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ABSTRACT

Rabies is a widespread disease affecting all warm-blooded animals. In the current study the incidence and associated risk factors of rabies in humans and livestock were conducted in North-West Ethiopia with the aim of quantifying the incidence and associated risk factors of rabies. The prospective follow-up of rabid victims was recorded in seven districts of northwest Ethiopia for 18 consecutive months. Information from victims or bit animal owners was collected, entered into Excel, and were analyzed using Stata 17. A total of 393 rabid suspected cases were recorded during the follow-up period, of which 293 were bites by potentially rabid animals and 100 were probable rabid cases. Males to female ratio of human victims was (59.46% vs. 40.54%, respectively). Dog owners were more affected (62%) than non-dog owners. Dogs were the major animals (>96%) for exposure. The 5–14 years age group had the highest number of bites in human cases. The legs/feet (53.5%) were the most affected body part. The mortality rate of humans was 2.09 per 100,000 people per year during the current outbreak. People living in rural residences, males, and having dogs in the house were the main risk factors for exposure to rabies. Hence, rabies continues to pose a threat to humans and animals. The results of this research will provide a useful information for scientific communities and policy makers and governement health and veterinary professionals.

Keywords: Ethiopian, Incensedence, Rabies, Risk Factors, Exposure.

INTRODUCTION

Rabies is an ancient disease that has affected thousands of people worldwide since time immemorial and is still a major veterinary and public health problem (Pal *et al.* 2013; Gill *et al.* 2019)]. It is a widespread disease that affects all warm-blooded animals and is endemic to many countries, with the exception of islands such as Australia and Antarctica (Singh *et al.* 2017). In developing countries, 99% of human mortality from rabies is due to bites of rabid dogs. Human rabies originating from dogs is endemic to the entire African continent, where cases are often the highest in rural communities of resource-limited countries (Coetzer *et al.*, 2019; Spargo *et al.* 2021). Every year, rabies is responsible for an estimated 60,000 human deaths worldwide; 15 million people receive rabies post-exposure prophylaxis (PEP), 4 million disability-adjusted life years (DALYs), and 9 billion USD of economic loss (Beyene, *et al.*, 2018).

Ethiopia has a high endemicity of canine rabies owing to its large dog population size and ineffective dog management (Zulu *et al.* 2009; Ali *et al.*, 2010) but its impact remains unknown or underestimated. Because the majority of victims die at home in these places, the disease is poorly reported. As a result, public health agendas have failed to prioritise rabies prevention adequately (Hampson *et al.*, 2015). The lack of reliable data on the annual incidence of dog bite rabies in humans and animals represents a critical challenge for the formulation of policies and strategies to control the disease. Therefore, to formulate a reliable priority for this disease study, it is necessary to quantify the incidence of dog bites and the associated risk factors for rabies exposure in humans and animals in North-West, Ethiopia.

MATERIALS AND METHODS Descriptions of the Study Area Target Population and sampling

This study was conducted in the central, northern, southern and west

Gondar zones of Amhara Regional State, Ethiopia. The study population comprised of humans, livestock, and dogs in the study area.. The study was conducted in seven districts (Debre Tabor and Fogera from South Gondar, East Dembia and Tach Armachoho from Central Gondar, Genda wuha and, Metema from West Gondar, and Debark from North Gondar), which were selected based on previous vaccination history and their ease of accessibility for the study (Fig. 1). The area has a total estimated human population of 5,464,079 and a total livestock population of 5,474,545 cattle, 2,484,400 sheep, 2,461,942 goats, 44,860 horses, 847,780 donkeys, and 6,609 dogs (Central Statistics Agency, 2017).



Fig. 1: Map of study area

Study Design and source of the data: Incidence follow-up and data collection

The incidence study was based on a prospective follow-up of bite-exposed cases in human and domestic animal populations in the selected districts. Follow-up data were collected by the resident enumerators recruited from each selected district. All victims, both animals and humans, found in the study districts were registered, and cases or their owners (in the case of animals) were interviewed using a structured questionnaire (S1). To check whether the bite actually occurred during the study period of July 10, 2022 to December 15, 2023 cross-checking questions were asked by referring the incident to specific verifiable (family) events.

Data Management and Analysis

All information and recorded data from the victims or animal owners were collected and entered into Excel. Statistical analyses were performed using Stata 17.0 version (Statistics and Data Science, MP-Parallel Edition, StataCorp LLC, StataCorp, 4905 Lakeway Drive, College Station, TX 77845, USA).

RESULTS

During the follow-up of bite incidence, 393 cases were recorded, of which 293 were potentially rabid and 100 were probable rabies. Of the 293 rabid cases, 235 (23 human and 208 animal) cases ended with fatality. The mortality rate of human is 2.09 per 100,000 people per year. The total mortality rate of rabies in the study area was recorded as 6.63 per 100,000 inhibitions per year (Table 1).

Table 1. Estimated incidence of rabies in humans and domestic animals in Northwest Ethiopia

Species	Potentially	Probable	Total no.	Death	Population at	Bite cases/	Death/100, 000
	rabid case	bite cases	Bite cases		risk	100, 000/year	/year
Human	128	57	185	27	860, 809	14.33	2.09
Dog	25	13	38	38	6,609	383.27	383.27
Cattle	66	30	96	96	1,399,093	4.6	4.6
Equine	52	-	52	52	89,880	36.57	36.57
Shoat	22	-	22	22	868,748	1.7	1.7
Total	293	100	393	235	2,364,330	11.08	6.63

Socio-demographic characteristics and human bite cases

In relation to district distribution, the highest exposure was recorded in East Dembia (23.78%), whereas the lowest was recorded in Debre Tabor town. In the case of humans, males (59.46%) were more affected than females (40.54%). In terms of educational status, non-educated and basic educated groups were more affected than the other groups. Sixty-two percent of victims had one or more dogs, whereas 37.84% had no dogs in their houses. Most of the victims (96%) were bitten by dogs, and less than 4% were bitten by animals other than dogs. Forty-seven percent of bite victims visited health centers after exposure (bite), while 53% did not visit health centers and chose to visit traditional healers or take traditional medicines. Sixty-nine percent were bitten by potentially rabid animals, while 31% were bitten by probably rabid animals, and 85.19% of the deaths were recorded in potentially rabid dog bite cases (Table 2).

Variable		Bite case	Percentages	
Districts	E/dembia	44	23.78	
	T/armachiho	34	18.38	
	Fogera	27	14.59	
	Metema	30	16.22	
	Debark	29	15.68	
	G/wuha	14	7.57	
	D/tabor	7	3.78	
Gender	Male	110	59.46	
	Female	75	40.54	
Education status	No educated	74	40.00	
	Basic educated	83	44.86	
	Secondary	21	11.35	
	Tertiary	7	3.78	
Action taken after exposed	Went to traditional Healer	98	52.97	
	Went health center	87	47.03	
Exposed probablity	Dog owner	115	62.16	
	Non owner	70	37.84	
Fate of exposed	Survived	158	85.41	
	Death	27	14.59	
Spp of bite	Dog	179	96.76	
Animal	Equine	5	2.70	
	Cat	1	0.54	
Bite animal	Owned	143	77.72	
	Free roaming	41	22.28	
Charcteristic of bitten	Potentialy rabid	128	69.19	
animals	Probale rabid	57	30.81	
Number of suffient dose of	No	125	67.57	
PEP	Yes	60	32.43	
Death due bite	Potentially rabide case	23	85.19	
	Probality rabid case	4	14.81	

 Table 2: Description of the socio-demographic feature of the bite cases in human.

In terms of bite body parts, legs and feet were the most affected (53.5%) body parts, followed by the hands and arms (20%), whereas the least bitten area was the stomach or belly (Fig. 2). Wound severity of the bite showed; 41.08% scratches without bleeding (minor), 35.68% bleeding scratch or showed light opening on the skin (moderate), and 23.24% of the bite victims had an open wound or broken skin (severe) (Fig. 3).

Regarding the fate of the infected (bitten) animals, 59.6% were killed soon after the incident by the owner or the community, 28% left the area, and 12.4% were culled after showing clinical signs of rabies (Fig. 4). The age-wise distribution of the human victims showed that the 5–14 years age group had the highest number of bite cases, followed by the 0–4 and 30–44 year age groups (Fig. 5).



Fig. 2. Bite sites for all bite cases



Fig. 3. Severity of bite wound



Fig. 4. Fate of suspected animal after bite



Fig. 5. Age wise distrubution of bite case during the study period

Statistical comparison the rabies suspected bite cases with district and residence type

More than 69% of victims were bitten by potential rabid animals, whereas 31% were bitten by probable rabid animals. The results showed a statistically significant difference (p < 0.001) among the districts. In Metema district, 96.7% were bites of potentially rabid animals. Regarding bite incidence, 62.5% of the victims were male and 37.5% were female of those exposed to potentially rabid cases;, however there was no statistical difference (p > 0.05) between gender. According to the current incidence, urban districts were less likely to be rabid than rural districts when compared to probable rabid cases. A statistically significant difference (p < 0.001) was observed between the residence differences (Table 3).

 Table 3: The statistical associations of typical health states of rabies with some categorical socio-demographic characteristics.

Variable		Total bite	Potentially rabid case	Probable case	P-value
Districts	Metema	30	29(96.7)	1(3.3)	P = 0.000
	G/w	14	11(78.6)	3(21.4)	
	Fogera	27	20(74)	7(26)	
	T/Armachiho	34	25(73.5)	9(26.5)	
	E/Demibia	44	31(70.5)	13 (29.5)	
	D/T	7	4(57)	3(43)	
	Debark	29	8(27.6)	21(72.4)	
	Total	185	128(69.2)	57(30.8)	
Districts	Urban districts	50	23(46)	27(54)	P=0.000
	Rural Districts	135	105(77.78%)	30(22.22)	
	Total	185	128(69.2)	57(30.8)	
Gender	Male	111	80(62.5)	31(54.4)	P = 0.414
	Female	74	48(37.5)	26(45.6)	

The distribution of total bite and potentially rabid bite cases residence wise

The proportion of potential rabid bite cases visiting health centers was higher (82%) in urban areas compared to rural areas. However, the rabies-related human death cases compared to the number of total bite cases were higher in rural areas than in the urban areas (Table 4).

Table 4. Number of bite cases, by potentially rabid and probable cases visiting a health center and death proportion between urban and rural districts.

Indicators	Total	Urban disricts	Rural disricts	Indicators
Dog bite case	185	50	135	Dog bite case
Potentially rabid cases	128 (69.19)	23(18)	105 (82)	Potentially rabid cases
Potential rabid visiting	67 (52)	19 (82.61)	48 (17.39)	Potential rabid visiting
a health center				a health center
Death	27	5 (18.52)	22 (81.48)	Death

Bite incidence by body parts and age distribution

In relation to the location of the bite, the legs and feet had the highest incidence (53.5%), followed by the hands and arms (20%). Overall, the proportions of bite cases was not significantly different (p > 0.05) across all body parts according to the age category. Of the 27 deaths recorded, 44% occurred in victims with bites in the legs and feet region, whereas the least deaths (3.7%) occurred in victims with bites in the thigh region (Table 5).

Table 5. Number of bite cases and deaths (indicated in brackets) according to bite site and age of the bite victim.

Age	Anatomical location of bite and death frequency							
categories	Total	Hea/face/neck	Hand/Arm	Leg/Foot	Thigh	Buttock	Belly/stomach	Mixed
0-4	36	5(2)	9(3)	11	3	2	2	4(1)
5-14	38	0	7	20(3)	2(1)	3	0	6
15-29	30	2	7	19(3)	1	0	0	1
30-44	36	2	6(2)	23(2)	1	1	1	2
45-59	32	1	4(1)	21(4)	0	1	0	5(3)
>60	13	2(1)	4(1)	5	1	0	0	1
Total	185	12(3)	37(7)	99(12)	8(1)	7	3	19(4)

DISCUSSION

The current study was conducted based on a prospective follow-up of bite cases in humans and domestic animals over 18 months. From the total incidence, the highest number of infections were recorded in dogs (383.27 cases per 100,000 per year) followed by equine cases (36.57 cases per 100,000 per year), and in humans it was 11.08 cases per 100,000 per year. Our evaluated numbers of exposures and deaths were similar to the previous estimation of Jemberu *et al.* (2013) in the North Gondar zone, who recorded 412.83 cases in dogs, 67.68 cases in equines, and 2.33 cases in humans per 100,000 population (Table 1). Similarly, Deressa et al. (2010) reported a similar incidence from 2010 to 2012 in Ethiopia, with 12 human exposure cases per 100,000 population and 1.6 rabies deaths per 100,000 population. During the follow-up period, 235 cases of rabies were recorded, of which 27 humans and 208 animals died. The mortality rate in humans was 2.09 per 100,000 people per year in the current study. This result is similar to a previous result in Central Ethiopia (Beyene, et al., 2018). The current estimation of the number of exposures and deaths was higher than previous national estimates (Beyene, et al., 2018; Deressa et al., 2010), consisting of 12 cases per 100,000 inhabitants and 1.6 rabies deaths per 100,000 inhabitants.

The sociodemographic information of the exposure cases is summarized in Table 2. A large number of victims were reported from East Dembia (23.78%) and Tach Armachiho (18.38%) districts, whereas the fewest bite cases were recorded in Debre Tabor (3.78%) towns. Yibraha and Damitie, 2015) reported similar results for the Gondar Health Canter in Ethiopia. This might be due to the close relationship between humans and dogs in rural areas, because most rural societies use dogs as guards for their livestock as well as for their homes.

In relation to sex in humans, the study showed that males (59.46%) were more affected than females (40.54%). This result was supported by Mazigo et al. (2010) (52.5%), Tenzin et al. (2011) (62%), Abubakar and Bakari (2016) (82.71%), and Yibrah and Damitie (2015) (62.8%), from Tanzania, Bhutan, Nigeria, and Ethiopia, respectively. In relation to educational background, non-educated (40.54%) and primary/basic educated (44.84%) households were more exposed than households with higher levels of education (15.13%). This result was also similar to that of Tenzin et al. (2012) in Bhutan. In the case of dog ownership, dog owners were more exposed (62.16%) than non-dog owners (37.84%). This result showed that it might be the close attachment of dogs to dog owners, leading to exposure of their own dogs (Al-Mustapha *et al.*, 2021).

More than 96% of the bites were orginated from dogs, whereas less than 45% of the bites orginated from other than dogs. Beyene et al. (2018) reported that 96.5% of bites orginated from dogs, while others also reported that dogs accounted for an estimated 99% of all recorded human cases (Knobel et al., 2005; Hasoon et al., 2020). Domestic dogs were the main sources of exposure and primary transmitters of human rabies in this study (Fahrion et al., 2015; Yizengaw et al., 2018). From all dog bite victims identified during follow-up, 47.02% had visited a health center and 52.97% had not visited a health center. This result is also supported by Beyene et al. (2018) who reported that approximately half of the bite victims in rural areas did not report to health center but visited traditional or spiritual healers in a previous study of three disticts in Ethiopia. In this study, 80% of exposed cases were recorded in rural districts. Similarly, Jemberu et al. (2013) reported on the North Gondar district of Ethiopia.

Of all bite incidences (victims), 68.19% were bitten by potentially rabies suspected dogs, according to the WHO (2006) criterion. More than 85% of the deaths were recorded from potentially rabid animal bites in the current study. However, some people who were bitten by animals considered probably rabid also died. This might be due to the loss of follow-up of the owner, or sometimes, carrier dogs would not show the correct clinical signs.

According to bite (affected) body parts, 73.5% of the bites were to the extremities (both upper and lower extremities) of the body. Similarly, our findings are supported by previous studies conducted in different countries. Our results

are similar to those of Khokhar et al. (2003) (88.17%), Sudarshan et al. (2006) (84.7%), Beyene et al. (2018) (88.6%), and Nomoto et al. (2023) (88.1%). In relation to bite wound 41.08% were non-oozing wounds (minor) while 35.68% of them were recorded as a bleeding scratch or showed light opening (moderate) and 23.24% were open wounds or broken skin (severe). Regarding the fate of the infected (bit) animals, 59.6% died soon after being bitten, 28% left the area, and 12.4% were culled by the owner after they showed clinical signs of rabies. These culled animals died naturally after 5-7 days. We collected the heads of some of these tied/culled animals when they died naturally and all were positive. In relation to age-wise incidence, the 5-14 years age group showed the highest number of bites, followed by the 0-4 and 30-44 years groups. This result was supported by Yibrah and Damte (2015), who reported that 38.5% were under the age 15 vears, and Yizengaw et al. (2018) (46.3%) and Kebata et al. (2014) (59.4%) in the Gondar and Jima areas of Ethiopia, respectively. According to WHO reports, rabies causes tens of thousands of deaths every year, mainly in Asia and Africa, 40% of which are children under 15 years of age (World Health Organization, 2023). This may be due to the close attachment of children to domestic dogs and cats in the house.

More than 69% of victims were bitten by potentially rabid animals, and 31% were bitten by probably rabid animals. This result was statistically significant (p = 0.000) among the districts. The retio of potential rabid bites and probable rabid cases was 96.7% bitten by potentially rabid animals in Metema district. According to the current results, districts far from the center have less vaccination coverage (Tenzin and Ward, 2012; Bogel and Meslin, 1990)

On the other hand, Metema district, as it is found at the periphery of the country, near to Sudan, needs dogs as guards when they went to awy from the residence for search of pasture and farming. Some tribes in these districts use dogs for hunting purposes in nearby forests. Due to this close attachment of dogs to humans, there is a higher chance of being bitten by dogs. Regarding bite incidence, 62.5% of the victims were males and 37.5% were females;, however there was no statistical difference (p >0.05) between gender. This result is in agreement with studies in western and northern Ethiopia by Teklu et al. (2017) (62.3%), Kebata et al. (2014) (61.5%), Yibrah and Damte (2015) (62.8%), and Yizengaw et al. (2018) (55%) in different parts of Ethiopia, Abubakar and Bakari (2012) (83%) in Nigeria, and Mazigo et al. (2010) (52.5%) in Mwanza, Tanzania. This might be explained by the fact that males spent most of their time in field work culturally and had closer contact with dogs than females because of their work behavior.

Urban district residents were less likely to be bitten by potential rabid cases than rural district residents, and this was statistically significant (p < 0.01). The results of our study are similar to those of Yibrah and Damte (2015) for the central Gondar zone. The age category 5-14 years of age were highly exposed, while elderly people >60 years of age were the least exposed age categories in all study districts. There was no statistically significant difference (p > 0.05)in the proportion of rabies-suspected dog bites among age groups across districts (Table 6). This result is supported by a previous study in Zimbabwe, which stated that the majority of rabies cases occurred in children (Pfukenyi et al., 2007).

Salomão *et al.* (2014) reported that 12 of 14 cases of human rabies occurred in

children under the age of 15 years, in Maputo, Mozambique. Body bites and deaths according to patient age. Out of the rabies exposed cases, the highest proportion (53.5%) occurred in the legs and feet region, with hands and arms being the next highest bite (20%) region while the belly or stomach region was least bitten area. Overall, the proportions of rabid-exposed cases did not significantly differ (p > 0.05) across body parts being bitten, with the highest proportion of bites on the legs and the lowest proportion on the head and neck area.

Of the total death records from the current study, the highest (70.37%) occurred in victims being bitten on their extremities. Similarly, 73% (Tenzin and Ward, 2012) and 83.3% (Beyene, *et al.*, 2018) were reported in Bhutan and Ethiopia, respectively. A possible explanation for this could be that hands or legs are used to abuse/tease dogs, and it may be that people use hands andlegs to fight dogs or defend against dog attacks, resulting in more attacks on the extremities ((Rosado *et al.*, 2009; Susilawathi *et al.*, 2012).

Conclusion and Recommendations

In conclusion, this study provides important information about the total incidence of dog-mediated rabies and the risk factors associated with dog rabies exposure in communities in the North-West part of Ethiopia. Dog-bite injuries and tracing of biting dogs can provide clear information about public health hazards. The disease remains a threat to economic losses, owing to livestock deaths and disease control measures. Residence (rural), sex (male), age (5-15 years), educational status (low level), and extrimity of the body (legs/feet) were identified in the findings as the most at-risk. Therefore, this study indicates that rabies continues to pose a threat to both humans and animals.

It was recommend the following suggestions:

- ✓ Policymakers, health workers, and their stakeholders should pay attention to this disease, similar to other priority diseases.
- ✓ Rabies needs national and global attention.
- ✓ The disease has an effect on the rural economy directly or indirectly, and those in rural communities should be provided a vaccine and taught about the effect of the disease.

Ethical Approval and Consent to Participate

The study protocol and consent procedure were approved by the Institutional Ethical Review (Ref. No VP/RTT/05/1037/ 2022, July 27, 2022).

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Author Contributions

All authors made a significant contribution to the work reported, whether in the conception, study design, execution, acquisition of data, analysis, and interpretation, or all these areas, took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; agreed on the journal to which the article has been submitted; and agreed to be accountable for all aspects of the work.

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الإصابة بداء الكلب وعامل الخطر المرتبط به في الإنسان والماشية في شمال غرب إثيوبيا

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المستخلص

داء الكلب هو مرض واسع الانتشار يصيب جميع الحيوانات ذوات الدم الحار. وفي البلدان النامية، تنشأ معظم الوفيات البشرية بسبب الكلاب المسعورة. في كل عام، يكون داء الكلب مسؤولاً عن ما يقدر بنحو 60.000 حالة وفاة بشرية في جميع أنحاء العالم، مع حصول 15 مليون شخص على العلاج الوقائي بعد التعرض لداء الكلب، و 4 ملايين سنة عمر معدلة حسب الإعاقة، وخسائر اقتصادية قدر ها 9 مليارات دولار أمريكي. تم إجراء حالات الإصابة بداء الكلب و عوامل الخطر المرتبطة به في البعار و أن المرتبطة به التعرض لداء الكلب، و 4 ملايين سنة عمر معدلة حسب الإعاقة، وخسائر اقتصادية قدر ها 9 مليارات دولار أمريكي. تم إجراء حالات الإصابة بداء الكلب و عوامل الخطر المرتبطة به في البشر والماشية في شمال غرب إثيوبيا بهدف تحديد كمية الإصابة بداء الكلب و عوامل الخطر المرتبطة به أمر تنقبة لمحايا داء الكلب في سبع مناطق في شمال غرب إثيوبيا لمدة 18 شهرًا متتاليًا. تم جمع المعلومات من الضحايا أوصحاب الحيوانات الصغيرة، وإدخالها في برنامج Exce) وتحليلها باستخدام 17 منهرا متتاليًا. تم جمع المعلومات من الضحايا أوصحاب الحيوانات الصغيرة، وإدخالها في برنامج Exce) وتحليلها باستخدام 17 معدل أن تكون مصابة بداء الكلب و 100 أوصحابة معنات من حيوانات بحمل أن تكون مصابة بداء الكلب خلال فترة المتابعة، منها 203 حالة عضات من حيوانات يحتمل أن تكون مصابة بداء الكلب و 100 أوصحاب في برنامج Exce وكانت نسبة المن و 100 أوصحاب أور 20% أوصحاب في التوالي أوصحاب في الخاب في التوالي أوصحاب في أوصحاب في الخلاب و 200%. كان أدى الفلاب أكثر تأثراً (62%) من أصحاب غير الكلاب. وكانت الكلب هي الحيوانات الرئيسية المعرضة (>96%). كان أدى الفئة العمرية من 5 إلى 14 عاماً أكبر عدد من اللداعات في الحالات البشرية. وكانت الأور 40% أول 40% أ

الكلمات المفتاحية: إثبوبي، البخور، داء الكلب، عوامل الخطر، التعرض.