JIDC | THE JOURNAL OF INFECTION IN DEVELOPING COUNTRIES

Original Article

Prevalence of Visceral Leishmaniasis among Wildlife Rangers in Dinder National Park, Sudan

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Abstract

Introduction: Visceral leishmaniasis (VL) is a significant public health concern in Sudan, particularly among populations exposed to vector-rich environments. This study aimed to determine the prevalence of VL and associated risk factors among Wildlife Rangers in Dinder National Park, Sudan.

Methodology: A descriptive, cross-sectional, community-based study was conducted among all 500 wildlife rangers in Dinder National Park using total population sampling. Data were collected using a pre-prepared and pre-tested questionnaire covering demographic information, risk factors, and clinical signs and symptoms of VL. Data analysis involved descriptive statistics, chi-square tests, and logistic regression to assess the association between VL prevalence and various risk factors.

Results: The prevalence of VL was 27.6%. Significant associations were observed between VL prevalence and educational level ($p = 0.001$), military rank ($p = 0.004$), with soldiers showing a reduced risk compared to officers (OR = 0.45, 95% CI: 0.27–0.75), and knowledge of (VL signs and symptoms ($p = 0.000$), with a substantially lower risk among the unaware group (OR = 0.20, 95% CI: 0.10–0.39)., transmission methods ($p = 0.000$), with lower odds in the unaware group (OR = 0.36, 95% CI: 0.21–0.61), and control measures ($p = 0.012$), with reduced odds for the unaware group (OR = 0.63, 95% CI: 0.34–1.18).), and sleeping under a mosquito net ($p = 0.001$), with higher odds in those not using a net (OR = 1.93, 95% CI: 1.28–2.92).

Conclusions: The high prevalence of VL among wildlife rangers in Dinder National Park underscores the need for targeted public health intervention. Strategies should include enhancing educational programs, improving awareness of VL prevention and control measures, and ensuring better access to protective measures, such as mosquito nets. Future research should focus on longitudinal studies, detailed environmental assessments, and intervention trials to further reduce the burden of VL in high-risk populations.

Key words: Dinder National Park; visceral leishmaniasis; wildlife rangers; prevalence; risk factors; Sudan.

J Infect Dev Ctries 2026; 20(5):755-763. doi:10.3855/jidc.20568

(Received 08 July 2024 – Accepted 19 December 2024)

Introduction

Visceral leishmaniasis (VL), also known as kala-azar, is a severe parasitic disease caused by protozoa of the *Leishmania* genus [1,2]. It is transmitted through the bite of infected female phlebotomine sandflies and primarily affects internal organs, such as the spleen, liver, and bone marrow [2,3]. With an estimated 50,000 to 90,000 new cases annually, VL is a significant public health concern, particularly in tropical and subtropical regions, where environmental conditions favour the sandfly vectors and reservoirs of the parasite [2,4-6].

Globally, over 90% of new human cases occur in six nations, predominantly in Asia and Africa, although outbreaks in regions such as Southern Europe highlight its geographic spread and importance in travel medicine [7,8]. VL affects approximately two million people annually and poses a severe socioeconomic challenge due to high treatment costs and mortality if left untreated. It is often associated with vulnerable communities, where conflict, displacement, and poor access to healthcare exacerbate the disease's impact [9]. Immunocompromised individuals are particularly susceptible, as seen in regions such as Portugal, where cases have declined with better healthcare [10].

Sudan is one of the six countries contributing to more than 90% of the global VL cases [1,6]. The disease is endemic in the eastern and central regions, where it poses a substantial health burden [11-14].

Visceral leishmaniasis (VL) is a significant health concern in Sudan, particularly in the central and eastern regions [12,14]. The prevalence of VL in these areas is high, particularly among children [15,16]. The disease

is associated with a range of clinical symptoms, including fever, pallor, weight loss and splenomegaly [15]. Despite the availability of treatment, VL continues to pose a public health challenge [16], with a significant mortality impact in Sudan, influenced by factors such as conflict, malnutrition, and access to healthcare. Historically, Sudan experienced a devastating epidemic in 1988, resulting in over 100,000 deaths [12]. Recent data show a declining trend in mortality in Eastern Sudan, from 4.8% in 2002 to 1.1% in 2014; however, challenges remain, particularly in rural areas [17].

Dinder National Park, located in southeastern Sudan, is a prominent conservation area that houses diverse wildlife and is a known habitat for sand flies [18-20]. The interaction between wildlife, sandflies, and humans in this ecological setting creates a conducive environment for VL transmission [21-23].

Wildlife rangers working in Dinder National Park are at a heightened risk of VL due to their prolonged exposure to the park's environment. Rangers are essential for the protection and management of wildlife resources; however, their occupational activities often place them near the vectors and reservoir hosts. Despite the critical role rangers play, there is a paucity of data on the prevalence of VL among this vulnerable population, limiting the implementation of targeted health interventions in this population.

Understanding the prevalence of VL among wildlife rangers is vital for several reasons, including the following. First, it highlights the occupational health risks associated with their work and the need for protective measures. Second, it will provide insights into the epidemiology of VL in a unique ecological niche, thereby contributing to the broader public health knowledge. Third, such data can inform policymakers and health authorities to develop effective strategies for disease prevention and control in similar high-risk groups.

This study aims to determine the prevalence of VL and associated risk factors among Wildlife Rangers in Dinder National Park, Sudan.

By investigating the extent of VL infection and associated risk factors in this population, we hope to provide evidence-based recommendations for improving the health and safety of wildlife rangers. Additionally, the findings may offer a model for addressing VL in other conservation areas and occupations with similar exposure risk.

Through this research, we seek to bridge the gap in the literature on occupational health risks of VL and emphasise the importance of integrated approaches to disease management in endemic regions. This study underscores the need for continuous surveillance, enhanced diagnostic facilities, and comprehensive health education programs to mitigate the impact of VL in those most at risk.

Methodology

This descriptive cross-sectional community-based study was conducted in Dinder National Park, Sinnar State, Sudan, from 5th July to 14 November 2021 using mixed methods to investigate the prevalence of Visceral Leishmaniasis (VL) and associated risk factors among wildlife rangers.

Dinder National Park, located in southeastern Sudan along the border with Ethiopia, serves as a significant study area because of its extensive biodiversity and varied ecosystems. Established in 1935 and covering approximately 10,292 square kilometers, the park is named after the Dinder River, a tributary of the Blue Nile that flows through it. The park features diverse habitats, including woodlands dominated by Acacia and other indigenous tree species, extensive grasslands that support a wide range of herbivores, and seasonal wetlands that are crucial for aquatic species. This rich habitat diversity supports an array of wildlife, including African elephants, lions, leopards, cheetahs, buffaloes, giraffes, various antelope species, over 200 bird species, and numerous reptiles and amphibians. The flora of Dinder ranges from dense woodlands to open grasslands and marshy areas, further contributing to its biodiversity [24].

The study population comprised all 500 wildlife rangers in Dinder National Park, who were selected through a census sampling method to ensure comprehensive data collection. All participants were interviewed face-to-face using a structured questionnaire, allowing for the collection of detailed and accurate information directly from all participants.

The questionnaire used for data collection was designed by the research team based on a thorough review of the relevant literature and consultation with subject matter experts to ensure its relevance to the study objectives. It was pre-prepared to cover key topics such as demographic information and risk factors, such as mosquito net usage and awareness of visceral leishmaniasis control measures, as well as self-reported questions based on clinical signs and symptoms of infection. The questionnaire was also pre-tested on a small subset of participants outside the study population to assess its clarity, validity, and reliability, with adjustments made accordingly before full deployment.

The data collection involved three primary phases.

First, a validated questionnaire was administered to gather detailed information on demographic characteristics and various aspects related to the VL. Second, existing medical records were reviewed on 7 October 2021 to extract relevant data, including health history and documented cases of illnesses or injuries among wildlife rangers. A total of 500 medical records corresponding to the entire study population were systematically examined to ensure their completeness and consistency. The data extraction process involved using a standardised form designed by the research team to capture key variables relevant to the study objectives. Third, a Key Informant Interview (KII) was conducted with the Director of the Department of Primary Health Care in Dinder locality using a structured KII guide developed by the research team. The guide was informed by the study objectives and included questions on the visceral leishmaniasis (VL) rate among soldiers and an assessment of the quality of health services provided to them. The director was not part of the 500 Soldiers for Wildlife but was selected because of their expertise and oversight role in healthcare services in the region. Data were collected from wildlife rangers through face-to-face interviews in a convenient environment to ensure the confidentiality of the respondents.

Data were entered and analysed using the Statistical Package for Social Science (SPSS) version 24.0. Descriptive statistics were used to summarise the demographic data and prevalence rates, while the associations between different variables were assessed using the chi-square test, with a $p \leq 0.05$ considered statistically significant. Logistic regression was also performed, with the calculation of Odds Ratios (OR) and 95% Confidence Intervals (CI). Bivariate analysis was conducted at a 5% significance level and 95% confidence interval to examine the relationships between the prevalence of VL and risk factor variables, and binary regression (logistic regression) was used to calculate the direction of association between infection and risk factors using odds ratios (OR) at 95% CI. The Odds Ratio (OR) and corresponding 95% confidence intervals (CIs) used in the bivariate analysis (as crude odds ratio) and embedded in logistic regression analysis (as adjusted odds ratio) determined the relationships between the prevalence of visceral leishmaniasis and several risk factors.

Ethics Statement

This study was conducted in accordance with the relevant recommendations and regulations, following the guidelines of the Declaration of Helsinki. Ethical approval for this study was obtained in three stages. First, approval was secured from the Research Committee, Ministry of Health and Social Development, Sennar State - General Administration of Basic Health Care - Diseases Department-Kala-azar Department on 2/5/2021. Second, it was approved by the Health Services Administration of Al-Dindar Locality under the number A Kh S / M D / 50/ 1, dated 4/5/2021. Finally, approval was granted by the Police Presidency of the Dinder Federal Park, affiliated with the General Administration for Wildlife Protection, headed by the Police Forces-Ministry of Interior, under the number A A H H B/M D/M1/, dated 4/5/2021. Informed consent was obtained from all the adult participants. For participants under 18 years of age, consent was obtained from their parents or guardians.

Results

Demographic characteristics

The study included 500 participants, predominantly male (93%), with only 7% females. The age distribution showed that 13.4% of the participants were under 20 years old, 68% were between 20 and 30 years old, and

Table 1. Demographic characteristics of wildlife rangers in Dinder National Park, Sudan, (n = 500).

Characteristic	Frq.	%
Sex		
Male	465	93
Female	35	7
Age groups (years)		
< 20	67	13.4
20 – 30	340	68
> 30	93	18.6
Religion		
Muslim	477	95.4
Not Muslim	23	4.6
Marital status		
Married	229	45.8
Single	226	45.2
Divorce	40	8
Widow	5	1
Educational level		
Illiterate	60	12
Primary school	71	14.2
High school	304	60.8
Graduate	65	13
Monthly income		
Low	40	8
Medium	347	69.4
High	113	22.6
Family size		
< 5	127	25.4
5 – 8	268	53.6
> 9	105	21
Years of Experience		
< 1 year	43	8.6
2 - 5 years	229	45.8
> 5 years	228	45.6
Military rank		
Officer	78	15.6
Soldier	422	84.4

18.6% were over 30 years old.

Regarding religious affiliation, 95.4% of the participants were Muslim and 4.6% identified as non-Muslim. The marital status of the participants was nearly evenly split, with 45.8% married, 45.2% single, 8% divorced, and 1% widowed. In terms of educational level, 12% were illiterate, 14.2% had completed primary school, 60.8% had a high school education, and 13% were college graduates. Monthly income levels varied, with 8% of the participants earning a low income, 69.4% earning a medium income, and 22.6% earning a high one. Family size was categorised into three groups: 25.4% had less than five members, 53.6% had between five and eight members, and 21% had more than nine members in their families. Regarding participants' years of experience in their roles, 8.6% had less than one year of experience, 45.8% had between two and five years of experience, and 45.6% had over five years of experience. Regarding military rank, 15.6% of the participants were officers, while the majority (84.4 %) were soldiers. All demographic characteristics are presented in Table 1.

Prevalence of VL and associated factors

The prevalence of visceral leishmaniasis (VL) among the participants was 27.6% (n = 138) positive, while 72.4% (n = 362) were negative (Figure 1).

Regarding the previous history of VL infections, (7.4%) of participants reported having an infection within the past month, (11%) within the past year, and (10.6%) two years ago. The majority (71%) of the participants reported no history of VL infection (Figure 2). The study revealed the following associations between various demographic and risk factors and the prevalence of visceral leishmaniasis (VL). Table 2 shows the odds ratios for the different variables related to VL infection.

Figure 1. Self-reported Prevalence of VL among wildlife rangers in Dinder National Park, Sudan (n = 500).

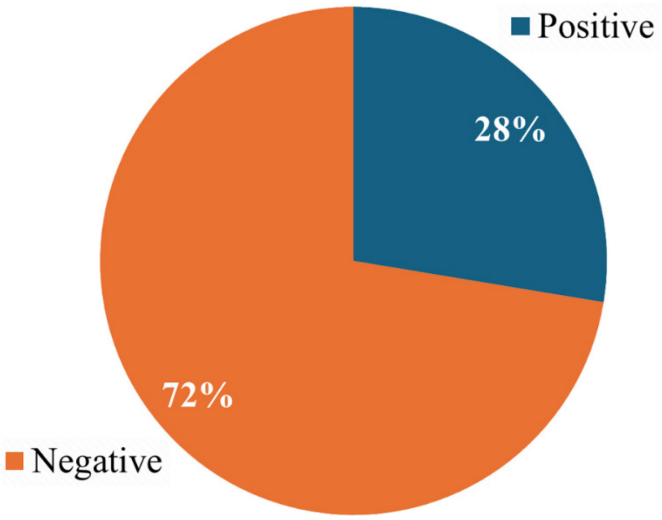

Figure 2. Previous infection with VL among wildlife rangers in Dinder National Park, Sudan (n = 500).

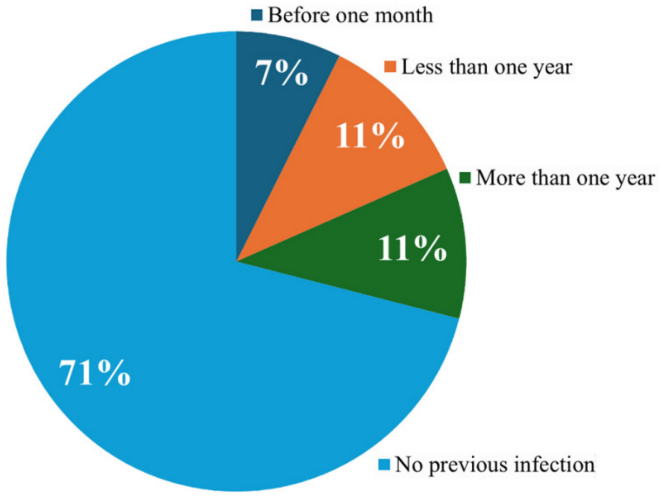

Table 2. Relationship between prevalence of VL and risk factors among wildlife rangers in Dinder National Park, Sudan (n = 500).

Variable	Category	Positive (%)	Negative (%)	Total (%)	*p*	OR (95% CI)
Educational Level	Illiterate	16 (3.20)	44 (8.80)	60 (12.00)	0.001	--
	Primary school	29 (5.80)	42 (8.40)	71 (14.20)		1.895 (0.901 - 3.983)
	High school	67 (13.40)	237 (47.40)	304 (60.80)		0.777 (0.413 - 1.462)
	Graduate	26 (5.20)	39 (7.80)	65 (13.00)		1.833 (0.861 - 3.906)
Family Income	Low	14 (2.80)	26 (5.20)	40 (8.00)	0.352	--
	Medium	96 (19.20)	251 (50.20)	347 (69.40)		0.71 (0.36 - 1.42)
	High	28 (5.60)	85 (17.00)	113 (22.60)		0.61 (0.28 - 1.33)
Military Rank	Officer	33 (6.60)	45 (9.00)	78 (15.60)	0.004	--
	Soldier	105 (21.00)	317 (63.40)	422 (84.40)		0.45 (0.27 - 0.75)
Awareness about Signs and Symptoms of VL	Yes	128 (25.60)	260 (52.00)	388 (77.60)	0.000	--
	No	10 (2.00)	102 (20.40)	112 (22.40)		0.20 (0.10 - 0.39)
Awareness of VL Transmission Methods	Yes	120 (24.00)	255 (51.00)	375 (75.00)	0.000	--
	No	18 (3.60)	107 (21.40)	125 (25.00)		0.36 (0.21 - 0.61)
Awareness about Control of VL	Yes	124 (24.80)	307 (61.40)	431 (86.20)	0.012	--
	No	14 (2.80)	55 (11.00)	69 (13.80)		0.63 (0.34 - 1.18)
Sleeping under the Net	Yes	44 (8.80)	172 (34.40)	216 (43.20)	0.001	--
	No	94 (18.80)	190 (38.00)	284 (56.80)		1.93 (1.28 - 2.92)

Regarding educational level, 16 illiterate individuals (3.2%) were infected with VL, 29 individuals with primary school education (5.8%) were infected, 67 individuals with higher education (13.4%) were infected, and 26 individuals with graduate studies (5.2%) tested positive for VL. The *p* for the association between VL infection and educational level was 0.001, indicating a statistically significant difference. Participants with a low income had 14 individuals (2.80%) who tested positive and 26 (5.20%) who tested negative. Those with a medium-income had 96 individuals (19.20%) test positive and 251 (50.20%) test negative, with an OR of 0.71 (95% CI: 0.36 - 1.42). Participants with a high income had 28 individuals (5.60%) test positive and 85 (17.00%) test negative, with an OR of 0.61 (95% CI: 0.28 - 1.33). The *p* for family income was 0.352, indicating no statistically significant difference in the results. Among the officers, 33 (6.60%) tested positive for VL and 45 (9.00%) tested negative. Soldiers had 105 individuals (21.00%) test positive and 317 (63.40%) test negative, with an OR of 0.45 (95% CI: 0.27 - 0.75). The *p* for military rank was 0.004, indicating a statistically significant difference.

Participants who were aware of the signs and symptoms of VL had 128 individuals (25.60%) who tested positive and 260 (52.00%) who tested negative. Those who were not aware had 10 individuals (2.00%) test positive and 102 (20.40%) test negative, with an OR of 0.20 (95% CI: 0.10 - 0.39). The *p* for awareness of the signs and symptoms was 0.000, indicating a statistically significant difference. Among participants aware of VL transmission methods, 120 (24.00%) tested positive and 255 (51.00%) tested negative. Those unaware had 18 individuals (3.60%) test positive and 107 (21.40%) test negative, with an OR of 0.36 (95% CI: 0.21 - 0.61). The *p* for awareness of VL transmission methods was 0.000, indicating a statistically significant difference. Among participants aware of VL control methods, 124 (24.80%) tested positive and 307 (61.40%) tested negative. Those unaware had 14 individuals (2.80%) test positive and 55 (11.00%) test negative, with an OR of 0.63 (95% CI: 0.34 - 1.18). The *p* for awareness of VL control was 0.012, indicating a statistically significant difference.

Participants who slept under a net, 44 (8.80%), tested positive, and 172 (34.40%) tested negative. Those who did not sleep under a net had 94 individuals (18.80%) test positive and 190 (38.00%) test negative, with an OR of 1.93 (95% CI: 1.28 - 2.92). The *p* for sleeping under the net was 0.001, indicating a statistically significant difference.

The 2021 interview results with the Director of the Department of Primary Health Care in Dinder Locality revealed several key insights. According to the Director, wildlife rangers stationed in forested areas are at a heightened risk because of the presence of Leishmania vectors, increasing their susceptibility to infection compared with other populations. Additionally, many soldiers lack adequate protective equipment, such as mosquito nets, and even those who possess them often do not use them consistently. One of the wildlife rangers indicated, "*When I sleep under a mosquito net, I feel short of breath and as though I am in a grave, so I prefer not to use it*". *The director said, "The problem is that flies breed frequently in the state, particularly in the enclosure area, where workers are often present without personal protective equipment. Although mosquito nets are distributed annually to workers, some do not use them because of a lack of interest, highlighting the need for greater awareness of their importance*" [25]. These factors likely contribute to the high prevalence of visceral Leishmaniasis in the area.

Discussion

This study investigated the prevalence of visceral leishmaniasis (VL) and its associated risk factors among wildlife rangers in Dinder National Park, Sudan. The findings revealed significant associations between VL prevalence and various demographic and risk factors, including educational level, military rank, awareness of VL signs and symptoms, awareness of VL transmission methods, awareness of VL control measures, and sleeping under a mosquito net. The prevalence of VL in this study was 27.6%, which is alarmingly high compared to the global average, particularly in regions outside endemic areas. This high prevalence aligns with findings from studies conducted in other parts of Sudan and East Africa, where environmental conditions and socioeconomic factors contribute to higher rates of infection. A recent systematic review by [14] in Sudan revealed that the overall pooled prevalence of human leishmaniasis in Sudan is 21%. Cutaneous leishmaniasis (CL) is the most common type, with a prevalence of 26%, followed by visceral leishmaniasis (VL) at 18%. Notably, the prevalence of VL reported in the [14] review was lower than that observed in our current study. The review also indicated that central Sudan has the highest prevalence of human leishmaniasis at 27%, which aligns with the findings of our current study in the same region. This high prevalence highlights significant public health challenges, including the need for strengthened surveillance systems, improved access to diagnosis and

treatment, and enhanced vector-control measures. Additionally, the social and economic impacts of leishmaniasis on affected communities underline the importance of targeted health education and awareness campaigns to reduce its transmission. Addressing these challenges will require collaborative efforts between local health authorities, policymakers, and international organizations to develop sustainable intervention strategies. However, the overall prevalence of human leishmaniasis has decreased over time [14]. Another study [15] conducted in Eastern Gedaref State, Sudan, among children, reported that 47 out of 145 suspected cases (32%) were identified as having VL. This prevalence is higher than that among adults, indicating that children are more likely to contract VL than adults. The study also found a significant association between rural residence, male sex, and VL among children. This suggests that rural areas are higher-risk zones owing to socioeconomic conditions, poor housing, and inadequate sanitary conditions. Similarly, in the same eastern region, [16] reported that VL represents a significant health burden in the villages of Eastern Gedaref State, being one of the major causes of death in the area. A study conducted by [24] investigated the clinical and demographic features of visceral leishmaniasis (VL) in an African population. The findings indicate that males are at a higher risk than females, with the majority of patients being children aged < 15 years. A similar study [25] conducted in Gadaref, Eastern Sudan, also reported that children and men were at a higher risk of visceral leishmaniasis (VL). This increased risk among children is attributed to their tendency to play outside, making them more likely to be exposed to sandfly vectors that transmit Leishmania parasites. For men, the higher risk is due to their likelihood of working in outdoor environments, such as farming and forestry, where they are more frequently exposed to the sandflies. The association between educational level and VL prevalence was significant, with illiterate participants having a higher prevalence of infection (3.20%) than literate participants. This finding suggests that education plays a crucial role in disease prevention and increasing awareness. Similar results have been reported in other studies, where higher educational levels were correlated with lower prevalence rates of various infectious diseases, including VL. The ORs indicated that primary and graduate participants had increased odds of VL compared to illiterate participants, though the difference was not statistically significant. Family income was not significantly associated with the prevalence of VL in this study. However, those with low and medium incomes had higher prevalence rates than those with high incomes. This finding is consistent with previous research, indicating that a lower socioeconomic status is often linked to higher rates of VL due to limited access to healthcare and preventive measures. The lack of statistical significance might be due to the relatively small sample size or other confounding factors that were not accounted for in this study. Military rank was significantly associated with VL prevalence, with soldiers having a higher prevalence (21.00%) than officers (6.60%). This disparity may be attributed to differences in living conditions, exposure to infected sandflies, and access to protective measures against the disease. Similar patterns have been observed in other occupational health studies, where lower-ranking personnel often face greater exposure to occupational hazards than higher-ranking personnel. Awareness of the signs and symptoms of VL, transmission methods, and control measures was significantly associated with lower prevalence rates. Participants who were aware of these aspects had a much lower VL prevalence. This finding underscores the importance of health education and awareness campaigns in controlling the spread of the VL. Previous studies have highlighted the critical role of awareness and education in reducing the incidence of VL and other vector-borne diseases. Sleeping under a mosquito net was significantly associated with lower VL prevalence. Participants who did not sleep under a net had nearly twice the odds of contracting VL compared to those who did sleep under a net. This finding aligns with extensive research demonstrating the effectiveness of insecticide-treated nets in reducing the transmission of vector-borne diseases, including malaria and VL.

Implications for Future Research

The findings of this study highlight several key areas for future research to further understand and mitigate the burden of visceral leishmaniasis (VL) among wildlife rangers in the Dinder National Park in Sudan. Detailed epidemiological studies are needed to track the incidence and prevalence of VL over time and identify seasonal variations and long-term trends. These studies should explore the role of environmental factors specific to Dinder National Park, such as climate patterns, wildlife interactions, and habitat characteristics in influencing VL transmission dynamics.

Research on socio-economic and behavioural factors is crucial. This includes investigating the socio-economic determinants of health that contribute to VL

risk, focusing on the impacts of poverty, education, and access to health care services. Assessing the effectiveness of current health education programs and developing targeted interventions to improve awareness and preventive behaviours among different demographic groups within the soldier population is important.

Intervention strategies should be evaluated to determine the effectiveness of various preventive measures, such as insecticide-treated nets, personal protective equipment, and environmental management, in reducing VL transmission. Community-based intervention trials should be implemented and assessed to determine the best practices for VL control in the context of wildlife rangers and other at-risk populations in similar settings. The accessibility and quality of healthcare services available to wildlife rangers must be examined, focusing on diagnostic capabilities, treatment availability, and overall healthcare infrastructure. Qualitative research is necessary to understand the barriers to healthcare access and utilisation, including cultural beliefs, stigma, and logistical challenges. Molecular and genetic studies can provide valuable insights into the specific strains of Leishmania parasites circulating in this region and their potential resistance to standard treatments. Exploring the genetic susceptibility of the local population to VL and identifying potential genetic markers that could inform personalised treatment and prevention strategiess also important. Occupational health and safety research should investigate the specific conditions that increase exposure to sand flies and other wildlife conservation work-associated vectors. Developing and evaluating occupational health and safety programs tailored to the unique needs and risks faced by wildlife rangers is thus crucial. Collaboration among local, national, and international health organisations should be fostered to share knowledge, resources, and best practices for VL control. Policy changes that support the allocation of resources to VL research, prevention, and treatment programs should be advocated to ensure sustained efforts to combat this disease. By addressing these research areas, future studies can provide a more comprehensive understanding of VL in Dinder National Park and contribute to the development of effective, evidence-based interventions to reduce the burden of this disease among wildlife rangers and other at-risk populations.

Limitations

This study, while providing valuable insights into the prevalence of visceral leishmaniasis (VL) and associated risk factors among wildlife rangers in Dinder National Park, Sudan, has several limitations that should be considered when interpreting the results of the study. First, the cross-sectional design of the study limits the ability to establish causal relationships between the identified risk factors and VL prevalence. While associations can be observed, it is not possible to determine the direction of these relationships or to infer causality. Second, reliance on self-reported data for certain variables, such as awareness of the VL signs and symptoms and the use of mosquito nets, may introduce reporting bias. Participants may have over-reported positive behaviours or under-reported negative behaviours due to social desirability bias. Third, the study's focus on wildlife rangers may limit the generalisability of the findings to other populations in the country. The unique environmental and occupational conditions faced by wildlife rangers in Dinder National Park may not reflect those experienced by the general population or other occupational groups in Sudan or other regions. Fourth, this study did not account for potential confounding variables that could influence the observed associations. Factors such as nutritional status, other underlying health conditions, and genetic predispositions were not controlled for, which may have affected the study's findings. Fifth, the sample size, while comprehensive for wildlife rangers in Dinder National Park, may still be limited for certain subgroup analyses. Small sample sizes within specific categories, such as those with low educational levels or income, might reduce the statistical power to detect significant differences. Sixth, the use of a single diagnostic method for VL prevalence may not accurately capture all cases. Misclassification of cases, either false positives or false negatives, could affect the prevalence estimates and the strength of the associations with risk factors. Seventh, this study did not include detailed environmental and ecological data, which are crucial for understanding the transmission dynamics of VL. Factors such as vector density, habitat characteristics, and climatic conditions were not assessed, limiting the ability to fully understand the environmental determinants of the VL risk.

Finally, the study period and timing may have influenced the results. Seasonal variations in sandfly activity and VL transmission could affect prevalence rates, and this study might not have captured these temporal dynamics accurately. Acknowledging these limitations is essential for contextualising the findings and guiding future research efforts to address these gaps and build a more comprehensive understanding of VL in this high-risk population.

Conclusions

This study highlights the alarmingly high prevalence of visceral leishmaniasis (VL) among wildlife rangers in Dinder National Park, Sudan, with significant associations between VL prevalence and various demographic and behavioural risk factors. These findings emphasise the critical role of education, awareness, and preventive practices, such as sleeping under mosquito nets, in reducing the risk of VL. Furthermore, the disproportionate burden observed among soldiers of lower military ranks underscores the need for targeted interventions to address occupational and environmental exposure risks in this vulnerable population group.

Data availability

The data supporting this study are available upon reasonable request from the corresponding author.

Author contributions

Conceptualisation: BI, ME, SH, MGAA, and AEEA; data collection coordination: BI, MGAA, and SH; methodology and data analysis: BI, ME, and SH; writing original draft preparation: BI, ME, SH, and MGAA; writing review and editing: ME and SH; supervision: AEEA. All authors have read and agreed to the submitted version of the article.

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Conflict of interest

No conflict of interest is declared.

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