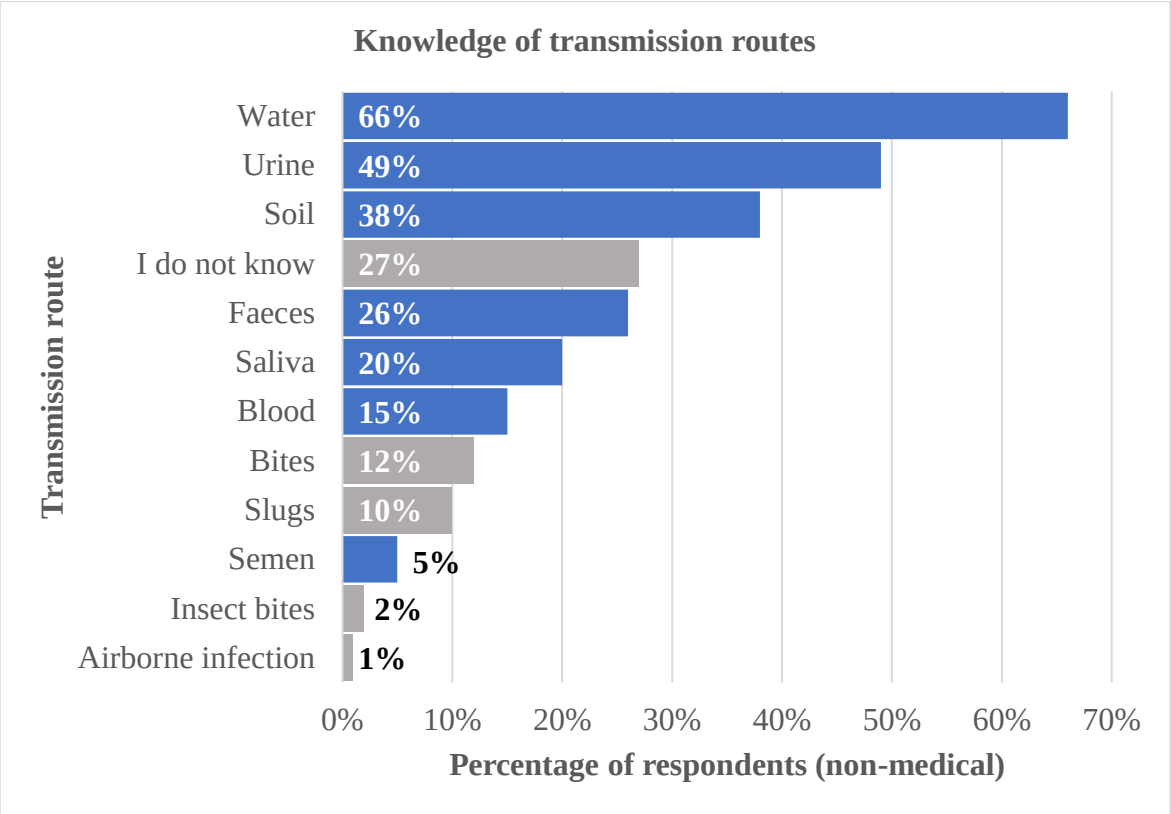

Chart 17. Non-medical respondent transmission route identification

Chart 17 demonstrates that 66% of non-medical respondents identified water contamination as a transmission route. Semen was the lowest recognised route (5%).

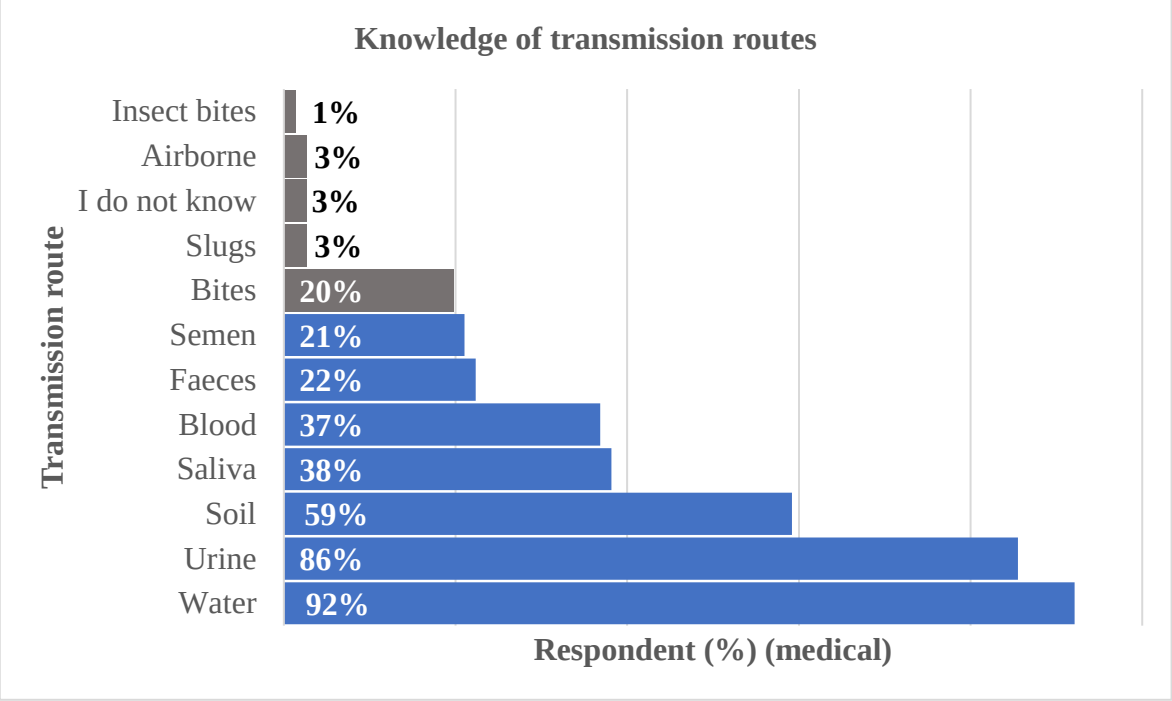

Chart 18.Medical respondent transmission route identification

Chaet 18 demonstrates that 92% of medically trained respondents identified water contamination as a transmission route, with semen being the lowest recognised transmission route (21%).

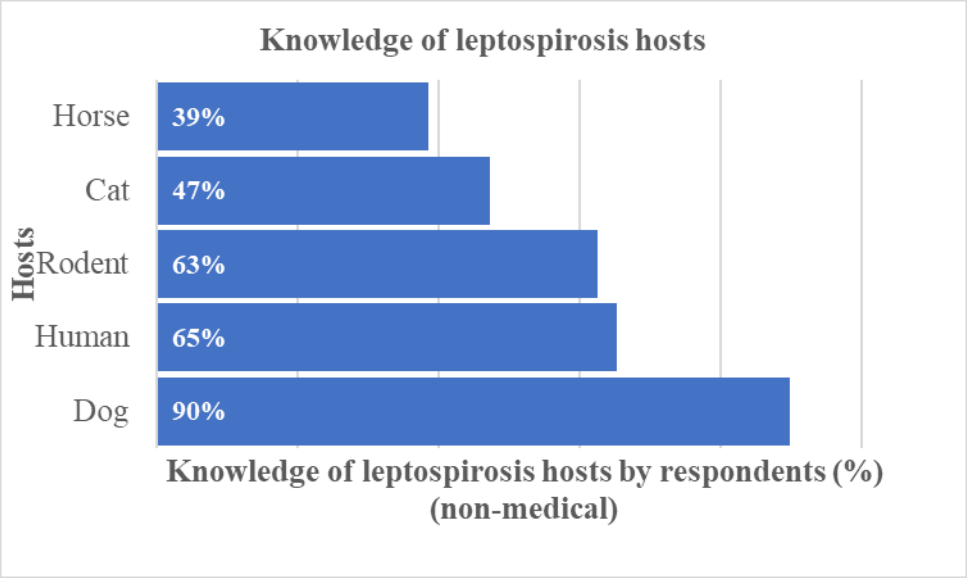

Chart 19.non-medical respondent host identification

Chart 19 shows that the most recognised host species by non-medical respondents was dogs (90%).

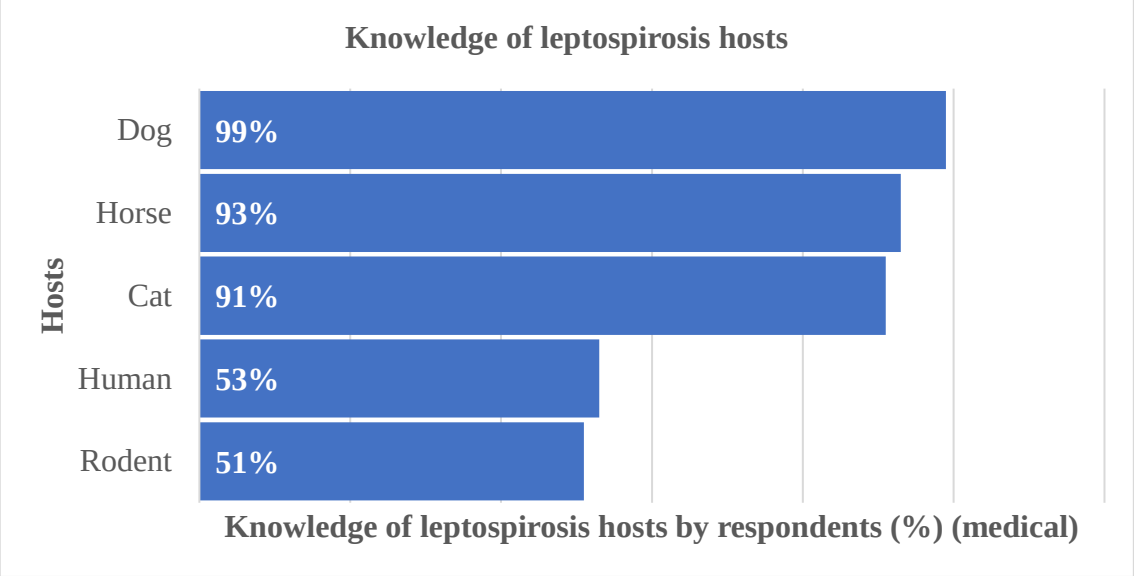

Chart 20.Medical respondent host identification

Chart 20 shows the most recognised host species by medically trained respondents was dogs (99%).

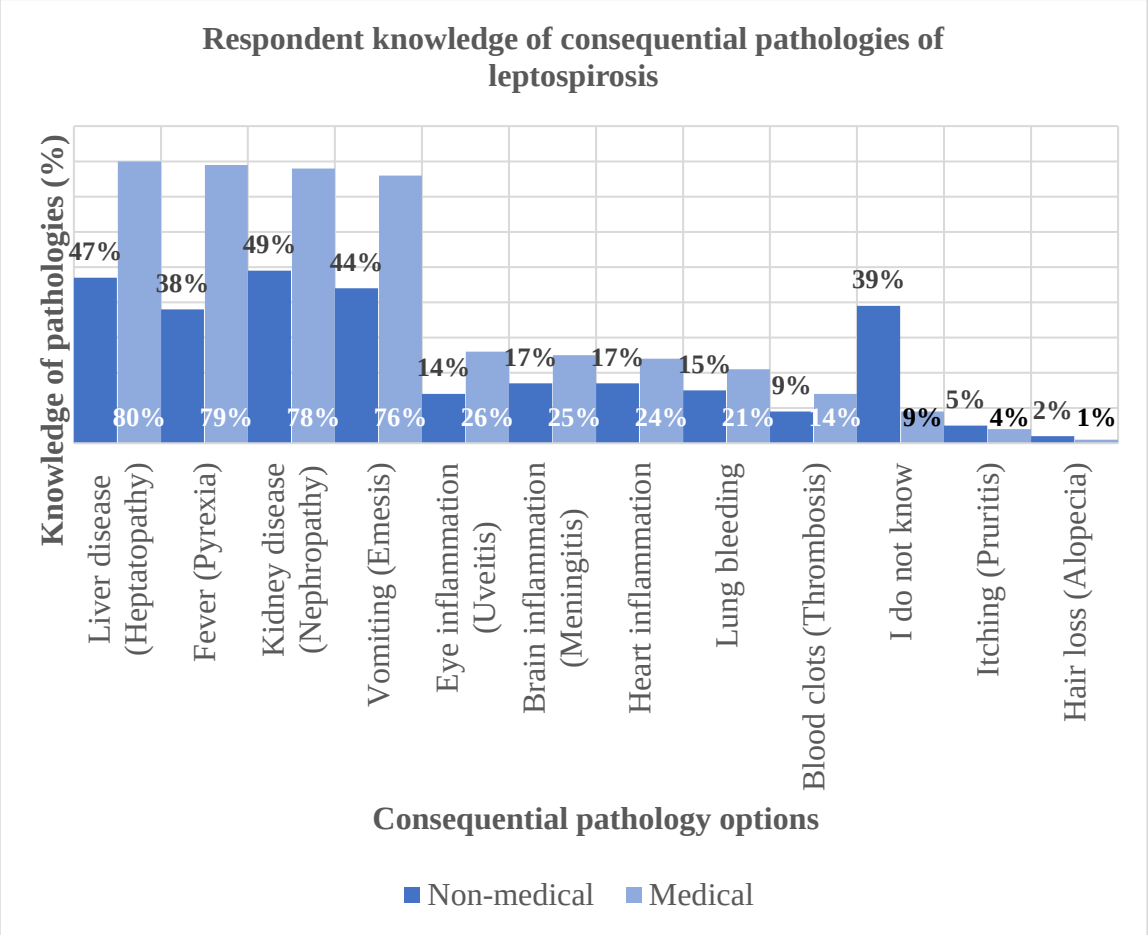

Chart 21.Respondent consequential pathology identification

Chart 21 demonstrates that the most reported consequential pathology of non-medical respondents was kidney disease (nephropathy) (49%), and liver disease (hepatopathy) in medically trained respondents (80%). Thrombosis was the least recognised consequential pathology (9% non-medical; 14% medical). 19% of non-medical respondents admitted they do not know the consequential pathologies of leptospirosis.

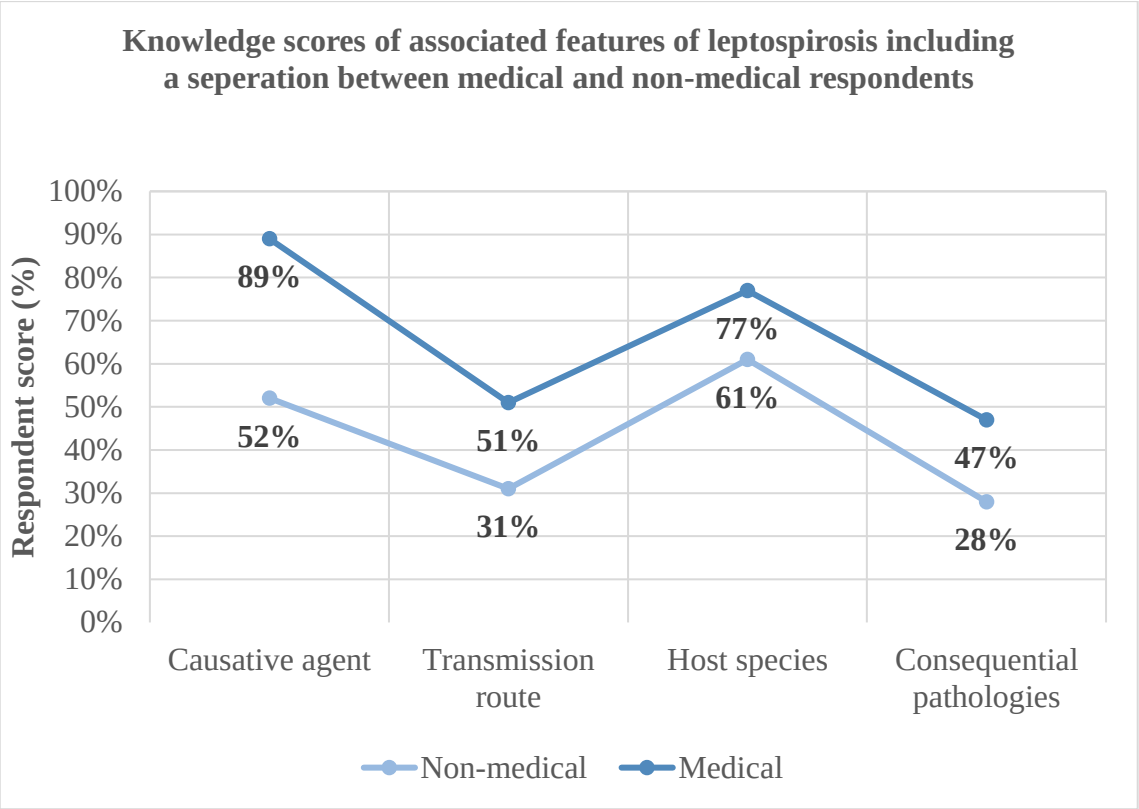

Chart 22. Respondent knowledge scores

Chart 22 demonstrates the overall higher knowledge scores seen in medically trained respondents compared to non-medically trained respondents. Highest scores were achieved in relation to the causative agent for medically trained respondents (89%) as opposed to the host species identification (61%) identified by non-medically trained respondents.

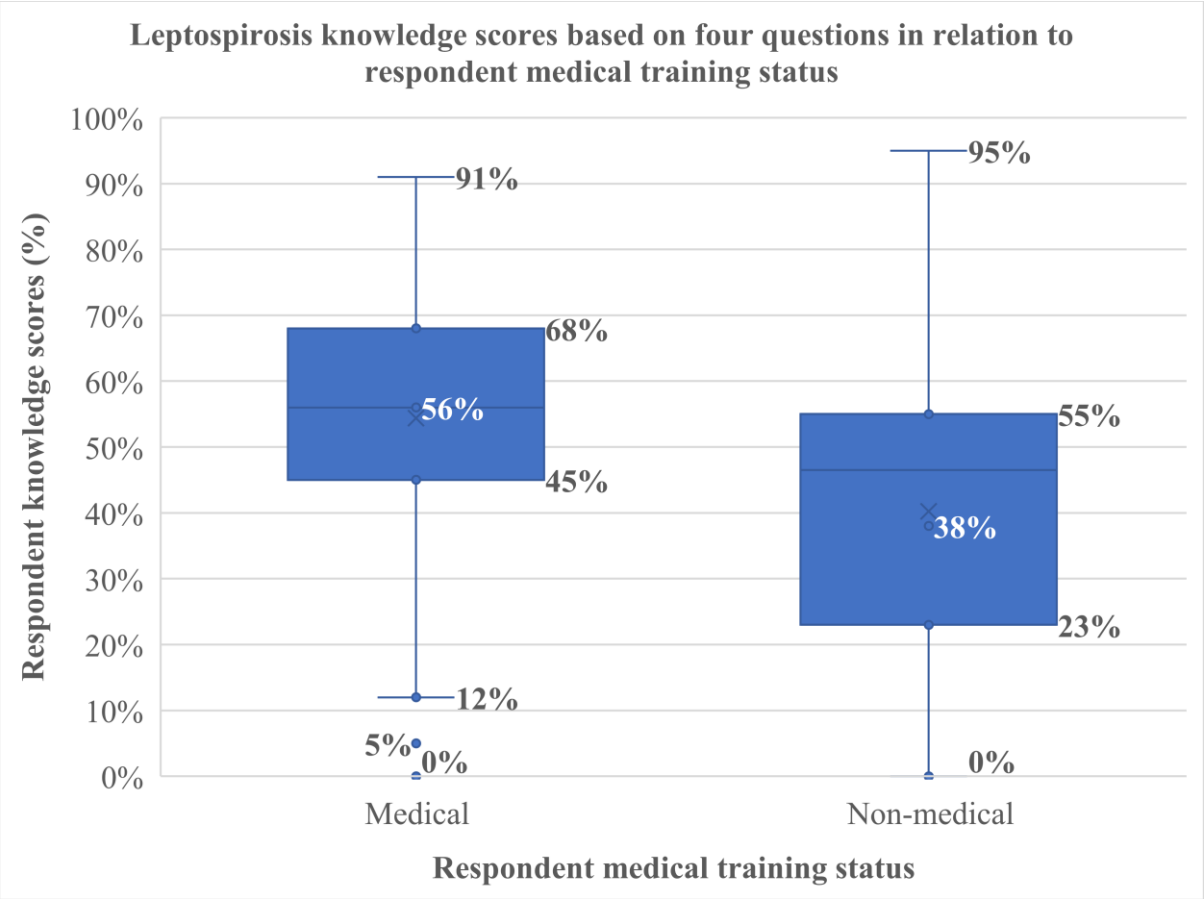

Chart 23. Respondent total knowledge score distribution

Chart 23 shows an average knowledge score of 56% by medically trained respondents as opposed to 38% with non-medically trained respondents. Table 7 demonstrates the further analysis of knowledge score based on age categories with the highest total knowledge scores of non-medically trained respondents being seen in the 40-50-year-old age category (47%), and the lowest in 29-39-year-olds. Table 8 shows that medically trained respondents highest scores were seen in the 62+ age group (72%) and lowest in the 51-61-year-old category (58%).

Table 7. Non-medical respondent knowledge scores separated by age categories.

Non-medical background owners					
Knowledge question	**Average percentage score**				
	18-28	**29-39**	**40-50**	**51-61**	**62+**
12. What do you believe leptospirosis is caused by?	45.45%	34.38%	65.71%	53.85%	55.77%
13. How do you believe leptospirosis can be transmitted? (Select all that you believe may apply)	33.77%	27.23%	33.88%	31.87%	31.59%
16. Who do you believe can contract leptospirosis? (Select all that apply)	63.64%	60.00%	55.43%	65.00%	61.92%
17. Which of the following do you believe to be an effect of leptospirosis? (Select all that apply)	32.32%	22.22%	32.70%	29.27%	26.50%
Average knowledge score	43.8%	36.0%	46.9%	45.0%	43.9%

Table 8. Medical respondent knowledge scores separated by age categories.

Non-medical background owners					
Knowledge question	**Average percentage score**				
	18-28	**29-39**	**40-50**	**51-61**	**62+**
12. What do you believe leptospirosis is caused by?	90.9%	95.65%	85.71%	75.00%	100.00%
13. How do you believe leptospirosis can be transmitted? (Select all that you believe may apply)	51.9%	52.80%	55.10%	38.10%	54.29%
16. Who do you believe can contract leptospirosis? (Select all that apply)	75.5%	80.00%	78.57%	68.33%	92.00%
17. Which of the following do you believe to be an effect of leptospirosis? (Select all that apply)	39.9%	51.21%	51.59%	50.00%	40.00%
Average knowledge score	64.6%	69.9%	67.7%	57.9%	71.6%

5.3. Section three: Importance

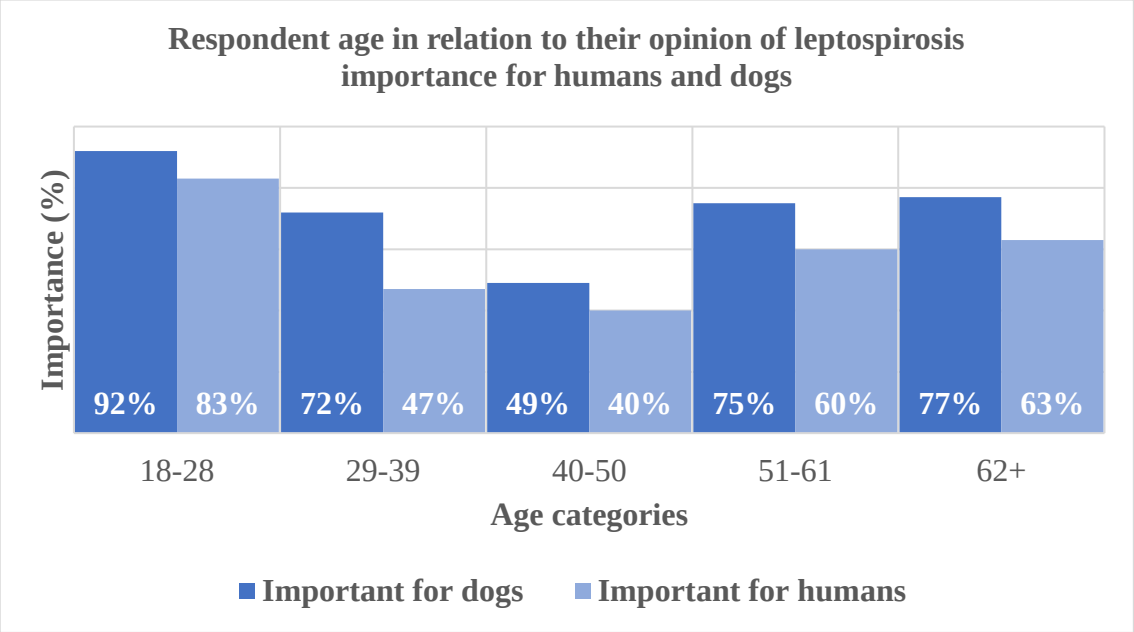

Chart 24. Respondent association of importance of leptospirosis based on age category.

Chart 24 demonstrates a higher importance of leptospirosis for both humans and dogs from respondents in the 18-28-year-old age category (92%;83%) as opposed to the lowest importance assigned by 40-50-year-olds (49%;40%).

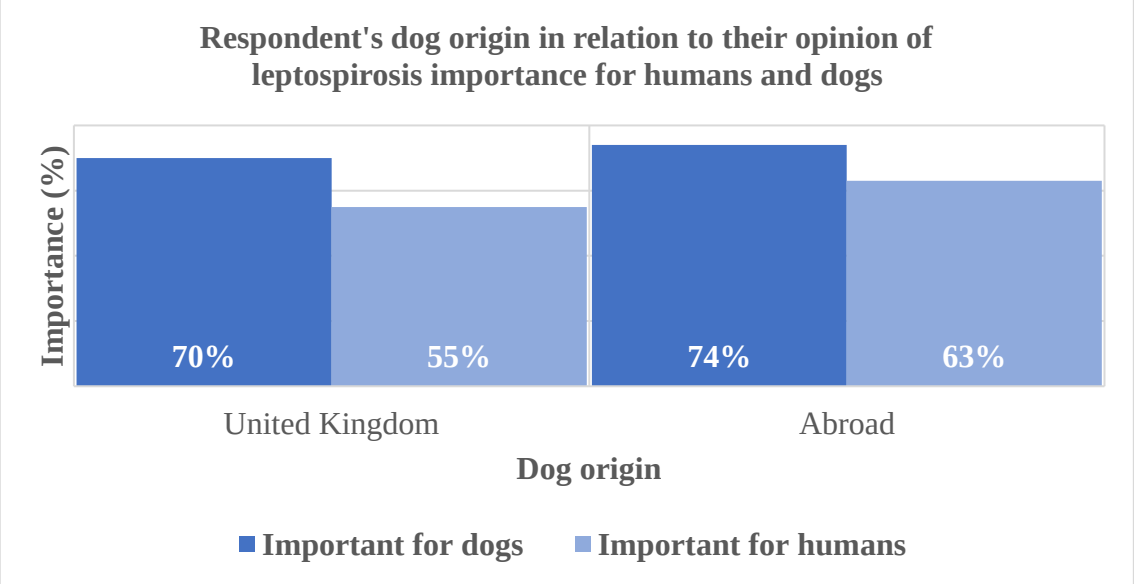

Chart 25. Respondent association of importance of leptospirosis based on dog origin.

Chart 25 demonstrates higher importance of the disease associated with respondents obtaining their dogs from abroad (74%; 63%).

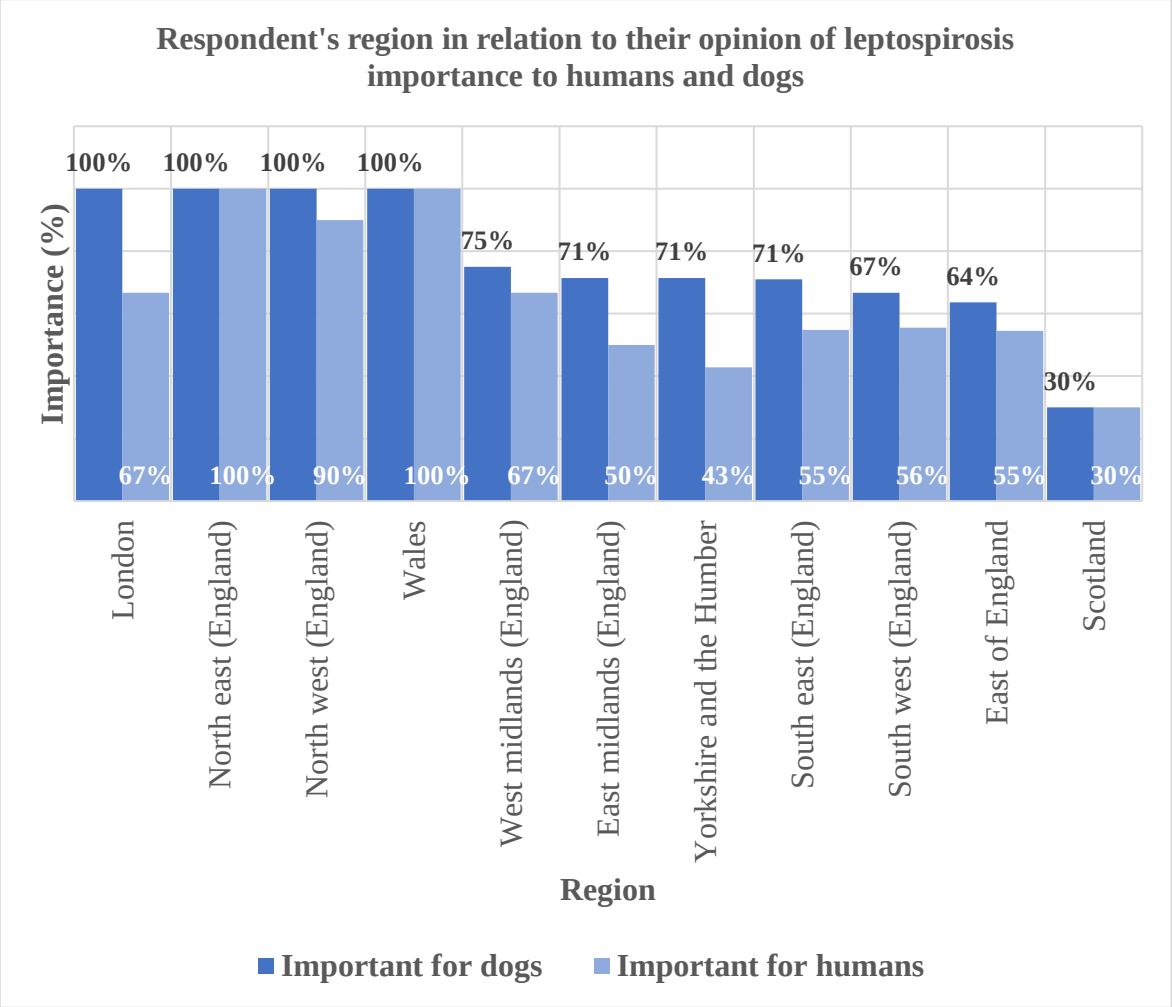

Chart 26. Respondent association of importance of leptospirosis based on region.

Chart 26 shows London, north-east, north-west, and Welsh based respondents to have associate the highest importance of the disease for dogs (100%), with the highest association with human health being from Welsh and north-east respondents. Lowest associated importance of the disease for both dogs and humans were from residents of Scotland (30%; 30%).

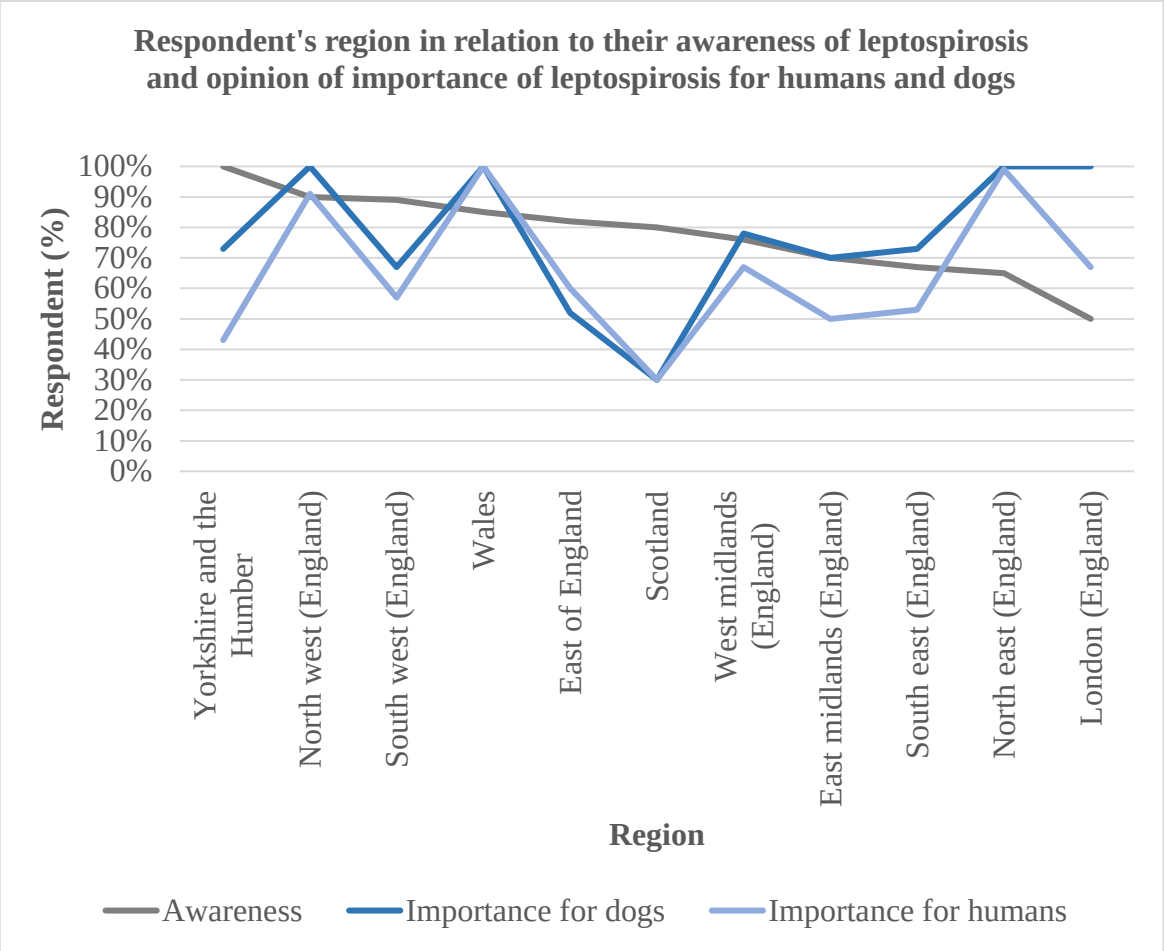

Chart 27. Respondent association of importance of leptospirosis based on region, compared with awareness of the disease in the regions.

Chart 27 demonstrates the highest level of awareness of leptospirosis as well as deemed importance from respondents in the Yorkshire and Humber region.

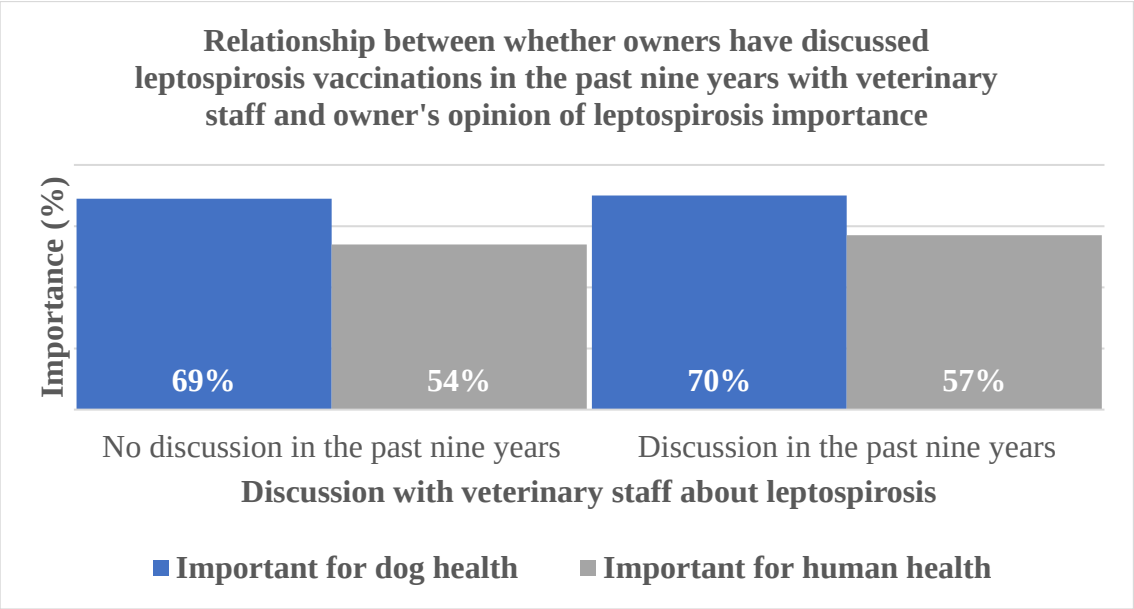

Chart 28. Respondent association of importance of leptospirosis based on discussion with veterinary staff.

No significant differences were seen in relation to importance of leptospirosis with respondents who had discussed leptospirosis in the past nine years in chart 28.

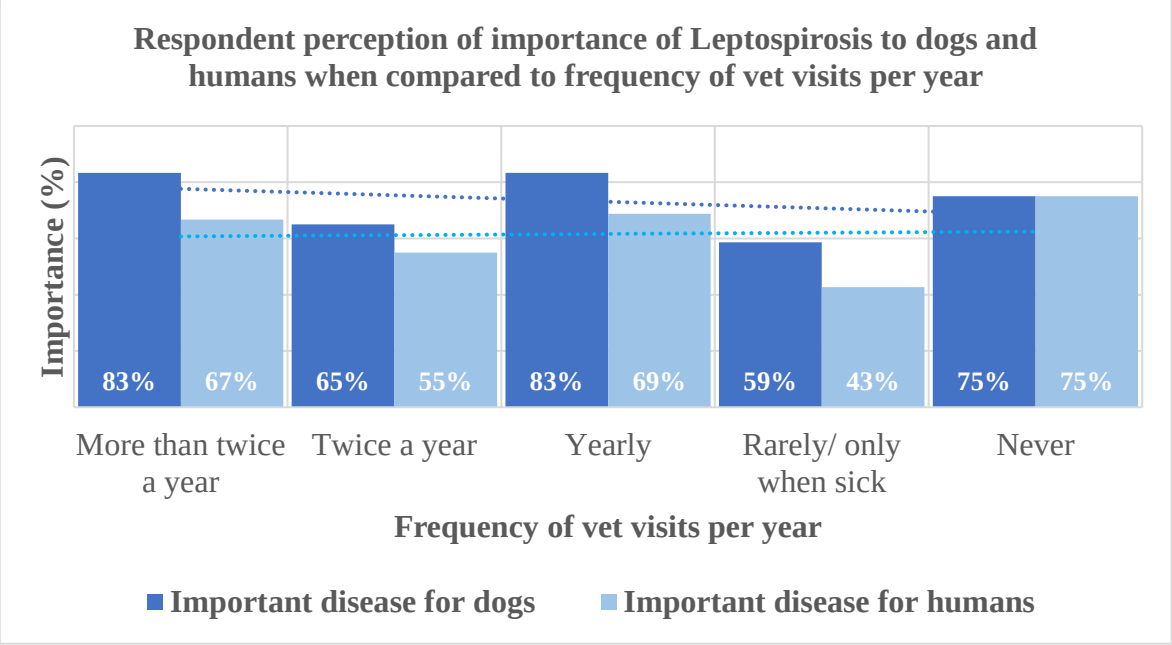

Chart 29. Respondent association of importance of leptospirosis based on frequency of vet visits.

Chart 29 shows a slight positive trend in relation to respondent associated importance of leptospirosis in dogs and the frequency of veterinary visits per year.

5.4. Section four: Influence

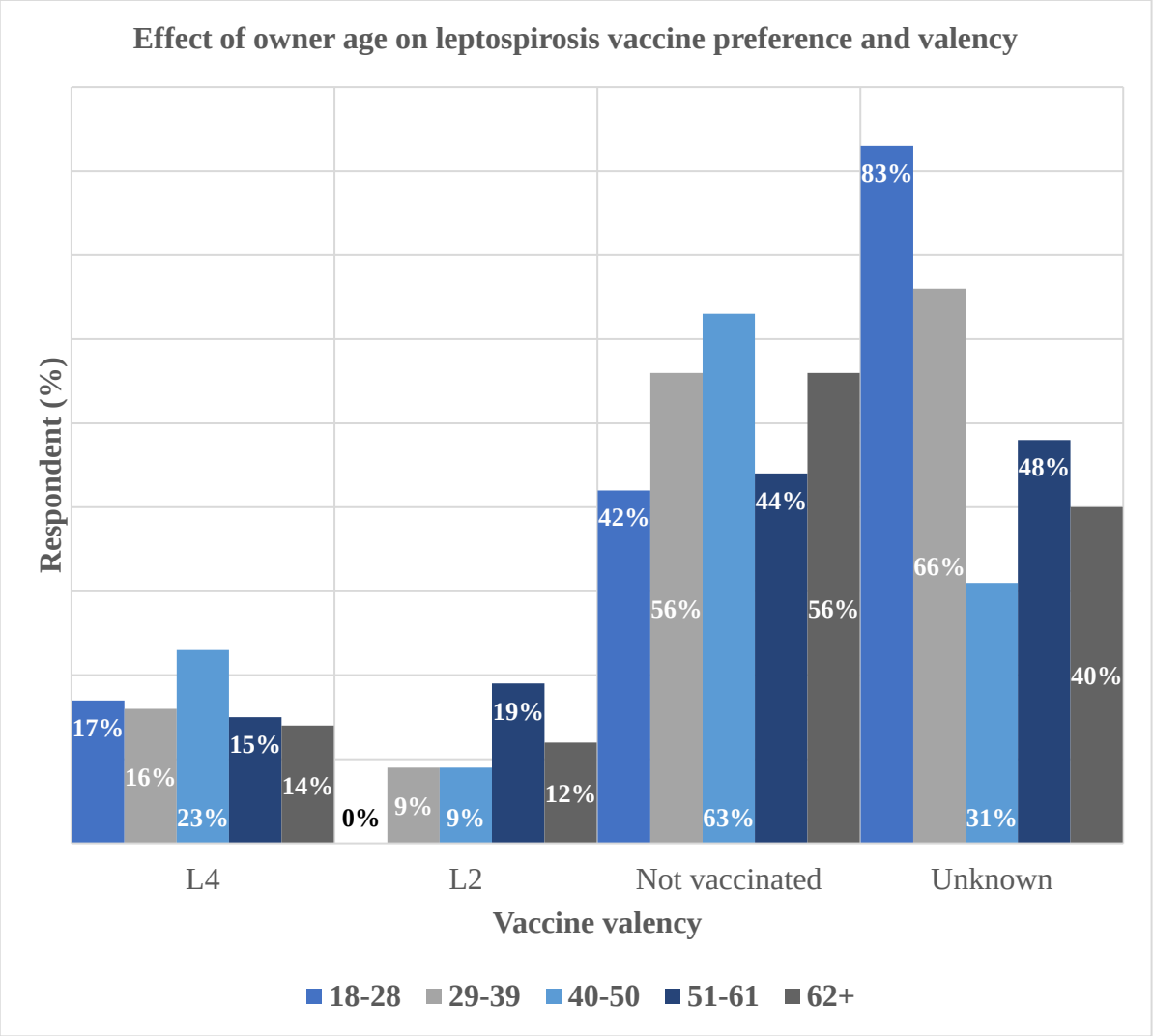

Chart 24. Vaccine valency dependent on age category

Chart 30 demonstrates the highest number of respondents who do not know what their dogs are vaccinated against to be those in the age category of 18-28-years-old (83%). 40-50-year-olds are least likely to vaccinate (63%).

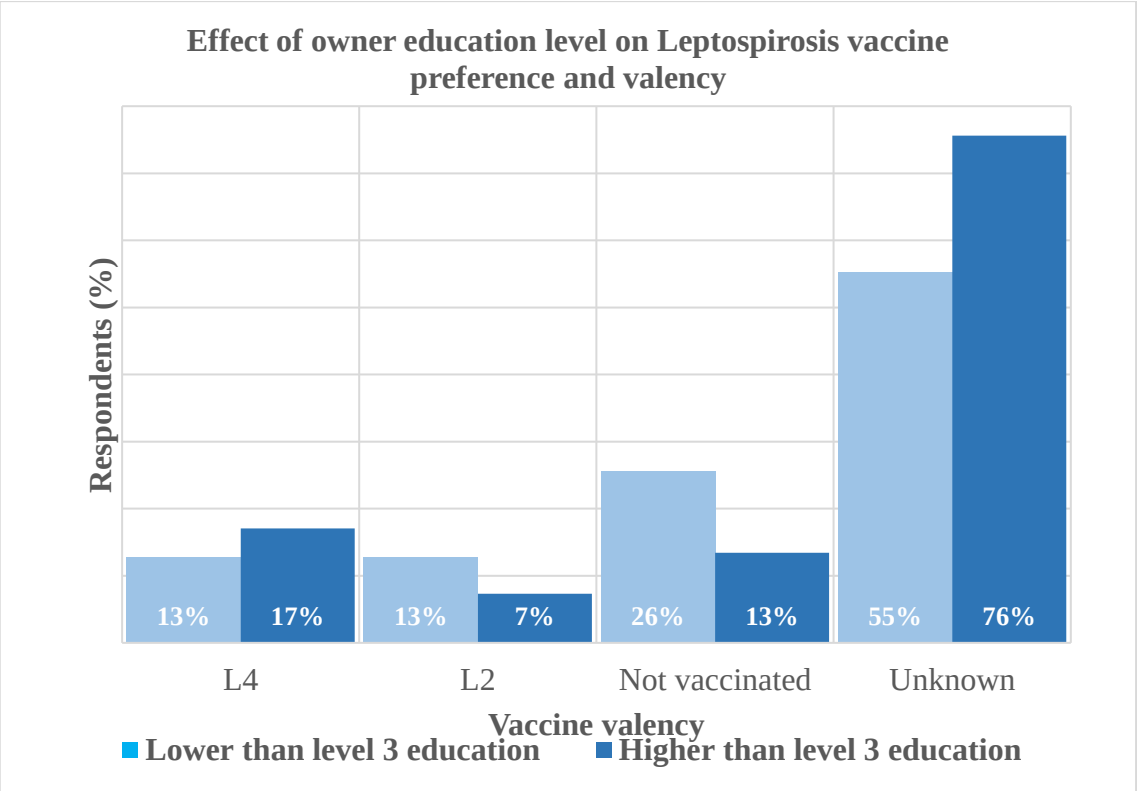

Chart 31. Vaccine valency dependent on education level

Chart 31 shows a higher uptake of L4 (17%) in respondents with higher than level 3 education. A higher percentage of respondents are less likely to vaccinate with leptospirosis with education lower than level three (26%).

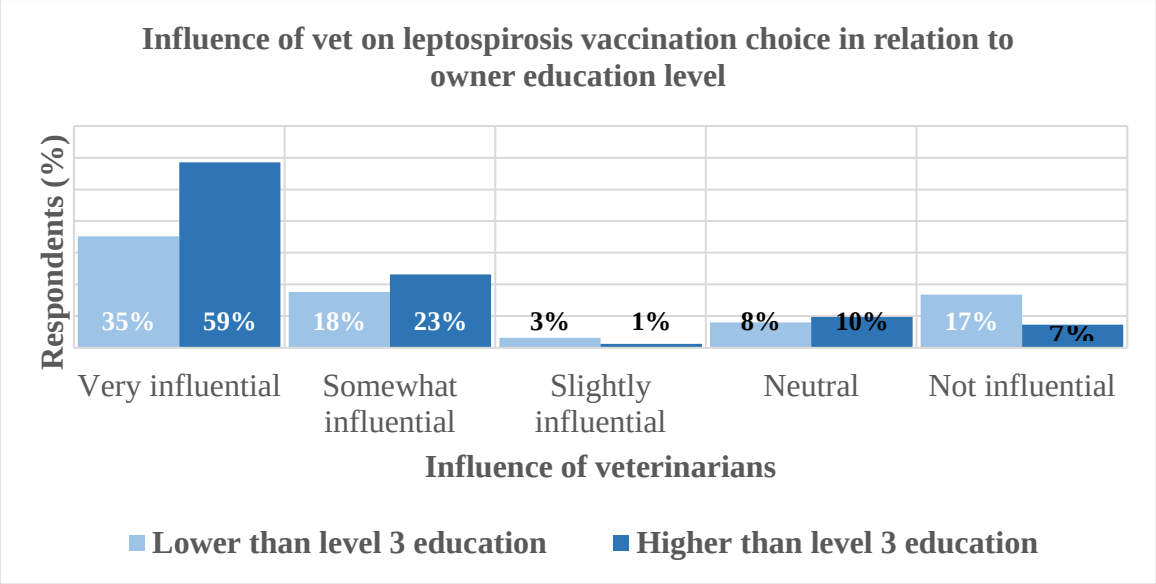

Chart 32. Owner perceived influentiality of veterinarians on their leptospirosis vaccination choice based on education level.

Chart 32 demonstrates that respondents with education level higher than level three were more likely to find veterinarians very influential when compared to those with lower than level three education (59%; 35%).

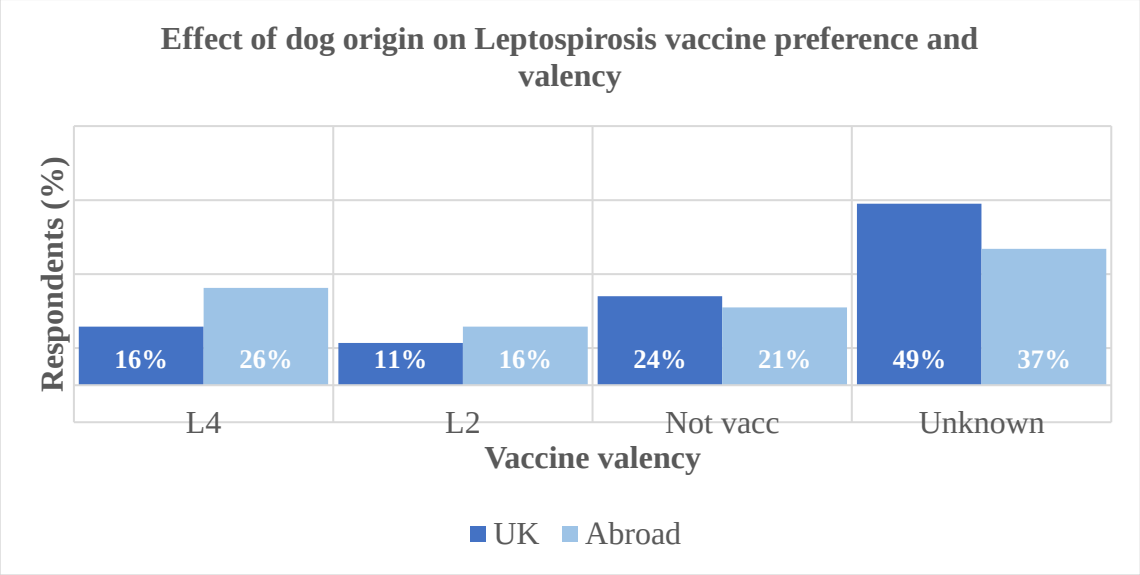

Chart 33. Vaccine valency dependent on dog origin

Chart 33 shows an increased tendency for respondents to not vaccinate their dog when their dog originates from the UK (24%). Respondents with dogs originating from the UK were more likely not to know what leptospirosis vaccination their dogs have received (49%).

Table 9. Average respondent knowledge score when compared with whether they discussed leptospirosis in the past nine years.

Discussion with veterinary staff in past nine years	**Knowledge score average**
No discussion	33%
Discussion	48%

Highest uptake of L4 vaccine was seen in Wales according to table 10, and highest uptake of L2 from North-east (England).

Table 10. Vaccine valency when compared to region.

Region	L4	L2	Not vaccinated	Unknown
East midlands (England)	14%	21%	57%	50%
East of England	27%	0%	45%	45%
London	17%	17%	50%	**67%**
North-east (England)	0%	**33%**	33%	**67%**
North-west (England)	10%	10%	60%	60%
Scotland	10%	10%	**70%**	40%
Southeast (England)	16%	13%	55%	47%
Southwest (England)	22%	11%	44%	33%
Wales	**29%**	0%	43%	57%
West midlands (England)	0%	0%	50%	50%
Yorkshire and the Humber	14%	14%	43%	57%

(Highest uptake of each category are highlighted in bold)

Table 11. Vaccine valency when compared to number of dogs per household.

Number of dogs	L4	L2	Not vaccinated	Unknown
1	14%	9%	16%	**60%**
2	21%	5%	19%	54%
3	0%	13%	**47%**	40%
>4	**23%**	**35%**	42%	0%

(Highest uptake of each category are highlighted in bold)

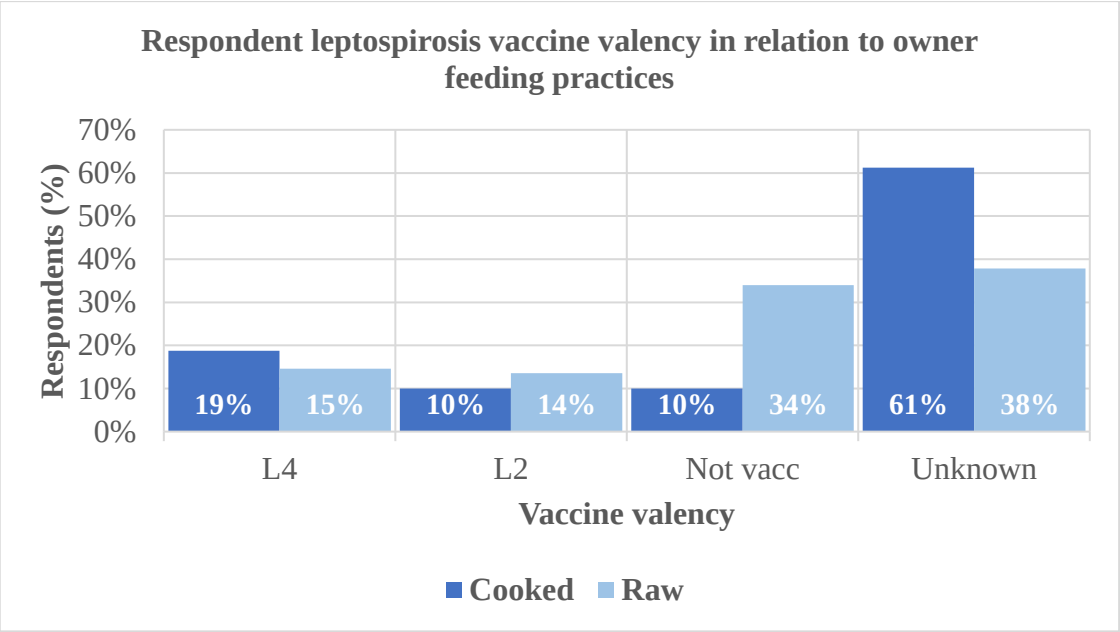

Chart 34. Vaccine valency based on owner feeding practices.

Chart 34 shows a higher percentage of respondent's not knowing what leptospirosis vaccination their dogs have received in those who feed cooked food (61%), and highest number of non-vaccinated dogs in relation to raw feeding practices (34%) compared to cooked feeding (10%). When statistically analysed using a T-test, shown in table 12 this was found to be statistically significant (P= <0.001). Hedge's G effect size showed that feeding practices have a large effect on knowledge of leptospirosis vaccine used.

Table 12. Statistical analysis of the relationship between owner feeding practices and dogs not vaccinated against leptospirosis.

	Cooked food	**Raw food**
Sample size (n)	123	61
Mean (M)	0.13	0.46
Standard deviation (s)	0.30	0.47
t-value	5.24	
P-value	**0.00001**	
Hedge's G effect size	**0.90**	

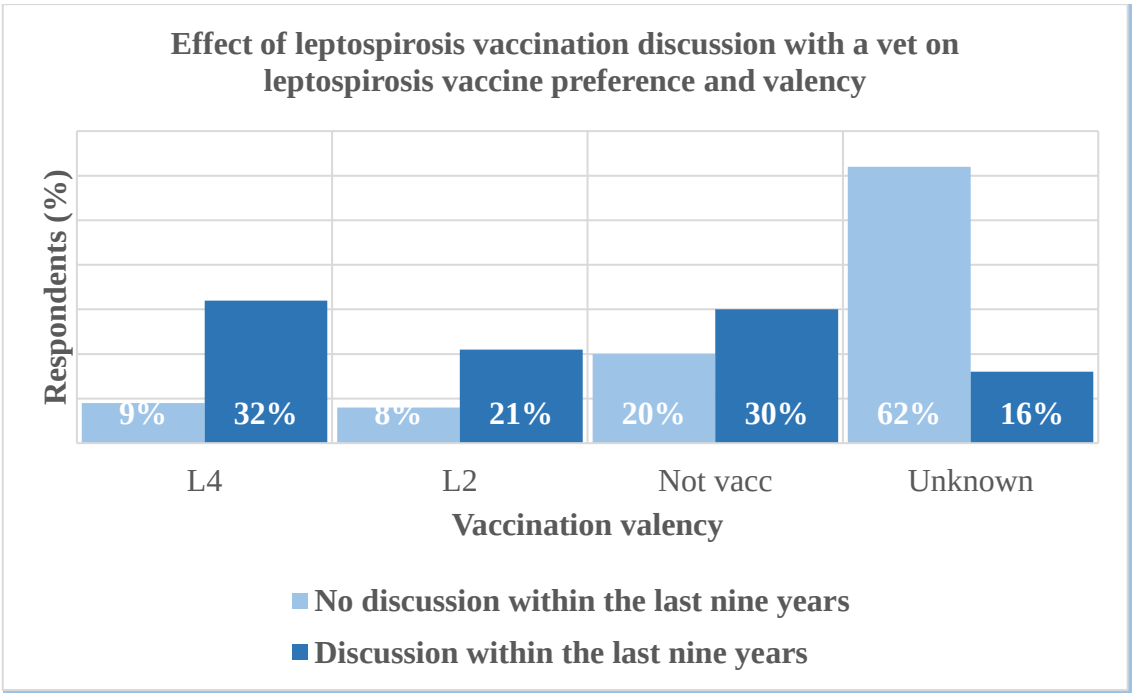

Chart 255. Vaccine valency based on discussion with veterinary staff in the past nine years.

Chart 35 shows a higher number of respondents who did not have a discussion with veterinary staff about leptospirosis in the past nine years in relation to not knowing what leptospirosis vaccine was used in their dog (62%), as opposed to those who had discussed (16%).

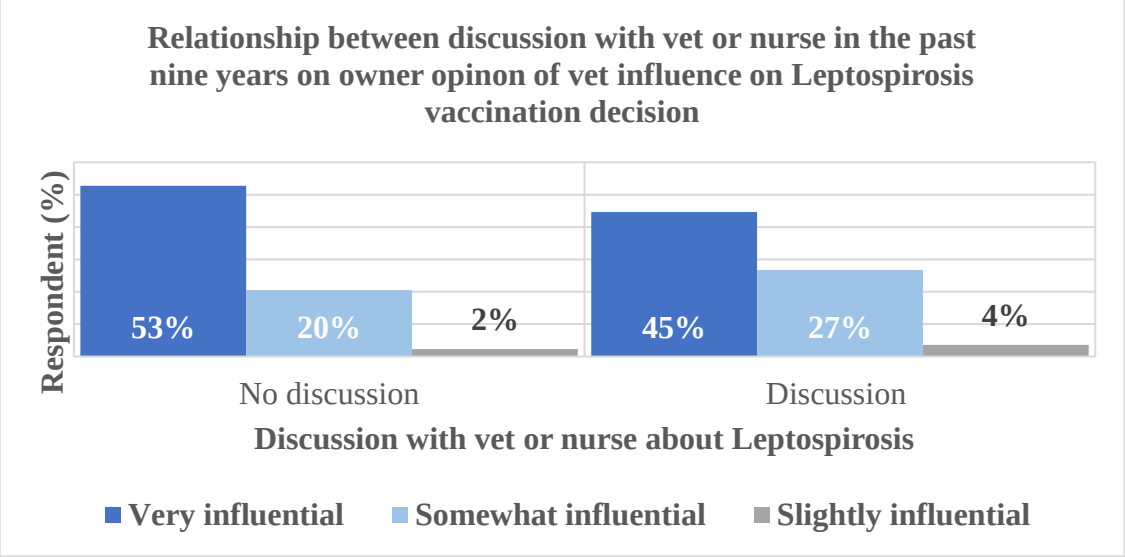

Chart 36. Respondent perceived influence of veterinarians based on discussion on leptospirosis in the past nine years.

Chart 36 shows a higher influentiality of veterinarians in respondents who had discussed leptospirosis within the last nine years (53%).

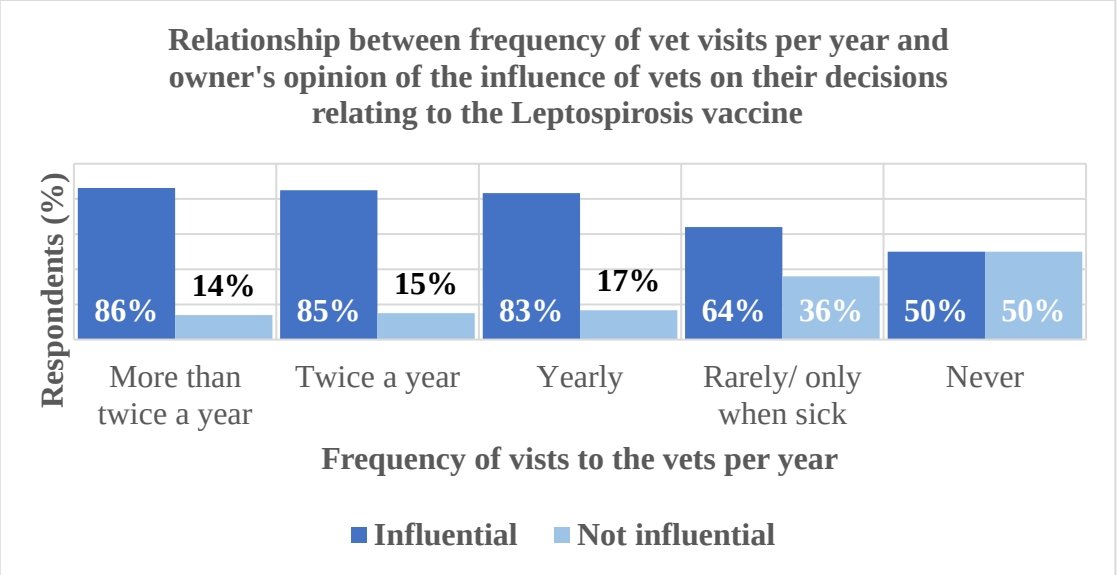

Chart 37. Respondent perceived influence of veterinarians based on frequency of visits.

Chart 37 demonstrates owners visiting vets more than twice a year found veterinarians more influential (86%) compared to those who never visit (50%).

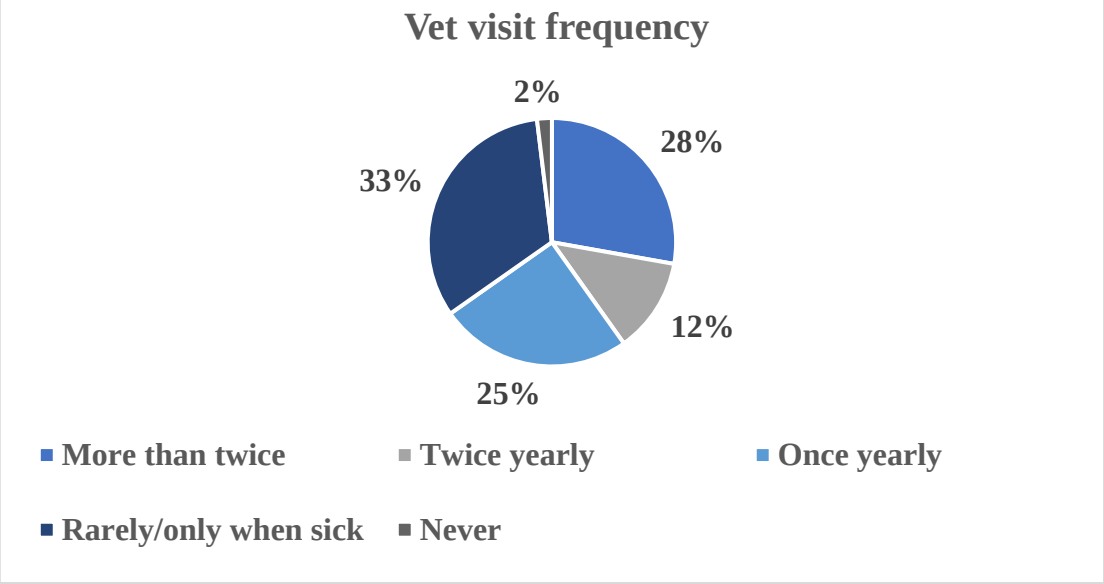

Chart 38.Respondent frequency of vet visitations.

Chart 38 shows that respondents visit vets most commonly only when sick to discuss general health (33%). Table 13 further shows that respondents from the 51-61-year-old

age category are more likely to attend more than twice yearly compared to others (29%). 18-28-year-old respondents were more likely to never attend (17%).

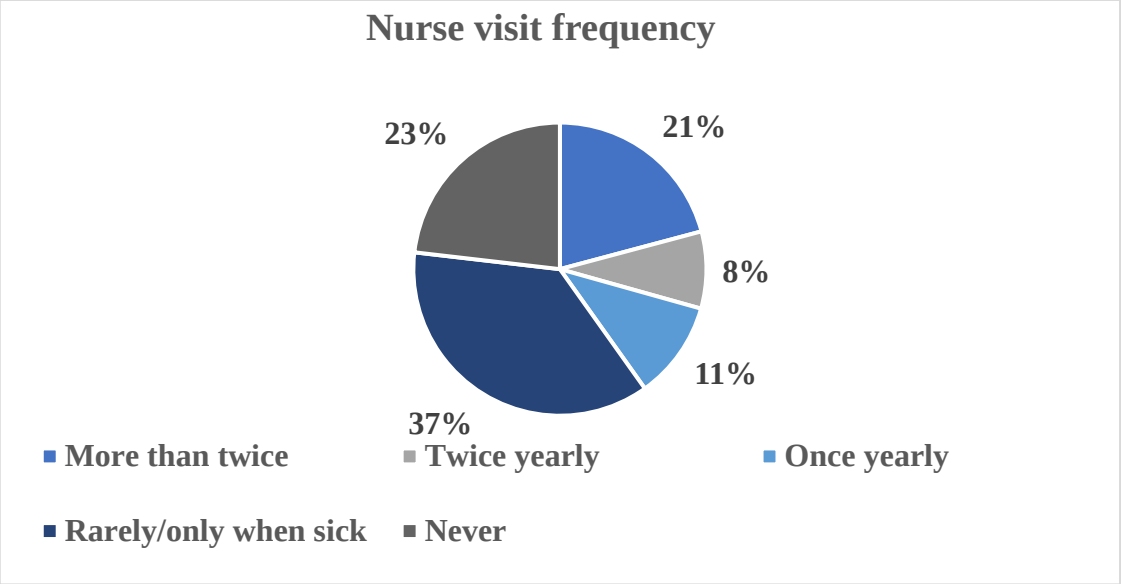

Chart 39.Respondent frequency of vet nurse visitations

Chart 39 shows that respondents visit nurses most commonly only when sick (37%) with a higher percentage never attending nurse clinics to discuss general health (23%).

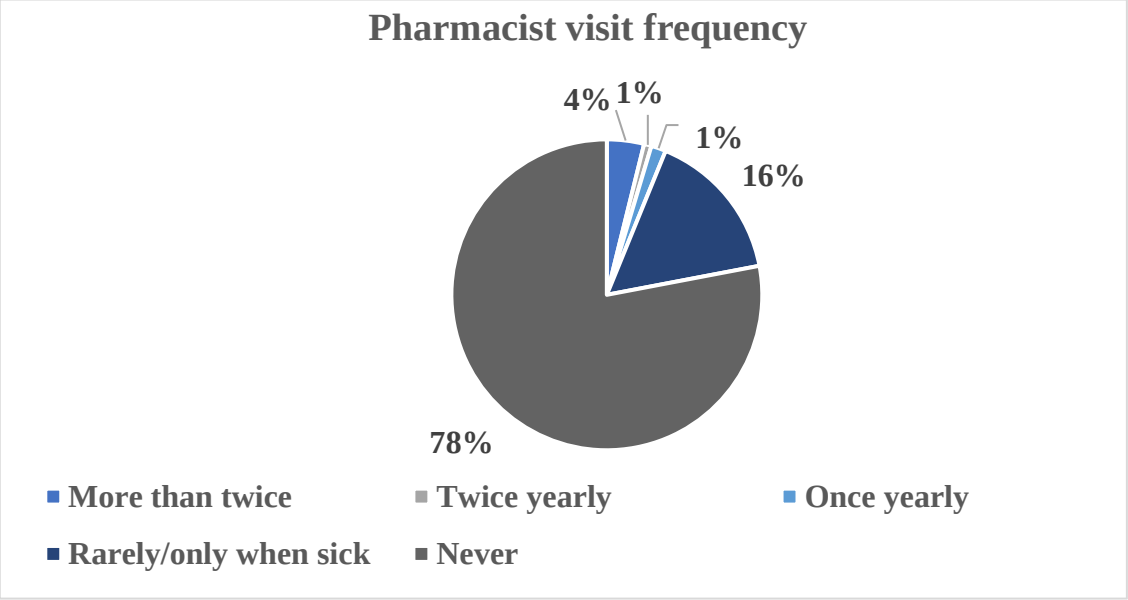

Chart 40. Respondent frequency of pharmacist visitations

Chart 40 demonstrates that respondents mostly never visit pharmacists to discuss general health (78%).

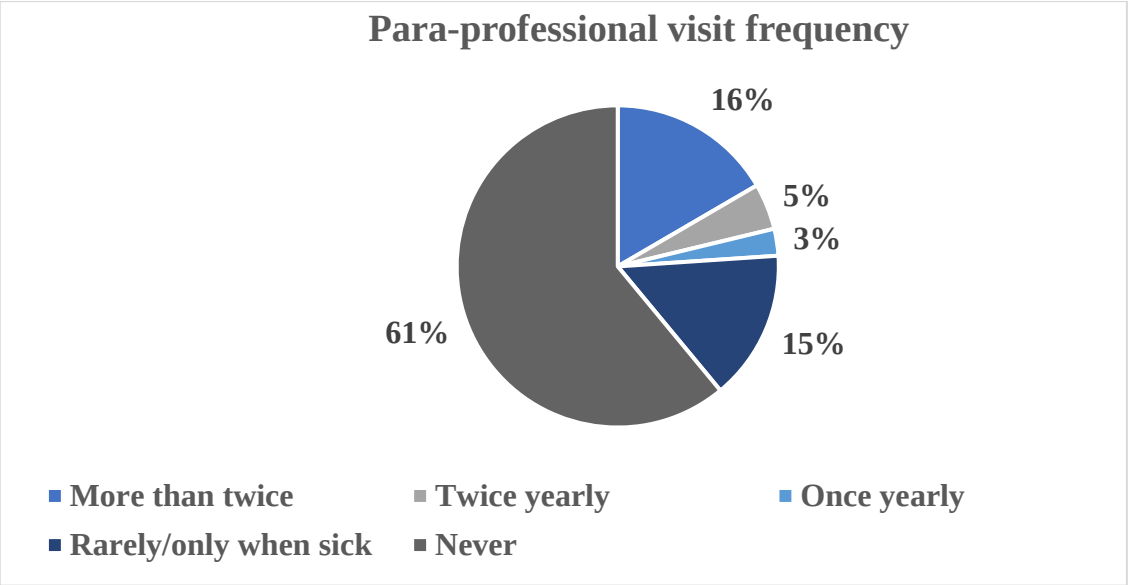

Chart 41. Respondent frequency of para-professional visitations

Chart 41 demonstrates that respondents mostly never visit paraprofessionals to discuss general health (61%).

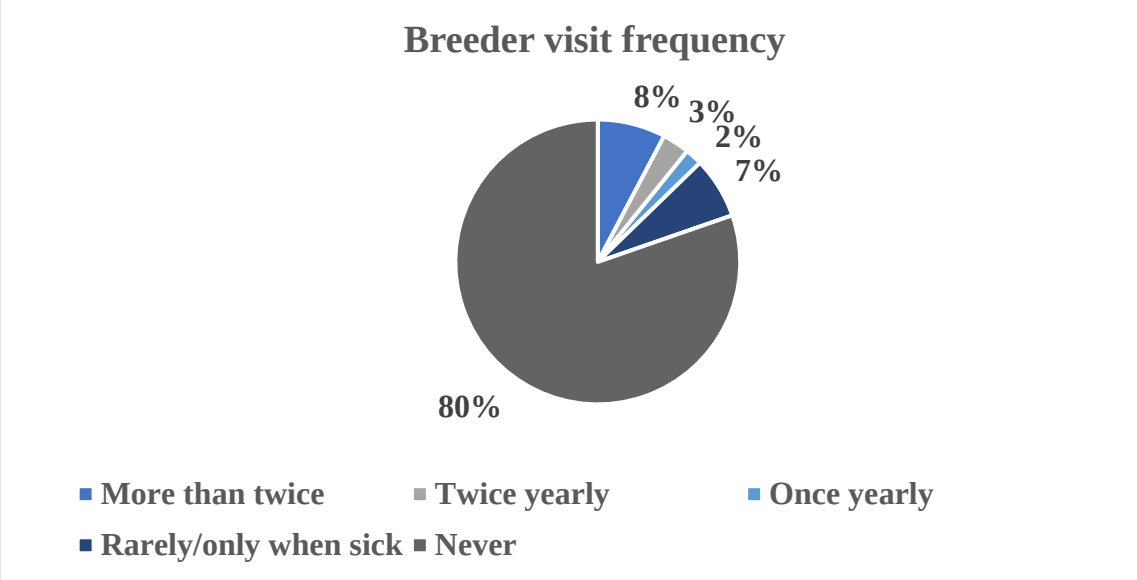

Chart 26.Respondent frequency of breeder visitations

Chart 42 demonstrates that respondents mostly never visit breeders to discuss general health (80%).

Table 13. Frequency of veterinary visits per year based on age categories.

Frequency of vet visits per year	**Age categories**				
	18-28	**29-39**	**40-50**	**51-61**	**62+**
More than twice a year	8%	19%	11%	**29%**	19%
Twice a year	**17%**	13%	9%	15%	6%
Yearly	33%	53%	**54%**	23%	44%
Rarely/ only when sick	33%	53%	**54%**	23%	44%
Never	**17%**	0%	0%	0%	4%

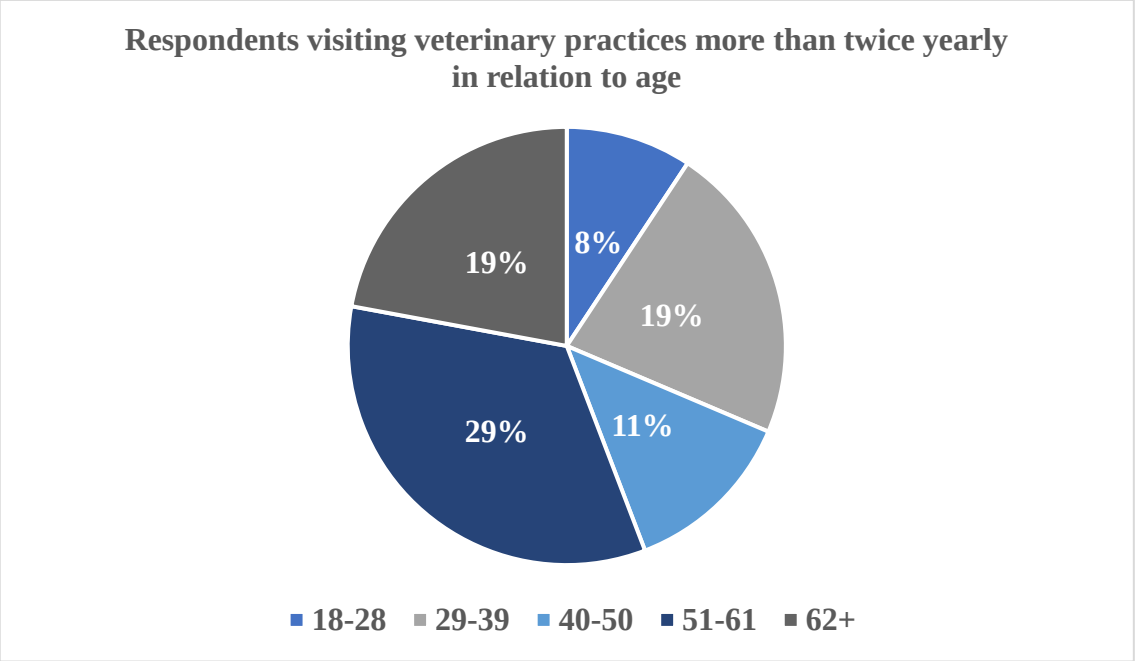

Chart 43. Respondents visiting veterinarians more than twice yearly based on age categories.

Chart 43 demonstrates the highest frequency of respondents visiting veterinarians is from those in the 51-61-year-old age category (29%), with the lowest seen in 18-28-year-olds.

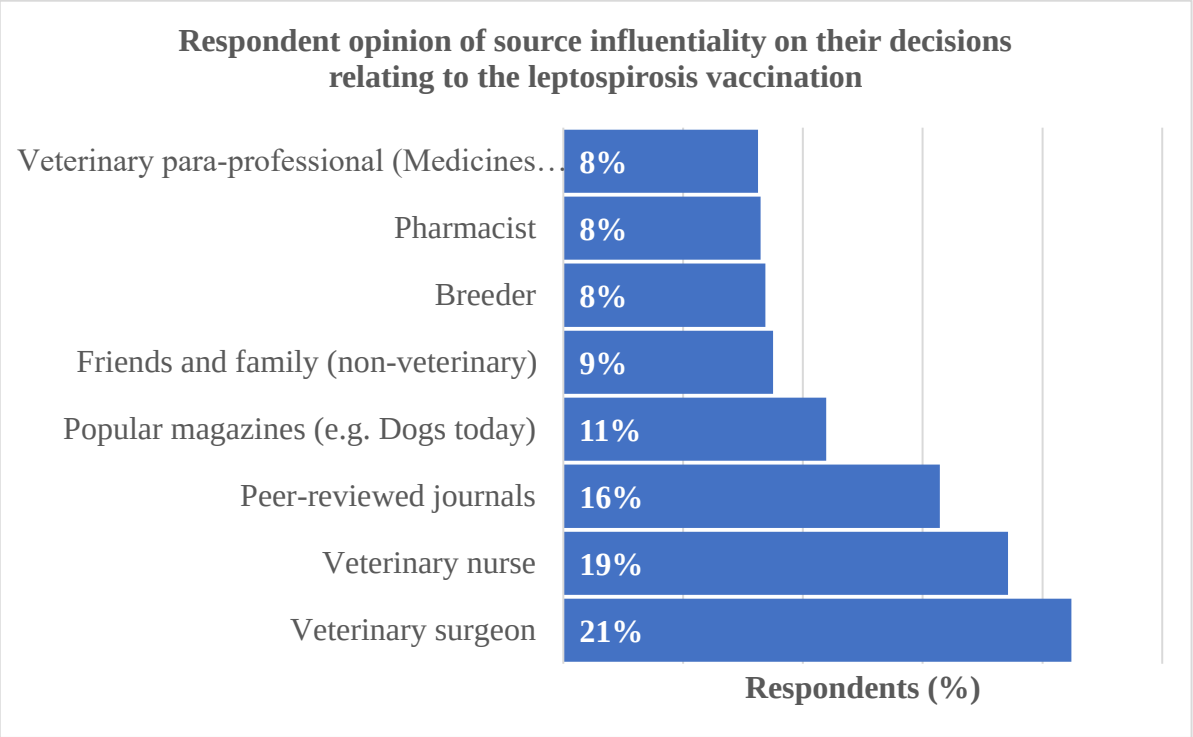

Chart 44. Respondent opinions of the influence of sources on their decisions relating to leptospirosis vaccination

Chart 44 shows that respondents deem veterinary surgeons to be the most influential source of information relating to the leptospirosis vaccine (21%), whereas paraprofessionals, pharmacists and breeders were all the least influential (8%). Table 14 assessed the influentiality in relation to age categories. All age groups found the veterinarian to be influential, with the highest opinion being seen in those between 18-28. 40-50-year-olds had the highest percentage of respondents deeming veterinarians to not be influential (34%).

When analysed using a one-way ANOVA in table 15 it was found that with increased visits to the veterinarians the respondent's perception of influentiality of veterinarians also increases (P = 0.002).

Table 14. Influentiality of veterinarian based on age categories.

Influentiality of the veterinarian	**Age categories**				
	18-28	**29-39**	**40-50**	**51-61**	**62+**
Very influential	67%	66%	37%	50%	46%
Somewhat influential	17%	44%	26%	25%	19%
Slightly influential	8%	29%	3%	2%	4%
Influential	**92%**	**88%**	**66%**	**77%**	**69%**
Not influential	8%	13%	34%	23%	31%

Table 15. ANOVA analysis of frequency of veterinary visits per year on owner perception of influentiality of veterinarians

Frequency of vet visits per year	**Influential**	**Not influential**
More than twice a year	86.11%	13.89%
Twice a year	85.00%	15.00%
Yearly	83.33%	16.67%
Rarely/ only when sick	64.00%	36.00%
Never	50.00%	50.00%
Sum of square (SS) within treatments	0.21	
Mean square (MS) within treatments	0.56	
F statistic	21.79 (higher than F critical value (7.7086)	
P-value	**0.001607 (0.02%)**	

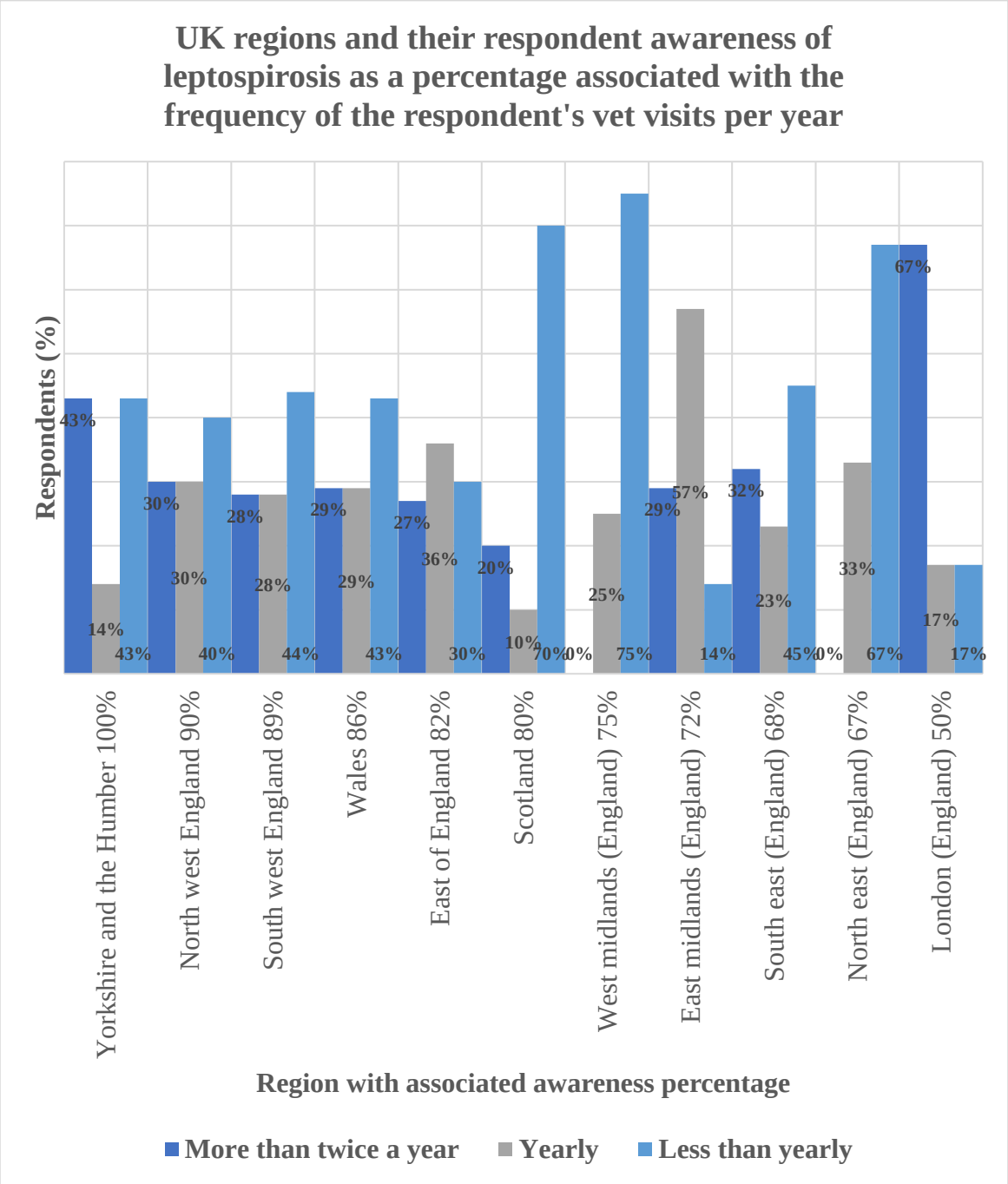

Chart 45. Awareness of leptospirosis when compared to region and frequency of veterinarian visits per year.

Chart 45 demonstrates the highest frequency of veterinary visits being from respondents in London (67%) in comparison to their low awareness score (50%), with the lowest frequency being from respondents in the west midlands (75%), matching their 75% awareness score.

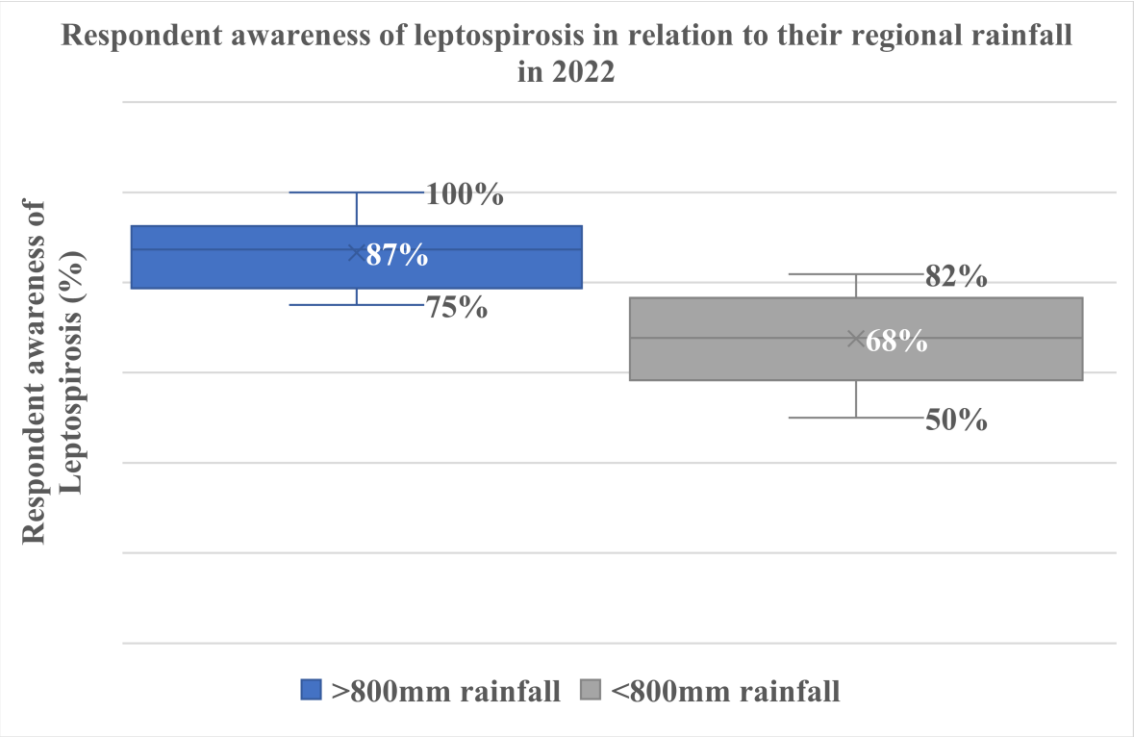

Chart 46. Awareness of leptospirosis when compared to regional rainfall in 2022.

Chart 46 demonstrates owner awareness of leptospirosis in relation to their regional rainfall data from 2022. Positive correlation is shown with increased rainfall and increased awareness (average of 86.6%), compared to rainfall of less than 800mm (67.5%).

6.0. Discussion

During the seven-month course of survey circulation 364 respondents were recorded, of which 104 were incomplete and excluded from the study. 259 (71%) complete responses were recorded, of which 76 claimed to have veterinary or medical training and were therefore excluded from the third section of the survey results as their responses on influentiality would be bias. Responses were analysed into four sections, demographics, awareness and knowledge, importance, and influentiality.

6.1. Section one: Demographics

The majority of respondents were 51-61-year-old (25%) females (93%), with the most common highest level of qualification of non-medically trained respondents being GCSE/ N5/ Highers/ O-level (29%). The largest proportion of respondents originate from the Southeast of England (44%), in one dog households (49%) and feed commercial dry food (45%).

6.2. Section two: Awareness and Knowledge

Leptospirosis awareness of non-medically trained respondents accounted for 80% of those surveyed, 20% claiming they did not know what it was. The highest awareness was seen in 18–28-year-olds (50%), whereas owners 62 years and older had the lowest awareness (17%). Those respondents with education levels higher than level three showed lower awareness of the disease (60%) when compared to those with lower education level (76%), this was contrary disease awareness and education levels shown in a study on owner awareness of parasitic diseases [29]. Regionally the highest awareness was seen in Yorkshire and the Humber (100%) whereas the lowest was reported in London (50%). When comparing awareness with regional annual rainfall in 2022 there was no statistical significance, however a positive correlation was shown between increased rainfall higher than 800mm and increased awareness as illustrated in chart 47, in relation to rainfall figures in the UK as shown in figure 3 this may be due to areas of increased rainfall reflecting higher risk for disease transmission [21]. It was reported by [30] that rural areas carry a higher prevalence of leptospirosis, therefore areas with higher rainfall may represent a higher risk, and as a result increased education and uptake of vaccination being sought.

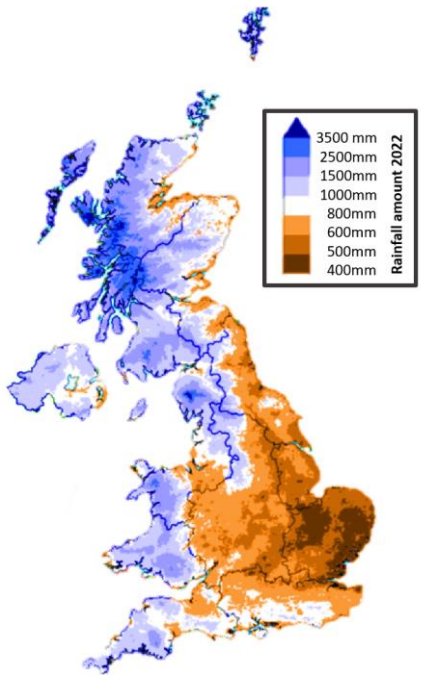

Figure 3. UK actual annual rainfall 2022 adapted from [53])

Households with more than four dogs showed the highest awareness (96%), with increased recognition from those rescuing dogs from abroad (78.95%) compared to those

owners who obtained dogs from the UK. Another variable investigated was whether owners had discussed the leptospirosis vaccination with veterinary staff in the past nine years. Owners who had discussed the vaccination demonstrated 98% awareness of the disease, as opposed to those without (64%). An unpaired T test was used to investigate the relationship between owner discussion and awareness of leptospirosis. Those who had spoken to veterinary staff within the last nine years where more likely to be aware of the disease ($P<0.0001$) and have a slightly increased knowledge (48% knowledge score opposed to 33% without discussion), demonstrating the effectivity of veterinary-owner discussions on their dog's health.

As well as this, a positive correlation was seen with owners who visited veterinary practices twice a year or more and them having heard of leptospirosis (80% twice yearly; 75% more than twice yearly) emphasising the importance of veterinary professional involvement to enhance awareness.

When assessing knowledge, respondents who answered that they had medical training were included in this section with caution, their answers were analysed separately in order to differentiate between them.

Leptospirosis knowledge was explored with four questions to ascertain whether respondents knew the causative agent, transmission routes, possible host species and the consequential pathologies. Each question had a possible maximum score with a point given per correct answer recognised, only positive point allocation was used. Respondents were then scored out of the total points they could have received and given a knowledge percentage.

Question one focussed on the causative agent, seven options were given, only the answer of "Bacteria" was scored as correct and allocated a point towards the total knowledge score. Of those from a non-medical background 53% identified the correct causative agent, 27% reporting "I do not know", highlighting a lack of knowledge of the causative in over one quarter of the respondents. Medically trained persons as expected, scored a higher level of understanding of the causative (91%), the 9% of respondents with incorrect answers were analysed separately, 3/7 had administrative roles, 2/7 were retired veterinary nurses, 1/7 had a degree in psychology and 1/7 had an undisclosed medical training. Although 5/7 of these respondents had questionable medical training credentials which could explain the variation in responses, the veterinary nurse respondent answers

were concerning, both of which cited “Viruses” as the causative agent, this may be due to the common association of vaccinations being only for viruses. Overall scores between medical and non-medical respondents were widest for this question suggesting that the largest knowledge gap for leptospirosis may be the causative agent itself. Highest scores for this question were achieved by owners over 62 years of age.

Question two focussed on the transmission routes, twelve options were given, of which only the answers “water”, “urine”, “soil”, “saliva”, ”blood”, “faeces”, and “semen” were scored as correct, a total of seven points were available to be added towards total knowledge score. Contaminated water was identified by respondents as the most commonly recognised method of transmission (non-medical 66%; medical 92%), with Urine (non-medical 49%; medical 86%) and contaminated soil (non-medical 38%; medical 59%) as second and third most popular answers. Over one quarter (27%) of the non-medical respondents stated that they did not know how leptospirosis is transmitted with 25% believing airborne, insect bite, slug ingestion and bite wound transmission to be transmission routes, further increasing the attributable percentage of unknown. Sexual transmission via semen accounted for the lowest known transmission route amongst respondents with both medical (21%) and non-medical training (5%). Awareness of leptospirosis transmission route in semen is an important consideration for breeding of dogs [54], knowledge of this route is therefore important to be improved, especially within the breeding and veterinary community. Although the majority of respondents recognised contaminated water as a route of transmission, 44% were not aware of this, showing a gap in owner education. Overall scores between medical and non-medical respondents were closest for this question reflecting a consistent education of transmission route, although not accounting for all possible methods. Highest scores for this question were achieved by owners between 40 and 50 years of age.

Question three focussed on owner’s knowledge of potential hosts for leptospirosis, five options were given of which all answers were true. Each correctly chosen host resulted in a correct score, a total of five points were available to be added towards the total knowledge score. Dogs were identified most commonly (90%) as potential hosts for leptospirosis, this was a predictable response due to the nature of the survey title and may not be true reflection of owner knowledge. 65% of non-medical respondents identified that humans may be hosts of leptospirosis. Rodents were recognised as hosts by 63% of respondents, of which 71% Were aged between 51 and 61-years-old This may be due to

the Weil's disease publicity [55] and subsequent vaccine launch in the UK during the 1960s [56]. The lowest recognised host species was the horse (39%). Highest scores for this question were achieved by owners between 51 and 61 years of age.

Question four focussed on owner's knowledge of pathologies as a consequence of leptospirosis, twelve options were given, of which only nine were appropriate. Correct answers based on literature findings were as follows "Liver disease (Hepatopathy)", "Fever (Pyrexia)", "kidney disease (Nephropathy)", "Vomiting (Emesis)", "Eye inflammation (Uveitis)", "Brain inflammation (Meningitis)", "Heart inflammation (Myocarditis)", "Lung bleeding", "Blood clots (Thrombosis)". Most commonly recognised pathology was liver disease (47% non-medical; 90% medical), followed by fever, kidney disease, and vomiting. Kidney disease was more commonly recognised by non-medical respondents (49%). The least recognised pathology was thrombosis (9% non-medical; 14% medical). Whereas 39% of non-medical respondents stated, "I do not know" for this question, a further 7% associated the incorrect answers of "Itching" and "Hair loss", further reflecting the lack of owner knowledge. Highest scores for this question were achieved by owners between 40 and 50 years of age. Abortion was not added to the list of possible pathologies, due to the importance of this consequence [57] it is recommended that future studies also analyse owner awareness of this pathology.

Total knowledge scores were based on a cumulation of the four knowledge-based questions. Respondents with no medical training achieved an average score of 38%, however the range of results was large and varied between 95% and 0%. Medically trained respondents as expected delivered higher scores on average (56%), whereas non-medical respondents delivered 38% as an average score. Highest scores from non-medical respondents were achieved by owners between 40 and 50 years of age (47%).

6.3. Section three: Importance

Owners were asked their opinion of the importance of the disease for dogs and humans in question fourteen and fifteen respectively. 18-28-year-olds, and those with dogs from abroad placed the highest importance of the disease for both dogs and humans (92% dogs; 83% humans), this may correlate with higher knowledge scores of those owners with dogs originating from abroad. The author believes that this may be due to the bias created by the presence of the survey itself. Owners with dogs originating from abroad are required to navigate UK importation rules, including the UK government pet passport scheme and

Animal Health certification. These documents require owners to ensure appropriate vaccination and anti-parasitic treatment with veterinary certification, this may lead to increased awareness of their dog's health status. It was not investigated in this survey how long-ago animals had been obtained from abroad and or from which countries, this may have also influenced results due to different requirements of importation.

London, north-east, north-west, and Welsh based respondents had the highest importance associated with dog health (100%), although London residents perceived a high importance of the disease in relation to dogs (100%) they also had the fourth highest importance for humans (67%), their opinion of human importance may correspond with the fact that London owners had the lowest awareness of leptospirosis (50%) and understanding of potential hosts. The lowest importance for both humans and dogs combined were from owners from Scotland, this may also explain why respondents from this region had the highest number of dogs that had not been vaccinated against leptospirosis (70%). Region associated awareness was not correlated with owner's perception of importance. Equally no significant correlation was seen with whether owners had discussed leptospirosis with their veterinarian or veterinary nurse in the last nine years, and only a slight positive trend was seen with frequency of vet visits and importance.

6.4. Section four: Influence

When calculating influentiality, owners who claimed to have medical training were excluded from analysis (n = 183).

Owners aged between 18 and 28-years-old had a higher tendency to not know what their dog was vaccinated against (83%). Preference towards not vaccinating against leptospirosis was larger in the 40 to 50-year-old age category (63%), contrary to a study into anti-vaccinating attitudes whereby respondents over 65 years-old were more likely to not vaccinate [58]. This category also had the lowest opinion of the disease importance (49% importance for dogs; 40% importance for humans) and lowest frequency of vet visits per year (less than yearly (54%)). Overall L4 vaccines had a higher uptake than L2 vaccines, with the exception of owners in the age category of 51-61. This age category represented the highest frequency of vet visits per year (more than twice yearly (44%), suggestive that with higher vet visit frequency owners may be more inclined to administer L2 vaccine. This would need to be assessed further with a larger representative sample.

17% of respondents with education of higher than level three responded that their dogs were given L4 vaccine, as opposed to 13% with education levels lower than level three. Those with lower levels of education were more inclined to not vaccinate against leptospirosis and also had higher awareness of which valency was used (45%) when compared to those with higher education levels (24%). Although not statistically significant in this study, vaccine hesitancy has been found to be related to lack of further education in relation to COVID-19 [58], this may explain the increased percentage of those choosing not to vaccinate and being sceptical, however further research is required to clarify this correlation. Owners with education level above level three also found veterinarians to have a higher influence on their decision making, therefore are more likely to be receptive to veterinary advice, indicating a possible area of improvement by practicing veterinarians.

Dogs originating from abroad were slightly more likely to be vaccinated against Leptospirosis (79%) of which L4 represented 26%, as opposed to those from the UK (76%). Discussion with veterinary staff was positively associated with uptake of L4 vaccination, and a significant correlation was seen with owners knowing which leptospirosis vaccination was administered ($P<0.0001$). However, a 10% increase of not vaccinated dogs were seen when compared with those owners who had not discussed leptospirosis in the past nine years.

The largest uptake of L4 was reported by the Welsh respondents (29%), with the lowest reported in the Northeast and West midlands (0%). The Northeast respondents represented the highest percentage of L2 uptake (33%) and those from Scotland were the highest proportion of dogs not vaccinated against leptospirosis (70%). These findings are both agreeing and contrary to those reported by [30]. Wales was reported in both studies as having the highest uptake of L4, differences between the authors findings and those of [30] may be due to many reasons, such as the smaller sample used in the current study or the additional variable of the direct effect of public anti-L4 campaigns. When analysing the open question responses as to why owners chose not to vaccinate (n=40) “vaccines are administered too excessively” was the most frequently given response (58%), with 39% of these owners admitting to administering the first vaccine course only and 14% supplement with titre testing to guide their decisions. Vaccine efficacy measurement in dogs is a hotly debated topic, MAT is the most commonly used technique for antibody detection, however results poorly correlate to derived protection due to the lifespan of

agglutinating antibodies [39]. Protective effects of vaccines are known to not be limited to the humoral response, a cell-mediated response involving interferon-gamma release from T cells also plays a key role [59]. Serovar-specific ELISA testing may also not detect true antibody levels, currently only antibodies against surface antigens are detectable, instead of those involved in bacterial neutralisation exist, therefore antibodies present may not represent truly protective antibodies. Side effect concern accounted for 8% of those who chose not to vaccinate. Highest rainfall in the UK in 2022 was recorded in Wales [53], higher uptake of L4 may reflect this due to increased risk associated with rainfall, however, this does not correlate with the lower uptake of Scotland and would need further investigation.

Owners with more than two dogs per household were more likely to not vaccinate their dogs against leptospirosis (45%), with lower numbers of dogs per household correlating with not knowing what vaccination is used, this may be due to owner experience. A question asking the number of years of dog ownership would have enabled the author to further investigate this link and is a limitation to this study.

Correlation was found between dog feeding preference and vaccine choice. An unpaired T test was used to investigate this relationship. Owners who followed raw feeding practices reported more frequently that their dogs were not vaccinated against leptospirosis as shown in Chart 35 and Table 12., ($M = 0.34$, $SD = 0.47$) compared to the 80 respondents who followed cooked feeding, $t(60) = 5.24$, $p<0.0001$. The effect size of this relationship was deemed as a high size effect (Hedge's $G = 0.90$). Although a very rare transmission route, contaminated offal such as kidneys from infected animals may lead to infection following raw ingestion [60], this highlights a concern that owners may not be aware of this transmission route when making choices of food or vaccine preference. This correlation was not predicted at the time of survey construction and therefore this form of transmission was not added to the transmission knowledge-based questions.

Discussion with veterinary staff in the past nine years was statistically associated with owner awareness of the leptospirosis vaccination valency used ($P<0.0001$), this highlights the importance of veterinary discussion in owner awareness and understanding, therefore providing an interface for informed decision making and trust.

The majority of respondents visited the veterinarian or veterinary nurses rarely or only when sick (33% veterinarians; 37% veterinary nurses). Breeders represented the lowest visited veterinary professional/ para-professional with 80% never visiting. Owner opinion of relationship with their veterinarian and subsequent vaccination compliance has been found to be positively correlated [52], this was not assessed in the scope of this study but may be an important variable. Veterinarians, veterinary nurses and peer-reviewed journals were regarded as having the largest influence on owners, these are the same findings as those reported previously [52]. Owners in the 51-61 age category and from London reporting more frequent veterinary visits per year (29%; 67% (more than twice yearly) respectively), this may reflect financial stability, which was not assessed in the scope of this study.

Using a one-way ANOVA, the relationship between frequency of owners visiting veterinary practices and owner perception of the influentiality of veterinarians was assessed. Statistically significant difference was found ($P < 0.01$; F statistic 21.79 (critical value 7.71)), rejecting the null hypothesis that there was no influence on vet visit number per year and vet influentiality. This may indicate that if owners were encouraged to visit the vets more frequently they may be more influenced by the vet's opinion on leptospirosis vaccination. Wellness schemes such as those offered by many veterinary corporate chains consisting of packages of consultations and services per year may encourage increased presence within veterinary practice. Average UK veterinary vaccination consultation time is between ten and sixteen minutes[61, 62]. Shared decision-making (SDM) frameworks are recommended to increase owner informed decisions and owner satisfaction, therefore increasing the perception of influentiality of veterinarians on decision making processes such as vaccination choice. Routinely, UK practitioners often do not incorporate SDM into their consultations, this may be due to increased time pressures, leading to an inconsistency of standard of care and owner population opinion [62, 63]. The current study did not assess the length of time per consultation, reasons for visiting veterinary practice and age of clinician, these factors are also found to influence owner decisions based on the differences of consulting style [62]. Time is used due to discussing non-vaccination related concerns such as behaviour, noting that longer consults are needed for older and younger patients [63]. Pre-visit nurse consultations may improve efficiency, however many vets deem this to be an impractical approach due to staff shortages [63]. In the authors opinion, further study is needed to

assess vet visit influence on vaccination choice, to enable better understanding on what types of consultation play key roles in influencing owners of trust in their veterinarian's recommendations and provide better informed consent for vaccinations.

7.0. Conclusion

The study provides good basis for the understanding of current owner awareness and knowledge of leptospirosis, as well as understanding owner opinions of the influence various sources have on their vaccine choices.

Knowledge scores of respondents were low for owners without medical training, with higher scores found in the 40 to 50-year-old age group, possibly reflective of Weil's disease education campaigns. Knowledge of the: agent, transmission route, host species and pathological consequences of the disease, are important in order to create informed decisions on vaccination choice as required by the WSAVA vaccination guidelines, as well as understanding how to reduce transmission risk. It is therefore recommended by the author that owner education is increased in these areas, with focus on agent and transmission route as shown in this study to be the most lacking areas of understanding. The survey found a significant link between raw feeding practices and owners choosing not to vaccinate their dogs although this is a possible transmission route for the bacteria itself. The relationship between raw feeding and vaccination has previously been noted in other studies, the author believes that it would be beneficial to understand owner motivations with regards to this link to provide better more targeted education.

Respondents in the youngest age category were deemed to be the least informed about their dog's current vaccination status, it is unknown as to the reasoning behind this, and would therefore be an area of recommended future research. Veterinarians are well placed to provide education and promote awareness of this disease as shown by owner opinions of their influence and owner knowledge score and awareness correlations with regards to veterinary visit frequency. Veterinarians however should consider adapting their methods of education to ensure it is tailored towards owners of all education levels and age groups with the integration of increased visit frequency by the use of care packages and or increased consultation times.

Contrary to the authors prediction, owners appeared un-influenced by breeders and L4 uptake was higher than expected based on author experience in practice. True vaccination

uptake based on this study alone is not sufficient to fully understand the UK dog owning population, true uptake may only be fully understood with further studies using nationwide collaborative tools such as the VetCompass^{TM} used by the Royal Veterinary College in the UK.

Due to the risk of increasing serovars of leptospirosis seen in the UK, alongside the risk of disease in both humans and animals it is of increasing importance that L4 vaccinations be used to avoid vaccination fatigue and ensure population immunity.

Results of this study are not reflective of the UK population, instead it provides insight into a representative sample of the UK dog population, therefore results should be taken with caution when extrapolating.

8.0. Summary

Leptospirosis is an important zoonotic disease. The bacterium has a complex taxonomy and many serovars affecting varied species. Due to complexity and geographical distributions, vaccine companies and healthcare professionals must determine what serovars to incorporate into protective vaccines. In 2023, Europe focuses on a bivalent vaccine (L2) and tetravalent (L4) vaccine. The L4 vaccine having broader protection. It is unknown as to what UK dog owners understand about the disease, their opinions of its importance, and the influential factors determining their knowledge of the disease or preference of vaccination status.

The study aimed to quantify the knowledge of the UK dog owning population regarding the causative agent, transmission routes, possible hosts, and consequential pathologies, and also owner opinion of the importance of the disease for both humans and dogs and allocate the influence of various sources.

A survey was distributed via social media over a seven-month period receiving 259 respondents, it was descriptively scrutinised and analysed for statistical significance in areas of interest. Knowledge scores were variable between questions, the highest awareness of non-medical owners being the host species (61%) and causative agent (52%) and lowest awareness of transmission routes (31%) and pathologies (28%), a similar trend was observed in medical respondents. A significant relationship was found between owners feeding raw food to their dogs not vaccinated against leptospirosis ($p < 000.1$), as well as an increase of owner perceived awareness of the disease when they had discussed leptospirosis in the past nine years ($p < 0.0001$), only a slight positive trend was seen with regards to knowledge score. Owner's opinion of the influence of vets was positively associated with frequency of vet visits per year ($p < 0.002$) with owners finding veterinarians to be the most influential source of information when making decisions on leptospirosis vaccination (n=208). It was outside of the scope of the study to understand the specific factors of influence, and therefore further research would be required to optimise education for owners on critical issues such as this.

Future recommendations are to optimise veterinarian, owner contact time to improve education. It is hoped that in doing so owner knowledge and opinion of importance would increase alongside their opinion of the influence of veterinarians. Subsequently reducing vaccination fatigue and protecting both humans and animals in a one health approach.

9.0. Bibliography

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11.2.Competing interests

None declared.

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