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Acid Fast Positivity Rate and Associated Factors of Leprosy in a Tertiary Care Hospital of Northeastern Ethiopia: Its Implication for Evidence-Based Leprosy Prevention and Control

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ABSTRACT

Background and Aim: Leprosy is one of the most common skin neglected tropical diseases in Ethiopia posing social stigma, physical disability, deformity, discrimination, loss of social status, and poor quality of life in families. Hence, evidence-based collaborative inter-sectoral actions should be performed to reduce and eliminate its burden in endemic areas. Thus, the aim of this study was to assess the acid-fast positivity rate and associated factors of leprosy among suspected cases in Northeastern Ethiopia: a cross-sectional study.

Method: A cross-sectional study was conducted from September 2022 to March 2023 among 256 leprosy-suspected cases selected using a simple random sampling technique. A semi-structured questionnaire was used to collect socio-demographic, clinical, and predictor variables of leprosy through face-to-face interviews. Skin slit specimens were collected and stained using Ziehl–Neelsen staining technique. STATA 17 was used for analysis. The scale reliability coefficient was checked using Cronbach's α and the goodness-of-fit test of the model was assessed by the Hosmer–Lemshow test. Moreover, bivariable and multivariable logistic regression were computed. Finally, variables with an adjusted odds ratio and their $p < 0.05$ were taken as statistically significant.

Result: The mean ± standard deviation of the age of participants was 43.25 ± 16.35. The overall, prevalence of acid-fast positivity among suspected cases was 19.6% (95% CI: 15.8%, 23.4%). Multivariable logistic regression analysis showed that sex being male ($p = 0.045$), rural residence ($p = 0.047$), not eating three times meals frequency ($p = 0.014$), not eating a balanced diet ($p = 0.036$), poor personal hygiene ($p = 0.028$), distant from health facility ($p = 0.039$), not washing hands usually ($p = 0.013$), presence of current co-infection ($p = 0.002$), type of leprosy ($p = 0.004$), and close contact with leprosy cases ($p = 0.003$) were more likely to be positive for leprosy.

Conclusion: The prevalence of leprosy was remained high. Thus, early detection and treatment are necessary to reduce delayed diagnosis and hidden transmission of leprosy in the community. By addressing the driving factors through evidence-based intervention, we can significantly control the burden of leprosy in the affected communities, and improve their health outcomes and quality of life.

Abbreviations: AFB, acid-fast bacilli; AOR, adjusted odds ratio; CI, confidence interval; NTD, neglected tropical disease; SSS, slit skin specimens; WHO, World Health Organization.

1 | Introduction

Leprosy is a chronic infectious disease caused by *Mycobacterium leprae*. Although *M. leprae* transmission has been effectively controlled in a number of nations in recent decades, leprosy still poses a threat to public health in many parts of the world [1]. Depending on the type of host immunological response, the disease, which is common in most tropical and subtropical parts of the world [2] can present itself in a variety of clinical manifestations where the upper respiratory tract mucosa, the skin, peripheral nerves, and the eyes are all impacted by the illness. When incidence begins to decline, the characteristics of newly diagnosed cases differ from those observed in highly endemic areas, thus offering important insights into potential routes of transmission that may persist [1]. Droplets from the nose to the mouth are the primary way that it spreads. Close and frequent contact with untreated, infected people increases the risk of transmission [3].

The disease known as leprosy is a neglected tropical disease (NTD) that persists in over 120 countries and reports over 200,000 new cases annually. The majority of countries had eradicated leprosy by 2010, and the disease had been eradicated internationally by 2000. Slowly, both globally and within the World Health Organization (WHO) areas, the number of new cases has been declining. According to data from 2022, 174,087 new cases were reported worldwide, with 22,022 (12.6%) of those cases coming from 42 of the 47 countries in the African Region. This means that 18.5 cases were detected for every million people. Six countries such as the Democratic Republic of the Congo, Mozambique, Madagascar, Ethiopia, Nigeria, and the United Republic of Tanzania reported more than 1000 new cases [4]. In certain impoverished nations, the disease is still a major contributor to disability, peripheral neuropathy, and disfigurement.

Leprosy is one of the major skin NTDs in Ethiopia with high disparity across the regions or districts. Amhara region was one of the major contributors to the national prevalence of leprosy. Agglomeration [5], low nutritive diet [6], low educational level [7], social inequality [8], geographic and socioeconomic determinants [9], and poverty are the known drivers of accelerating disease burden. However, the decentralization of treatment centers and the introduction of multidrug therapy (MDT) had contributed a significant role for the burden to be decreased [10]. In addition, early detection and treatment are essential to reduce the disfiguring and disabling sequelae [11]. Thus, the WHO declared a leprosy elimination strategy and exerts a significant effort for the decline of the burden. However, the target of elimination strategy was affected by shortening in the duration of treatment, clearing of case registers as well as decreasing the detection rate of new cases were not coincided [12, 13]. Supporting evidence in Ethiopia showed that, the national prevalence of leprosy is decreased while the occurrence of new cases becoming accelerated and challenging. Thus, the endemicity exists for a long time [10].

In developing countries including Ethiopia, the most significant barriers for eradication of leprosy are social inequities such as poor living conditions, low levels of education, health-care deficiencies, low salaries, and migration from rural to urban areas [14]. In addition, leprosy patients faced negative social views, stigma, isolation, and discrimination as a result of their disfigurements and deteriorating physical disabilities, which had an influence on their lives and interactions with others [15, 16]. Different intervention strategies have been shown to aid in the early detection of leprosy to prevent its transmission to the community [17, 18]. Several initiatives that include diagnosis and treatment, and health education have successfully reduced the burden of leprosy [14]. Moreover, effective implementation of an integrated skin NTD elimination strategy requires an evidence-based public health intervention. These interventions are also evidence driven but as the disease is neglected, no more evidence have been generated but were quite important. Thus, the available evidence is scarce for undertaking evidence-based public health decision, the local epidemiological burden is not well known and essential. Thus, the aim of this study was to determine the prevalence and associated factors of leprosy in a tertiary care hospital in Northeastern Ethiopia where the findings will be utilized for evidence-based leprosy prevention and control strategies or programs.

2 | Methods

2.1 | Study Setting, Design, Period, and Population

A cross-sectional study was conducted from September 2022 to March 2023 among suspected cases attending at Boru Meda General Hospital (BMGH), Northeastern Ethiopia. Dessie is located in North Central far from the capital Addis Ababa. BMGH is a tertiary hospital found in the region mainly used as a referral center for dermatological problems such as (noninfectious and infectious NTDs including leprosy) multidrug resistance TB treatment center in addition to other common family health services, pharmacy, and 24 h laboratory services. All participants who were attending at the hospital with complaints of dermatological NTDs and were able to give consent were included in the study while those who were seriously ill and unable to speak were excluded.

2.2 | Sample Size Determination and Sampling Technique

The sample size was calculated by considering the assumption of a single population proportion formula taking 10.9% of leprosy [19], 95% confidence level, and 4% margin of error

$$n = \frac{(Z \propto /2)^2 P \quad (1-P)}{d^2} = \frac{(1.96)^2 0.109 \quad (1-0.109)}{(0.04)^2} = 233,$$

where n = sample population; P = acid fast positivity rate (0.109); d = margin of error (0.04); Z ($\propto/2$) = the reliability coefficient of 95% is 1.96. Finally, by adding a 10% nonresponse rate the final sample size was 256. A simple random sampling technique was employed to select the study subjects. The flow of daily participants was used as baseline data for the proportional allocation of dermatologic problems particularly leprosy suspected cases to select at random while coming into the hospital.

2.3 | Variables

Acid-fast bacilli (AFB) positivity rate (coded as 1 if AFB positive and coded as 0 if AFB negative) was the dependent variable whereas socio-demographic characteristics (age, residence, marital status, educational status, occupation, number of rooms in a house, family size and monthly income), clinical characteristics (sites of slit taken, clinical features of leprosy, disability, type of Leprosy), water sanitation and hygiene (WASH) related factor (sources of drinking water, personal hygiene, environmental hygiene, hand washing habit), number of meals, ever heard about leprosy, history of a family member with leprosy, know sign and symptoms and ways of transmission, cured by multiple drug therapy, intra-familial transmission of leprosy, close contact with leprosy patients, and duration of contact with leprosy patients were independent variables.

2.4 | Data Collection and Laboratory Data Analysis

All necessary information was collected from participants attending at the dermatologic unit of the hospital who fulfilled the inclusion criteria using a semi-structured questionnaire (Supporting Information) intended for collecting sociodemographic characteristics, clinical characteristics, laboratory data, water sanitation and hygiene-related factors, and other potential risk factor data after written informed consent was obtained.

Slit skin specimens (SSS) were collected by the attending medical microbiologist who has been trained to take a skin smear and who was authorized to do so after written informed consent was obtained from each suspected case. The patient sat down and relaxed during SSS collection. About 5 mm long and a 3 mm deep enough incision was made using a blade fixed in the scalpel and handled by pinching the skin to be incised holding the scalpel 90° and held at a right angle to cut the skin from the blood-free part of the most contagious, expanding, and erythematous area following a standard operating procedure aseptically. Finally, three smears were prepared and stained using the Ziehl–Neelsen method followed by microscopic examination of AFB [20]. The diagnosis of leprosy is established by the dermatologist by relying on clinical examination, patient clinical history and laboratory tests, such as SSS, to confirm the presence of M. leprae.

2.5 | Quality Assurance

To generate quality and reliable data, all quality control checks were done before, during, and after data collection. All the questions in a structured questionnaire were prepared in a clear and precise way and translated into the local language (Amharic). Pretests were made in 5% of the study participants in Haik District Hospital. During data collection, proper categorization and coding of questionnaires and formats were made, and the collected data was checked carefully on a daily basis for completeness, accuracy, and clarity. The quality of laboratory test results was assured and standard operation procedure was used throughout all processes of sample collection and processing. The quality of test results was maintained using internal quality control (IQC) of the reagent's staining quality. The analysis, reporting, and interpretation of this study strongly followed the Guidelines for reporting statistics for clinical research in urology" [21], SAMPL guidelines [22], and STROBE checklist for observational studies [23].

2.6 | Data Processing and Analysis

Data was coded and entered into Epi-data version 3.1 and exported into STATA version 17 for analysis. Descriptive statistics were computed and presented in tables and figures. The scale reliability coefficient was checked using Cronbach's α. The relationship between exposure variables and leprosy was computed using the χ^2 test and Fisher's exact test as required depending on the nature of the variables. Moreover, bivariable and multivariable logistic regression were computed. The goodness of fit test of the model was assessed by the Hosmer-Lemshow test. Finally, variables with an adjusted odds ratio (AOR) and their p-value results < 0.05 were taken as statistically significant.

2.7 | Ethical Consideration

Ethical approval was obtained from the College of Medicine and Health Sciences Research and Ethics Review Committee of Wollo University. A permission letter was obtained from Boru Meda General Hospital before the actual data collection was started. Written informed consent was obtained from each leprosy suspected cases participated in the study. Finally, those who were AFB positive were communicated and linked to the attending physician for further management, consultation and care.

3 | Result

3.1 | Leprosy Across Socio-Demographic Characteristics

The mean ± standard deviation (SD) of the age of participants was 42.9 ± 16.23 with 50% (128/256) participants being found in the age group of 30–49. The proportion of AFB positivity concerning gender was 19.2% (27/141) among male participants and the frequency of leprosy was statistically varied ($p = 0.032$). Of 69.9% (179/256) participants who were rural dwellers, 16.2% (29/179) were positive for AFB. In this study, 33.9% (87/256) participants were illiterates of which 19.5% (17/87) were positive for AFB. Likewise, from 16 (3.8%) participants who had no job 4 (36.4%) had leprosy ($p = 0.027$). About 125 (48.8%) of participants had a family size of greater than 5 of which 27 (21.6%) had leprosy with a statistically significant difference between those who had 5 and lower family numbers ($p = 0.003$) (Table 1).

3.2 | Leprosy Across Behavioral, and Environmental Characteristics

Among all participants, 211 (82.4%) used tap water, 247 (96.5%) directly used water without filtration or chemical treatment, 22 (86.7%) had good personal hygiene, 226 (88.3%) used detergents, and 204 (79.7%) participants usually washed their hands. Nearly 9% (23/256) participants had no history of three times meals

TABLE 1 | Socio-demographic characteristics of leprosy suspected cases attending Boru Meda General Hospital, Northeast Ethiopia, 2023.

Variables	Category	Overall frequency	Leprosy		χ^2 test
			Positive	Negative	
Age group	< 30	48 (18.8)	7 (14.7)	41 (85.3)	0.051
	30–49	128 (50.0)	13 (10.2)	115 (89.8)	
	≥ 50	80 (31.2)	18 (22.5)	62 (77.5)	
Sex	Male	141 (55.1)	27 (19.1)	114 (80.9)	0.032
	Female	115 (44.9)	11 (9.6)	104 (90.4)	
Marital status	Single	59 (23.0)	7 (11.9)	52 (88.1)	0.466
	Married	152 (59.4)	26 (17.1)	126 (82.9)	
	Divorced	45 (17.6)	5 (11.1)	40 (88.9)	
Residence	Rural	179 (69.9)	29 (16.2)	150 (83.8)	0.352
	Urban	77 (30.1)	9 (11.7)	68 (88.3)	
Educational status	Illiterate	87 (34.0)	17 (19.5)	70 (80.5)	0.065
	Able to read and write	41 (16.0)	6 (14.6)	35 (85.4)	
	Primary	40 (15.6)	8 (20.0)	32 (80.0)	
	Secondary	51 (19.9)	7 (13.7)	44 (86.3)	
	College and above	37 (14.5)	0 ()	37 (100.0)	
Occupation	Daily labor	13 (5.1)	0 (0)	13 (100.0)	0.094
	Student	40 (15.6)	7 (17.5)	33 (82.5)	
	Housewife	17 (6.6)	2 (11.8)	15 (88.2)	
	Farmer	115 (44.9)	20 (17.4)	95 (82.6)	
	Merchant	29 (11.3)	3 (10.3)	26 (89.7)	
	Government worker	31 (12.1)	2 (6.5)	29 (93.5)	
	No job	11 (4.3)	4 (36.4)	7 (63.4)	
Family size	1–5	131 (51.2)	11 (8.4)	120 (91.6)	0.003
	> 5	125 (48.8)	27 (21.6)	98 (78.4)	
Number of rooms	< 4	229 (89.5)	35 (15.3)	194 (84.7)	0.564
	≥ 4	27 (10.5)	3 (11.1)	24 (88.9)	

[a]Fisher's exact test was used.

frequency of them, 30.4% (7/23) had leprosy compared with 13.3% (31/233) women who had three times meals frequency ($p = 0.027$). In addition, 22.2% (57/256) of participants hadn't eaten a balanced diet of which 36.8% had leprosy ($p < 0.001$). One hundred thirteen (44.1%) participants had a big problem reaching the health facility or were distant of which 26(23%) had leprosy compared with 12 (8.4%) participants who weren't distant from health facilities ($p = 0.001$). About 4.7% (12/256) of participants knew how to prevent and control leprosy infections very well and no leprosy was found among these groups ($p = 0.039$). Furthermore, 97 (37.9%) had a history of close contact with leprosy cases of which 20 (20.6%) had leprosy compared with 18 (11.3%) positives among those who had no history of close contact ($p = 0.042$) (Table 2).

3.3 | Acid Fast Positivity and Associated Factors

The most frequently used type of skin slit was earlobe (85.6%). The frequent clinical epidemiologic distribution of leprosy signs and symptoms was loss of sensation [67.9% (284/418)] followed by pink-colored skin lesions [12.9% (54/418)]. The proportion of AFB positivity among those who had painless ulcers, loss of sensation, and pink-colored skin lesion was 27.8% (5/18), 24.3% (69/284), and 7.4% (4/54), respectively (Figure 1). The overall prevalence of acid fast positivity among leprosy suspected cases was 14.8% (95% CI: 12.6%, 17.9%) as stated in Figure 2.

The analysis of factors associated with leprosy was computed with a classical logistic regression model. The goodness-of-fit test of the model was assessed by the Hosmer–Lemshow test ($p = 0.421$) and the reliability coefficient using Cronbach's α was 0.852. In bivariable logistic regression analysis about 11 variables (being male, rural residence, family size, three times meals frequency, eating a balanced diet, personal hygiene, use detergent, distant from the health facility, hand washing habit, current co-infection, and close contact with leprosy cases) were found associated with leprosy ($p < 0.05$). While, after

TABLE 2 | Behavioral, and environmental characteristics of leprosy suspected cases attending Boru Meda General Hospital, Northeast Ethiopia, 2023.

Variables	Category	Overall frequency	Leprosy		χ^2 test
			Positive	Negative	
Water source	Tap	211 (82.4)	27 (12.8)	184 (87.2)	< 0.001[a]
	Spring/river	33 (12.9)	3 (9.1)	30 (90.9)	
	Pond	12 (4.7)	4 (33.3)	8 (66.7)	
Water utilization	Directly	247 (96.5)	35 (14.2)	212 (85.8)	0.039[a]
	Filtered	6 (2.3)	3 (50.0)	3 (50.0)	
	Chemically treated	3 (1.2)	0 (0.0)	3 (100.0)	
Personal hygiene	Yes	222 (86.7)	20 (9.0)	202 (91.0)	< 0.001
	No	34 (13.3)	18 (52.9)	16 (47.1)	
Use detergent	Yes	226 (88.3)	24 (10.6)	202 (89.4)	< 0.001
	No	30 (11.7)	14 (46.7)	16 (53.3)	
Three times meal frequency	Yes	233 (91.0)	31 (13.3)	202 (86.7)	0.027
	No	23 (9.0)	7 (30.4)	16 (69.6)	
Eating balanced diet	Yes	199 (77.7)	17 (8.5)	182 (91.5)	< 0.001
	No	57 (22.3)	21 (36.8)	36 (63.2)	
Hand washing habit	Sometimes	52 (20.3)	21 (40.4)	31 (59.6)	< 0.001
	Usually	204 (79.7)	17 (8.3)	187 (91.7)	
Environmental hygiene	Poor	17 (6.6)	1 (5.9)	16 (94.1)	< 0.001
	Medium	137 (53.5)	31 (22.6)	106 (77.4)	
	Good	102 (39.8)	6 (5.9)	96 (94.1)	
Distant from health facility	Yes	113 (44.1)	26 (23.0)	87 (77.0)	0.001
	No	143 (55.9)	12 (8.4)	131 (91.6)	
Current co-infection	Yes	50 (19.5)	16 (32.0)	34 (68.0)	< 0.001
	No	206 (80.5)	22 (10.7)	184 (89.3)	
Do you know leprosy is transmitted from one person to another?	Very well	13 (5.1)	0	13 (100.0)	0.122
	Partially	243 (94.9)	38 (15.6)	205 (84.4)	
Do you know signs and symptoms of leprosy?	Very well	11 (4.3)	2 (18.2)	9 (81.8)	0.758
	A little bit	51 (19.9)	9 (17.6)	42 (82.4)	
	Never	194 (75.8)	27 (13.9)	167 (86.1)	
Do you know how to prevent and control leprosy infections?	Very well	12 (4.7)	0	12 (100.0)	0.039
	Partially	53 (20.7)	13 (24.5)	40 (75.5)	
	Never	191 (74.6)	25 (13.1)	166 (86.9)	
Is leprosy treatable?	Yes	17 (6.6)	0	17 (100.0)	0.075
	No	239 (93.4)	38 (15.9)	201 (84.1)	
Do you believe leprosy is hereditable?	Yes	28 (10.9)	0	28 (100.0)	0.019
	No	228 (89.1)	38 (16.7)	190 (83.3)	
Family history	Yes	63 (24.6)	9 (14.3)	54 (85.7)	0.532
	No	193 (75.4)	29 (15.0)	164 (85.0)	
Close contact with leprosy cases	Yes	97 (37.9)	20 (20.6)	77 (79.4)	0.042
	No	159 (62.1)	18 (11.3)	141 (88.7)	
Duration of contact with leprosy cases ($n = 97$)	≥ 3 years	62 (63.9)	15 (24.2)	47 (75.8)	0.199
	< 3 years	35 (36.1)	5 (14.3)	30 (85.7)	

[a]Fisher's exact test was used.

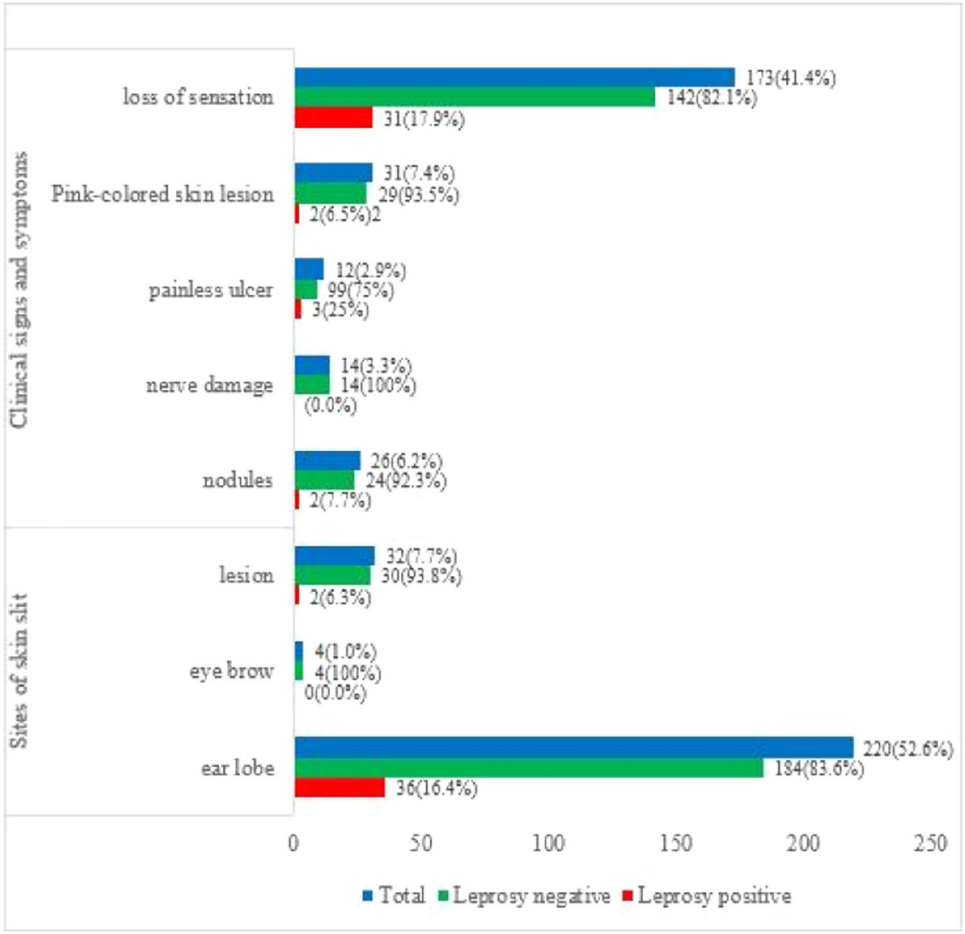

FIGURE 1 | Clinical spectrum of leprosy and its distribution by sites of skin slits.

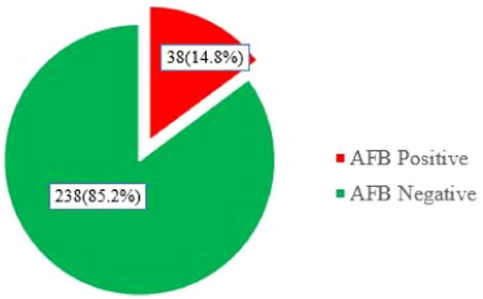

FIGURE 2 | Showing prevalence of leprosy among suspected cases.

controlling confounding, the multivariable logistic regression analysis showed that the following nine factors were independently associated with leprosy. Leprosy was independently predicted by sex being male (AOR: 1.77; 95% CI: 1.09, 3.17; $p = 0.045$), rural residence (AOR: 2.01; 95% CI: 1.01, 3.98; $p = 0.047$), three times meals frequency (AOR: 2.15; 95% CI: 1.45, 4.38; $p = 0.014$), eating balanced diet (AOR: 3.36; 95% CI: 1.69, 5.67; $p = 0.036$), personal hygiene (AOR: 5.26; 95% CI: 1.13, 11.35; $p = 0.028$), distant from health facility (AOR: 2.58; 95% CI: 1.06, 5.63; $p = 0.039$), not washing hands usually (AOR: 3.46; 95% CI: 1.3, 9.22; $p = 0.013$), current co-infection (AOR: 2.95; 95% CI: 1.51, 5.79; $p = 0.002$), and close contact with leprosy cases (AOR: 2.38; 95% CI: 1.35, 4.2; $p = 0.003$) (Table 3).

4 | Discussion

Skin NTDs are a set of diseases that are especially common in low and middle-income countries including Ethiopia. According to the WHO, one or more of these diseases affects over one billion people, the majority of whom live in low-income countries [24]. Leprosy is one of the most common skin NTDs in Ethiopia [25] and it is still continued as a public problem requiring sustainable prevention strategy and policy. In this study, the overall prevalence of leprosy was 14.8%, which implies that nearly one in every seven suspected cases might develop leprosy. This figure revealed that leprosy has continued to be a significant cause of social and economic burden, including social stigma, physical disability, deformity, discrimination, and loss of social status [26, 27]. All of these interconnected results contribute to poor quality of life on families, communities, and countries as a whole particularly in resource-limited countries like Ethiopia. Thus, collaborative intersectoral actions should be performed to reduce the burden of this NTD. If we exert our maximum effort for elimination of leprosy, we can limit the transmission of infections to the coming generations unless and otherwise the rate of active and hidden leprosy will aggravate more than the expected endemic state.

However, the exact role of malnutrition on susceptibility to leprosy and the development to a clinical stage remains unclear

TABLE 3 | Behavioral and environmental characteristics of leprosy suspected cases attending Boru Meda General Hospital, Northeast Ethiopia, 2023.

Variables	Category	COR (95% CI)	*p* value	AOR (95% CI)	*p* value
Sex	Male	2.05 (1.23, 3.43)	0.006	1.77 (1.09, 3.17)	0.045[a]
	Female	1		1	
Residence	Rural	1.99 (1.12, 3.55)	0.020	2.01 (1.01, 3.98)	0.047[a]
	Urban	1		1	
Family size	1–5	1	0.050	1	0.24
	> 5	2.44 (1.19, 4.05)		1.67 (0.95, 2.31)	
Three times meal frequency	Yes	1	0.007	1	0.014[a]
	No	2.85 (1.32, 5.44)		2.15 (1.45, 4.38)	
Eating balanced diet	Yes	1	< 0.001	1	0.036[a]
	No	4.19 (2.32, 6.59)		3.36 (1.69, 5.67)	
Personal hygiene	Yes	1	< 0.001	1	0.028[a]
	No	11.2 (5.6, 18.58)		5.26 (1.13, 11.35)	
Use detergent	Yes	1	0.010	1	0.089
	No	7.26 (3.06, 10.3)		4.11 (1.87, 7.88)	
Distant from health facility	Yes	3.25 (1.07, 6.84)	0.025	2.58 (1.06, 5.63)	0.039[a]
	No	1		1	
Hand washing habit	Sometimes	7.4 (3.98, 11.5)	< 0.001	3.46 (1.3, 9.22)	0.013[a]
	Usually	1		1	
Current co-infection	Yes	3.88 (1.24, 7.84)	0.007	2.95 (1.51, 5.79)	0.002[a]
	No	1		1	
Close contact with leprosy cases	Yes	2.07 (1.33, 3.55)	0.002	2.38 (1.35, 4.2)	0.003[a]
	No	1		1	

[a]Statistically significant.

[28], the odds of developing leprosy were higher among participants who had no three times meal frequency and not eating a balanced diet than their counterparts. This might be due to the fact that insufficient intake of nutrients due to food shortage may affect the immune system and influence the progression of infection to clinical leprosy [6]. shortage of food or food poverty has been known to affect the transmission of leprosy. The linkage of nutritional deficiencies and leprosy susceptibility might be due to the weakness of immune system competency against *M. leprae* infection as a result of inadequate nutrition [29–31].

In lined with previous evidence [32], the odds of developing infection were higher among rural dwellers and those who are distant from health facility. This relationship might be due to local and sociodemographic characteristics where access to health services in rural areas are highly restricted. This will further have a significant role for delayed diagnosis of new cases, hidden leprosy transmission and new case development [33]. Thus, it implicates lack of knowledge and awareness about the disease transmission and scarcity of diagnostic facilities and skilled health professionals will lead to the detection and dissemination of the disease to be delayed [34]. Therefore, developing appropriate public health intervention in rural areas are highly advisable particularly in areas low health service coverages. In addition, health education through behavior changes communication materials such as information, education, and communication (IEC) materials among rural dwellers and those who lived at distant area from health facilities as well as empowering health care workers to suspect, diagnose and interrupting the transmission chain of the disease as early as possible. This will decrease the rate of hidden leprosy transmission with in the community.

Despite, the direct mode of transmission of *M. leprae* remained uncertain, the probability of infection and development of leprosy is increases as a result of direct close contact for a long time with known leprosy cases in household or neighborhood. The finding of the present study had also revealed the highest odds of developing leprosy among those who had close contact with known Leprosy cases than their counterparts. This finding was supported with previous findings of Ethiopian study [19] where the risk of developing leprosy was increased as their duration of contact extends for more than 3 years with known Leprosy cases. Although, close person-to-person contact was known to be one of the ways of transmission of leprosy [35]; the shared values of poverty, sanitary, environmental and social conditions among families and neighbors' contribution for leprosy transmission aren't well addressed or accounted. Additionally, the crowdedness of households might facilitate the transmission and associated with infection and/or disease development [36]. The present study finding showed that contact tracing and

screening is quite essential. This is also supported by previous evidence where the inclusion of social contacts allowed for 15% additional incident cases identification [30].

The odds of participants to be positive for AFB was higher among those who had poor personal hygiene and those who were not usually washing their hands. This might be due to the fact that leprosy can be transmitted through respiratory tract as well as long and close direct contact via skin. *M. leprae* reaches to the surface of the skin of an infected case through sweat glands and hair follicles. Thus, another contact might expose and acquire the bacterium unless hand washing practice and maintenance of personal hygiene are promoted because contact is a medium to transmit leprosy. This implies that the transmission of leprosy might be tackled by improving personal hygiene [37, 38].

The other factor associated with leprosy in this study was the presence of current co-infection where the odds of developing leprosy was 2.95 times higher among those who had co-infection than their counterparts. This might be due to the fact that the likelihood of leprosy reactions increases as a result of secondary infections such as nonviral co-infections of Leishmaniasis, Tuberculosis, Chromoblastomycosis, and Helminths [39]. Additionally, the occurrence of two or more genetically distinct pathogens in developing countries is highly prevalent which leads to modification of the progression of the disease and increases the likelihood of leprosy reaction as well as the treatment efficacy [40].

Furthermore, the odds of leprosy in this study were higher among males than females in lined with evidence [36], which might be explained by differences in exposure level to different risk markers between male and females [36]. The finding revealed that males might be highly exposed to the pathogen in relation to cultural and behavioral factors. Moreover, evidence has shown the possibility of correlation with male hormones and leprosy. Male hormones are essential to induce immune response which might not be effective for control of the disease process [41, 42].

The implication of the present study was to develop an evidence-based leprosy control and prevention strategy. In addition, it indicates the need for facilitating the progress of integrated skin NTD control approaches are quite important for achieving the 2021–2030 NTD Roadmap, it guides the collaborative and multisectoral actions for reducing the burdens of skin NTDs as well as skin NTDs elimination and/or eradication. The main limitation of this study was utilization of Ziehl-Neelsen staining technique for the detection of AFB where the exact magnitude might be underestimated due to the sensitivity of the method. The sample size might be also another limitation. Therefore, the interpretation of this study finding should be with attention. Furthermore, to increase the power of generalizability further largescale studies will be needed.

5 | Conclusion

The prevalence of leprosy (AFB positive) among leprosy-suspected cases at a tertiary care hospital in Northeast Ethiopia remained high. Sex being male, rural residence, not eating three times meals frequency, not eating balanced diet, poor personal hygiene, distant from health facility, not washing hands usually, presence of current co-infection, type of leprosy, and close contact with leprosy cases were found statistically significantly factors for leprosy. The clinical and bacteriological characteristics of newly detected leprosy cases implies the problem has been actively transmitted in the community. Thus, early detection and treatment is highly advisable to reduce delayed diagnosis and hidden transmission of leprosy. Additionally, evidence-based public health interventions should be done on the driving factors of leprosy, which will significantly control the burden of leprosy in the affected communities, improve their health outcomes and quality of life.

Author Contributions

Alemu Gedefie: conceptualization, investigation, funding acquisition, writing–original draft, writing–review and editing, visualization, validation, methodology, project administration, formal analysis, software, resources, supervision, data curation. **Agumas Shibabaw:** conceptualization, formal analysis, writing–review and editing, data curation, methodology, software. **Zewudu Mulatie:** conceptualization, methodology, software, data curation, project administration, writing–review and editing. **Hussen Ebrahim:** conceptualization, methodology, software, data curation, investigation, formal analysis, writing–review and editing. **Habtu Debash:** conceptualization, methodology, software, data curation, investigation, formal analysis, project administration, writing–review and editing. **Mihret Tilahun:** conceptualization, methodology, software, data curation, investigation, formal analysis, writing–review and editing. **Ermiyas Alemayehu:** conceptualization, methodology, software, data curation, investigation, formal analysis, supervision, writing–review and editing. **Melaku Ashagrie Belete:** conceptualization, methodology, software, data curation, investigation, formal analysis, writing–review and editing. **Ousman Mohammed:** writing–original draft, resources, project administration, visualization, funding acquisition, supervision, validation, investigation. **Saba Gebremichael Tekele:** writing–original draft, resources, project administration, visualization, funding acquisition, supervision, validation, investigation. **Daniel Gebretsadik Weldehanna:** writing–original draft, project administration, resources, visualization, funding acquisition, validation, investigation. **Bruktawit Eshetu:** writing–original draft, project administration, resources, visualization, funding acquisition, supervision, validation, investigation.

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Ethics Statement

This cross-sectional study has been ethically approved by the College of Medicine and Health Sciences Research and Ethics Review Committee of Wollo University.

Consent

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The datasets used and/or analysed during the current study available within the manuscript. If additional data are needed, it can be obtained from the corresponding authors upon request.

Transparency Statement

The lead author Alemu Gedefie affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.