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TEMPORAL PATTERN OF SUSPECTED CEREBROSPINAL NEMATODIASIS IN GOATS IN KANDY DISTRICT: A RETROSPECTIVE STUDY USING CASE RECORDS OF THE FARM ANIMAL VETERINARY TEACHING HOSPITAL

W. K. K. S. Sithara[1], K. M. G. W. C. P. B. Abeyratne[1], H. E. L. De Seram[1*]

[1]Department of Farm Animal Production and Health, Faculty of Veterinary Medicine and Animal Science, University of Peradeniya, Peradeniya, 20400, Sri Lanka

SUMMARY: Cerebrospinal nematodiasis (CSN) is a neuropathological disease in goats caused by migration of third-stage larvae of *Setaria* spp., which is transmitted by mosquitoes. It often leads to lifelong neurological complications, productivity losses, and culling recommendations. Understanding its regional epidemiology is essential for developing effective prevention and control strategies. This retrospective descriptive study analysed the temporal patterns of CSN occurrence in the Kandy district using clinical records from 4,524 goats presented to the Farm Animal Veterinary Teaching Hospital, University of Peradeniya, from 2016 to 2023. The overall prevalence of suspected CSN cases was low (5.0%) among study goats. However, a distinct temporal variation in CSN prevalence was observed, with peak disease occurrence between February and April, reaching its highest in March (13.6±6.4%). This period coincided with the region's convectional rainfall episodes, suggesting that optimal rainfall conditions may have contributed to increased CSN occurrence. A decline in CSN prevalence was observed from May to September, corresponding with reduced rainfall. Additionally, a substantial drop in cases from April to May and again from September to November aligned with periods of higher-than-average rainfall, which may have disrupted mosquito breeding. These findings suggest that rainfall patterns significantly influence the temporal distribution of CSN, likely by affecting mosquito populations, the intermediate hosts of *Setaria digitata*. The findings emphasise the need for targeted disease prevention strategies, such as implementing strategic deworming protocols before the peak disease period and enhancing farmer awareness of mosquito control measures to mitigate CSN risks in the study region.

KEYWORDS: Cerebrospinal nematodiasis, epidemiology, goats, Kandy district, weather patterns

INTRODUCTION

Cerebrospinal nematodiasis (CSN) is a neuropathological disease caused by *Setaria* spp. in non-natural (i.e., aberrant) hosts, such as sheep, goats, and horses (Smith and Sherman, 2011). The migration of third-stage larvae of *Setaria* spp. into the central nervous system damages nervous tissues, leading to neuropathological lesions in the affected animals (Ahmad and Srivastava, 2007). Depending on the extent of central nervous system damage, the disease can be fatal, even with appropriate medical management (Innes *et al*., 1952). Affected animals that respond to treatment may still experience lifelong complications (e.g., paralysis and incoordination) due to the initial neurological damage caused by the parasite, resulting in productivity losses, animal welfare issues, and recommendations for culling (Smith and Sherman, 2011).

For decades, goat farming has played a pivotal role in strengthening rural economic stability and is popular in all agroclimatic regions of Sri Lanka (DAPH, 2023). In the Central Province, there has been a significant expansion in the goat population under intensive management over the past few years. The goat population in the Central Province primarily consists of high-producing exotic breeds at a higher risk of experiencing high morbidity and mortality associated with CSN (DAPH, 2023). The prevalence of *Setaria* spp. was confirmed in cattle (the reservoir host) in the Central Province decades ago, supporting the existence of the disease in the regional goat population (Gunawardhane, 1991).

Mosquito-borne diseases are typically seasonal and strongly influenced by weather patterns (Coalson *et al.*, 2021). Cerebrospinal nematodiasis also occurs in seasonal outbreaks (Karki, 2008). However, in-depth assessments of the longitudinal and seasonal patterns of CSN occurrence are currently lacking in both global and local contexts. The diagnosis of CSN in goats is typically tentative in clinical settings, relying on clinical observations. Confirmation necessitates necropsies or molecular analyses, often limited in availability (Garcia *et al.*, 2023). Confirmation based on the clinical picture

Corresponding author: H. E. L. De Saram, E- mail: eranga.seram@vet.pdn.ac.lk

can occasionally lead to inaccurate diagnosis and treatment. Hence, predicting disease occurrence based on its temporal patterns can be beneficial for prevention and preparation to control possible outbreaks in disease-endemic regions.

This study determined the temporal epidemiological pattern of suspected CSN in the Kandy district by retrospectively analysing goat case records from the Farm Animal Veterinary Teaching Hospital at the University of Peradeniya, which serves as a representative cohort for the district's goat population.

MATERIALS AND METHODS

Data collection

Clinical case records of goats presented to the Farm Animal Veterinary Teaching Hospital, Faculty of Veterinary Medicine and Animal Science, University of Peradeniya, from 2016 to 2023 were selected for this study. Written consent to use the dataset was obtained from the teaching hospital administration. Details such as the date of case presentation, city of origin, breed type, sex, age, and diagnosis were extracted from the records.

The inclusion criteria for identifying suspected cases of CSN in this study were based on information recorded in the tentative or definitive diagnosis section of the manual case record books maintained at the Farm Animal Veterinary Teaching Hospital. Cases were classified as “suspected CSN” if the attending clinician had documented a diagnosis or clinical suspicion of CSN based on their clinical judgment. Detailed clinical presentations of individual goats were not consistently documented and could not be considered in the case classification. Goat cases with confirmed or suspected diagnoses other than CSN were categorised as “other cases.”

To assess the potential associations between temporal pattern of the CSN and weather patterns, data on rainfall, temperature, and humidity were obtained from the Katugasthota weather station, Department of Meteorology, Sri Lanka. These data, published by the Department of Census and Statistics, were accessed at https://www.statistics.gov. lk/abstract2023/chapter1#gsc.tab=0.

Data analysis

The following descriptive data analysis was implemented. The suspected CSN cases and other reported goat cases were initially categorised by gender, breed, and age. For age, all goat cases were classified as either young (≤1 year) or adult (>1 year). To determine the temporal pattern of suspected CSN cases, the total number of goat cases (i.e., suspected CSN cases + other goat cases) and suspected CSN cases were also recorded by month and year. The overall prevalence (%) of suspected CSN cases was calculated for the study period using the formula: (Number of suspected CSN cases/ total number of reported goat cases) × 100. The monthly prevalence (%) of suspected CSN cases was calculated for each study year using the formula: (Number of suspected CSN cases/ total number of goat cases in a particular month) × 100. The average prevalence for each month across all years (± standard deviation) was plotted as a line graph. Similarly, the average monthly temperature, rainfall, and humidity (RH; average day and night) (± standard deviation) were plotted to compare their trends with the disease occurrence pattern.

Due to the unavailability of data in the year 2020, this was omitted from the dataset. Due to the low prevalence of suspected CSN cases, inferential statistical analysis was not conducted to assess potential associations with identified potential risk factors (age, gender, breed, and weather variables). Given the limited suspected CSN case numbers (i.e., <20% of total data), such analyses would not yield epidemiologically meaningful or reliable conclusions (Dohoo *et al.*, 2010).

RESULTS

Overall prevalence and the distribution of suspected CSN cases by gender, breed, and age of goats

This retrospective study analysed data from 4,524 goat (Average age: 1.5±1.7 years; range: 0.1–20 years) cases reported to the Farm Animal Veterinary Teaching Hospital from 2016-2023. Based on city of origin records, all cases originated within the Kandy district and were included in the analysis. Among them, 225 (5.0%) were suspected CSN cases (Table 1). Among the suspected CSN cases, 42.7% (96/225) were males, while 52% (117/225) were females. Saanen goats accounted for the highest proportion of suspected CSN cases (55.6%; 125/225). Based on age classification, the majority (85.3%; 192/225) of suspected CSN cases were adults.

Monthly prevalence of suspected CSN cases from 2016-2023

The average monthly prevalence of suspected CSN cases observed was 7.5% (range: 0–24.3%) in 2016, 3.8% (range: 0–11.1%) in 2017, 7.1% (range: 0–17.1%) in 2018, 6.0% (range: 0–17.7%) in 2019, 5.0% (range: 0–15.7%) in 2020, 4.1% (Range: 0–11.1%) in 2022, and 4.4% (range: 0–11.5%) in 2023 (Table 2).

Table 1. The number (%) of suspected cerebrospinal nematodiasis (CSN) and other goat cases presented to the Farm Animal Veterinary Teaching Hospital from 2016 to 2023, categorised by gender, breed, and age.

Variable	Suspected CSN cases (%)	Other cases (%)	Total (%)
Overall	225 (5.0)	4299 (95.0)	4524 (100)
Gender			
Male	96 (2.1)	1180 (26.1)	1276 (28.2)
Female	117 (2.6)	2709 (59.9)	2826 (62.5)
Not reported	12 (0.3)	410 (9.0)	422 (9.3)
Breed			
Saanen	125 (2.8)	2020 (44.7)	2145 (47.5)
Jamnapari	27 (0.6)	809 (17.9)	836 (18.5)
Cross-Bred	22 (0.5)	687 (15.2)	709 (15.7)
Alpine	21 (0.4)	286 (6.4)	307 (6.8)
Boer	3 (0.1)	22 (0.5)	25 (0.6)
Toggenburg	0 (0)	32 (0.7)	32 (0.7)
Not reported	27 (0.6)	443 (9.6)	470 (10.2)
Age			
Young (≤1 year)	5 (0.1)	392 (8.7)	397 (8.8)
Adult (>1 year)	192 (4.2)	3400 (75.1)	3592 (79.3)
Not reported	28 (0.6)	507 (11.2)	535 (11.8)

Table 2. The number (%) of total and suspected cerebrospinal nematodiasis (CSN) goat cases presented at the Farm Animal Veterinary Teaching Hospital from 2016 to 2023.

Month	2016		2017		2018		2019		2020		2021		2022		2023	
	Tot[1]	CSN (%)	Tot	CSN (%)	Tot	CSN (%)	Tot	CSN (%)	Tot	CSN (%)	Tot	CSN (%)	Tot	CSN (%)	Tot	CSN (%)
January	20	0 (0)	33	0 (0)	42	3 (7.14)	75	5 (6.67)	DNA	DNA	55	0 (0)	52	2 (3.85)	54	1 (1.85)
February	23	1 (4.35)	23	1 (4.35)	50	4 (8.00)	47	2 (4.26)	DNA	DNA	58	4 (6.90)	91	1 (1.10)	59	4 (6.78)
March	37	9 (24.32)	23	1 (4.35)	41	7 (17.07)	59	9 (15.25)	DNA	DNA	95	13 (13.68)	104	9 (8.65)	61	7 (11.48)
April	23	4 (17.39)	33	2 (6.06)	47	3 (6.38)	34	6 (17.65)	DNA	DNA	70	11 (15.71)	89	10 (11.24)	71	7 (9.86)
May	41	1 (2.44)	36	4 (11.11)	49	3 (6.12)	32	1 (3.13)	DNA	DNA	70	2 (2.86)	58	2 (3.45)	72	2 (2.78)
June	28	1 (3.57)	40	0 (0)	33	2 (6.06)	47	1 (2.13)	DNA	DNA	74	0 (0)	48	2 (4.17)	64	2 (3.13)
July	24	1 (4.17)	40	2 (5.00)	24	0 (0)	34	1 (2.94)	DNA	DNA	112	2 (1.79)	27	1 (3.70)	77	1 (1.30)
August	23	3 (13.04)	36	3 (8.33)	29	1 (3.45)	20	0 (0)	DNA	DNA	40	1 (2.50)	55	5 (9.09)	55	0 (0)
September	29	2 (6.90)	26	1 (3.85)	49	4 (8.16)	6	0 (0)	84	3 (3.57)	72	0 (0)	67	0 (0)	65	1 (1.54)
October	20	1 (5.00)	40	2 (5.00)	32	0 (0)	39	0 (0)	78	4 (5.13)	131	12 (9.16)	46	0 (0)	69	4 (5.80)
November	33	1 (3.03)	41	0 (0)	43	0 (0)	25	0 (0)	63	1 (1.59)	82	1 (1.22)	82	0 (0)	102	6 (5.88)
December	18	0 (0)	55	0 (0)	55	8 (14.55)	DNA[2]	DNA	100	2 (2.00)	85	1 (1.18)	64	0 (0)	66	1 (1.52)
Overall	319	24 (7.52)	426	16 (3.76)	494	35 (7.09)	418	25 (5.98)	325	10 (3.08)	944	47 (4.98)	783	32 (4.09)	815	36 (4.42)

[1]Total number of goat cases presented.
[2]Data Not Available; primarily due to the hospital's temporary closure during the COVID-19 pandemic.

Overall temporal pattern of suspected CSN

When assessing the temporal disease pattern, the prevalence of suspected CSN cases was notably higher from February to April across all study years, averaging 10.2% (range: 5.1–13.5%), with a peak in March (Figure 1). In contrast, prevalence remained relatively low between May and December, averaging 3.2% (range: 1.5–5.2%), with a slight increase observed from July to August.

Overall weather patterns

During the study period, the monthly rainfall ranged from 45.1 to 330.1mm (Figure 1). Rainfall increased from February to May (average: 149.4 mm, range: 45.1–253.4mm), peaking notably in May (253.4mm) before sharply declining in June (87.7mm). Rainfall levels in June and July remained relatively low (average: 90.1mm, range: 87.7–92.4mm) compared to the February–May period. From July to September, rainfall increased with minor fluctuations (August-September average: 130.3mm, range: 112.1–148.5mm). A sharp rise was observed from September to November, peaking in October (October–November average: 296.6mm, range: 263.1–330.2mm). Overall, the rainfall from September to November (average: 235.1 mm, range: 112.1–330.2mm) was notably higher than that from February to May.

The monthly temperatures fluctuated between 24 and 26.6°C throughout the study years (Figure 1). The monthly RH ranged from 79.1 to 87.4%, with the lowest recorded in March and the highest in November. Similar to the temperature, the monthly RH fluctuations are minor across the study period.

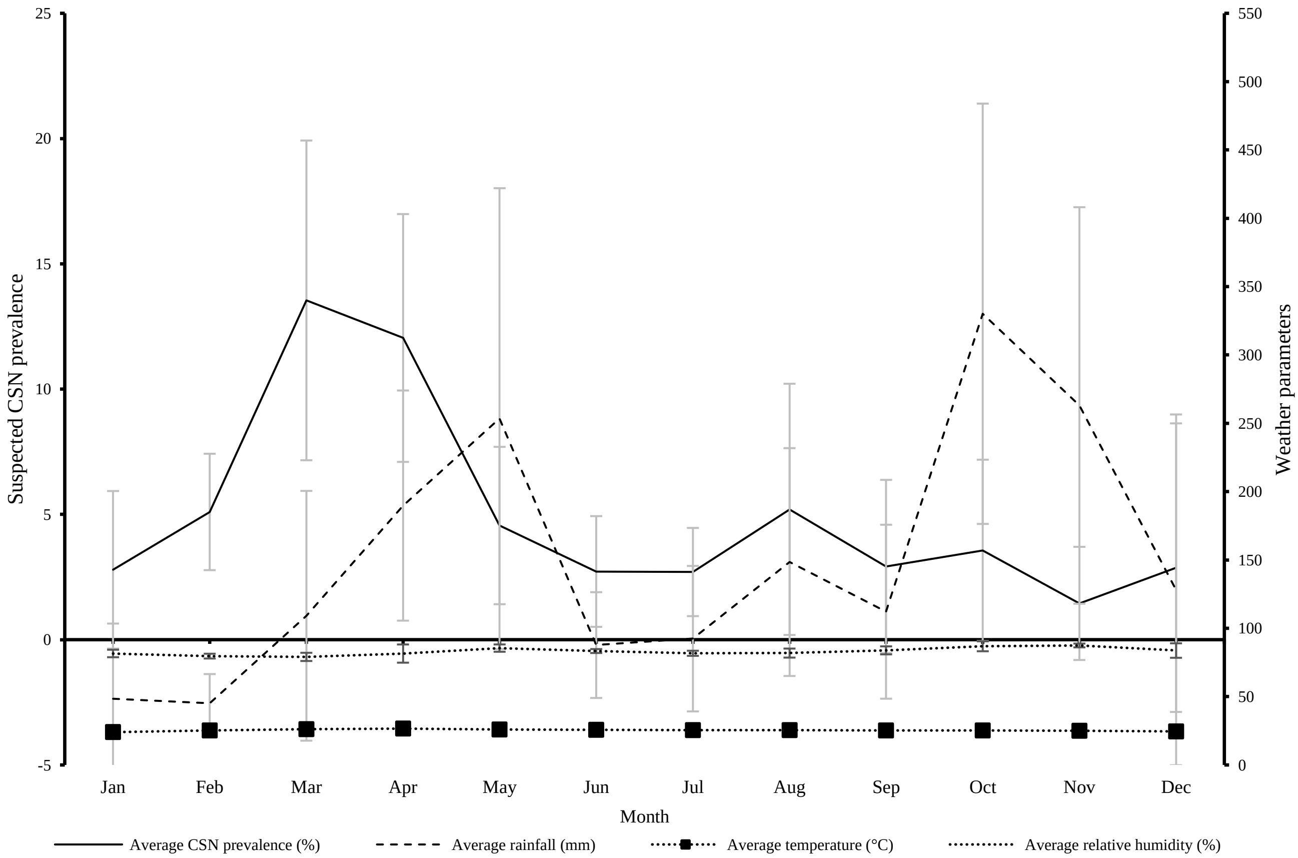

Figure 1. The average monthly prevalence of suspected cerebrospinal nematodiasis (CSN) cases in goats presented to the Farm Animal Veterinary Teaching Hospital, University of Peradeniya, Sri Lanka (2016–2023), alongside the monthly average temperature, rainfall, and relative humidity. Weather data were adapted from the Katugasthota weather station, maintained by the Department of Meteorology, and obtained from the Department of Census and Statistics website. Goat data were limitedly available for 2020 (hospital closure due to the COVID-19 global pandemic); therefore, they were not used for the average CSN prevalence calculation. Consequently, weather data for 2020 were also excluded, as their inclusion would not be logically appropriate. Error bars represent the standard deviation for the respective study years

DISCUSSION

The overall prevalence of the suspected CSN cases during the study period (2016-2023) considered for this retrospective study was low. The overall low prevalence of the disease in the goat population is also supported by the limited published previous epidemiological investigations carried out in both the local and global set-up. For example, three decades ago, a study reported a 6.3% prevalence of CSN in goats from Sri Lanka's dry zone (Gunawardhane, 1991). A study carried out in Iran reported a 1.3% prevalence of the disease in 3190 tested goats further supporting the overall low prevalence of the disease in the goat populations in the global set-up (Bazargani *et al*., 2008).

Several factors may contribute to the low occurrence of CSN in goats. First, it is worth noting that a large portion of the goat population may not be infected by *S. digitata*. The disease is primarily transmitted from cattle to goats through the intermediate host mosquito (Hendrix, 2019). Therefore, the presence of nearby cattle farms and mosquito breeding sites is likely the most significant risk factor for infection in goats. However, since goat farms are generally isolated from cattle farms, the likelihood of disease transmission to goats is reduced. This separation likely contributes to the lower prevalence of CSN observed in goat populations locally and globally. Second, not all infected goats exhibit clinical signs, complicating detection efforts. Generally, the clinical outcome of a disease is influenced by numerous factors, including the intensity of the infection and the immune tolerance capacity of the host (Thrusfield, 2017). Goats with lower infection intensities or higher immune tolerance may not show noticeable symptoms, masking the presence of the disease and potentially allowing it to persist undetected within the population. This variability in clinical expression highlights the challenges of accurately diagnosing and managing the CSN in goats. Additionally, some clinically affected goats may not have been brought to the Farm Animal Veterinary Teaching Hospital for diagnosis, further lowering the observed prevalence.

The relatively higher prevalence of suspected CSN cases between February and April, averaging 10.3%, followed by a gradual decline from May to December with a minor peak in July to August, suggests a distinct seasonal pattern in disease occurrence. This trend is likely influenced by weather conditions that affect mosquito breeding, as mosquitoes serve as the intermediate host for *Setaria digitata*. Rainfall patterns exhibited a seasonal trend, increasing from February to May, with a notable rise between March and May, a period characterised by convectional rain episodes in the Kandy district (Meegahakotuwa and Nianthi, 2018). Specifically, between March and April, average monthly rainfall ranged from 109.2 mm to 189.8 mm, aligning with the seasonal peak of CSN cases. The monthly temperature (24-26.6°C) and RH (79.1-87.4%) fluctuations remained within the optimal ranges (temperature: 25-30°C, RH: 70-90%) for mosquito breeding in tropical regions (Agyekum *et al*., 2021; Regis *et al*., 2008). These weather conditions likely created an optimal environment for mosquito breeding, facilitating the completion of the *S. digitata* life cycle and increasing parasite transmission from definitive hosts (cattle, buffaloes) to goats (Garcia *et al*., 2023).

The substantial reduction in rainfall levels from May (253.4mm) to June (87.7mm) may have contributed to a decline in mosquito populations, aligning with the observed decrease in CSN prevalence during this period. The temporal pattern of suspected CSN showed a notable decline in disease prevalence from April (12.0%) to May (4.6%) and again from October (3.6%) to November (1.5%), periods characterised by relatively high monthly rainfall compared to other months. Prolonged and excessive rainfall during these months may have disrupted mosquito breeding habitats by flushing out larvae and pupae, reducing their survival rates, while also limiting oviposition opportunities, further contributing to a decline in mosquito populations (Dieng *et al*., 2012; Koenraadt and Harrington, 2008). Consequently, the lower mosquito density may have contributed to reduced CSN transmission rates compared to the peak observed between February and April when more stable and moderate rainfall conditions likely supported higher mosquito proliferation and disease transmission.

Given these observations, rainfall appears to be the key driving factor influencing the temporal pattern of CSN in the study region. However, the validity of this hypothesis requires further in-depth modelling to assess the complex interactions and compounding effects of various weather factors. Such an analysis falls beyond the scope of the present study but would provide valuable insights into the precise role of climatic variables in CSN transmission dynamics.

Supporting the findings of the present study, a seasonal high occurrence of CSN in goats has also been reported in exotic goat breeds in Sri Lanka's dry zone, particularly from November to December (Gunawardhane, 1991). In this region, this period coincides with the North-East monsoon season, during which rainfall is relatively high. These conditions likely create a favourable environment for the increased prevalence of the disease observed in that study.

These temporal patterns provide valuable insights for designing effective disease prevention programmes. For example, strategic deworming of cattle and goats with effective anthelmintics against *Setaria* spp. before the onset of the high-risk periods in February and April, with subsequent treatments as needed based on the residual efficacy of the drugs used, could be implemented. Additionally, educating farmers to eliminate potential mosquito breeding sites, particularly during months when CSN cases are likely to increase, could help reduce the disease burden in goats.

A few limitations have also been identified in the present study. The diagnosis of suspected CSN cases was primarily based on clinical signs, which can overlap with other diseases such as Gliricidia toxicity, pregnancy toxaemia, and listeriosis. However, the clinicians at the Farm Animal Veterinary Teaching Hospital are highly competent and follow rigorous diagnostic procedures, which are likely to reduce the probability of misdiagnosis. It is noteworthy that even in field settings, CSN diagnosis remains tentative, primarily relying on the clinical presentation of affected goats. Moreover, the weather data used in this study may not fully represent the conditions at individual farms where suspected cases were reported, as farms in the Kandy district are geographically dispersed, and local weather conditions can differ significantly from the overall district averages.

Future research should focus on conducting detailed longitudinal epidemiological studies to accurately determine the temporal pattern of CSN. These studies should cover multiple geographic areas to confirm the observed trends and assess regional variations in disease prevalence. Specific weather data related to the geographical areas where the farms are located should be used for accurate modelling and prediction. Incorporating molecular diagnostics and necropsy data where feasible would further strengthen the accuracy of CSN diagnosis.

CONCLUSIONS

The overall low prevalence of suspected CSN in the studied goat population suggests a generally low occurrence of the disease in the Kandy district. However, the disease appears to peak between February and April, likely coinciding with moderately high convectional rainfall episodes. Based on this pattern, implementing targeted parasite and mosquito control programmes at the onset of convectional rainfall may help minimise infection risks in the region. Further epidemiological studies covering multiple geographical areas within the region are necessary to better assess the disease's overall prevalence and to explore the influence and potential interactions of other climatic factors, such as temperature and humidity.

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