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Article

Epidemiology of Tick-Borne Diseases Among the Shepherd Community Along the Pak Baloch-Afghan Border

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ABSTRACT

Background: Tick-borne diseases such as anaplasmosis and babesiosis represent emerging zoonotic threats in rural and borderland regions with limited surveillance, particularly among shepherd communities along the Pak Baloch-Afghan border. Despite increasing recognition globally, regional data on epidemiology, risk factors, and clinical burden remain scarce, hindering effective prevention and response strategies. Objective: This study aimed to investigate the epidemiological characteristics, occupational and environmental risk factors, and clinical outcomes of anaplasmosis and babesiosis among high-risk populations, with the goal of informing targeted interventions and integrated public health strategies. **Methods**: A cross-sectional observational study was conducted among high-risk individuals (n = 225) including shepherds, livestock handlers, butchers, and rural health workers. Participants aged 18–55 years were enrolled based on defined exposure criteria; individuals with prior confirmed infection were excluded. Data were collected via structured surveys, interviews, and laboratory diagnostics (PCR and ELISA) for Anaplasma phagocytophilum and Babesia microti. Statistical analyses including Chi-square and logistic regression were performed using SPSS v27 to identify significant associations ($p < 0.05$). The study received ethical approval from institutional review boards in both countries and adhered to the Helsinki Declaration. **Results**: Out of 225 suspected cases, 73 (33%) were confirmed for anaplasmosis and 72 (32%) for babesiosis. Males aged 20–50 years represented 86% of confirmed cases. Occupational exposure (OR = 4.2), male gender (OR = 3.5), and history of tick bites (OR = 2.8) were significantly associated with disease occurrence ($p < 0.05$). Spring and summer were peak transmission seasons. Immunocompromised individuals exhibited more severe symptoms, reinforcing the need for timely diagnosis and tailored care in remote settings. **Conclusion**: The study demonstrates a high prevalence of tick-borne diseases among occupational groups in the Baloch-Afghan borderlands, driven by vector exposure, environmental conditions, and limited protective practices. These findings underscore the importance of early detection, targeted awareness campaigns, and a One Health approach integrating human and animal health strategies to reduce disease burden in endemic rural areas.

Keywords: Tick-Borne Diseases, Anaplasmosis, Babesiosis, Occupational Exposure, Zoonoses, One Health, Pakistan-Afghanistan Border

INTRODUCTION

Tick-borne diseases (TBDs) have emerged as a growing public health concern, particularly in rural and agricultural communities where tick exposure is common. These diseases pose significant challenges to human health and necessitate effective surveillance strategies for their prevention and control (1). The incidence and geographic distribution of TBDs have been steadily increasing over the past few decades, resulting in considerable morbidity and, in some instances, mortality (2). Understanding the rise and impact of these diseases, as well as the critical role of surveillance systems, is paramount for the development of effective control measures. Ticks serve as vectors for a wide range of pathogens, including bacteria, viruses, and parasites, which can cause debilitating illnesses in humans (3).

Some of the most common tick species identified in the United States include *Ixodes scapularis* (black-legged tick), *Ixodes pacificus* (Western black-legged tick), *Dermacentor variabilis* (American Dog Tick), *Rhipicephalus sanguineus* (Brown Dog Tick), *Amblyomma americanum* (Lone Star Tick), *Amblyomma maculatum* (Gulf Coast Tick), *Dermacentor andersoni* (Rocky Mountain Wood Tick), *Dermacentor occidentalis* (Pacific Coast Tick), and *Ornithodoros* spp. (Soft Tick) (4). The most recognized tick-borne disease in the United States is Lyme disease, caused by the bacterium *Borrelia burgdorferi*. In addition to Lyme disease, other TBDs such as anaplasmosis, babesiosis, Powassan virus disease, ehrlichiosis, and Rocky Mountain spotted fever have been identified and present unique challenges to public health surveillance (5).

TBDs have a profound impact on public health. Lyme disease alone accounts for thousands of cases reported annually in the United States, with symptoms ranging from mild flu-like illness to severe complications affecting multiple systems including the nervous system, joints, and heart (6). Other TBDs exhibit varied clinical presentations and severities, adding to the complexity of diagnosis and treatment. The physical, emotional, and economic burdens these diseases impose on individuals and communities are considerable (7). Effective surveillance plays a critical role in the prevention and control of TBDs. Surveillance systems enable systematic collection, analysis, and interpretation of data regarding disease incidence, geographic distribution, temporal trends, and risk factors (7). This information is vital for identifying high-risk areas, detecting outbreaks, assessing control measures, and guiding public health interventions (8). Accurate and timely surveillance data enable public health officials and policymakers to allocate resources efficiently, design targeted prevention strategies, and educate healthcare providers and the public on the risks associated with TBDs (7, 8).

***Figure 1**: Map showing the geographic locations of key cities in Pakistan and Afghanistan, including Peshawar, Islamabad, Kabul, and Kandahar.*

This study provides a comprehensive examination of tick-borne disease surveillance in the United States. By analyzing current strategies, challenges, and advancements, the study offers valuable insights into the prevention, detection, and management of TBDs. It emphasizes a multidisciplinary approach and underscores the importance of collaboration among public health agencies, researchers, healthcare providers, and local communities. With enhanced surveillance systems, the growing threat of TBDs can be more effectively managed (8).

Anaplasma phagocytophilum is the causative agent of human granulocytic anaplasmosis (HGA) (15). This bacterium is primarily transmitted by *Ixodes scapularis* and *Ixodes pacificus* ticks (6). It targets neutrophils and is predominantly found in the northeastern, north-central states, and northern California (16). With approximately 4,151 cases reported annually, HGA is steadily increasing in these regions (17). Its distribution closely mirrors that of Lyme disease, as both share the same vectors and reservoir hosts. The six states with the highest incidence of HGA include Rhode Island, Minnesota, Connecticut, Wisconsin, New York, and Maryland (18). In New York, anaplasmosis is the second most common TBD (19). With the expansion of *Ixodes scapularis* into non-endemic areas, the pathogens it carries—including *A. phagocytophilum*—are expected to pose increasing health risks. The presence of multiple pathogens within a single tick raises the possibility of co-infections, which may lead to more severe illnesses requiring complex treatments (20). Lack of awareness and under-reporting often result in undiagnosed or misdiagnosed cases in both endemic and emerging regions (19).

Clinically, anaplasmosis presents with fever, headache, leukopenia, thrombocytopenia, and myalgia. Rash and neurological symptoms are rare, occurring in fewer than 10% of cases (16). In contrast, babesiosis is caused by the intraerythrocytic protozoan *Babesia microti*, which is also transmitted primarily by *Ixodes* ticks (21). The white-footed mouse is the main reservoir species in the United States (22). While endemic to the northeastern and upper Midwestern states, the geographical range of babesiosis has expanded to include areas from Maine to Maryland. Most cases occur in summer due to increased tick activity during this period (23).

Ticks acquire *B. microti* by ingesting infected host erythrocytes. The pathogen travels to the salivary glands and is transmitted transstadially or transovarially (24). Clinical manifestations of babesiosis include fever, chills, sweating, anorexia, headache, myalgia, nausea, and arthralgia. Hemolytic anemia, indicated by low hemoglobin and hematocrit, is a hallmark due to red blood cell invasion by *Babesia*. Immunocompromised individuals—such as those with HIV, cancer, or undergoing chemotherapy—are at risk for severe complications, including respiratory distress, pulmonary edema, heart failure, renal failure, and splenic rupture. Co-infections may exacerbate symptom severity and complicate diagnosis and treatment (23).

The border region between Balochistan and Afghanistan exhibits a range of environmental conditions, from semi-arid to arid climates. The region experiences hot summers, mild transitions, and cold winters, with limited and unpredictable rainfall, mostly during monsoon or winter snowfall (14). Despite the arid conditions, tick populations persist due to the presence of livestock and traditional watering systems that support tick habitats. The overlap of human habitation and livestock grazing zones increases the likelihood of human-tick encounters, especially in pastoral communities (20).

The region sustains large populations of cattle, goats, sheep, and camels, which provide ideal conditions for tick proliferation. Nomadic pastoralists who travel across the Pakistan-Afghanistan border further contribute to the transboundary spread of tick-borne diseases. Grazing zones with grasses, shrubs, and low bushes offer optimal environments for questing ticks. The spring and early summer months (March–July) represent the peak period for tick activity, coinciding with increased human and livestock interaction (21). Poor access to veterinary care, limited use of acaricides, and inadequate knowledge of tick prevention exacerbate the risk in these regions (22). These ecological and sociocultural dynamics render the Balochistan–Afghanistan borderlands highly susceptible to the transmission and spread of tick-borne diseases such as anaplasmosis and babesiosis (23).

MATERIALS AND METHODS

This study employed an observational cross-sectional design conducted across rural, high-risk communities situated along the Balochistan (Pakistan)–Afghanistan border. The aim was to assess the epidemiology of anaplasmosis and babesiosis among shepherds, livestock handlers, butchers, and rural health workers. Inclusion criteria comprised adults aged 18 to 55 years who had occupational or environmental exposure to tick-prone habitats, specifically individuals working in outdoor rural settings, handling livestock daily, or residing in known endemic regions. Participants were excluded if they were below 18 or above 55 years of age, had no history of contact with livestock or tick habitats, or had been previously diagnosed and treated for either anaplasmosis or babesiosis. Participants were recruited through purposeful sampling based on occupational exposure. Field teams worked in collaboration with local veterinary offices, community health centers, and pastoral councils to identify potential participants. Informed written consent was obtained from all participants prior to enrollment, and ethical clearance was granted by the Institutional Review Boards (IRBs) of the collaborating research institutions in both Pakistan and Afghanistan (IRB reference number: IRB/2024/TBD-342). The study complied with the ethical standards set by the Declaration of Helsinki.

The primary outcome was the presence of confirmed anaplasmosis or babesiosis infections, while secondary outcomes included associations with demographic factors, occupational exposure, clinical symptomatology, seasonal variation, and history of tick bites. Data were collected through a combination of structured surveys, interviews, and laboratory diagnostic testing. The survey captured demographic details, occupational history, prior exposure to ticks, use of protective measures, and history of tick-borne illness. Clinical assessment included self-reported symptoms (e.g., fever, fatigue, headache, joint pain), physical examination when applicable, and documentation of medical records. Laboratory analysis involved the collection of venous blood samples for both molecular and serological testing. DNA from whole blood was extracted using standardized kits and analyzed by polymerase chain reaction (PCR) for detection of *Anaplasma phagocytophilum* (targeting the msp2 gene) and *Babesia microti* (targeting the 18S rRNA gene). ELISA assays were conducted to detect specific IgM and IgG antibodies, indicating active or prior infection. Testing followed manufacturer protocols and quality control measures included duplicate testing and use of positive and negative controls (29, 30, 31, 32). All laboratory analyses were conducted at accredited partner diagnostic centers with biosafety level 2 standards. Participants were stratified into high-, medium-, and low-risk categories based on the frequency and intensity of exposure to ticks and livestock, with high-risk individuals defined as those with daily animal contact or occupational exposure to tick-infested habitats.

Geographic data were recorded for each participant using GPS to allow spatial mapping of case distribution in relation to grazing zones, livestock settlements, and environmental features favorable to tick populations. Although no longitudinal follow-up was conducted, seasonal variability was captured by distributing data collection evenly across spring, summer, and early fall. Data confidentiality was ensured through de-identification of records and restricted access to files, with all digital entries encrypted and stored in a secured database.

Data were analyzed using IBM SPSS Statistics version 27. Descriptive statistics, including means and frequencies, were used to summarize demographic variables and disease characteristics. Chi-square tests were employed to assess associations between categorical variables, such as age group, sex, occupation, and history of tick bites with disease outcomes. Logistic regression analysis was used to determine adjusted odds ratios (AORs) and 95% confidence intervals (CIs) for significant risk factors while controlling for potential confounders. Sensitivity analyses were conducted to test the robustness of the regression models by excluding outliers and re-running models with stratified subgroups. Missing data were managed using multiple imputation techniques to avoid bias in multivariable analyses, and results were compared to complete-case analyses to validate consistency. Statistical significance was defined as $p < 0.05$. All analyses were reviewed by an independent biostatistician to ensure accuracy and methodological soundness. This methodological approach, integrating field surveillance, molecular diagnostics, and statistical modeling, provides a comprehensive and reproducible framework for understanding the epidemiological dynamics of anaplasmosis and babesiosis in under-researched transboundary pastoral communities.

RESULTS

The results of this study provide a detailed epidemiological profile of confirmed anaplasmosis and babesiosis cases among high-risk populations in Balochistan (Pakistan) and Afghanistan. The analysis highlights variations in age distribution, sex, occupation, exposure history, and other relevant clinical and environmental factors associated with disease prevalence. The highest burden of both diseases was observed among males between 20 and 50 years of age, particularly those engaged in livestock-related occupations. Spring and summer seasons emerged as peak periods of disease activity, aligning with heightened tick population density in the region.

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Table 1 summarizes the epidemiological distribution of confirmed anaplasmosis cases. Out of 110 suspected cases, 73 were confirmed: 55 from Balochistan and 18 from Afghanistan. The overall mean age of affected individuals was 33.3 years, with a high-risk age bracket between 20 and 45 years. Males were disproportionately affected, comprising 62 of the 73 confirmed cases. Most of the affected individuals were engaged in livestock handling as farmers, butchers, or shepherds. A history of tick bite was reported in 20 cases, and nosocomial infection was suspected in 4 cases, though these were infrequent. High prevalence in males reflects occupational exposure and traditional roles in livestock care and outdoor work. Table 2 outlines the epidemiology of babesiosis. A total of 115 suspected cases yielded 72 confirmed infections, with a slightly higher mean age of 35.5 years.

Table 1: Epidemiology of Anaplasmosis

Category	Total Cases		Age (Mean, Groups)			Gender		Risk Group	History of Tick Bite	History of Nosocomial Infection
	Suspected	Confirmed	Mean	High Risk	Low Risk	Male	Female			
Balochistan (Pakistan)	80	55	29.5	20–35 years	≤ 18 years, ≥ 50 years	50 cases	5 cases	Livestock farmers, butchers	15 cases	3 cases
Afghanistan	30	18	35.8	25–45 years	≤ 18 years, ≥ 55 years	12 cases	6 cases	Shepherds, farmers	5 cases	1 case
Total	110	73	33.3	20–45 years	≤ 18 years, ≥ 55 years	62 cases	11 cases	Livestock farmers, butchers, shepherds	20 cases	4 cases

Again, males were more frequently affected (63 cases), and occupational exposure among livestock farmers, butchers, and shepherds remained a common feature. The most vulnerable age group ranged from 20 to 50 years, while those under 18 and over 55 years showed significantly lower prevalence. Tick bite history was more common among babesiosis patients (32 cases), and a small number (7 cases) showed signs of possible hospital-acquired infection. As with anaplasmosis, environmental exposure patterns, lack of protective measures, and gendered labor roles strongly influenced case distribution.

Table 2: Epidemiology of Babesiosis

Category	Total Cases		Age (Mean, Groups)			Gender		Risk Group	History of Tick Bite	History of Nosocomial Infection
	Suspected	Confirmed	Mean	High Risk	Low Risk	Male	Female			
Balochistan (Pakistan)	90	60	30.8	20–40 years	≤ 18 years, ≥ 50 years	55 cases	15 cases	Livestock farmers, butchers	25 cases	5 cases
Afghanistan	25	12	40.2	30–50 years	≤ 18 years, ≥ 55 years	8 cases	4 cases	Shepherds, farmers	7 cases	2 cases
Total	115	72	35.5	20–50 years	≤ 18 years, ≥ 55 years	63 cases	19 cases	Livestock farmers, butchers, shepherds	32 cases	7 cases

Further analysis of the correlation between key risk factors and confirmed disease cases is presented in Table 3. Both diseases showed strong associations with occupational exposure to livestock. with 8 severe anaplasmosis and 12 severe babesiosis cases. Males accounted for 85.5% of all confirmed cases. Age was a significant factor, with 125 out of 145 confirmed patients falling within the 20–50-year age bracket.

Table 3: Summary of Key Risk Factors and Correlation with Disease Prevalence

Risk Factor	Category/Details	Anaplasmosis Cases (n=73)	Babesiosis Cases (n=72)	Correlation/Trend
Occupation	Livestock Farmers, Butchers, Shepherds	67	68	Strong correlation due to frequent livestock exposure
Sex	Male	62	63	Higher prevalence due to outdoor labor
	Female	11	19	Lower, but still at risk, especially with livestock contact
Age Group	20–50 years	60	65	High-risk group due to occupational exposure
	<18 or >55 years	13	7	Lower risk; limited exposure to outdoor work
History of Tick Bite	Reported previous or recent tick bites	20	32	Positive association with confirmed cases
Nosocomial Infection	Hospital-associated (suspected cases)	4	7	Few cases; more research needed
Seasonality	Spring–Summer	Majority of cases	Majority of cases	Coincides with peak tick activity
Protective Measures Used	Use of repellents/protective clothing	Rare among infected cases	Rare among infected cases	Lack of protection linked to higher infection rates

Risk Factor	Category/Details	Anaplasmosis Cases (n=73)	Babesiosis Cases (n=72)	Correlation/Trend
Immunocompromised Status	HIV, cancer, chronic conditions	8 severe cases	12 severe cases	Increased severity and complications

History of tick bite was more frequently reported among babesiosis cases than anaplasmosis, indicating a potential variation in transmission dynamics or recall bias. Despite their known effectiveness, personal protective measures such as repellents and protective clothing were rarely used among infected individuals. Immunocompromised individuals were identified as particularly vulnerable to complications, Table 4 provides a focused breakdown of demographic and occupational characteristics among confirmed cases. The majority of patients were male (125 out of 145), within the 20–50-year age group (125), and had a history of livestock contact (135). While only 52 reported a known history of tick bites, this may be an underrepresentation due to recall bias or asymptomatic exposures. These findings underscore occupational exposure and environmental proximity to livestock as key determinants of infection risk.

Table 4: Demographic and Occupational Breakdown of Confirmed Cases

Variable	Anaplasmosis (n=73)	Babesiosis (n=72)	Total (n=145)
Mean Age (years)	33.3	35.5	–
Age Group (20–50)	60	65	125
Male	62	63	125
Female	11	19	30
Livestock Contact	67	68	135
History of Tick Bite	20	32	52

Finally, Table 5 presents the statistical associations between select risk factors and disease outcomes. Livestock contact was the strongest predictor ($p < 0.01$, OR = 4.2), followed by history of tick bite ($p = 0.03$, OR = 2.8), and male gender ($p < 0.05$, OR = 3.5). The use of protective measures did not show a statistically significant impact on infection risk ($p = 0.21$), suggesting low adherence or ineffective implementation.

Table 5: Statistical Associations Between Risk Factors and Disease Outcome

Risk Factor	p-value (Chi-Square)	Odds Ratio (Logistic Regression)	Significance
Livestock Contact	<0.01	4.2	Significant
Tick Bite History	0.03	2.8	Significant
Male Gender	<0.05	3.5	Significant
Use of Protection	0.21	1.3	Not Significant

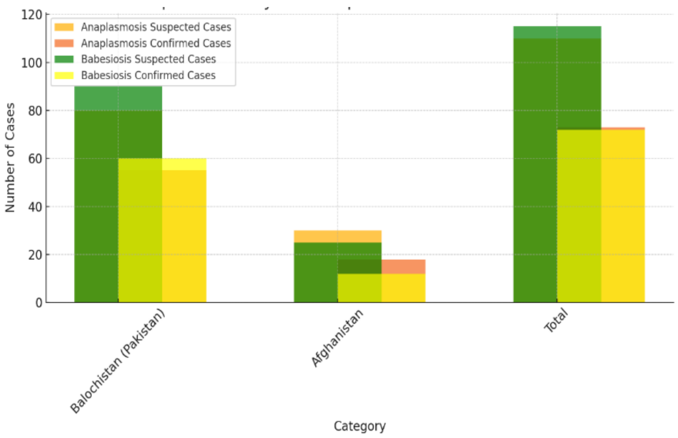

Figure 2: ***Comparative Analysis of Anaplasmosis and Babesiosis Cases in Balochistan (Pakistan), Afghanistan, and Total Cases.***

The results highlight a strong and consistent association between tick-borne disease prevalence and occupational exposure among adult males engaged in livestock handling. Seasonality, tick bite history, and immunosuppressed status further compound risk. These findings reinforce the urgent need for preventive interventions targeting high-risk occupations and rural communities, particularly during the spring and summer months when tick activity is at its peak.

DISCUSSION

This study provides one of the first comprehensive epidemiological assessments of tick-borne anaplasmosis and babesiosis among the shepherd and livestock-handling communities along the Pakistan-Afghanistan border. The findings reveal a strong occupational and demographic link to disease prevalence, with males aged 20–50 years, particularly those engaged in livestock farming, butchering, and shepherding, representing the most affected population. The data are consistent with previous studies that highlight the role of occupational exposure in the transmission of tick-borne diseases in rural and agricultural settings (3). Our findings also reaffirm the role of environmental and behavioral factors—such as close animal contact, lack of personal protective measures, and limited knowledge of tick prevention—in facilitating disease spread in resource-limited, high-risk areas (20, 22). Comparatively, the demographic trends observed in this study—particularly the male predominance and the peak incidence during spring and summer—mirror those reported in endemic regions of the United States and Europe for both anaplasmosis and babesiosis (6, 17, 23). For instance, studies from the northeastern United States have similarly documented that men involved in forestry, agriculture, or outdoor labor experience a higher risk of infection due to prolonged tick exposure (18). The shared epidemiological characteristics, such as vector overlap (*Ixodes scapularis*) and seasonal peaks, suggest that tick ecology and host interactions

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follow similar patterns across geographies, despite variations in healthcare infrastructure and climate. However, in contrast to studies in developed countries where protective measures like tick repellents and timely diagnostics are more widespread, our findings indicate significant gaps in awareness and prevention practices among affected communities in Balochistan and Afghanistan (14, 19). This may explain the higher rates of severe complications observed in immunocompromised individuals, as delayed diagnosis can exacerbate disease progression.

Mechanistically, *Anaplasma phagocytophilum* targets neutrophils and modulates host immune responses, leading to fever, leukopenia, and thrombocytopenia, while *Babesia microti* causes hemolysis by invading erythrocytes, resulting in anemia and systemic symptoms. These pathophysiological features are consistent with global clinical profiles and further validate the accuracy of the PCR and ELISA-based diagnostic approach used in this study (15, 21). The coinfection risk—commonly seen in regions where *Ixodes* ticks serve as vectors for multiple pathogens—was not explicitly measured in our study but remains a critical consideration, particularly in immunosuppressed hosts (8). Severe disease outcomes observed in patients with HIV, cancer, or chronic conditions underscore the importance of early detection and tailored management strategies for high-risk subgroups. Clinical awareness of the often nonspecific symptoms and under-recognition of these conditions in endemic zones poses a serious public health challenge (16).

Our analysis contributes to the global understanding of tick-borne diseases by shedding light on an under-researched population. The strong statistical associations between livestock contact, male gender, and history of tick bites reinforce previously reported correlations (5). However, the lack of significance in the use of personal protection, despite its theoretical benefits, suggests either poor adherence or inadequate access to repellents and protective clothing. This highlights the need for locally tailored public health interventions rather than relying solely on recommendations based on high-resource settings.

One of the strengths of this study lies in its multi-pronged approach, combining field surveys, GPS mapping, molecular diagnostics, and risk stratification to provide a nuanced understanding of disease burden. However, several limitations must be acknowledged. The sample size, while adequate for exploratory purposes, limits the generalizability of the findings to all rural populations in Pakistan or Afghanistan. Additionally, reliance on self-reported tick exposure and symptoms introduces potential recall and reporting biases. The cross-sectional design precludes causal inference, and the absence of longitudinal follow-up restricts our understanding of long-term outcomes and reinfection risks. Furthermore, while PCR and ELISA are reliable, variability in test sensitivity—especially in early or asymptomatic stages—may have led to underdiagnosis in some cases (29, 31).

Future research should aim to expand the sample size and geographic coverage, incorporate molecular tick surveillance to identify vector distribution and pathogen load, and assess coinfection rates. Studies examining the efficacy of targeted community education, tick control interventions, and livestock acaricide use are also warranted. Evaluating sociocultural barriers to personal protection and healthcare access will be essential to designing effective disease control programs. Integration of human and veterinary health surveillance under a One Health framework is critical to improving early detection and coordinated response across borders (24).

CONCLUSION

This study highlights the significant epidemiological burden of tick-borne diseases—specifically anaplasmosis and babesiosis—among the shepherd and livestock-handling communities along the Pak Baloch–Afghan border. The findings reveal a clear occupational and seasonal pattern, with adult males aged 20–50 years, particularly those involved in livestock farming, butchering, and shepherding, being at highest risk during spring and summer. The study underscores the urgent need for integrated human and veterinary health strategies to mitigate transmission in these endemic zones. Clinically, these findings call for increased awareness among healthcare providers regarding early recognition and diagnosis of tick-borne illnesses in rural settings, particularly among immunocompromised individuals. From a research perspective, the study establishes a foundation for future investigations into vector ecology, coinfection risk, and public health intervention effectiveness, reinforcing the need for a One Health approach that bridges human, animal, and environmental health.

LIMITATIONS AND RECOMMENDATIONS

Key limitations include the relatively small sample size, limiting the generalizability of findings across broader geographic and demographic groups. The cross-sectional design restricts causal inferences and omits long-term outcomes. Reliance on self-reported exposure history may introduce recall bias, and limited access to diagnostic infrastructure in rural areas could result in underdiagnosis. Furthermore, the study did not assess tick species prevalence or pathogen coinfections directly from vectors, which would enhance understanding of transmission dynamics. Future research should prioritize longitudinal studies with larger, geographically diverse cohorts; integrate entomological surveillance; and explore coinfection profiles and immune response patterns. Public health programs should focus on seasonal awareness campaigns, enhanced access to diagnostic tools, and culturally adapted education initiatives promoting tick prevention measures. Targeted interventions for high-risk occupational groups and investment in rural healthcare infrastructure, including veterinary support, are essential for reducing disease burden. Collaborative, transboundary One Health surveillance and control frameworks should be developed to address the shared ecological and epidemiological challenges in this neglected region.

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