Burden of snakebite envenoming in northern Benin: A Retrospective Cross-Sectional Study in the Tchaourou District

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Short Title: **Burden of snakebite envenoming in northern Benin**

Abstract

Background: SBE is a significant public health problem, yet its incidence and associated disabilities and fatalities have been vastly underestimated.

Objective: To estimate the burden of snakebite envenoming in rural Tchaourou, Northern Benin.

Methods: A retrospective descriptive and analytical cross-sectional survey was conducted from 2018 to 2023 in the Tchaourou district. Data were collected through household interviews among participants of the ENABLE Lassa research program. Statistical analyses included incidence-rate calculations and multivariable logistic regression.

Results: Among 261 household respondents, 74 reported snakebites, yielding an incidence of 399 per 100,000 person-years [95% CI 314–501]. These 74 victims had a median age of 25.5 years and a male/female distribution of 55%:45% (41:33). Of the 74 victims, 32 (43%) reported that snakebites occurred while farming; and snakebites were most frequent during the rainy season (June and July) when farming activity was at its most intense. The most frequently bitten of the body was the foot or leg (74%), and the most reported symptoms included local swelling (78%), pain (78%), bleeding (66%), and headache (64%). The complications were reported by 22/74 (30%) victims. The risk of a snakebite complication was 3.0 times higher for female (14/33) than male victims (8/41; p=.032) and appeared to be higher when the first point of care was a traditional healer (12/44) or treatment at home (10/24) rather than at a health centre (0/6). Ultimately, only 18/74 (24%) victims attended a health centre.

Conclusion: Snakebite envenoming poses a significant health problem in Benin. Comprehensive strategies involving training of healthcare providers, community engagement, and improved immediate access to health centres should reduce morbidity.

Keywords: Snakebite, envenoming, Benin, symptoms, management.

Author Summary

Snakebite envenoming (SBE) is the second most deadly neglected tropical disease (NTD) and is a priority NTD for the World Health Organisation. In low-income tropical countries, SBE is

a significant public health problem, yet its incidence and associated disabilities and fatalities have been vastly underestimated. We undertook a retrospective descriptive and analytical cross-sectional survey of 74 snakebite victims collected from 2018 to 2023 in the Tchaourou district of Benin, Africa. Our study suggested that the increased risk of snakebite comes from intensive farming in these tropical regions, and that previous underestimates may be related to only a minority of victims attending health centres where statistics are typically gathered. Moreover, our study suggested that improved immediate access to health centres should reduce morbidity, most notable for women.

Introduction

Snakebite envenoming (SBE) is the second most deadly neglected tropical disease (NTD) (1), and is a priority NTD for the World Health Organisation (WHO) (2). Globally each year, 4.5 to 5.4 million people are bitten by snakes, 1.8 to 2.7 million are envenomed, and 81,000 to 138,000 die, with a case-fatality rate of 4 to 7% (2). Similarly, around 400,000 victims are left with disabilities, amputations, skin or muscle scars, brain, eye or kidney damage, social stigmatization and post-traumatic stress disorders (3–5).

In low-income tropical countries, SBE is a significant public health problem, yet its incidence and associated disabilities and fatalities have been vastly underestimated(2,3,6–9). In West Africa, the incidence of snakebites has been estimated at 8.9 to 93 per 100,000 person years, with a mortality rate of 0.5 to 5.9 per 100,000 person-years(8,9). In Benin, snakebites are most frequent in the departments of Borgou and Atacora, with an incidence of 144 per100,000 people-years and a case-fatality rate of 5.9% (10).

SBE imposes a substantial but often underestimated economic burden worldwide, as highlighted by a recent systematic review (11). In Southeast Asia, across seven countries including Malaysia, Thailand, Indonesia, the Philippines, Viet Nam, Lao PDR, and Myanmar,

the total annual economic cost of snakebites was estimated at approximately USD 2.5 billion in 2019, representing about 0.09% of the region's gross domestic product. Notably, more than 95% of this burden was attributable to premature mortality, underscoring the profound human and societal losses associated with snakebite-related deaths (12). In Benin, the use of antivenom has been shown to be highly cost-effective, with the cost per disability-adjusted life year averted estimated at approximately USD 83 (13). Furthermore, a hospital-based study in Benin reported a median direct hospital cost of snakebite management of around €168 per case, with costs varying considerably by clinical severity, ranging from approximately €31 for dry bites to €179 for cases complicated by external bleeding (14). Together, these findings illustrate not only the clinical but also the significant economic impact of SBE on affected households and health systems, particularly in resource-limited settings.

The district of Tchaourou is one of eight in the Borgou department and the largest district in Benin (15,16). The main activities in this district are farming and livestock breeding (15,16). In Benin, it has been shown that snakebite victims are often farmers and poor, and that there is a shortage of antivenomous serum in the areas concerned, with insufficient treatment equipment in health centres (17,18). The true disease burden of snakebite has been less well studied in Benin, and little attention has been paid to it by health authorities, relegating snakebite to a group of neglected public health problems (18).

WHO launched in 2019 the goal of reducing snakebites deaths and disabilities by 50% by 2030 (5). To measure impact and progress it is important to have baseline data at snakebite disease burden not only at national but also district level. Therefore, this study was conducted to: (i) determine the incidence of snakebites in rural areas of Tchaourou district (October 2018 to October 2023), (ii) analyse the profile of snakebite victims in Tchaourou communities, (iii) identify the factors associated with snakebites in Tchaourou communities.

Methods

Study area

This retrospective cross-sectional study was carried out in the district of Tchaourou, Benin (Figure 1). Tchaourou is the largest district in Benin, covering 7256 km², or around 6.5% of the national territory. Tchaourou borders Parakou, Pèrèrè and N'Dali to the north. To the east, it borders the Federal Republic of Nigeria, and to the west, the communes of Bassila and Djougou. Most roads are unpaved.

In 2013, the population of Tchaourou was 223,118 according to the fourth General Census of Population and Housing (RGPH4) published in May 2013 (19), with an equal split between male and females. The agricultural population was 170,524. The main ethnic groups were the Baribas (40%), Peulhs (30%) and Nagots/Yorubas (6.0%). The population reported as being Muslim (66%), Catholic (15%), and, among others, animists (2.9%). The most common economic activities were classified under agriculture, livestock, fishing and hunting, which included 76% of the population (15,16). The climate is Sudanian, with a single rainy season. Annual rainfall varies between 900 and 1,300 mm. The rainy season begins in April and lasts around seven months. The average annual temperature is around 26°C, with a maximum of 32°C in March, dropping to around 23°C in December-January. Relative humidity varies between 30% and 70%. Four types of vegetation can be distinguished (15,16,19): the grassy savannah, tree and shrub savannah, wooded savannah.

Data source:

This study collected data from among households enrolled in the ENABLE 1.0 Lassa research program in Benin. This program was a prospective multi-site cohort study to estimate incidence of infection and disease due to Lassa fever virus in West African countries (20).

The study localities were in well-defined geographical areas, including multiple rural and peri-urban localities, with healthcare facilities. To facilitate the acceptance of the study by the population, recruitment was done at household level rather than at individual level.

Two-stage cluster sampling method was used for the random selection of locations and households. A total of 34 villages in proportion to their population size, from a total of 36 villages in Tchaourou, Parakou districts was randomly selected. We used satellite imagery and a random selection algorithm to select 12 dwellings in each village plus six dwellings in reserve. The dwellings have been visited consecutively using a smartphone equipped with a GPS application until approximately 63 (+/- 3) participants were included.

The survey covered a five-year period from October 2018 to October 2023, and 264 households were interviewed.

The occurrence of snakebites and sociodemographics were considered for analysis. Data were collected during a face-to-face interview with the head of the household and/or its members, using a pre-established and validated questionnaire.

Data analysis

All participating household members formed the analysis population. We validated the data by checking the completeness of the information collected using Kobocollect, a mobile data collection application, developed as part of the KoboToolbox platform and built on the Open Data Kit (ODK) framework. This was followed by data analysis using IBM SPSS Statistics 21 software.

We analysed the factors associated with the occurrence of complication by multivariable analysis using a top-down stepwise logistic model. For logistic regression, the dependent variable was crossed with the independent variables that were significant or had a p value ≤

0.20 in univariate analysis. Statistical analysis used a p value of < 0.05 for all parameters to determine significant changes. Model fit was verified using the Lemeshow test. The odds ratios were presented with their 95% confidence intervals.

Ethics and Data Privacy

The study was approved by the ethics committee of the University of Parakou (Comité Local d'Ethique pour la Recherche Biomédicale de l'Université de Parakou) N^0: 0550/CLERB-UP/P/SP/R/SA. Rules of courtesy and privacy were respected towards each participant. Written informed consent was obtained from all adult participants. For participants younger than 18 years, written informed consent was obtained from a parent or legal guardian. In addition, written assent was obtained from children aged 10–17 years prior to participation. Written informed consent of the heads of household was obtained before the interview.

Results

The study population of the 264 households included a total of 3706 participants with a median age of 18 years and a male/female distribution of 47%:53%. During the 5-year observation period from 2018 to 2023, 74 participants reported snakebites, representing an incidence rate of 399 bites per 100,000 person-year (95% CI 314–501). These 74 victims had a median age of 25.5 years and a male/female distribution of 55%:45% (41:33 victims; Table 1). The predominant age strata for male victims were 10 to 19 years (12), and 20 to 29 years (12), whereas for female victims it was ≥50 years (9). Most victims reported being bitten in the morning than other times of the day (28/74 [38%]), and during the rainy season between June and July (21/74 [28%]) than other months of the year (Table 2 and Figure 2). For male victims, the most prevalent activity in which the bite occurred was farming (21/41; 51%), whereas for female victims these activities were farming (11/33; 33%), walking outdoors (9/33;27%) and gathering wood (8/33; 24%) (Table 2).

167 **Table 1: Categorisation of snakebite victims**

	Categorisation of Snakebite Victims					
Age Category (year):	**1-9**	**10-19**	**20-29**	**30-39**	**40-49**	**≥ 50**
Female (N=33), n (%)	2 (6)	5 (15)	6 (18)	6 (18)	5 (15)	9 (27)
Male (N=41), n (%)	5 (12)	12 (29)	12 (29)	2 (5)	4 (10)	6 (15)
Total (N=74), n (%)	7 (9)	17 (23)	18 (24)	8 (11)	9 (12)	15 (20)
Means of transport to health centre:	**On foot**			**Household motorcycle**		
All health-centre patients (N=18), n (%)	1 (6)			17 (94)		
Time between bite & health centre visit:	**Same day**		**Next day**		**≥2 days**	
All health-centre patients (N=18), n (%)	10 (56)		2 (11)		6 (33)	

Table 2: Distribution of victims by time of snakebite, activity at time of bite and first place of care

	Number (Percentage)		
	Female (N=33)	**Male (N=41)**	**Total (N=74)**
Time of snakebite			
Morning	12 (36)	16 (39)	28 (38)
Noon	2 (6)	3 (7)	5 (7)
Afternoon	11 (33)	13 (32)	24 (32)
Evening	8 (24)	9 (22)	17 (23)
Activity at time of bite			
Farming	11 (33)	21 (51)	32 (43)
Walking outdoors	9 (27)	7 (17)	16 (22)
Gathering wood	8 (24)	0 (0)	8 (11)
Livestock breeding	1 (3)	5 (12)	6 (8)
Sleeping	2 (6)	2 (5)	4 (5)
Hunting	0 (0)	3 (7)	3 (4)
Playing outdoors	1 (3)	1 (2)	2 (3)
While traveling	0 (0)	2 (5)	2 (3)
Open defecation	1 (3)	0 (0)	1 (1)
First place of care			
Tradional healer	22 (67)	22 (54)	44 (59)
Home	8 (24)	16 (39)	24 (32)
Health centre	3 (9)	3 (7)	6 (8)

The snake responsible for the bite was identified by 53/74 (72%) of victims, with sand vipers (*Cerastes vipera)* being the most frequently reported type (16/53 [30%]; Table 3). The snakebites occurred on the foot or leg (58/74, 78%) and the finger, hand or forearm (16/74, 16%; Table 1). The most frequent symptoms reported by the snakebite victims were local swelling (58/74, 78%), local pain (58/74, 78%), local bleeding (49/74, 66%), and headaches (47/74, 64%; Figure 3).

176 **Table 3: Potential risk factors associated with snakebite complications**

	Complication		Odds Ratio	95%	*p*-value
	N	n (%)	(versus Reference [Ref])	Confidence Interval	
Age (years)					
1-9	7	1 (14)	Ref	-	-
10-19	17	6 (35)	3.27	0.31-33.94	.320
20-29	18	4 (22)	1.71	0.15-18.72	.659
30-39	8	2 (25)	2.00	0.14-28.41	.609
40-49	9	4 (44)	4.80	0.39-58.01	.217
≥50	15	5 (33)	3.00	0.27-32.20	.364
Sex					
Male	41	8 (20)	Ref	-	-
Female	33	14 (42)	**3.03**	**1.07-8.56**	**.032**
Snake type					
Echid	7	0 (0)	Ref	-	.082
Striking viper	4	1 (25)	0.77	0.07-7.91	.831
Elapsoide	4	1 (25)	0.77	0.07-7.91	.831
Naja	3	1 (33)	1.19	0.10-13.85	.889
Causas macule	6	1 (17)	0.47	0.05-4.41	.465
Black mamba	5	4 (80)	**11.3**	**1.18-108.2**	**.011**
Horned viper	6	2 (33)	1.21	0.20-7.08	.841
Sand Viper	16	5 (31)	1.09	0.33-3.63	.881
Body part bitten					
Hand/finger/forearm	16	5 (31)	1.09	0.33-3.63	.881
Foot/leg	58	17 (29)	Ref	-	-
1st care place					
Traditional healer	44	12 (27)	Ref	-	-
Health centre	6	0 (0)	-	-	.142
Home	24	10 (42)	1.95	0.66-5.43	.228
Surgery done					
No	61	15 (25)	Ref	-	-
Yes	13	7 (54)	**3.57**	**1.03-12.31**	**.036**
Hospital stays					
0-3 days	10	3 (30)	Ref	-	-
4-7 days	7	2 (29)	1.41	0.19-10.03	.737
More than 7 days	1	1 (100)			.235
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4-7 days	7	2 (29)	1.41	0.19-10.03	.737
More than 7 days	1	1 (100)			.235

The first point of care was similar for female and male victims, but overall, only 6/74 (8.1%) of snakebite victims were treated initially at a health centre, whereas 44/74 (59%) were treated initially by a traditional healer, and 24/74 (32%) were treated at home (Table 2). However, 18/74 (24%) of victims were treated ultimately at a health centre (Table 1), and 13/74 (18%) of victims had surgical interventions. Of those 18 victims, 10 attended the health centre on the same day, but eight victims arrived at least 2 days after the snake bite (Table 1). Seventeen were transported by a household motorcycle, and one by foot. Only one victim was hospitalised for more than 7 days (Table 3).

About a third of the snakebite victims (22/74, 30%) had complications (Table 3). These complications mainly concerned long-term pain (9/22, 41%), pain at the bite site during the rainy season (5/22, 23%), and physical problems affecting the ability to perform activities (5/22, 23%) (Figure 4). The risk of a complication from a snake bite was 3.0 times higher (p=0.032) for a female than a male victim (14/33 versus 8/41 victims; Table 3). The risk of a complication was 11 times higher (p=.011) with a black mamba bite than an echid bite (and concerned 3/4 versus 0/6 victims). The risk of complications was not associated with age or the site of the bite (notably, there were no bites to the face, which are considered to have higher complication rates). Although not statistically significant, the risk of complications may have been lower when the first point of care was at a health centre. No complication was

reported by the six victims who were first given care at a health centre. By contrast, complications were reported by 12/44 (27%) victims who were first treated by a traditional healer and by 10/24 (42%) of victims who were treated at home. The risk of a complication was 3.6 times higher (p=.036) for victims who had surgery (7/13[54%]) than for those who did not (15/61[25%]). However, it was not documented whether the complications were present prior to or as a consequence of surgery.

Discussion

Our study identified 74 snakebite victims in a major rural province in Benin between 2018 and 2023 representing an annual incidence rate of 399 per 100,000 person-years. Our study had several limitations: firstly, the study was retrospective and embedded in the Lassa epidemiology study, and therefore we could not assess in depth, the acute complications of a snakebite. Second, complications may have been missed in victims who were home treated and not followed up by a health centre. Third, no information was obtained on (i) whether a victim needed and received antivenom treatment, (ii) the victim's family income, or (iii) the cost of the medical intervention. Nevertheless, our study points towards measures that could reduce the health burden caused by snakebite envenoming in Benin.

The incidence of snakebites of 399 per 100,000 person-years reported in this study was higher than earlier estimates in household surveys potentially because of the high degree of intensive farming in the Tchaourou province and therefore risk of exposure to snakes (19, 20), and stringent surveillance in the Lassa protocol. In other household surveys, the incidence was estimated as 144 per 100,000 person-years throughout Benin (10), 40 per 100,000 person-years in the plateau department of Benin (21), and 130 per 100,000 person-years in Burkina-Faso (22). Our estimate of snakebite incidence was also lower than estimates from hospital

surveys in Benin (46 and 66 per 100,000 person-years (21)), which can be explained by the observation from our survey that only 24% of snakebite victims attended a health centre.

As in other studies (Benin and Ghana), adults appeared to be more at risk of snakebites than young children (6, 23). In our study, this may have been due to more adults being involved in farming (43% of bites occurred while farming), and by young adult males because 24 victims were male aged between 10 and 29 years). Moreover, as with other studies, the peak incidence of snakebites occurred during the rainy season, which coincides the peak farming period, for either planting, weeding, or harvesting (10,24,25). By contrast, female victims tended to be older than male victims, which may have been related to them also being involved in other activities in addition to farming, concurring with two other studies in Benin (10,18).

The types and frequencies of snakes responsible for the bites were typical of the region (26–28). The most frequent symptoms reported by the victims in the Tchaourou district were also typical for viper bites (local swelling [78%], pain [78%], and bleeding [66%], and headaches [64%]). However, the greatest risk of complications appeared to be with a black mamba bite.

The risk of a complication from a snake bite was 3.0 times higher for a female than a male victim, and this may have been related to the type of care received. The risk of complications appeared to be higher when the first point of care was a traditional healer or treatment at home rather than at a health centre. A factor behind these data may lie with insufficient means to attend health centres (lack of transport, time or finance), or lack of education or knowledge in best practice. Traditional treatments may have included, tourniquets, constricting bands and incisions for application of native herbs, which have no proven health benefit (10,21,23,29,30). By contrast, health benefits may have come from first aid measures such as victim reassurance, immobilization of the bitten limb with a splint or sling, and prompt visit to

a health clinic, for potential treatment with an antivenom. The implementation of such approach has been achieved in Brazil, another country with a high SBE burden, where the majority of victims received medical assistance within 1 to 3 hours after being bitten (31). In one national study, medical assistance initiated within 6 hours was associated with about 42% lower odds of severe envenoming compared with later medical assistance (32).

Acknowledgements

We thank the CEPI and ENABLE 1.0 program team, the community health workers, and the residents of Tchaourou, Benin for their participation and support. Special thanks to Dr. Michael Greenberg and Celine Pompeia for their guidance throughout this research. Matthew Morgan (MG Science Communications, Belgium) provided scientific writing services.

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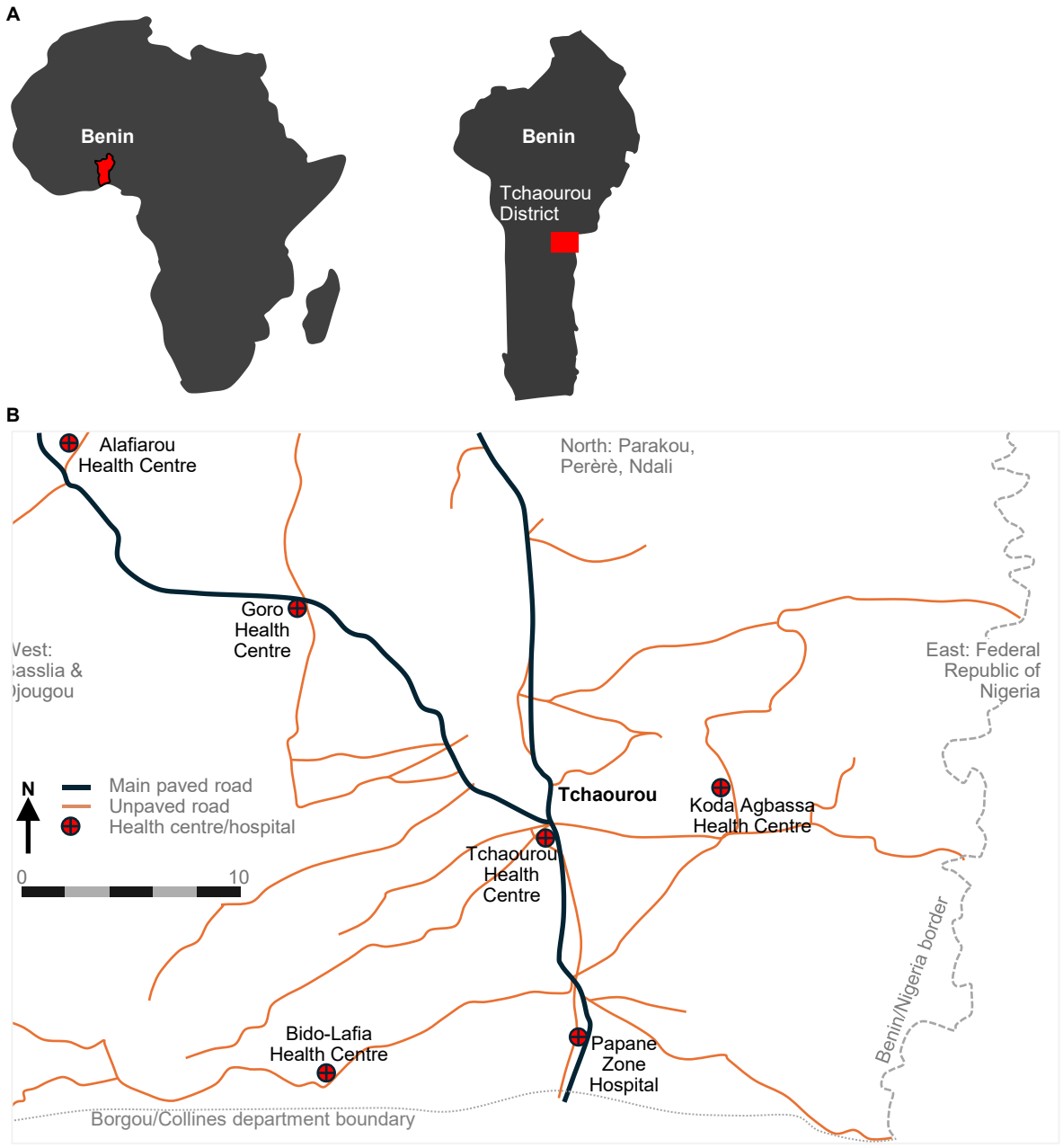
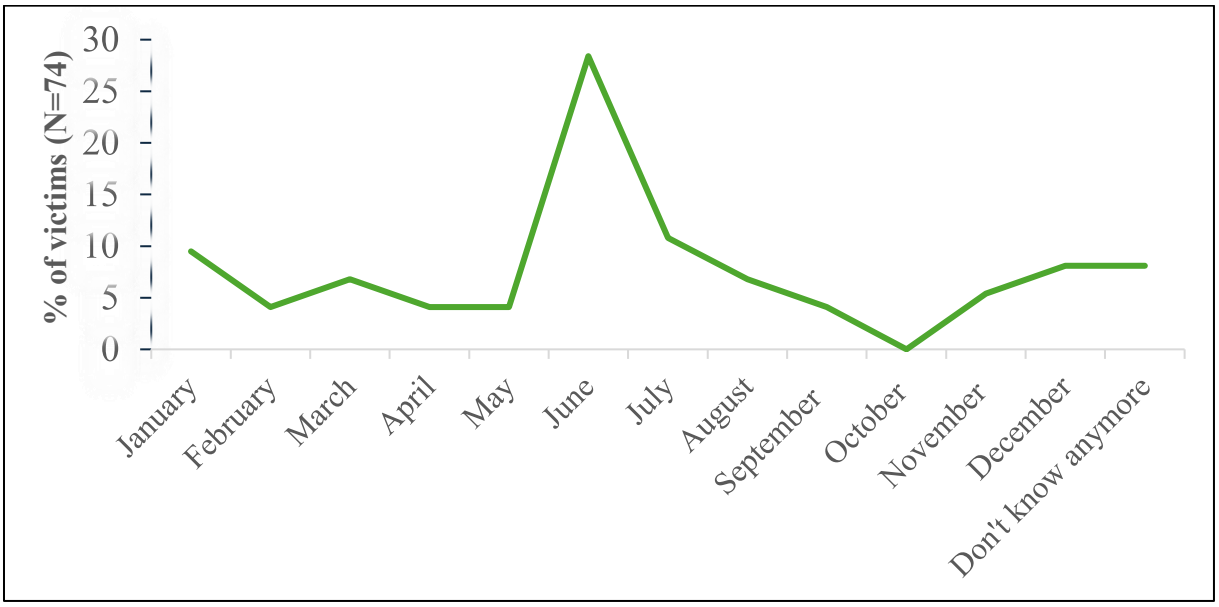
354 **Figure 1: Geographical location of the district of Tchaourou in Benin**. (A) The
355 Tchaourou district in situated in the central region of Benin in Sub-Saharan Africa. (B) The
356 district includes several health centres and is traversed by two principal paved roads.



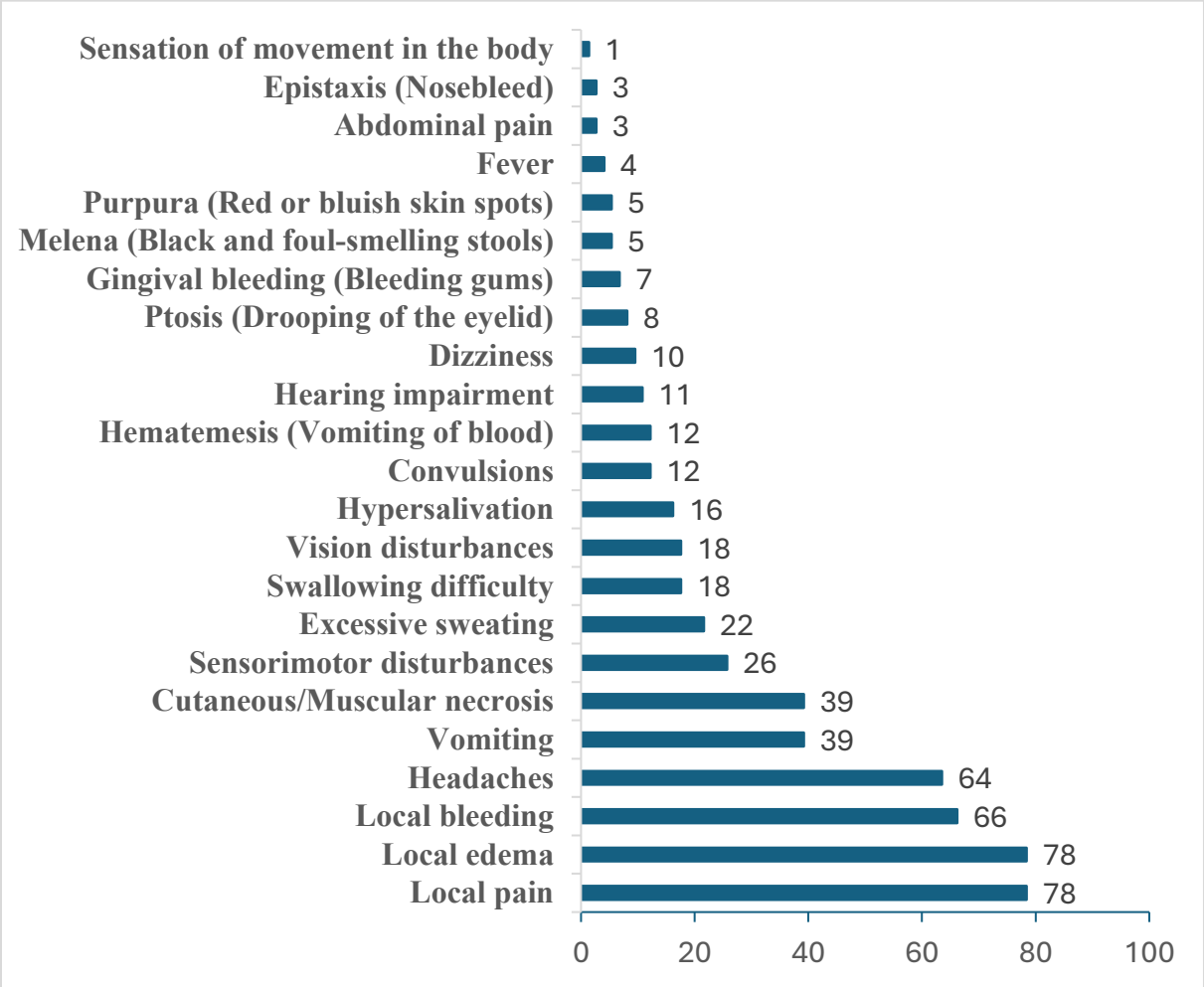
357

358 **Figure2: Distribution of snakebite victims by month of bite (N=74)**



359

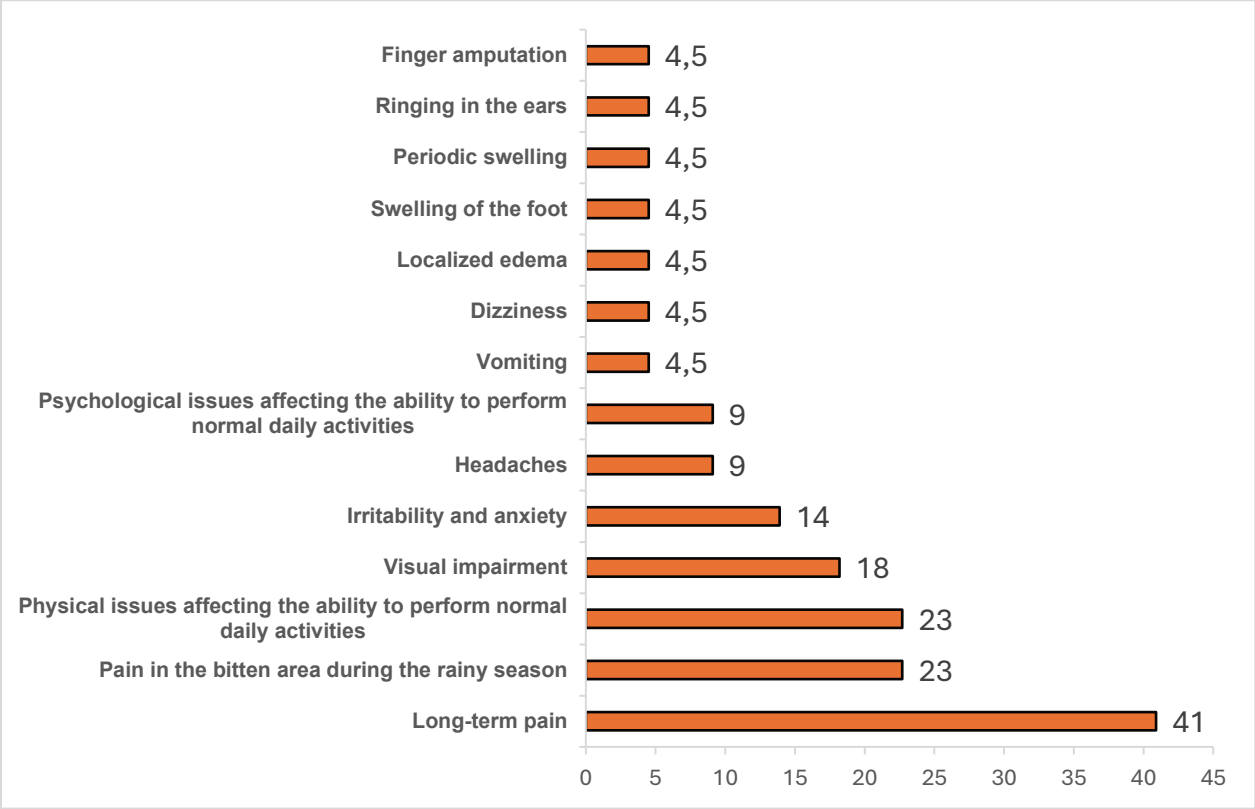
360 **Figure 3: Distribution of symptoms reported by snakebite victims (N=74)**



361

362 **Figure 4: Complications in snakebite victims in the district of Tchaourou in 2023 by**

363 **complications experienced after the bite (N=22)**



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