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Disease-specific and opposing beliefs about four co-endemic skin neglected tropical diseases in southern Benin: a within-individual cross-sectional study

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Disease-specific and opposing beliefs about four co-endemic skin neglected tropical diseases in southern Benin: a within-individual cross-sectional study

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Abstract

Background: Integrated screening for skin-related neglected tropical diseases (skin NTDs) is being scaled up in Benin, usually with a single message promoting screening and early care for all diseases. Whether a common message is appropriate depends on whether beliefs are shared across diseases. We compared, within the same individuals, disease-related beliefs about four co-endemic skin NTDs (leprosy, Buruli ulcer, yaws and scabies).

Methods: Cross-sectional study from October 2024 to February 2025 in 11 communes of the Plateau and Zou departments, southern Benin, among 746 randomly sampled residents living within 100 m of registered multibacillary leprosy cases and 175 persons affected by leprosy (PAL). A single questionnaire covered awareness, causes, early signs, transmission and treatment of each disease. Awareness and beliefs were compared within individuals using standard and clustered McNemar tests; associations were estimated as adjusted prevalence ratios by modified Poisson regression, with village as the cluster.

Results: Awareness ranged from 12.5% (yaws) to 83.5% (scabies), and supernatural attribution from 5.4% (yaws) to 46.1% (Buruli ulcer). Among the 394 residents aware of both Buruli ulcer and leprosy, Buruli ulcer was more often attributed to supernatural causes (47.0% vs 27.7%, $p < 0.001$) and to traditional treatment (36.0% vs 18.8%, $p < 0.001$). Although Buruli ulcer is not transmitted between people, 24.9% of these residents believed it was, whereas only 44.9% recognised that leprosy is. Awareness was higher among older residents for all four diseases and in Zou, whereas supernatural attribution was geographically concentrated (Zou vs Plateau: adjusted prevalence ratio [aPR] 0.45, 95% CI 0.37-0.56 for Buruli ulcer and 0.23, 0.15-0.36 for leprosy). Supernatural attribution was associated with citing traditional treatment (Buruli ulcer: aPR 2.11, 95% CI 1.57-2.83; leprosy: aPR 2.51, 95% CI 1.69-3.73). Compared with informed residents, PAL more often recognised the anaesthetic patch (77.9% vs 45.5%) and cited supernatural causes (35.5% vs 26.5%).

Conclusions: Within the same individuals, beliefs about co-endemic skin NTDs were disease-specific and, for Buruli ulcer and leprosy, called for corrections in opposite directions. Integrated screening may therefore need health education differentiated by disease and adapted to local belief profiles, whose effectiveness remains to be tested.

Keywords: Skin neglected tropical diseases; Leprosy; Buruli ulcer; Yaws; Scabies; Knowledge, attitudes and practices; Health education; Integrated control; Benin

Background

Neglected tropical diseases (NTDs) are a diverse group of conditions concentrated in tropical and subtropical regions, where they impose heavy health, social and economic burdens, particularly in settings with limited access to health care and basic services. Nine NTDs manifest primarily on the skin [1]; among them, leprosy, Buruli ulcer, yaws and scabies are frequently co-endemic in the same rural communities of West Africa. All four typically present as a skin lesion, and at first contact health workers without dermatological training may find it difficult to distinguish them from one another or from far more common dermatoses. This clinical overlap, combined with limited human and financial resources, led the World Health Organization (WHO) to recommend integrated management of skin NTDs [2, 3], based on a common skin screening platform on which multipurpose health workers screen for several diseases at once.

Behind this shared entry point, the four diseases differ in aetiology, transmission, treatment and prevention. Leprosy, caused by *Mycobacterium leprae*, is transmitted between people through close and prolonged contact, which is why people living around a diagnosed case are examined and offered chemoprophylaxis. Buruli ulcer, caused by *Mycobacterium ulcerans*, is acquired from the environment in association with wetlands and slow-moving water and is not transmitted from person to person; detected at the nodular stage it is cured with antibiotics,

whereas at the ulcerative stage treatment becomes long, costly and often disabling. Yaws, caused by *Treponema pallidum* subsp. *pertenue*, mainly affects children and is cured by a single oral dose of azithromycin. Scabies, an infestation by the mite *Sarcoptes scabiei*, spreads readily within households and is controlled by treating all household members at the same time [1, 2]. What communities need to understand therefore differs from one disease to another, most sharply for leprosy and Buruli ulcer: the former is transmitted between people, the latter is not.

Community misconceptions, such as attributing skin NTDs to witchcraft or divine punishment or holding incorrect beliefs about person-to-person transmission, together with gaps in knowledge and care-seeking practices such as first consulting a traditional healer, may each contribute to delayed care-seeking, despite subsidised care, and may sustain stigma [4-7]. Addressing them is therefore a central objective of health education. Yet integration has generally been extended, implicitly, from the screening platform to the educational message: a single "skin NTD" campaign promoting screening and early care-seeking for all diseases alike.

Benin illustrates both the appeal of integration and the gap it leaves. The National Leprosy and Buruli Ulcer Control Programme (Programme National de Lutte contre la Lèpre et l'Ulcère de Buruli, PNLLUB) has long managed the two mycobacterial skin NTDs jointly, and integrated skin screening has been evaluated in the district of Lalo (south-western Benin) [8] and through mobile outreach consultations in the Ouémé and Plateau departments (south-eastern Benin) [9]. The 2PEP4LEP project extends this approach by combining integrated skin NTD screening with post-exposure prophylaxis with rifampicin for the contacts of leprosy cases in the Plateau and Zou departments (southern Benin). The project is a feasibility and effectiveness study investigating the combined use of integrated screening for neglected tropical diseases and single double-dose rifampicin post-exposure prophylaxis (SDDR-PEP). These evaluations report the numbers of people examined and cases detected; they do not assess whether the

95 educational message delivered alongside screening is equally relevant to every disease
96 screened.

97 This assumption has rarely been tested. Knowledge, attitude and practice (KAP) surveys on
98 skin NTDs usually address one disease at a time: Buruli ulcer in Benin [4] and Cameroon [5],
99 yaws in Ghana [10], and scabies in Guinea-Bissau [6] and central Ghana [7]. Any difference
100 read across two such surveys is therefore confounded with differences between the populations
101 questioned. One survey questioned the same respondents about three co-endemic skin NTDs
102 in Nigeria [11], but it assessed beliefs for the group of diseases as a whole rather than disease
103 by disease. A disease-by-disease measurement within the same individuals, in which the
104 disease rather than the respondent is the variable of interest, has been lacking.

105 The objective of this study was to compare, within the same individuals, knowledge and
106 disease-related beliefs about four co-endemic skin NTDs, and to identify the individual and
107 area-level factors associated with them. A secondary, descriptive objective was to compare
108 knowledge and beliefs about leprosy between persons affected by leprosy (PAL) and residents
109 aware of the disease.

110 Methods

111 *Study design and setting*

112 This cross-sectional study was conducted within the 2PEP4LEP project, which evaluates the
113 feasibility and effectiveness of integrated skin NTD screening and management combined with
114 single double-dose rifampicin as post-exposure prophylaxis (SDDR-PEP) for leprosy in Benin
115 and Côte d'Ivoire. It covered 11 communes in the Plateau department (Adja-Ouèrè, Ifangni,
116 Kétou, Pobè and Sakété) and the Zou department (Abomey, Agbangnizoun, Bohicon, Djidja,
117 Za-Kpota and Zogbodomey), southern Benin. Reporting follows the Strengthening the

Reporting of Observational Studies in Epidemiology (STROBE) recommendations for cross-sectional studies [12] (Additional file 1).

The two departments were selected because the four diseases are endemic there and both host reference centres for skin NTD treatment. They accounted for 22.4% and 19.3%, respectively, of the 295 leprosy cases notified nationally over 2022-2025 (PNLLUB, unpublished programme monitoring data), and for 17.2% and 18.9% of the 2,785 cases notified over 2006-2018 [13]. Grade 2 disability was present at diagnosis in 40 of the 66 new leprosy cases recorded in Plateau over 2022-2025 (60.6%) and in 23 of the 57 recorded in Zou (40.4%) (PNLLUB, unpublished programme monitoring data). Among skin NTDs detected during integrated outreach in Plateau and the neighbouring Ouémé department, 88.4% were scabies, 5.8% Buruli ulcer and 3.4% leprosy [9]. Buruli ulcer, yaws and scabies are also endemic in the same catchment areas.

Participants and sampling

Two groups were included: Persons affected by leprosy (PAL) and residents living in their neighbourhoods. Because the 2PEP4LEP strategy is centred on PAL and their surrounding communities, participants were identified from leprosy cases recorded in programme registers, and residents were then recruited around them; recruitment was therefore both register-based and community-based.

Persons affected by leprosy. PAL were identified from the PNLLUB register, which records both leprosy and Buruli ulcer cases; only leprosy cases were drawn from it. All people diagnosed with multibacillary leprosy (defined by the WHO field classification as more than five skin lesions [14]) in the two departments between 2013 and 2023 were eligible. This window is the most recent period over which programme records are complete enough to support exhaustive tracing. People with paucibacillary leprosy were excluded, as were people

whose severe mental illness would have prevented participation or valid consent. The dwelling of each registered case was located on site by global positioning system (GPS) and stored as a track in GPX Viewer, and all eligible cases were invited to participate. No sample size calculation applied to this group, whose size was fixed by the registers.

Neighbourhood residents. Residents were people aged 14 years or over living within 100 m of the home of a registered case, including those sharing the same dwelling or compound. For each included case, eligible residents were enumerated with the trackbook function of GPX Viewer and selected by simple random sampling in R, using a fixed sampling fraction that guaranteed at least one resident per case. Eligibility depended on geographical proximity alone, irrespective of family or social relationship, so residents could be household members or unrelated neighbours. The registered case was not identified and their diagnosis was not disclosed to residents, who were not told that their selection was based on proximity to a PAL. Residents were analysed as a sample of the general population of leprosy-endemic communities.

The number of residents was fixed in advance with Schwartz's formula, assuming the least favourable expected proportion (50%), an absolute precision of 4 percentage points and an alpha of 5%. This gave 601 participants, raised by 15% to 692 to allow for non-response.

Variables

Disease-related beliefs. For each of the four diseases in turn, the questionnaire recorded whether the respondent had ever heard of the disease and, if so, the causes they attributed to it, the early signs they could name, how they thought it was transmitted and how they thought it should be treated. Questions were open, and answers were coded against predefined response options that were not mutually exclusive.

Disease-related beliefs were classified a priori, identically for each disease, into three categories. Misconceptions comprised supernatural attribution, defined as citing witchcraft or bewitchment or divine punishment or a curse among the causes, and, for Buruli ulcer, belief in person-to-person transmission. For leprosy, belief in person-to-person transmission is correct and was analysed as correct knowledge; transmission beliefs were recorded for these two diseases only. Knowledge gaps comprised inability to name any cause, early sign or mode of transmission. Care-seeking practice was captured by citing a traditional healer among the modes of treatment; because response options were not mutually exclusive, this did not preclude also citing medical treatment.

Diagnostic pathway among PAL. Mode of detection was recorded as passive (the person presented to a health facility on their own initiative) or active (the case was identified by a health worker during a screening activity). The interval in months between symptom onset and first contact with a health worker was self-reported. PAL answered the same questionnaire as residents, with additional items on their diagnostic pathway.

Data collection

Data were collected from 29 October 2024 to 28 February 2025 at participants' homes by ten interviewers working under two field supervisors. Interviewers were trained for ten days on study procedures and the questionnaire, including a pre-test in Zou and Plateau whose observations were incorporated. Interviews were conducted face to face in Fon or Nagot, the local languages of the study area, depending on locality, and entered directly on tablets with ODK Collect together with the GPS position of the household. Interviews lasted approximately 90 minutes. Completed questionnaires were reviewed daily by the field team to resolve inconsistencies. The four disease modules were administered to all participants in the same fixed order (leprosy, Buruli ulcer, yaws, scabies).

Statistical analysis

Categorical variables were described as counts and percentages, and quantitative variables were described as median and interquartile range (IQR). Indicators were reported separately for residents and PAL. Awareness was computed on all 746 residents; belief indicators were computed among residents who had heard of the disease concerned. Because the number of residents aware of yaws was small (n = 93), estimates for yaws were treated as descriptive. Because the four modules were administered to every respondent, comparisons between diseases were paired and tested with McNemar's test with continuity correction. Because residents were clustered within villages, each paired comparison was also tested with the clustered McNemar test of Durkalski et al., with village as the cluster [15]. Awareness was compared across all 746 residents; beliefs were compared, for each pair of diseases, among residents who had heard of both. In this within-individual design, each respondent serves as their own control for fixed characteristics such as age, sex, education and place of residence; the design does not remove disease-specific influences such as previous contact with health services, exposure to campaigns or the order in which modules were administered. Associations with awareness of each disease and with supernatural attribution were estimated as adjusted prevalence ratios (aPR) by multivariable modified Poisson regression, fitted as a generalised estimating equation with the geeglm function of the R package geepack (Poisson family, log link, exchangeable working correlation, robust variance) with village as the cluster, to account for the clustering of residents living in the same village. Village identifiers were harmonised in the cleaned database, and villages with the same name in different departments were kept distinct; this gave 154 villages (79 in Plateau, 75 in Zou), with a median of 3 residents

per village (interquartile range 2-6; range 1-31). Models included age group (14-34, 35-49 and ≥ 50 years), sex, educational level, department and place of residence (urban or rural), chosen a priori on conceptual grounds. A finer age categorisation was not used because the small number of residents aged under 15 years (n = 9) caused complete separation for several outcomes. Models were fitted only when approximately ten outcome events per parameter were available; this criterion was met for the four awareness models and for supernatural attribution of Buruli ulcer and leprosy, but not for supernatural attribution of scabies or yaws. The association between supernatural attribution and citing traditional treatment was estimated with the same approach for Buruli ulcer and leprosy, adjusting for age group, sex, educational level and department. PAL and residents were compared with the χ^2 test or Mann-Whitney test for sociodemographic characteristics and with Fisher's exact test for knowledge and belief indicators. Because several outcomes were frequent, prevalence ratios were estimated rather than odds ratios, which overstate relative risks when outcomes are common.

Three of the 175 PAL left the entire knowledge module unanswered, so the denominator for PAL knowledge indicators is 172; the same three had no recorded care-seeking delay, and three further out-of-range values for that delay were treated as missing, leaving 169 observations. No other analysed variable had missing values in either group. No imputation was performed, and all models were fitted on complete records. The paired comparisons were specified in advance; no adjustment was made for multiple comparisons, so p values close to 0.05 should be read as exploratory. The two-sided significance level was 0.05. Analyses were performed with R version 4.5.3 (package geepack). The statistical analyses were performed by the authors. Claude Opus 5.5 (Anthropic) was used to assist with restructuring and language editing of the manuscript, re-plotting the figures and verifying the statistical analyses; the authors reviewed all content and take full responsibility for it.

Ethical approval and consent procedures are described under Declarations.

Results

Participants

Of the 273 registered multibacillary leprosy cases, 98 could not be included: 47 had moved away (41 in Plateau, 6 in Zou), 50 had died (39 in Plateau, 11 in Zou) and one, in Zou, was unable to complete the interview. The remaining 175 PAL were interviewed (participation 64.1%, no refusals): 83 of the 163 registered in Plateau (50.9%) and 92 of the 110 registered in Zou (83.6%) (Fig. 1). The 746 residents (403 in Plateau, 343 in Zou) were spread over 154 villages (79 in Plateau, 75 in Zou).

Compared with residents, PAL were older (median 43 vs 35 years, $p < 0.001$), more often male (53.1% vs 42.2%, $p = 0.011$) and more often without formal schooling (73.7% vs 59.4%, $p < 0.001$); both groups were predominantly rural (Table 1). Among PAL, detection had been passive in 79.4% of cases; the median self-reported interval between symptom onset and first contact with a health worker was 5 months (IQR 1-12), and 24.3% had waited more than one year.

Table 1: Characteristics of persons affected by leprosy and neighbourhood residents

Characteristic	PAL (n = 175)	Residents (n = 746)	p value
Age, median [IQR], years	43 [32-60]	35 [25-50]	< 0.001[a]
14-34 years, n (%)	47 (26.9)	352 (47.2)	< 0.001
35-49 years, n (%)	56 (32.0)	204 (27.3)	
≥ 50 years, n (%)	72 (41.1)	190 (25.5)	
Male sex, n (%)	93 (53.1)	315 (42.2)	0.011
No formal schooling, n (%)	129 (73.7)	443 (59.4)	< 0.001
Rural residence, n (%)	168 (96.0)	686 (92.0)	0.091
Zou department, n (%)	92 (52.6)	343 (46.0)	0.137
Plateau department, n (%)	83 (47.4)	403 (54.0)	

Column percentages. p values: χ^2 test; [a]Mann-Whitney test. No formal schooling includes literacy in a local language only and Koranic schooling only. Two PAL aged 11 and 12 years are included in the 14-34 years group. PAL: persons affected by leprosy; IQR: interquartile range.

Awareness and disease-related beliefs among residents

Among the same 746 residents, 83.5% had heard of scabies, 68.1% of Buruli ulcer, 66.9% of leprosy and 12.5% of yaws. Residents were aware of a median of 2.3 of the four diseases; 45 (6.0%) knew none and 80 (10.7%) knew all four (Table 2, Fig. 2).

Supernatural attribution ranged from 5.4% for yaws and 7.7% for scabies to 26.5% for leprosy and 46.1% for Buruli ulcer. Attribution to poor hygiene showed the reverse pattern, from 64.4% for scabies to 9.8% for leprosy. Inability to name a cause was most frequent for leprosy (60.7%). Traditional treatment was cited most often for Buruli ulcer (34.6%) and least often for leprosy (18.0%), while medical treatment was cited by 69.9% to 79.6% of respondents, depending on the disease (Table 2).

Table 2: Disease-related beliefs and care-seeking practices for four skin NTDs among the same residents

Disease	Aware, n (%)	Super-natural cause, %	Witch-craft alone, %	Poor hygiene, %	Cause unknown, %	Medical treatment, %	Traditional treatment, %
Scabies	623 (83.5)	7.7	6.9	64.4	29.9	74.3	27.8
Buruli ulcer	508 (68.1)	46.1	44.1	16.7	40.0	69.9	34.6
Leprosy	499 (66.9)	26.5	25.5	9.8	60.7	79.6	18.0
Yaws	93 (12.5)	5.4	5.4	34.4	58.1	77.4	22.6

Awareness is computed on the 746 residents; other indicators are computed among those who had heard of the disease (denominator in the second column). Supernatural attribution: witchcraft or bewitchment, or divine punishment or curse; "witchcraft alone" isolates the first option. Misconception: supernatural attribution; knowledge gap: cause unknown; care-seeking practice: traditional treatment cited. Response options were not mutually exclusive.

Within-individual comparisons between diseases

Awareness differed significantly between all pairs of diseases except Buruli ulcer and leprosy (68.1% vs 66.9%; 114 vs 105 discordant respondents, $p = 0.59$) (Table 3, Panel A). Among residents aware of both diseases in each pair, all contrasts in supernatural attribution involving Buruli ulcer or leprosy were significant (Table 3, Panel B). Among the 451 residents aware of both scabies and Buruli ulcer, supernatural attribution reached 44.8% for Buruli ulcer and 7.8% for scabies ($p < 0.001$), with 173 respondents holding this belief for Buruli ulcer only and 6 for

scabies only. These conclusions were unchanged when clustering by village was taken into account: every contrast that was significant with McNemar's test remained significant with the clustered test, and every non-significant contrast remained non-significant (Table 3).

Table 3: Within-individual comparisons between diseases: awareness, supernatural attribution and traditional treatment

Comparison	n	Proportion (first vs second)	Discordant pairs	p	Traditional treatment	p
Panel A. Awareness of the disease (all residents)						
Scabies vs Buruli ulcer	746	83.5% vs 68.1%	172 / 57	< 0.001 (< 0.001)		
Scabies vs leprosy	746	83.5% vs 66.9%	181 / 57	< 0.001 (< 0.001)		
Scabies vs yaws	746	83.5% vs 12.5%	534 / 4	< 0.001 (< 0.001)		
Buruli ulcer vs leprosy	746	68.1% vs 66.9%	114 / 105	0.59 (0.58)		
Buruli ulcer vs yaws	746	68.1% vs 12.5%	423 / 8	< 0.001 (< 0.001)		
Leprosy vs yaws	746	66.9% vs 12.5%	411 / 5	< 0.001 (< 0.001)		
Panel B. Supernatural attribution and traditional treatment (residents aware of both diseases)						
Buruli ulcer vs leprosy	394	47.0% vs 27.7%	95 / 19	< 0.001 (< 0.001)	36.0% vs 18.8%	< 0.001 (< 0.001)
Buruli ulcer vs scabies	451	44.8% vs 7.8%	173 / 6	< 0.001 (< 0.001)	35.0% vs 28.6%	0.014 (0.040)
Buruli ulcer vs yaws	85	30.6% vs 5.9%	22 / 1	< 0.001 (< 0.001)	27.1% vs 24.7%	0.79 (0.56)
Leprosy vs scabies	442	25.6% vs 8.4%	95 / 19	< 0.001 (< 0.001)	18.3% vs 29.0%	< 0.001 (0.005)
Leprosy vs yaws	88	17.0% vs 5.7%	11 / 1	0.009 (0.004)	17.0% vs 23.9%	0.24 (0.083)
Scabies vs yaws	89	6.7% vs 5.6%	5 / 4	1.00 (0.74)	30.3% vs 23.6%	0.18 (0.16)

Panel A: proportion aware of each disease. Panel B: proportion with supernatural attribution (columns 3-5) and citing traditional treatment (columns 6-7), restricted to residents who had heard of both diseases. Discordant pairs: respondents with the attribute for the first disease only / the second disease only. McNemar's test with continuity correction; in parentheses, p value from the clustered McNemar test of Durkalski et al., with village as the cluster.

Buruli ulcer and leprosy among residents aware of both

Among the 394 residents who had heard of both diseases, supernatural attribution was more frequent for Buruli ulcer than for leprosy (47.0% vs 27.7%; 95 vs 19 discordant respondents, $p < 0.001$), as was citing traditional treatment (36.0% vs 18.8%, $p < 0.001$). Beliefs about transmission ran the other way: 24.9% considered Buruli ulcer transmissible from person to person, compared with 44.9% for leprosy; 98 respondents attributed person-to-person transmission to leprosy only and 19 to Buruli ulcer only ($p < 0.001$; clustered McNemar $p < 0.001$) (Fig. 3). Among all residents who had heard of leprosy, 42.9% could not name any mode of transmission. Among residents who had heard of Buruli ulcer, 57.1% could not name any

mode of transmission and only 5.9% cited transmission by microbes, two thirds of whom also cited direct contact with a patient.

Early signs

Among the 508 residents aware of Buruli ulcer, 59.1% cited the ulcer as an early sign and 17.7% the nodule. Among the 499 aware of leprosy, 45.5% cited the anaesthetic skin patch and 38.3% could name no early sign. For scabies, 89.1% cited itching. Among the 93 residents aware of yaws, 36.6% cited the papilloma and 29.0% could name no early sign.

Factors associated with awareness, supernatural attribution and traditional treatment

Awareness of Buruli ulcer was higher in the older age groups (aPR 1.55, 95% CI 1.39-1.73 for 35-49 years and 1.58, 1.40-1.78 for ≥ 50 years, relative to 14-34 years), among men (1.16, 1.05-1.28), among residents with secondary or higher education (1.21, 1.06-1.37) and in Zou (1.25, 1.12-1.39) (Table 4). Awareness of the other diseases was also higher in the older age groups, most strongly for yaws (≥ 50 years: aPR 5.59, 3.33-9.37), followed by leprosy (2.13, 1.86-2.45) and scabies (1.19, 1.08-1.31). Secondary or higher education was also associated with higher awareness of scabies (1.16, 1.06-1.28). Awareness was higher in Zou for all four diseases (leprosy: aPR 1.21, 1.09-1.34; scabies: 1.27, 1.17-1.38; yaws: 7.97, 3.92-16.23), and lower in urban than in rural areas for leprosy only (0.77, 0.62-0.95).

Supernatural attribution of Buruli ulcer was less frequent in Zou than in Plateau (aPR 0.45, 95% CI 0.37-0.56). Supernatural attribution of leprosy was also less frequent in Zou (0.23, 0.15-0.36) and increased with age (35-49 years: 1.77, 1.06-2.96; ≥ 50 years: 2.22, 1.35-3.64) (Table 4).

Citing traditional treatment was likewise less frequent in Zou (Buruli ulcer: aPR 0.59, 95% CI 0.45-0.78; leprosy: 0.51, 0.32-0.83). After adjustment for age group, sex, educational level and department, supernatural attribution was associated with citing traditional treatment, with a

similar magnitude for Buruli ulcer (aPR 2.11, 95% CI 1.57-2.83) and leprosy (aPR 2.51, 95% CI 1.69-3.73). For Buruli ulcer, citing traditional treatment was also more frequent among men (1.28, 1.01-1.63) and among respondents with primary education than among those with none (1.52, 1.18-1.98) (Table 4, continued).

Table 4: Factors associated with awareness and supernatural attribution, by disease: adjusted prevalence ratios

Variable	Aware: leprosy (n = 746)	Aware: Buruli ulcer (n = 746)	Aware: scabies (n = 746)	Aware: yaws (n = 746)	Supernatural: Buruli ulcer (n = 508)	Supernatural: leprosy (n = 499)
35-49 vs 14-34 years	1.95 (1.71-2.22)	1.55 (1.39-1.73)	1.18 (1.09-1.28)	2.71 (1.56-4.71)	0.92 (0.70-1.20)	1.77 (1.06-2.96)
≥ 50 vs 14-34 years	2.13 (1.86-2.45)	1.58 (1.40-1.78)	1.19 (1.08-1.31)	5.59 (3.33-9.37)	1.08 (0.83-1.39)	2.22 (1.35-3.64)
Male vs female	1.04 (0.94-1.15)	1.16 (1.05-1.28)	0.96 (0.90-1.02)	1.39 (0.99-1.94)	1.10 (0.92-1.32)	1.34 (0.99-1.81)
Primary vs none	0.95 (0.86-1.05)	0.97 (0.86-1.08)	1.03 (0.95-1.12)	1.09 (0.78-1.51)	1.15 (0.88-1.50)	1.06 (0.69-1.63)
Secondary+ vs none	1.13 (0.95-1.35)	1.21 (1.06-1.37)	1.16 (1.06-1.28)	1.44 (0.83-2.47)	0.91 (0.69-1.19)	1.13 (0.72-1.77)
Zou vs Plateau	1.21 (1.09-1.34)	1.25 (1.12-1.39)	1.27 (1.17-1.38)	7.97 (3.92-16.23)	0.45 (0.37-0.56)	0.23 (0.15-0.36)
Urban vs rural	0.77 (0.62-0.95)	0.91 (0.76-1.08)	1.07 (0.96-1.18)	0.49 (0.19-1.24)	0.97 (0.60-1.56)	0.94 (0.43-2.05)

Adjusted prevalence ratios (95% confidence intervals) from multivariable modified Poisson regression (generalised estimating equation, Poisson family, log link, exchangeable working correlation, robust variance) with village as the cluster, including age group, sex, education, department and place of residence. Supernatural attribution models are restricted to residents aware of the disease and are shown only for Buruli ulcer and leprosy, the two diseases with enough events. Reference categories: 14-34 years, female, no schooling, Plateau, rural.

Table 4 (continued): Factors associated with citing traditional treatment, by disease: adjusted prevalence ratios

Variable	Traditional treatment: Buruli ulcer (n = 508)	Traditional treatment: leprosy (n = 499)
35-49 vs 14-34 years	1.01 (0.71-1.42)	0.88 (0.55-1.41)
≥ 50 vs 14-34 years	1.15 (0.88-1.49)	1.33 (0.88-2.02)
Male vs female	1.28 (1.01-1.63)	1.38 (0.96-1.98)
Primary vs none	1.52 (1.18-1.98)	1.42 (0.90-2.23)
Secondary+ vs none	1.00 (0.66-1.52)	1.29 (0.81-2.07)
Zou vs Plateau	0.59 (0.45-0.78)	0.51 (0.32-0.83)
Supernatural attribution (yes vs no)	2.11 (1.57-2.83)	2.51 (1.69-3.73)

Adjusted prevalence ratios (95% confidence intervals) from multivariable modified Poisson regression (generalised estimating equation, Poisson family, log link, exchangeable working correlation, robust variance) with village as the cluster, including age group, sex, education, department and supernatural attribution of the disease; place of residence was not included. Models are restricted to residents aware of the disease and are shown only for Buruli ulcer and leprosy, the two diseases with enough events. Traditional treatment: traditional treatment cited as a treatment for the disease. Reference categories: 14-34 years, female, no schooling, Plateau, no supernatural attribution.

Knowledge and beliefs about leprosy among persons affected by leprosy compared with informed residents

Compared with residents aware of leprosy, PAL more often cited the anaesthetic skin patch as an early sign (77.9% vs 45.5%, $p < 0.001$) and medical treatment (95.9% vs 79.6%, $p < 0.001$). They also more often attributed leprosy to supernatural causes (35.5% vs 26.5%, $p = 0.031$) and less often identified transmission by direct contact (29.1% vs 45.3%, $p < 0.001$) (Table 5).

Table 5: Knowledge and beliefs about leprosy: persons affected by leprosy and informed residents

Indicator	PAL (n = 172), n (%)	Residents aware of leprosy (n = 499), n (%)	p
Supernatural attribution	61 (35.5)	132 (26.5)	0.031
Cause: does not know	89 (51.7)	303 (60.7)	0.048
Transmission by direct contact	50 (29.1)	226 (45.3)	< 0.001
Early sign: anaesthetic patch	134 (77.9)	227 (45.5)	< 0.001
Medical treatment cited	165 (95.9)	397 (79.6)	< 0.001
Traditional treatment cited	29 (16.9)	90 (18.0)	0.82

Fisher's exact test. PAL: persons affected by leprosy.

Discussion

Measured within the same residents, knowledge and beliefs about four co-endemic skin NTDs were markedly heterogeneous, from the near absence of yaws from community awareness to the frequent supernatural attribution of Buruli ulcer. For Buruli ulcer and leprosy, the two diseases with comparable awareness, the beliefs that need correcting point in opposite directions. These findings question the implicit assumption that integrating screening also allows a common educational message, centred on screening and early care for all diseases alike.

Buruli ulcer and leprosy: corrections in opposite directions

Among residents aware of both diseases, Buruli ulcer, an environmental infection not transmitted between people, was more often attributed to supernatural causes than leprosy and

was wrongly believed transmissible by a quarter of them. Leprosy, which is genuinely transmissible through close and prolonged contact, was less often attributed to supernatural causes, but fewer than half of these residents recognised its transmission. For Buruli ulcer, health education therefore needs to reduce belief in contagion and supernatural causation. For leprosy, the correction runs the other way: transmission needs to be explained rather than left unsaid, because it is what makes contact screening and chemoprophylaxis intelligible to the households concerned. Explaining transmission need not amplify fear. Stating that it requires close and prolonged exposure, and that a person ceases to be infectious once treatment has begun, conveys the risk accurately while removing grounds for avoidance; a message that raised perceived danger without these qualifications could increase stigma, itself a cause of delay. A single message about "skin diseases" would be likely to work against the required correction for at least one of the two diseases.

The pattern of early signs adds a further reason for disease-specific content. Among residents aware of Buruli ulcer, the ulcer was named as an early sign three times as often as the nodule, which suggests that the disease is recognised mainly once it has reached the stage at which treatment becomes long and often disabling, rather than at the nodular stage, when antibiotic treatment is simpler. Messages about Buruli ulcer therefore need to describe the lesion to look for, not only correct beliefs about its cause.

Knowledge among persons affected by leprosy

Compared with residents aware of leprosy, PAL recognised the early sign far more often and almost all cited medical treatment, yet they more often attributed leprosy to supernatural causes and less often identified transmission by direct contact. One possible explanation is that clinical and therapeutic information is conveyed or retained better than information on cause and transmission during care, leaving room for local explanatory models. We did not observe what is said during consultations, and because beliefs were measured several years after diagnosis

this comparison is descriptive. The diagnostic consultation may nonetheless offer an opportunity to reinforce information on cause and transmission, which could also help PAL act as credible sources of information in their communities.

Individual knowledge, geographically concentrated beliefs

Factors associated with knowledge and with beliefs differed. Awareness followed an individual gradient, increasing with age for all four diseases and, for some of them, with male sex and education. Supernatural attribution, by contrast, was not associated with education for either disease, nor with age or sex for Buruli ulcer, and its prevalence was two to four times lower in Zou than in Plateau. This pattern suggests that health education aimed only at individual knowledge gaps may be insufficient, and that interventions engaging communities and traditional healers in the areas where such beliefs are most frequent may also be needed. We did not measure how beliefs are shared or transmitted within communities, and the departmental contrast should be interpreted with the caveats discussed below.

Comparison with other studies

In four leprosy-endemic districts of the same two departments, Djossou and colleagues found that three quarters (74.9%) of contacts of persons affected by leprosy recognised the disease by its visible deformities and 99.2% knew none of its early signs [16]. Our figure of 45.5% naming the anaesthetic patch among informed residents is higher, but corresponds to 30.4% of all residents. Among informed residents, the complications named spontaneously were the late and irreversible ones (death, 62.5%; disability or impairment, 47.5%), a pattern consistent with a disease known by its consequences rather than by its first signs.

For Buruli ulcer, frequent supernatural attribution and recourse to traditional healers have been described in Benin [4] and Cameroon [5], where belief in person-to-person transmission of this environmental disease was also reported. For yaws, a survey of 1,162 people in an endemic

area of Ghana found predominantly microbial attribution and supernatural attribution in 13% [10]; supernatural attribution was also low in our study (5.4%), but the main gap we observed lies upstream, since only 12.5% of residents had heard of the disease. For scabies, studies in the Bijagós archipelago and in central Ghana describe a disease attributed to dirt and contaminated water, rarely to supernatural causes, with little importance given to treating close contacts and with delayed care-seeking as a consequence [6, 7], a profile close to ours.

The only study we identified that questioned the same individuals about several co-endemic skin NTDs, a mixed-methods survey of 353 community members in Anambra State, Nigeria, on leprosy, Buruli ulcer and lymphatic filariasis [11], also found highly unequal awareness (66.9%, 91.8% and 37.5%, respectively), frequent attribution to witchcraft or curse (60.3%) and an association between that attribution and belief in traditional remedies (aOR 3.1, 95% CI 1.6-5.8), consistent in direction with the association we observed. Its questions on causes, transmission and treatment, however, addressed skin NTDs as a group, so heterogeneity between diseases could not be examined. The separate, disease-by-disease measurement of identical belief indicators, followed by paired comparison, is what allowed the present study to show that error profiles can point in opposite directions.

Evaluations of integrated skin NTD screening in West Africa, in Lalo [8], in Ouémé and Plateau [9] and in Côte d'Ivoire [17-19], establish that the screening platform works. Studies from the subregion have examined the role of community-based surveillance volunteers [20] and the financing of care for severe stigmatising skin diseases [21], and a study from Ethiopia has examined the dermatological consultation as an entry point to holistic care [22]. Research priorities defined with national NTD programme managers and researchers included understanding community perspectives on integration, communicating its aims and creating community demand, at a time when only four countries were implementing integrated skin NTD strategies (2020) [23]. In Liberia, introducing Buruli ulcer services into a leprosy

rehabilitation centre led some patients to see the two diseases as one entity and others to fear catching one by attending, a fear that joint education sessions helped allay [24]. This qualitative observation is consistent with our findings and suggests that placing a transmissible and an environmental mycobacterial disease on the same platform without explaining what separates them may encourage the transfer of beliefs from one to the other.

Implications for integrated skin NTD programmes

The same people can hold different, and sometimes opposing, beliefs about co-endemic skin NTDs. This provides a rationale for keeping structural integration (a common platform, common skin screening and multipurpose health workers) while differentiating health education by disease and adapting it to local belief profiles. Table 6 summarises, for each disease, the dominant belief observed and the corresponding priority message. This distinction is compatible with the WHO framework and the international call for integrated control of skin NTDs [2, 3], which promote integration of services without requiring educational content to be uniform. Whether differentiated messages are more effective than a common message was not assessed here and should be tested in implementation research.

Table 6: Health education messages differentiated by disease, derived from observed belief profiles

Disease	Dominant belief or gap observed	Priority message	Direction of correction
Buruli ulcer	Supernatural cause (46%); wrongly believed transmissible between people (25% of those also aware of leprosy); traditional healer cited (35%); recognised at the ulcer stage (59%) far more than at the nodule stage (18%)	Caused by an environmental, water-associated microbe; not transmitted from person to person; look for the painless nodule before ulceration; curable with antibiotics	Reduce belief in contagion and supernatural causation
Leprosy	Cause unknown (61%) or supernatural (27%); transmission poorly understood (43% cannot name any mode)	A curable bacterial disease, transmitted only through close and prolonged contact and no longer transmissible once treatment has begun; this is why people around a case are examined and offered preventive treatment, and why no one needs to be avoided; look for the anaesthetic skin patch	Explain transmission accurately without increasing fear
Yaws	Largely unknown (awareness 12.5%)	Introduce the disease: it affects children and a single dose of antibiotic cures it	Create baseline knowledge
Scabies	Well known (84%) but attributed to poor hygiene (64%)	A contagious infestation that must be treated in the whole household at the same time; hygiene alone does not cure it	Destigmatise and promote household treatment

Awareness is computed on all 746 residents; other percentages are among residents aware of the disease (Buruli ulcer n = 508, leprosy n = 499, scabies n = 623). The proposed messages are derived from the observed belief profiles; their effectiveness has not been tested.

Strengths and limitations

The main strength of this study is its within-individual design: because all four disease modules were administered to every respondent, comparisons between diseases are not confounded by fixed respondent characteristics. Belief indicators were constructed identically for the four diseases. Residents were drawn at random from an exhaustive geographical sampling frame, with a sample size fixed in advance, across 154 villages, and neither the identity nor the diagnosis of the registered case was disclosed to them. All registered multibacillary cases in the two departments were sought, with no refusals among those reached. Clustering of residents within villages was taken into account in both the paired comparisons and the regression analyses.

Several limitations apply. First, the four modules were administered in a fixed order within a single interview; any order effect was the same for all respondents but cannot be excluded. Second, the yaws estimates rest on 93 respondents and have confidence intervals of up to about ten percentage points on either side. Third, the design is cross-sectional, so the associations between beliefs and care-seeking practices cannot establish temporal order or causality; among PAL, beliefs measured at interview may also differ from those held at diagnosis, and the care-seeking interval was self-reported. Fourth, 98 of the 273 registered PAL could not be reached, mostly because of death or relocation, which may have excluded some of the most severe cases. Fifth, belief indicators were estimated only among residents aware of each disease, and awareness itself depended strongly on department; the departmental association with beliefs is therefore estimated within subgroups that department helps define and could be biased by unmeasured factors such as exposure to campaigns or proximity to a treatment centre. PAL participation also differed between Plateau (50.9%) and Zou (83.6%). The departmental

prevalence ratios should therefore be read as indicating where beliefs are concentrated rather than as unbiased measures of the size of the difference.

Finally, residents were sampled around registered PAL, and some shared a dwelling with one. Although the index case was not disclosed, these communities may have had more exposure to leprosy, related services or awareness activities than the general population, so awareness and beliefs concerning leprosy may differ from those in communities without registered cases. The absolute levels observed should not be assumed to represent Benin as a whole or other endemic settings. The within-individual contrasts between diseases are likely to depend less on these sampling characteristics than absolute prevalence estimates, but replication in other settings where several skin NTDs coexist is needed to establish whether the patterns observed for Buruli ulcer and leprosy are consistent.

Conclusions

Within the same individuals, beliefs about co-endemic skin NTDs were disease-specific and, for Buruli ulcer and leprosy, required corrections in opposite directions: Buruli ulcer was the most often attributed to supernatural causes and was wrongly believed transmissible by a quarter of residents aware of both diseases, whereas the transmission of leprosy was recognised by fewer than half of them. Supernatural attribution was associated with citing traditional treatment. Integrated skin NTD programmes may benefit from keeping a common screening platform while differentiating health education by disease and adapting it to local belief profiles; the effectiveness of this approach should be evaluated.

Abbreviations

aOR: Adjusted odds ratio

aPR: Adjusted prevalence ratio

CI: Confidence interval

GPS: Global positioning system

IQR: Interquartile range

KAP: Knowledge, attitudes and practices

NTD: Neglected tropical disease

PAL: Persons affected by leprosy

PNLLUB: Programme National de Lutte contre la Lèpre et l'Ulcère de Buruli (National Leprosy and Buruli Ulcer Control Programme)

SD: Standard deviation

SDDR-PEP: Single double-dose rifampicin post-exposure prophylaxis

STROBE: Strengthening the Reporting of Observational Studies in Epidemiology

WHO: World Health Organization

Declarations

Ethics approval and consent to participate

The protocol was approved by the National Ethics Committee for Health Research (Comité National d'Éthique pour la Recherche en Santé, CNERS) of the Ministry of Health of Benin at its plenary session of 27 August 2024; the favourable opinion took effect on 15 October 2024 for one year (ref. CNERS 011/2024). No activity involving participants preceded this date; the only preparatory step, in September 2024, was to build the sampling frame from existing programme records. The study was conducted in accordance with the Declaration of Helsinki. Participation was voluntary. Each adult participant, or the parent or guardian of each minor, signed an informed consent form after receiving full information on the objectives, methods,

expected benefits and potential risks of the study; participants who could not read gave a thumbprint in the presence of an independent witness, and minors gave their own assent in addition to parental consent. Confidentiality and anonymity were maintained throughout.

Consent for publication

Not applicable.

Availability of data and materials

The de-identified dataset supporting the conclusions of this article is available on the following website: https://irfp-benin.com/recherches-and-actions. De-identification removes direct identifiers and aggregates geographical information to commune level for residents and to department level for persons affected by leprosy, since finer location could re-identify participants in communities with few registered cases.

Competing interests

CJJ and AGM are employees of the Anesvad Foundation, and AT and PV are employees of the Raoul Follereau Foundation, which funded the study. AF is an employee of the German Leprosy and Tuberculosis Relief Association (DAHW). The other authors declare that they have no competing interests.

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Authors' contributions

Conception, design and data acquisition: RCJ, SDZ, FM, ASYH, JGH, CJJ, AGM, PV. Writing, original draft: SDZ, FNCG. Data curation: SDZ, FNCG, FM, JGH. Analysis and interpretation: SDZ, FNCG, RCJ, SGEA, VB, SIEA, KLMCS, CJJ, AGM, PV, AF. Review and editing: RCJ, SGEA, KLMCS, AT, CJJ, AGM, AF, ASYH. Funding acquisition: RCJ, AGM, CJJ, PV. All authors read and approved the final manuscript.

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Figure legends

Fig. 1 Flow of participants

Multibacillary leprosy cases registered by the national programme in Plateau and Zou over 2013-2023, non-inclusions by department and reason, persons affected by leprosy (PAL) interviewed, and neighbourhood residents drawn at random within 100 m of registered cases. Denominators used for disease-specific indicators are shown in the bottom boxes.

Fig. 2 Awareness, supernatural attribution and traditional treatment for four skin NTDs among residents

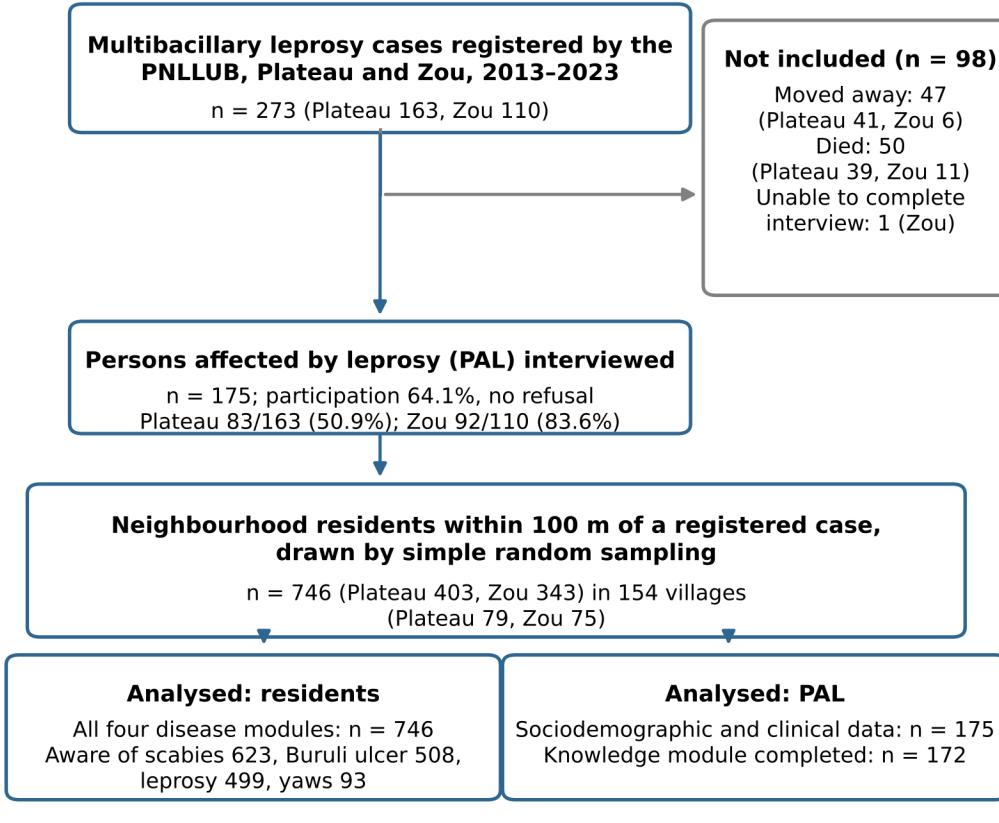
Awareness is computed on all 746 residents; supernatural attribution and traditional treatment are computed among residents who had heard of the disease (scabies n = 623, Buruli ulcer n = 508, leprosy n = 499, yaws n = 93).

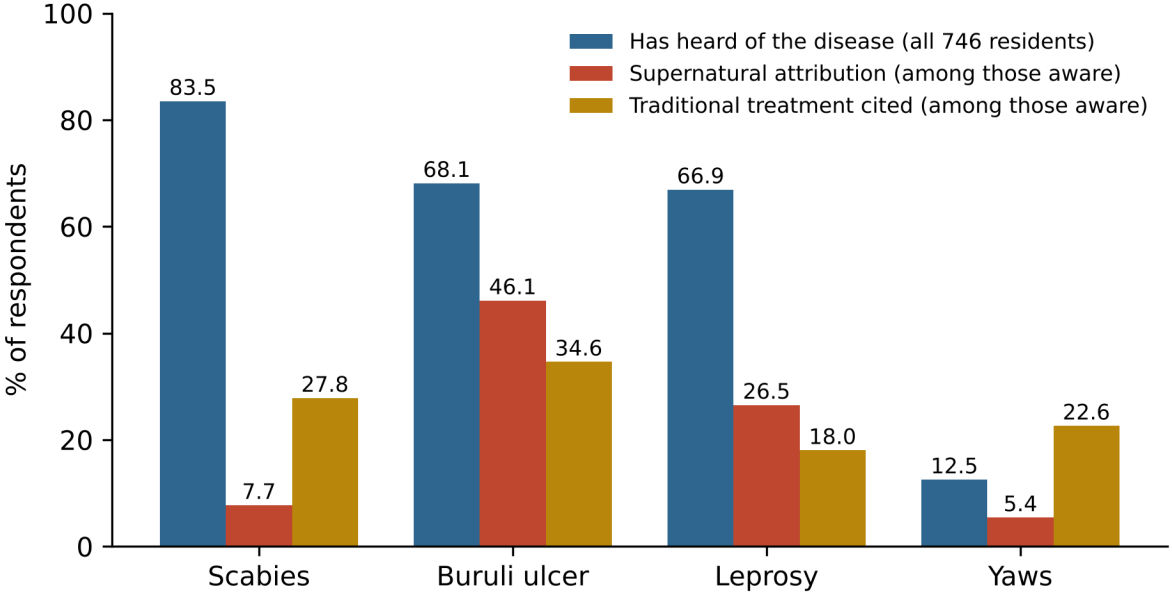
Fig. 3 Beliefs about Buruli ulcer and leprosy among 394 residents aware of both

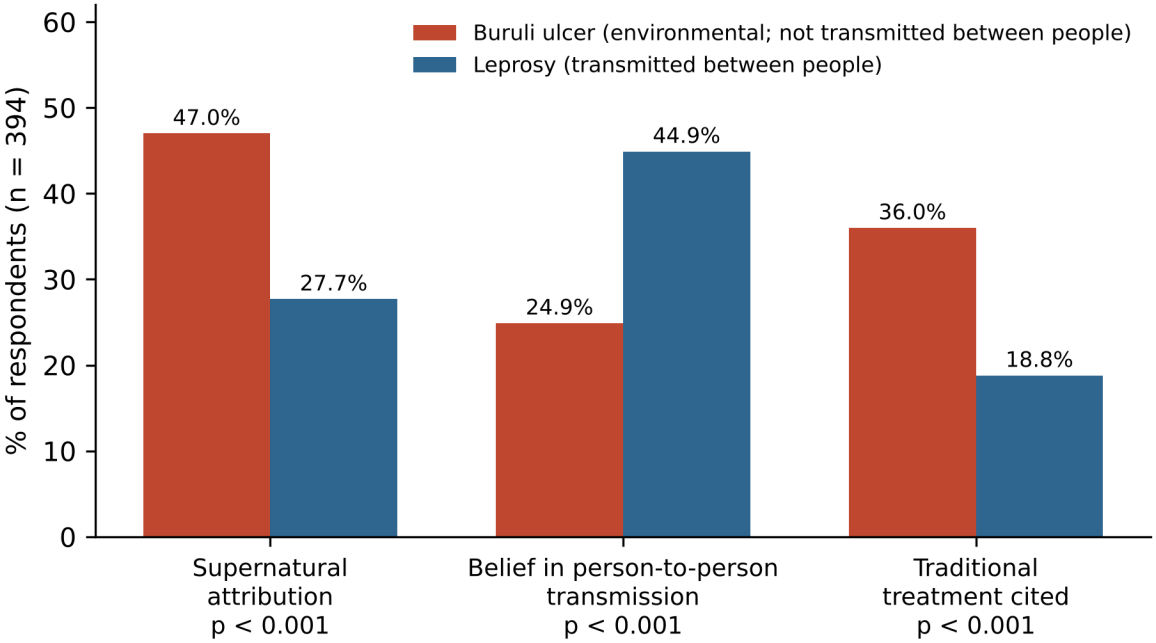
Percentages of the same 394 residents holding each belief for each disease. p values from McNemar's test with continuity correction; all three contrasts also had $p < 0.001$ with the clustered McNemar test.

Additional files

Additional file 1. STROBE checklist for cross-sectional studies (.docx).


Multibacillary leprosy cases registered by the PNLLUB, Plateau and Zou, 2013–2023
n = 273 (Plateau 163, Zou 110)
Not included (n = 98)
Moved away: 47
(Plateau 41, Zou 6)
Died: 50
(Plateau 39, Zou 11)
Unable to complete interview: 1 (Zou)
Persons affected by leprosy (PAL) interviewed
n = 175; participation 64.1%, no refusal
Plateau 83/163 (50.9%); Zou 92/110 (83.6%)
Neighbourhood residents within 100 m of a registered case, drawn by simple random sampling
n = 746 (Plateau 403, Zou 343) in 154 villages
(Plateau 79, Zou 75)
Analysed: residents
All four disease modules: n = 746
Aware of scabies 623, Buruli ulcer 508, leprosy 499, yaws 93
Analysed: PAL
Sociodemographic and clinical data: n = 175
Knowledge module completed: n = 172


Has heard of the disease (all 746 residents)
Supernatural attribution (among those aware)
Traditional treatment cited (among those aware)
% of respondents
100
80
60
40
20
0
83.5
7.7
27.8
68.1
46.1
34.6
66.9
26.5
18.0
12.5
5.4
22.6
Scabies
Buruli ulcer
Leprosy
Yaws


Buruli ulcer (environmental; not transmitted between people)
Leprosy (transmitted between people)
% of respondents (n = 394)
60
50
40
30
20
10
0
47.0%
27.7%
24.9%
44.9%
36.0%
18.8%
Supernatural attribution p < 0.001
Belief in person-to-person transmission p < 0.001
Traditional treatment cited p < 0.001

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Additionalfile1STROBEchecklist.docx