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RESEARCH ARTICLE

Epidemiology of Tick Infestation in Dogs: Prevalence, Risk Factors and Seasonal Trends in Pakistan

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Abstract

Dog ticks are the sever threat to both human and animal life due to their medical importance in transmission of tick borne diseases. The current study aimed to investigate tick infestation, associated risk factors, species diversity and seasonal abundance of ticks in selected regions of Pakistan. A total of 940 dogs (both free roaming and owned) were examined during 2023-24 and 712 tick samples were collected. These ticks were morphologically identified into three species comprising of *Rhipicephalus sanguineus* **(81.5%)**, *Rhipicephalus haemaphysaloides* (10.2%) and *Rhipicephalus turanicus* **(8.3%)**. All demographic and epidemiological information were recorded and chi-square test and logistic regression was performed. Overall prevalence of tick infestation in dogs was 27% (254/940). Infestation rates varied by age groups with highest prevalence observed in puppies <1 year (30.50%). Female dogs showed higher infestation rate (30.60%) compared to male dogs (23.72%). Dogs with short hair had significantly higher infestation rates (31.94%) than long-haired breeds (6.15%) and summer had the highest tick infestation rate (32.42%). The tick prevalence was highest in Gujar Khan while least prevalent in Taxila. Simpson's Diversity Index (D) and Shannon-Wiener Diversity Index (H') indicated a relatively low and moderate level tick diversity, which highlighted the need for dedicated tick control measures, particularly in regions of high infestation of tick in the dog population.

Keywords: Tick infestation, Prevalence, Risk factors, Seasonal trends, *Rhipicephalus sanguineus*, Dogs, Pakistan

INTRODUCTION

Ticks are ectoparasites that rely solely on blood of hosts including canines, bovines, and sometimes humans in all climatic zones of the world [1]. Ticks pose significant threats to animal and human health, being considered the second most important vector of human diseases after mosquitoes [2]. Dogs are among the first animals to be domesticated and kept as pet animals throughout the world [3]. The precise figures are lacking however global population of dog is estimated about 700 million exist, in which 75% are free roaming [4]. A developing country like Pakistan is experiencing rapid urbanization and socio-economic challenges [5]. The unregulated increase in dog populations has raised significant concerns regarding environmental sanitation, animal welfare and transmission of zoonotic diseases, particularly in densely populated urban and peri-urban areas [6]. Although official statistics on dogs population in Pakistan are lacking, however it is estimated that approximately 3 million dogs reside in the country [7,8]. Large-scale studies on tick from companion animals have recently gained attention due to the close relationship between humans and pets, as well as the shared disease risk posed by ticks [9]. Tick infesting dogs can infest humans and spread zoonotic diseases [10]. Dogs inhabiting urban and peri-urban environments are commonly infested by various hard tick species including *Rhipicephalus microplus, Rhipicephalus sanguineus, Rhipicephalus haemaphysaloides, Haemaphysalis erinacei,* and *Haemaphysalis parva* [11,12]. Accurate identification of these ectoparasites is essential for effective surveillance and control strategies, as these vectors are the confirmed carriers of several tick-borne pathogens with significant zoonotic potential [13]. Tick infestation and seasonal fluctuation are influenced by biotic and abiotic factors. Host availability, roaming behavior and habitat type are key biotic factors affecting the occurrence. Abiotic factors such as temperature, humidity, rainfall and other climatic factors impact ticks' survival and activity [1].

Several pathogens such as *Rickettsia, Borrelia burgdorferi* (Lyme disease), *Anaplasma, Ehrlichia,* and *Babesia* can infect both humans and animals, leading to severe health complications. These infections not only cause health risks but also result in financial losses and threaten the well-being of people, animals, and the environment. *Rhipicephalus sanguineus* is the most common species of dogs, transmits *Anaplasma capra, Anaplasma platys, Ehrlichia canis, Ehrlichia minasensis, Babesia canis, Rickettsia massiliae, Rickettsia aeschlimannii,* and *Rickettsia rickettsii*. More temperate tick species such as *Ixodes scapularis* and *Ixodes ricinus* are vectors of: *Borrelia burgdorferi* (causative agent of Lyme disease), *Anaplasma phagocytophilum* and *Babesia* spp. In addition to affecting canine health, these ticks can also transmit pathogens to humans [13-16]. The presence of tick in livestock or companion animals has been associated with several risk factors. Tick dispersion varies globally depending on host demographics (e.g., age, gender, and breed) and management practices (e.g., acaricidal usage, dogs roaming) [14]. Understanding the distribution of dog population and their associated tick diversity is critical to mitigating public health risks associated with the transmission of vector borne diseases [15]. In Pakistan, studies on risk factors for tick infection in companion animals have been conducted in only a few regions [7,16-20]. However, precise tick species identification is essential for developing effective tick management strategies, and this primarily relies on morphological keys [17,21]. The current study has been designed to investigate the diversity, prevalence and associated risk factors of hard tick species infesting dogs in the districts of Rawalpindi and Islamabad, Pakistan. The findings of the current research will contribute as a baseline in enhancing knowledge regarding future ticks' surveillance and control strategies against ticks and tick-borne diseases in both animal and humans.

Material and Methods

Ethical Approval

The study was approved by the Institutional Review Board (IRB) (Approval No: CUI/Bio/ERB/2024/43) of the Department of Biosciences, COMSATS University Islamabad Pakistan.

Study Area

Pakistan is primarily an agricultural country that is divided into five agroecological zones based on the examination of climatic/aridity data using the remote sensing climate compound index [22]. The northern cities of Pakistan including Islamabad and Rawalpindi were chosen as the study locations for this investigation on dog tick infestation. Its twin city, Rawalpindi, is a metropolitan center with a higher population density and more diverse climatic conditions, Islamabad, the capital, is renowned for its contemporary infrastructure, open spaces, and reasonably managed urban environment. According to the Köppen-Geiger classification [23], Islamabad has hot and humid summer with mild winter weather. The city has a temperate climate because the annual temperature averages is 21.3°C and annual precipitation is approximately 1201 mm. The weather in Islamabad shows a clear pattern between seasons as spring runs from March to May and summer arrives in June continuing through August. The following shift is autumn from September to November and the cold winter lasts all through December up until February. Sandstorms and heat create dry spring weather known as pre-monsoon that usually experiences drought conditions. The summer monsoon provides enough rainfall to counteract hot weather but has high moisture content in the air *(Fig. 1)*.

Tick Sampling and Morphological Identification

In the present study, we investigated tick infestation in dogs from May (2023) to April (2024). Dogs belonging to willing owners including caged pet dogs, were observed using random sampling method. A questionnaire was prepared to get data of dogs that were part of the study. The data regarding breed, age, gender, roaming behavior, acaricide usage, and bathing from the owners of dogs was collected. We also asked about tick infestations and whether they had used acaricides on their dogs. The dog' age was divided into three groups comprising puppy (<1

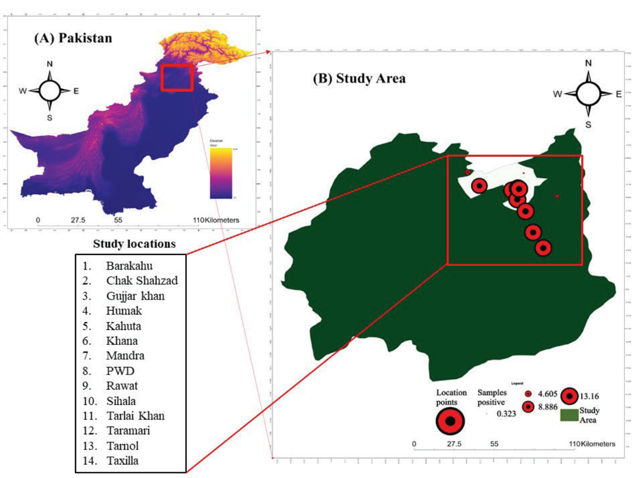

Fig 1. Map of the study area (red circles indicating sampling sites of dog ticks collection)

year), juvenile (1-3 years), and adult (>3 years). In the study, Specific breed data was lacking, so we classified dogs based on the length of their tail (long-haired or short-haired dogs) [24]. The term infestation rate describes the number of infected ticks as a proportion of the total number of ticks collected for each class.

Dogs were categorized as infested (at least one tick detected) or non-infested (no ticks found). This binary classification enabled us to determine the prevalence of tick infestation and to study potential risk factors associated with infestation status. In this study, 14 localities including towns and localities of the areas (Barakahu, Chak Shahzad, Gujjar khan, Humak, Kahuta, Khana, Mandra, PWD, Rawat, Sihala, Tarlai Khan, Taramari, Tarnol, and Taxilla) and dogs (n=940) were examined of tick incidence. Standard techniques were used such as by wearing gloves and using forceps to gather tick samples on the dogs; no physical strain or harm was put on the dogs when tick samples were gathered. To ensure a thorough examination, dogs were restrained using a mouth gag or muzzle by the owner or handler and Tick were carefully captured. The collected ticks were preserved, and stored in the Department of Biosciences, COMSATS University Islamabad, Pakistan for further research. Morphological identification to the species level was only for previously unfed ticks, using conventional identification keys [25,26] and a stereo zoom microscope (SZ61, Olympus®, Tokyo, Japan).

Statistical Analysis

Basic frequencies were determined, and Microsoft Excel was used for data recording. The data was then analyzed by using descriptive statistics, and the variables were first identified as independent and dependent variables. Independent factors included age, gender, breed, use of acaricides, bathing, dog roaming range, tick species, month, and season, whereas tick infestation (positive or negative) was the dependent variable. A chi square test and logistic regression were performed in SPSS to assess the association and peculiarity between independent and dependent variables. Results with $P<0.05$ were significant for hypothesis testing. Tick species diversity was computed using Shannon-Wiener diversity Index (H′) and Simpson's Diversity Index (D) in Microsoft Excel. Graphs were generated in GraphPad Prism software (10.0.1), and the study site mapping was conducted using ArcGIS Pro.

Results

In the present study, overall tick prevalence among dogs was 27% (254/940). With total collection of 712 ticks, three tick species including *Rhipicephalus sanguineus, R. turanicus,* and *Rhipicephalus haemaphysaloides* were identified by using taxonomic keys *(Fig. 2)*.

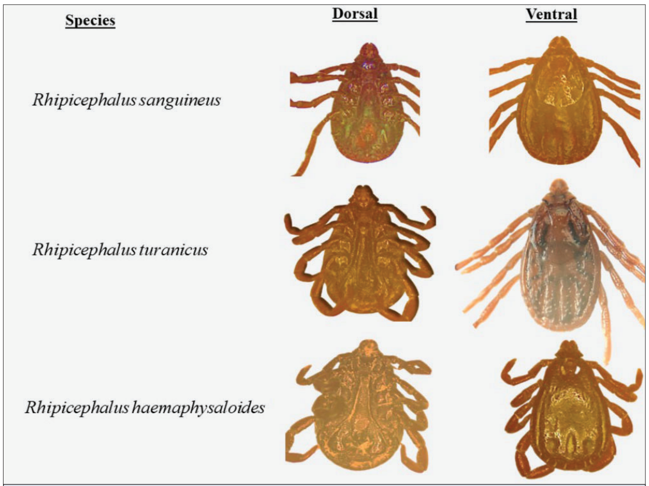

Fig 2. Representative images of three hard tick species including *Rhipicephalus sanguineus*, *Rhipicephalus turanicus* and *Rhipicephalus haemaphysaloides*, collected from dogs

Prevalence and Species Composition of Tick Infestation in Dogs

Rhipicephalus sanguineus had the highest (81.5%) prevalence in which female ticks (54.8%) were higher than males (26.7%) and *R. haemaphysaloides* (10.2%) had infestation in which female ticks (6%) showed higher prevalence as compared to male (4.2%) while *R. turanicus* had lower (8.3%) prevalence of tick infestation, female tick prevalence was little higher (4.9%) than male (3.4%). These results emphasized the abundance and the gender specific distribution of different tick species infesting dogs within the studied population *(Table 1)*.

Table 1. Prevalence and species composition of tick infestation in dogs

Species	Gender (n)		Prevalence (%)
R. turanicus	Male	24	3.4
	Female	35	4.9
	Total	59	8.3
R. sanguineus	Male	190	26.7
	Female	390	54.8
	Total	580	81.5
R. haemaphysaloides	Male	30	4.2
	Female	43	6
	Total	73	10.2

Risk Factors Studied in Dog Population

The infestation rate was higher in the puppies (30.50%), followed by juveniles (26.78%) and adults (24.65%), although the association was not statistically significant (P=0.525). Female dogs had the highest (30.60%) tick infestation than males (23.72%, Odd Ratios (OR)=0.73)

***Table 2.** Potential risk factors facilitating tick infestation of the dog population*

Categories		Tick Infestation		Total	Infestation Rate (%)	Coefficient (β)	Odds Ratio (OR)	95% CI for OR	Chi-Square	df	P-value
		Non-infested	Infested								
Age	Puppy (< 1)	98	43	141	30.50	0.24	1.27	0.79–2.04	1.287[a]	2	.525
	Juvenile (1-3)	481	176	657	26.78	0.11	1.12	0.73–1.71			
	Adult (>3)	107	35	142	24.65	0	1.00	-			
Gender	Female	313	138	451	30.60	0	1.00	-	5.626[a]	1	.018
	Male	373	116	489	23.72	-0.32	0.73	0.56–0.95			
Breed	Long-haired	168	11	179	6.15	0	1.00	-	48.864[a]	1	< 0.001
	Short-haired	518	243	761	31.94	1.77	5.87	3.16–10.91			
Acaricides usage	Irregular	41	30	71	42.25	1.47	4.35	2.38–7.94	33.771[a]	2	< 0.001
	No use	489	205	694	29.53	1.06	2.89	1.75–4.76			
	Regular	156	19	175	10.86	0	1.00	-			
Dog-bathing	No	564	244	808	30.20	1.49	4.44	2.31–8.55	29.446[a]	1	< 0.001
	Yes	122	10	132	7.58	0	1.00	-			
Dog roaming range	Free-roaming	321	213	534	39.89	0	1.00	-	102.284	1	< 0.001
	Non-roaming	365	41	406	10.10	1.76	5.81	4.03–8.38			

***Table 3.** Spatial distribution of ixodid tick species across the study area*

Study Sites	Latitude N	Longitude E	Non-infested	Infested	Total	Infestation Rate (%)	Coefficient	Odds Ratio	95% CI for OR	Chi Square X^2	df	P-value
Barakahu	33.73806085	73.18512218	52	1	53	1.89	0	1.00	-	178.9	13	< 0.001
Chak Shahzad	33.66160139	73.13995099	44	5	49	10.20	1.78	5.93	0.67-52.34			
Gujjar khan	33.26246316	73.30543805	49	68	117	58.12	5.12	167.43	22.63-1238.72			
Humak	33.53900802	73.14828967	27	0	27	0.00	-19.61	0.00	-			
Kahuta	33.59050237	73.38845047	43	3	46	6.52	1.28	3.60	0.36-35.67			
Khana	33.62912374	73.11354477	53	17	70	24.29	2.83	16.96	2.16-133.23			
Mandra	33.36149277	73.24286275	46	38	84	45.24	4.32	75.19	9.96-567.45			
PWD	33.5708391	73.14545694	68	15	83	18.07	2.34	10.38	1.34-80.52			
Rawat	33.49556111	73.19638253	56	32	88	36.36	3.82	45.60	5.98-347.81			
Sihala	33.54580694	73.1953947	36	0	36	0.00	-19.61	0.00	-			
Tarlai Khan	33.64238067	73.14955488	36	24	60	40.00	3.99	53.99	7.02-415.29			
Taramari	33.63715527	73.15620495	39	35	74	47.30	4.56	95.62	12.47-733.24			
Tarnol	33.65728874	72.91174182	78	12	90	13.33	2.03	7.62	0.96-60.68			
Taxilla	33.74487082	72.83878527	59	4	63	6.35	1.30	3.67	0.40-33.90			

(95% Confidence Interval (CI): 0.56-0.95) (P=0.018). The infestation rates varied significantly in breeds, with short-haired dogs having a higher infestation rate (31.94%, OR=5.87) (95% CI: 3.16-10.91) compared to long-haired breeds (6.15%) (P<.001). Preventive measures such as acaricide usage and regular bathing were also considered in this study. The highest infestation rate (42.25%) was observed in dogs that received the irregular acaricide application, while infestation was 1.5 times higher (29.53%) in dogs without acaricide usage. Irregular and no-use groups had significantly higher odds of infestation (OR: 4.35) compared to regularly treated dogs (OR: 2.89). Bathing was also a significant factor, infestation rate for non-bathed dogs was higher (30.20%) and the odds ratios were 4.44 times higher in unbathed dogs (95% CI: 2.31-8.55) than bathed dogs (7.58%) (P<0.001). Roaming behavior also played a significant role, with roaming dogs (39.89%) experiencing a much higher infestation compared to non-roaming dogs (10.10%) (P<0.001) (*Table 2*).

Spatial Distribution of Dog Ticks

Infestation rates varied across different locations in current study. The highest tick infestation was observed in Gujjar Khan (58.12%, OR=167.43) (95% CI: 22.63-1238.72), followed by Taramari (47.30%, OR=95.62), Mandra (45.24%, OR=75.19) and Tarlai Khan (40%, OR=53.99) all showed a strong statistical association. Moderate infestation rates were noted in Rawat (36.36%), Khana (24.29%), and PWD (18.07%) (OR=10 to 45 times higher. The lowest infestation rates were found for Humak (0%), Sihala (0%), and Barakahu (1.89%). The association between location and infestation rates was statistically significant (*Table 3*).

Temporal Dynamics of Tick Infestation in Dogs

The temporal dynamics varied significantly in the present study. Total 940 dogs were inspected, and 254 were extracted. The results showed the monthly variation in infestation rates, with the highest prevalence recorded in August (51.05%, OR=5.47) (95% CI: 2.89-10.36) followed by June (45.90%, OR=4.95) (95% CI: 2.48-9.87), May (43.90%, OR=4.48) (95% CI: 2.01-9.98). The lowest tick infestation rates were observed in December (OR=0.38, 95% CI: 0.19-0.75), November, and October.

Seasonal analysis revealed that ticks had the highest infestation rate during summer (32.42%), followed by spring (25.81%), winter (7.53%), and fall (7.32%). Chi-square analysis and odds ratios showed a statistically significant relationship between tick infestation and monthly and seasonal variations, indicating higher tick infestation risk during warmer periods (*Table 4*) (*Fig. 3*).

Assessment of Diversity of Tick Species Infesting Dogs

The current study determined the diversity of tick species infesting dogs through Shannon-Wiener and Simpson's Diversity Indices. *Rhipicephalus sanguineus* ticks dominated the others but *R. haemaphysaloides* ticks

Table 4. *Temporal dynamics of tick infestation in dogs*

Category		Tick' Infestation		Total	Infestation Rate (%)	Coefficient (β)	Odds Ratio	95% CI for OR	Chi-Square	df	P-value
		Non-infested	Infested								
Months	January	18	2	20	10.00	0	1.00	-	119.8[a]	11	0.0001
	February	10	4	14	28.57	1.08	2.94	0.92-9.39			
	March	26	9	35	25.71	0.96	2.61	1.16-5.85			
	April	20	7	27	25.93	0.98	2.66	1.10-6.45			
	May	23	18	41	43.90	1.50	4.48	2.01-9.98			
	June	66	56	122	45.90	1.60	4.95	2.48-9.87			
	July	308	77	385	20.00	0.69	2.00	1.26-3.18			
	August	70	73	143	51.05	1.70	5.47	2.89-10.36			
	September	5	1	6	16.67	0.51	1.67	0.29-9.62			
	October	33	2	35	5.71	-0.63	0.53	0.26-1.08			
	November	57	3	60	5.00	-0.69	0.50	0.29-0.86			
	December	50	2	52	3.85	-0.96	0.38	0.19-0.75			
Seasons	Winter (November - February)	135	11	146	7.53	0	1.00	-	46.43	3	0.0001
	Spring (March - April)	46	16	62	25.81	1.32	3.74	1.83-7.65			
	Summer (May - August)	467	224	691	32.42	1.80	6.05	3.22-11.37			
	Fall (September - October)	38	3	41	7.32	-0.03	0.97	0.28-3.36			

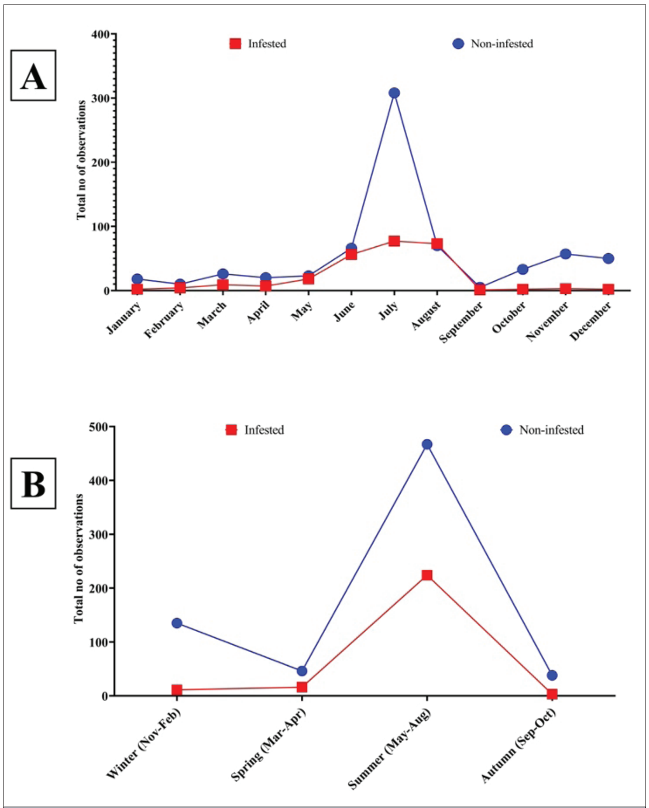

Fig 3. Temporal distribution of host wise prevalence of ticks in dogs (A: month wise data, B: seasonal pattern)

stimulated by the environmental conditions in Pakistan. However, previous reports have confirmed several tick species on different hosts across various regions of Pakistan, highlighting the need for further research focused specifically on canine tick infestations in urban settings [7,18-20,27-32].

The seasonal tick infestation pattern observed in this study were influenced by both biotic and abiotic factors. Warm temperatures and high humidity during summer and spring favored tick activity and survival. Dense vegetation and suitable habitats also supported tick growth in some areas. Dog related factors like roaming poor grooming and high population density raised infestation risks [9-11]. The overall infestation rate of the current study was 27%. The overall tick infestation rate in our study on dogs was relatively lower than reported studies conducted in Pakistan [11,20]. This difference could be attributed to Islamabad's relatively more urbanized and developed environment, lower livestock density, and better waste management [33,34], all of which likely contribute to reduced tick proliferation. Notably, our study found a high prevalence of *R. sanguineus*, which were consistent with previous studies [7,11,18,35-38] followed by *R. haemaphysaloides,* and *R. turanicus* [7,18,39]. These species have been associated with dogs in both rural

Table 5. *Assessment of the diversity of tick species infesting dogs*

Category	Shannon-Wiener Diversity Index (H')				Simpson's Diversity Index (D)			
Species	Total (n_i)	Proportion (p_i)	pi·ln(pi)	(H')	ni (ni−1)	Sum the values of ni(ni−1)	*N* (*N*−1)	(D)
R. turanicus	59	0.0829	−0.2065	0.6070	3422	344.498	506.232	0.3195
R. sanguineus	580	0.8146	−0.1670		335.820			
R. haemaphysaloides	73	0.1025	−0.2335		5.256			

[(H') is the Shannon-Wiener Diversity Index, where: pi is the proportion of each species in the total sample and ln pi is the natural logarithm of pi. While (D) is the Simpson's Diversity Index, ni = Number of individuals of each species and N = Total number of individuals of all species]

and *Rhipicephalus turanicus* were reported in lower ratios. The Shannon-Wiener Diversity Index (H') indicated a moderate level of species diversity because other species also inhabited in study area. Similarly, the Simpson's Diversity Index (D), which represented the probability that two randomly selected individuals belong to different species, showed a level of population diversity. This finding indicated that the majority of dogs were infested with *R. sanguineus* tick. Despite the presence of three tick species, one particular species exhibited dominance over others in terms of abundance *(Table 5)*.

Discussion

The current study investigated the diversity and prevalence of tick species infesting dogs in the cities of Rawalpindi and Islamabad. Tick reproduction and development are

and urban areas, as well as confirmed with detection of several rickettsial, protozoan pathogens, threatening both animal and public health in the region [13,15,38]. Differential accuracy often requires the use of molecular tools for tick species identification [40-43], which were outside the frame of our present study. The presence of *Rhipicephalus* species on canine hosts demonstrates the need for additional taxonomic studies, including at least genetic markers that will be helpful to determine species distribution patterns and host associations in this area.

There is significant variation in the risk factors associated with tick infestation across different research studies. Younger dogs had slightly higher prevalence than adults [17,44]. The active and exploratory behavior of younger dogs may increase their risk of encountering tick-infested environments such as fields and wooded areas as well as kennels and younger dogs fail to maintain proper self-grooming, allowing tick to remain attached longer periods [45,46].

Female dogs were statistically more infested than males. Our findings were consistent with reported studies [7,18-20,47]. The rest periods of pregnant or lactating female dogs are longer and more frequent [48] when they choose shaded areas or dense vegetative areas, increasing their risk of tick encounters. Coat length was the most significant factor influencing infestation rates; short haired breeds had significantly higher infestations than the long-haired breeds [21,49]. This is because short-haired dogs have more exposed skin, providing ticks with easier access to attach and feed, whereas long-haired breeds may offer a protective barrier that hinders tick attachment [20, 45]. Acaricide treatment and regular bathing were also important in keeping infestation rates at low levels. Dogs with irregular acaricide treatment showed the highest tick infestation. Dogs that were never received acaricide treatment had 1.5 times higher tick infestation than those treated regularly. Similarly, non-bathed dogs had a higher incidence of tick infestation than bathed dogs, which was consistent with previous studies [20,35]. Free-roaming dogs exhibited significantly higher infestation rates than confined dogs [50,51], which reported that free roaming behavior and exposure to the tick population of natural habitat had a direct association with tick infestation. Risk factors in present study such as, age, short haired breeds, use of acaricide, bathing, and roaming behavior [20,52].

Further, spatially distributed variations of tick infestations showed that the highest infestation rates were in Gujjar Khan, while Humak, Sihala, and Barakahu had significantly lower infestation rates. These differences could be due to because most of the dogs studied in Gujjar Khan were semi-stray or free roaming and in most instances were confined in peri-urban or rural environments where they had direct contact with vegetation, animal pens, and other possible tick foci. These dogs were not likely to get regular veterinary treatment or acaricidal treatment, hence exposing them to more ticks. On the other hand, dogs in Humak, Sihala, and Barakahu were companions of a more urbanized nature, with better hygiene, limited exposure to the external wild, and wider access to tick repellent strategies, which could all affect the lower instances of infestation. Summer and spring had the highest tick infestation than autumn and winter, which were consistent with previous literature [19,20,30,39,53] reported that tick activity peaks during warm and humid seasons when survival and host-seeking behavior are most favorable. Increased moisture and high temperature are responsible for the high tick infestation rate observed in the summer [54].

Simpson's Diversity Index (D) indicated a relatively low level of population diversity, demonstrating that many dogs were infested with *R. sanguineus*. In contrast, the Shannon-Wiener Diversity Index (H') suggested a moderate level of species diversity. Ecological studies on similar habitats often report the predominance of a single tick species due to habitat and host specificity; such a predominance may signal such specificity [55-57], but a study conducted in Lakki Marwat district, Khyber Pakhtunkhwa, Pakistan reported low diversity in dogs [58]. The current study highlights the necessity of specific tick management strategies, particularly in high-risk areas and during times when the dog population is at high risk of infestation. Future studies that incorporate molecular tools are highly recommended for dog-related tick research, and long-term surveillance of tick species should be done to assess the emerging species and tick distribution in Islamabad and Rawalpindi, Pakistan.

The present study provides comprehensive insight into the prevalence, diversity and risk factor factors of infestation in dogs from Rawalpindi and Islamabad, Pakistan. Our findings revealed *R. sanguineus* as the dominant species, with seasonal patterns showing peak infestation during summer. Several risk factors including young age, female gender, short hair, irregular acaricides use, lake of bathing, and free roaming, were significantly associated with higher infestation rates of ticks. Spatial variations highlighted certain areas hotspot for tick occurrence. The moderate species diversity and high prevalence emphasizes the need for targeted control measures in dogs. Regular acaricide treatments, proper hygiene, and restricted roaming could significantly reduce infestation risks. This current study also underscores the need for continued surveillance and future research employing molecular identification methods to better understand it ecology and control strategies in the region.

Declarations

Availability of Data and Materials: The datasets used and/or analyzed during the current study are available from the corresponding author (H. Ahmed) on reasonable request.

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