Rasayely
International Journal of Equine Science
https://rasayely-journals.com/index.php/ijes
Vol 4(1);21–29, 2025

Original Article Open Access

Seroepidemiology and Risk Factors Associated with *Theileria equi* and *Babesia caballi* Infections in Horses from Borno and Yobe States, Nigeria

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Received: 23 December 2024; Revised: 22 January 2025; Accepted: 29 January 2025; Published: 28 February 2025

Academic Editor: Mahmoud Rezk AbouLaila, Faculty of Veterinary Medicine, Damanhour University, Egypt

Abstract

Background: *Theileria equi* and *Babesia caballi* are tick-borne hemoparasites that infect horses, causing significant economic losses. This study aimed to determine the seroprevalence and risk factors associated with *T. equi* and *B. caballi* infections in horses from Borno and Yobe states, Nigeria. **Methods:** A cross-sectional study was done on 384 horses from Borno and Yobe states. Blood samples were collected and analyzed using ELISA to detect antibodies against *T. equi* and *B. caballi*. Relative risk (RR) and odds ratio (OR) were computed to determine the association between risk factors and seropositivity. **Results:** The overall seroprevalence of *T. equi* and *B. caballi* was 60.4% and 71.9%, respectively. The data were analyzed using relative risk and odds ratio, which revealed that horses from Borno state (RR = 0.7692, 95% CI: 0.6410 to 0.9231) were less likely to be *T. equi* seropositive. Similarly, horses from Yobe state (RR = 1.0714, 95% CI: 0.8519 to 1.3476) were at a higher risk of being *B. caballi* seropositive. **Conclusion:** This study revealed a high seroprevalence of *T. equi* and *B. caballi* in horses from Borno and Yobe states, Nigeria. Horses from Borno state and those with tick infestation were at a higher risk of *B. caballi* seropositivity, while horses from Yobe state and those with tick infestation were at a higher risk of *T. equi* seropositivity. These findings highlight the need for effective tick control measures and regular monitoring of horses for *T. equi* and *B. caballi* infections.

Keywords

Seroepidemiology; risk factors; piroplasmosis; horses

1. Introduction

Horses are retained for cultural, athletic, security, and research purposes in northern Nigeria. However, a serious health issue that affects horses in this region of the nation is equine piroplasmosis (EP) [1]. *Theileria equi* and *Babesia caballi* are two different intra-erythrocytic protozoan parasites that cause EP, a tick-borne illness that affects horses [2].

According to [3], the disease is primarily found in tropical, subtropical, and temperate regions of the world. It is transmitted by ixodid ticks belonging to the genera Hyalomma, Dermacentor, and Rhipicephalus [4]. Following a whole-genome sequence, a novel species was identified as *T. haneyi* [5], which was also found among horses in South Africa [6]. Microsatellite analysis of the Florida strain of *T. equi* recently showed significant genetic diversity and 48 SNP

differences in the 18SrRNA gene. The World Organization for Animal Health (OIE) has declared equine piroplasmosis (EP) a reportable disease because 90% of horses are thought to live in regions where the disease is endemic [7].

Numerous epidemiological studies on EP and its risk factors have been conducted on several continents throughout the world in the past 50 years [8]. Erythrocytes are parasitized by *Theileria equi* and *Babesia caballi*, which can co-infect animals [9]. Numerous symptoms including fever, anemia, jaundice, hematuria, and lymphadenopathy are indicative of the illness [10,11]. Although the initial acute phase can result in death, the animals that survive serve as carriers and reservoirs of infection [12]. Seroepidemiological and risk factor data regarding *Theileria equi* and *Babesia caballi* in Nigerian horses from Borno and Yobe States are scarce. Thus, the purpose of this study is to examine the risk factors and seroepidemiological characteristics linked to *Babesia caballi* and *Theileria equi* in horses from Nigeria's Borno and Yobe States.

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted in Borno and Yobe States of Northeastern Nigeria from August to October 2023. These two states are situated in the Savannah and Sahel ecological zones of Nigeria.

2.2. Samples Collection

The samples were collected from two local governments in Borno (Maiduguri Metropolitan Council (MMC) and Jere) and Yobe (Geidam and Nguru). A total of 384 blood samples were collected from clinically healthy equids of different breeds with ticks present on their bodies (192 horses from Borno state and 192 horses from Yobe state). The horses were randomly selected from various locations, including stables where they were kept and cared for by riders for business, hobby markets, and farming households (from August to October 2023). Horses of both sexes were used in this study. Horses were classified as young if their age ranged between 1–10 years, while those with ages ranging between 11 and above 20 years were classified as adults. The body weights of the horses ranged between 350 and 450 kg. The body weights of the horses were estimated using a weighing type method. Horses were properly restrained, and antiseptic gauze was used to disinfect the site of collection by wiping to help remove superficial dirt as well as help in visualizing the raised vein after which a sterile needle was used to collect 4 ml of blood from the jugular vein, the needle was removed gently and the collected blood was then transferred into a well-labeled plane vacutainer tubes and the needles were disposed of properly.

2.3. Sample Transportation

The collected blood samples were carefully taken and labeled with information such as age, sex, body weight, and location of the animals. The samples were then packaged using cushioning materials to minimize shifting and stored in a temperature-controlled environment at a temperature of 8°C.

The collected blood samples were allowed to clot at room temperature for 25–30 minutes. The samples were then centrifuged at a speed of 2000 rpm for 10 minutes to separate the serum from the cellular components. Following centrifugation, the supernatant (serum) was gently transferred into well-labeled cryotubes immediately and stored at a freezing temperature of -20°C.

2.4. Sample Preparation

2.4.1. Serum/Plasma

Dilute serum samples with a 20-fold dilution using sample diluent (5 µl of serum was added to 96 µl of sample diluent to obtain a 1:20 dilution). Dilution was performed at room temperature and used immediately. Serum samples were stored at -20°C.

2.4.2. Reagent Preparation

All frozen reagents were brought up to room temperature before use (1–2 hours at 20–25°C). All Solutions were prepared prior to performing ELISA. Also, all reagents were mixed by inversion before use. Strict measures were taken to avoid returning pipette tips or any reagent to the original stock tube. A disposable reservoir was used during the handling of reagents to minimize the risk of contamination.

2.4.3. Preparation of Wash Buffer Solution

One volume of 20X Wash solution was mixed with 19 volumes of distilled water. For a 96-well plate, multiply 250 µl by 5 and then by 2 to calculate the total volume required for the wash.

2.4.4. Preparation of Conjugated Antibody Solution

One volume of 25 ml HRP (horse radish peroxidase) conjugate antibody solution was mixed with 24 volumes of BC antibody diluent.

2.5. ELISA Protocol

Babesia equi antigen-coated plate and all reagent components were brought and kept at room temperature for at least an hour. 90 µl of BQ Assay Diluent was added to each well of antigen-coated plate/strips. An aliquot of *B. equi* positive control (10 µl per well) was added to two wells of the antigen-coated plate. An aliquot of *B. equi* negative control (10 µl per well) was added to two wells of the antigen-coated plate. The positive and negative controls were separated from each other by placing them at the upper left-hand and bottom-right-hand corner wells of the plate respectively. 10 µl of the previously diluted serum/plasma sample (1:20) was added per well, and the solutions were mixed in the well.

2.6. Data Analysis

The prevalence rate of *Theileria equi* and *Babesia caballi* infection in the serum samples from the horses was calculated using the formula:

$$\text{Seroprevalence} = \frac{\textit{Number of sample positive}}{\textit{Total number of samples analyzed}} \times 100$$

The data were analyzed using Chi-Square, relative risk, and odds ratio with MedCalc® Statistical Software version 23.0.9 (MedCalc Software Ltd, Ostend, Belgium; https://www.medcalc.org; 2024). The seroprevalence of piroplasmosis was evaluated using VassarStat for confidence intervals. A *P*-value less than 0.05 was considered significant.

3. Results

The relative risk (RR) and odds ratio (OR) are two commonly used measures to assess the association between risk factors and the development of piroplasmosis in equids in Borno and Yobe States, Nigeria.

3.1. Prevalence, Relative Risk, and Odds Ratio of Babesia caballi in Borno State (Jere and MMC), Nigeria

3.1.1. Prevalence

The prevalence of *Babesia caballi* in MMC and Jere local government areas was 71.9%, with a confidence interval of 65.1 to 77.8 **(Table 1)**.

3.1.2. Relative Risk (RR)

The relative risk is a measure of the ratio of the probability of developing piroplasmosis in the exposed group to the probability of developing piroplasmosis in the non-exposed group. An RR of 1 indicates no association between the risk factor and piroplasmosis, while an RR greater than 1 indicates a higher risk of developing piroplasmosis.

In the current study, as shown in **Table 1**, horses in MMC, Borno State, Nigeria, that were exposed to ticks had a relative risk (RR) of 0.7692 for developing piroplasmosis caused by *Babesia caballi*, compared to horses in Jere that were not exposed to ticks. This finding suggests that horses exposed to ticks in MMC were 23.08% less likely to develop piroplasmosis due to *Babesia caballi* than their unexposed counterparts in Jere.

In MMC, Borno State, Nigeria, young horses exposed to ticks exhibited a relative risk (RR) of 1.0738 for developing piroplasmosis caused by *Babesia caballi*, compared to those that were not exposed in Jere. This finding suggests that young horses in MMC with tick exposure face an elevated risk of developing piroplasmosis due to *Babesia caballi* in comparison to their unexposed counterparts in Jere.

In MMC, Borno State, Nigeria, male horses exposed to ticks demonstrated a relative risk (RR) of 6.1818 for developing piroplasmosis caused by *Babesia caballi*, in contrast to female horses that were not exposed in Jere. This finding indicates that male horses in MMC with tick exposure were substantially at greater risk of developing piroplasmosis due to *Babesia caballi* compared to their unexposed female counterparts in Jere.

3.1.3. Odds Ratio (OR)

The odds ratio is a measure of the ratio of the odds of developing piroplasmosis in the exposed group to the odds of developing piroplasmosis in the non-exposed group. An OR of 1 indicates no association between the risk factor and piroplasmosis, while an OR greater than 1 indicates a higher risk of developing piroplasmosis.

In the present study, horses in MMC with a history of tick infestation had an OR of 0.3846. They had reduced odds of developing piroplasmosis due to *Babesia caballi* compared to horses in Jere without a history of tick infestation **(Table 1)**. This means that horses with a history of tick infestation in MMC were 0.3846 times less likely to develop piroplasmosis due to *Babesia caballi* than horses without a history of tick infestation in the Jere local government area.

In addition, young horses with a history of tick infestation had an OR of 1.2830. They had increased odds of developing piroplasmosis due to *Babesia caballi* compared to adult horses without a history of tick infestation **(Table 1)**. This means that young horses with a history of tick infestation were 1.2830 times more likely to develop piroplasmosis due to *Babesia caballi* than adult horses without a history of tick infestation.

Furthermore, male horses with a history of tick infestation had an OR of 23.8000. They had increased odds of developing piroplasmosis due to *Babesia caballi* compared to female horses without a history of tick infestation **(Table 1)**. This means that male horses with a history of tick infestation were 23.8000 times more likely to develop piroplasmosis due to *Babesia caballi* than female horses without a history of tick infestation.

3.2. Prevalence, Relative Risk, and Odds Ratio of Theileria equi in Borno State (Jere and MMC), Nigeria

3.2.1. Prevalence

The prevalence of *Theileria equi* in MMC and Jere local government areas was 76%, with a confidence interval of 69.53 to 81.53 **(Table 2)**.

3.2.2. Relative Risk (RR)

In the current study, as shown in **Table 2**, horses in MMC, Borno State, Nigeria, that were exposed to ticks had a relative risk (RR) of 0.9211 for developing piroplasmosis caused by *Theileria equi*, compared to horses in Jere that were not exposed to ticks. This finding suggests that horses exposed to ticks in MMC were 7.89% less likely to develop piroplasmosis due to *Theileria equi* than their unexposed counterparts in Jere.

In MMC, Borno State, Nigeria, young horses exposed to ticks exhibited a relative risk (RR) of 0.8821 for developing piroplasmosis caused by *Theileria equi*, compared to those that were not exposed in Jere. This finding suggests that young horses in MMC with tick exposure faced a reduced risk (11.79%) of developing piroplasmosis due to *Theileria equi* in comparison to their unexposed counterparts in Jere.

In MMC, Borno State, Nigeria, male horses exposed to ticks demonstrated a relative risk (RR) of 3.2273 for developing piroplasmosis caused by *Theileria equi*, in contrast to female horses that were not exposed in Jere. This finding indicates that male horses in MMC with tick exposure were substantially at greater risk of developing piroplasmosis due to *Theileria equi* compared to their unexposed female counterparts in Jere.

3.2.3. Odds Ratio (OR)

In the present study, horses in MMC with a history of tick infestation had an OR of 0.7085. They had reduced odds of developing piroplasmosis due to *Theileria equi* compared to horses in Jere without a history of tick infestation **(Table 2)**. This means that horses with a history of tick infestation in MMC were 0.7085 times less likely to develop piroplasmosis due to *Theileria equi* than horses without a history of tick infestation in the Jere local government area.

Table 1: Prevalence, relative risk, and odds ratio of *Babesia caballi* in Borno State (Jere and MMC), Nigeria.

Babesia caballi	Locations		Prevalence %	95% C.I
	Jere	MMC (Exposed Location)		
Negative	18	36	54 (28.1)	22.3 to 34.9
Positive	78	60	138 (71.9)	65.1 to 77.8
Relative risk				0.7692
95% C.I				0.6410 to 0.9231
Significance level				$P = 0.0048$
Odds ratio				0.3846
95% C.I				0.1991 to 0.7429
Significance level				$P = 0.0044$
Babesia caballi	Age		Prevalence %	95% C.I
	Adult	Young (Exposed Group)		
Negative	24	30	54 (28.1)	22.3 to 34.9
Positive	53	85	138 (71.9)	65.1 to 77.8
Relative risk				1.0738
95% C.I				0.8921 to 1.2926
Significance level				$P = 0.4515$
Odds ratio				1.2830
95% C.I				0.6785 to 2.4260
Significance level				$P = 0.4432$
Babesia caballi	Sex		Prevalence %	95% C.I
	Male (Exposed Group)	Female		
Negative	14	40	54 (28.1%)	22.3 to 34.9
Positive	2	136	138 (71.9%)	65.1 to 77.8
Relative risk				6.1818
95% C.I				1.6866 to 22.6578
Significance level				$P = 0.0060$
Odds ratio				23.8000
95% C.I				5.1898 to 109.1444
Significance level				$P < 0.0001$

MMC = Maiduguri Metropolitan Council.

In addition, young horses with a history of tick infestation had an OR of 0.5764. They had increased odds of developing piroplasmosis due to *Theileria equi* compared to adult horses without a history of tick infestation **(Table 2)**. This means that young horses with a history of tick infestation were 0.5764 times more likely to develop piroplasmosis due to *Theileria equi* than adult horses without a history of tick infestation.

Furthermore, male horses with a history of tick infestation had an OR of 12.5294. They had increased odds of developing piroplasmosis due to *Theileria equi* compared to female horses without a history of tick infestation **(Table 2)**. This means that male horses with a history of tick infestation were 12.5294 times more likely to develop piroplasmosis due to *Theileria equi* than female horses without a history of tick infestation.

3.3. Prevalence, Relative Risk, and Odds Ratio of Babesia caballi in Yobe State (Geidam and Nguru), Nigeria

3.3.1. Prevalence

The prevalence of *Babesia caballi* in Geidam and Nguru local government areas of Yobe State was 60.4%, with a confidence interval of 53.4 to 67.0 **(Table 3)**.

Table 2: Prevalence, relative risk, and odds ratio of *Theileria equi* in Borno State (Jere and MMC), Nigeria.

Theileria equi	Locations		Prevalence %	95% C.I
	Jere	MMC (Exposed Location)		
Negative	20	26	46 (24.0%)	18.47 to 30.47
Positive	76	70	146 (76.0%)	69.53 to 81.53
Relative risk				0.9211
95% C.I				0.7854 to 1.0802
Significance level				$P = 0.3118$
Odds ratio				0.7085
95% C.I				0.3635 to 1.3808
Significance level				$P = 0.3114$
Theileria equi	Age		Prevalence %	95% C.I
	Adult	Young (Exposed Group)		
Negative	14	32	46 (24.0%)	18.47 to 30.47
Positive	63	83	146 (76.0%)	69.53 to 81.53
Relative risk				0.8821
95% C.I				0.7556 to 1.0298
Significance level				$P = 0.1123$
Odds ratio				0.5764
95% C.I				0.2839 to 1.1704
Significance level				$P = 0.1274$
Theileria equi	Sex		Prevalence %	95% C.I
	Male (Exposed Group)	Female		
Negative	12	34	46 (24.0%)	18.47 to 30.47
Positive	4	142	146 (76.0%)	69.53 to 81.53
Relative risk				3.2273
95% C.I				1.3769 to 7.5641
Significance level				$P = 0.0070$
Odds ratio				12.5294
95% C.I				3.8046 to 41.2626
Significance level				$P < 0.0001$

MMC = Maiduguri Metropolitan Council.

3.3.2. Relative Risk (RR)

According to **Table 3**, horses exposed to ticks in Geidam, Yobe State, Nigeria, had a relative risk (RR) of 1.0714 for contracting piroplasmosis caused by *Babesia caballi*, compared to horses in the Nguru local government area that were not exposed to ticks. This result indicates that horses in Geidam exposed to ticks had a higher risk of contracting *Babesia caballi*-caused piroplasmosis than horses in Nguru, Yobe State.

Young horses exposed to ticks in Geidam, Yobe State, Nigeria, had a relative risk (RR) of 1.0189 for contracting piroplasmosis caused by *Babesia caballi*, compared to those not exposed in Nguru, Yobe State. This finding suggests that juvenile horses in Geidam exposed to ticks were more likely to contract *Babesia caballi*-caused piroplasmosis than their counterparts in Nguru, Yobe State.

Compared to female horses that were not exposed in Nguru, Yobe State, male horses exposed to ticks in Geidam, Yobe State, showed a relative risk (RR) of 10.4545 for contracting *Babesia caballi*-caused piroplasmosis. According to this finding, male horses in Geidam exposed to ticks were significantly more likely to contract *Babesia caballi*-caused piroplasmosis than their unexposed female counterparts in Nguru, Yobe State.

Table 3: Prevalence, relative risk, and odds ratio of *Babesia caballi* in Yobe State (Geidam and Nguru), Nigeria.

Babesia caballi	Locations		Prevalence %	95% C.I
	Geidam (Exposed Location)	Nguru		
Negative	36	40	76 (39.6%)	32.9 to 46.6
Positive	60	56	116 (60.4%)	53.4 to 67.0
Relative risk				1.0714
95% C.I				0.8519 to 1.3476
Significance level				$P = 0.5554$
Odds ratio				1.1905
95% C.I				0.6671 to 2.1244
Significance level				$P = 0.5551$
Babesia caballi	Age		Prevalence %	95% C.I
	Adult	Young (Exposed Group)		
Negative	31	45	76 (39.6%)	22.3 to 34.9
Positive	46	70	116 (60.4%)	65.1 to 77.8
Relative risk				1.0189
95% C.I				0.8057 to 1.2885
Significance level				$P = 0.8757$
Odds ratio				1.0483
95% C.I				0.5813 to 1.8905
Significance level				$P = 0.8754$
Babesia caballi	Sex		Prevalence %	95% C.I
	Male (Exposed Group)	Female		
Negative	15	61	76 (39.6%)	22.3 to 34.9
Positive	1	115	116 (60.4%)	65.1 to 77.8
Relative risk				10.4545
95% C.I				1.5624 to 69.9546
Significance level				$P = 0.0155$
Odds ratio				28.2787
95% C.I				3.6479 to 219.2157
Significance level				$P = 0.0014$

3.3.3. Odds Ratio (OR)

Tick infestation history was associated with an OR of 1.1905 for horses in Geidam in the current investigation. They were less likely than horses in Yobe State's Nguru local government area without a history of tick infestation to contract piroplasmosis from *Babesia caballi* **(Table 3)**. Thus, compared to horses in the Nguru local government area of Yobe State that had never experienced a tick infestation, horses with a history of tick infestation in Geidam had a 1.1905-fold increased risk of contracting piroplasmosis from *Babesia caballi*.

Young horses with a history of tick infestation had an OR of 1.0483 in the current study. Compared to adult horses without a history of tick infestation, they were more likely to have *Babesia caballi*-caused piroplasmosis **(Table 3)**. This indicates that young horses with a history of tick infestation had a 1.0483-fold increased risk of contracting *Babesia caballi*-caused piroplasmosis than adult horses without a history of tick infestation.

Male horses with a history of tick infestation had an odds ratio (OR) of 28.2787 in the current study. Compared to female horses without a history of tick infestation, they were more likely to contract piroplasmosis caused by *Babesia caballi* **(Table 3)**. This indicates that male horses with a

history of tick infestation had a 28.2787-fold higher risk of contracting *Babesia caballi*-caused piroplasmosis than female horses without a history of tick infestation.

3.4. Prevalence, Relative Risk, and Odds Ratio of Theileria equi in Yobe State (Geidam and Nguru), Nigeria

3.4.1. Prevalence

The prevalence of *Theileria equi* in Geidam and Nguru local government areas of Yobe State was 63.0%, with a confidence interval of 56.00 to 69.53 **(Table 4)**.

3.4.2. Relative Risk (RR)

Compared to horses in the Nguru local government area that were not exposed to ticks, horses in Geidam, Yobe State, Nigeria, that were exposed to ticks had a relative risk of 1.4694 for acquiring piroplasmosis caused by *Theileria equi* **(Table 4)**. This study found that horses exposed to ticks in Geidam were more likely to contract *Theileria equi*-caused piroplasmosis than horses in Nguru, Yobe State.

The relative risk (RR) of *Theileria equi*-caused piroplasmosis was 1.0542 for young horses exposed to ticks in Geidam, Yobe State, Nigeria, compared to those not exposed in Nguru, Yobe State. This indicates that tick exposure increased the risk of piroplasmosis from *Theileria equi* in young horses in Geidam compared to those in Yobe State's Nguru local government area.

Male horses exposed to ticks in Geidam, Yobe State, Nigeria, had a relative risk (RR) of 1.2841 for acquiring *Theileria equi*-caused piroplasmosis, compared to female horses not exposed in the Nguru local government area of Yobe State. This study found that male horses in Geidam exposed to ticks had a significantly higher risk of developing piroplasmosis from *Theileria equi* than their unexposed female counterparts in Nguru, Yobe State.

3.4.3. Odds Ratio (OR)

In the current study, a history of tick infestation was linked to an OR of 2.8776 for horses in Geidam. In Yobe State's Nguru local government area, they had a lower risk of piroplasmosis from *Theileria equi* than horses without a history of tick infestation **(Table 4)**. Therefore, horses with a history of tick infestation in Geidam were 2.8776 times more likely to get piroplasmosis from *Theileria equi* than horses in Yobe State's Nguru local government area that had never had a tick infestation.

Additionally, the OR for young horses with a history of tick infection was 1.1520. *Theileria equi*-caused piroplasmosis was more common in these adult horses than in those without a history of tick infestation **(Table 4)**. This suggests that juvenile horses with a history of tick infestation had a 1.1520-fold higher risk of catching piroplasmosis from *Theileria equi* than adult horses without a tick infestation history.

Furthermore, the OR for male horses with a history of tick infestation was 1.7937. *Theileria equi*-caused piroplasmosis was more common in female horses with a history of tick infestation than in those without **(Table 4)**. This means that male horses with a history of tick infestation were 1.7937 times more likely to get piroplasmosis from *Theileria equi* than female horses without a tick infestation history.

4. Discussion

Piroplasmosis, caused by *Babesia caballi* and *Theileria equi*, is a significant disease affecting horses in Nigeria, particularly in Borno and Yobe States. This discussion provides an overview of the prevalence, relative risk, and odds ratio of piroplasmosis in horses in these states.

Studies have shown that piroplasmosis is prevalent in horses in Borno and Yobe States. A study **[12]** reported a prevalence of 34.38 % in donkeys in Yobe State. However, the current study revealed a prevalence of *Babesia caballi* and *Theileria equi* of 71.9% and 76.0%, respectively. This could attributed to climatic and environmental factors that favors the survival and multiplication of *Babesia caballi* and *Theileria equi*, which are commonly found in tropical and subtropical regions, as reported in **[13]**. Furthermore, the presence of vegetation and rainfall provides a conducive environment for the survival and multiplication of ticks, which are the primary vectors of *Babesia caballi* and *Theileria equi* **[14]**. Additionally, the distribution and abundance of ticks, particularly Dermacentor and Hyalomma species, are higher in tropical and subtropical regions, increasing the risk of transmission of *Babesia caballi* and *Theileria equi* **[13]**. Another reason for the higher prevalence of equine piroplasmosis could be attributed to the feeding behavior of ticks, as feeding on horses increases the risk of transmission of *Babesia caballi* and *Theileria equi* **[14]**.

The relative risk (RR) of piroplasmosis in horses in Borno and Yobe States has been investigated in several studies. A study **[15]** found that horses in Punjab (India) exposed to ticks had an RR of 2.27 for developing piroplasmosis compared to those that were not exposed. However, in the present study, the relative risk (RR) of piroplasmosis in horses in Borno and Yobe States for *Babesia caballi* and *Theileria equi* were 0.7692 and 0.9211 in Borno, while Yobe state had 1.0714 and 1.4694 for *Babesia caballi* and *Theileria equi*. This variation in RR could be due to human movement and activity, particularly in tropical and subtropical regions, which may increase the risk of transmission of *Babesia caballi* and *Theileria equi*, as reported in **[16]**. Moreover, a lack of awareness and knowledge among horse owners and handlers can contribute to the higher prevalence of *Babesia caballi* and *Theileria equi*.

The odds ratio (OR) of piroplasmosis in horses in Borno and Yobe States, as investigated in the current study, could be attributed to several factors associated with the risk of piroplasmosis in these states. These include exposure to ticks, which is a significant risk factor for piroplasmosis in horses in both states. Similarly, younger horses are more susceptible to piroplasmosis than older horses. Certain breeds of horses, such as the Arabian breed, are more susceptible to piroplasmosis than others. Additionally, the risk of piroplasmosis is higher during the wet season than during the dry season.

Table 4: Prevalence, relative risk, and odds ratio of *Theileria equi* in Yobe State (Geidam and Nguru), Nigeria.

Theileria equi	Locations		Prevalence %	95% C.I
	Geidam (Exposed Location)	Nguru		
Negative	24	47	71 (37.0%)	30.47 to 44.00
Positive	72	49	121 (63.0%)	56.00 to 69.53
Relative risk				1.4694
95% C.I				1.1705 to 1.8446
Significance level				$P = 0.0009$
Odds ratio				2.8776
95% C.I				1.5617 to 5.3023
Significance level				$P = 0.0007$
Theileria equi	Age		Prevalence %	95% C.I
	Adult	Young (Exposed Group)		
Negative	30	41	71 (37.0%)	30.47 to 44.00
Positive	47	74	121 (63.0%)	56.00 to 69.53
Relative risk				1.0542
95% C.I				0.8423 to 1.3194
Significance level				$P = 0.6447$
Odds ratio				1.1520
95% C.I				0.6347 to 2.0911
Significance level				$P = 0.6417$
Theileria equi	Sex		Prevalence %	95% C.I
	Male (Exposed Group)	Female		
Negative	8	63	71 (37.0%)	30.47 to 44.00
Positive	8	113	121 (63.0%)	56.00 to 69.53
Relative risk				1.2841
95% C.I				0.7771 to 2.1219
Significance level				$P = 0.3292$
Odds ratio				1.7937
95% C.I				0.6421 to 5.0107
Significance level				$P = 0.2650$

5. Conclusion

Piroplasmosis is a significant disease affecting horses in Borno and Yobe States. The prevalence, relative risk, and odds ratio of the disease have been investigated in several studies. The results of these studies suggest that exposure to ticks, age, sex, and location are significant risk factors for piroplasmosis in horses. Further research is needed to develop effective control measures for the disease.

Acknowledgment

The authors would like to express their deep gratitude to the staff of the Department of Veterinary Parasitology and Entomology, Faculty of Veterinary Medicine, University of Maiduguri, Nigeria, as well as to the livestock owners in Borno and Yobe States for their cooperation.

Authors' Contributions

The concept was developed and planned by Falmata Kyari, and Babagana K. Kayeri; the data were gathered and checked by Benjamen Joseph Haziel, and Ibrahim Nuhu Ibrahim. Falmata Kyari and Mohammed Kyari Zango wrote the paper, and Lawan Adamu reviewed the manuscript, evaluating and interpreting the data statistically.

Data Availability

The data supporting the findings of this study are available within the article.

Funding

This research received no grants from any funding agency.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Ethical Approval

The Institutional Animal Care and Use Committee (IACUC) of the University of Maiduguri authorized the study protocol using number 0758 prior to its start, ensuring that it adhered to the standards of studies involving animals.

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How to Cite

Kyari F, Kayeri BK, Zango MK, Haziel BJ, Ibrahim IN, Adamu L. Seroepidemiology and Risk Factors Associated with *Theileria equi* and *Babesia caballi* Infections in Horses from Borno and Yobe States, Nigeria. Int J Equine Sci 2025;4(1):21–29.