Baseline Malaria Prevalence at the Targeted Pre-elimination Districts in Ethiopia

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Abstract

Background: Encouraged by the success in malaria control and prevention strategies, several malaria endemic countries have adopted elimination strategies worldwide. Accordingly, Ethiopian ministry of health launched malaria elimination with a stepwise approach by primarily targeting the low-transmission districts and their adjacent areas/zones in order to shrink the country's malaria map progressively. Hence, this community survey was conducted to establish baseline malaria information at the preliminary phase of elimination for measuring future intervention success in elimination goal.

Methods: Community based cross-sectional survey was conducted at twenty malaria elimination targeted districts selected from five regional states and one city administration in Ethiopia. The GPS enabled smart phones programmed with Open Data Kit were used to enumerate 9326 study households and collect data from 29,993 residents. Care Start™ Malaria HRP-2/PLDH Rapid Diagnostic Tests (RDTs) were used for blood testing at field level. Armpit digital thermometers were used to measure axillary temperature.

Result: Overall malaria prevalence by RDTs was 1.17% (339/28973). The prevalence at district levels ranged from 0.0% to 4.7%. The total prevalence of febrile cases (axillary temperature >37.5^{o}c) in the survey was 9.2% (2760/29993). Among the 2,510 febrile individuals tested with RDTs, only 3.35% (84/2510) were malaria positive. Among all study participants, 0.88% (255/28973) malaria positives were afebrile and 0.29% (84/28973) were febrile individuals. The 75.2% (255/339) of all malaria positives were afebrile. Of the total afebrile malaria cases, 10.2% (26/255) were under-five children and 89.8% (229/255) were above 5 years of age.

Conclusion: The 1.17% malaria prevalence that ranges 0 to 4% in some districts by rapid diagnostic tests should be given due consideration by the elimination program. Especially the higher prevalence of afebrile individuals (0.88%) in these transmission settings indicates there may be sustaining hidden transmission. Therefore, active case detection with more sensitive diagnostic techniques than this conventional method is suggested to know more real magnitude of residual malaria in the elimination targeted low transmission areas and break the chain of transmission.

Background

During the last decade, substantial worldwide progress has been made in controlling malaria worldwide. The magnitude of the progress has led some malaria endemic countries to consider possibility of the malaria elimination [1–4]. Ethiopia experienced cycles of major malaria epidemics every 5 to 8 years in highland areas, where the last nationwide epidemic (> 4000 malaria deaths) occurred in 2003 and fewer epidemics since 2004 [5]. The apparent decrease of major malaria epidemics within the last decade is a result of the national scale-up of malaria control interventions in Ethiopia [5, 6]. Mass distribution of insecticide-treated bed nets (ITNs), indoor residual spraying (IRS) and adoption of Artemisinin-based combination therapy (ACT) contributed much for the substantial declines in malaria-related deaths and morbidity [5, 7, 8].

In its current national malaria strategic plan 2014–2020 [9] and in its roadmap [10], Ethiopia declared to achieve malaria elimination in targeted low malaria transmission settings by the end of 2020 and national elimination in 2030. Since a decrease in malaria burden noted earlier is not uniform, a sub-national elimination must be attempted before nationwide elimination can be attained [10]. Thus, the country aims to eliminate malaria with a stepwise approach by targeting first the low-transmission districts (Districts below five cases per 1000 people per year) and their adjacent areas/zones to shrink the country's malaria map progressively [9]. However, the magnitude of *Plasmodium* infections has not been well studied in wide geographies of Ethiopia and may turn out to be a great barrier particularly in the malaria elimination targeted settings.

Baseline malaria information gathered at the pre-elimination phase is essential to understand the community level transmission and measure the next outcomes towards the elimination goal. Baseline survey results enable programs (or program managers/interested people) to anticipate achievements and changes in the future regarding interventions administered for malaria prevalence reduction in the communities [11]. A baseline survey on malaria epidemiology and intervention coverage at the community level in the elimination-planned districts would help to know the status in terms of parasite distribution, intervention coverage and community awareness to malaria and control approaches, and to evaluate the success of activities exerted for elimination.

In addition to baseline data, malaria elimination strategies must consider all malaria-infected individuals including symptomatic and asymptomatic *Plasmodium* reservoirs, since the hidden infection reservoirs can maintain an active malaria transmission silently [12]. In geographies where malaria control efforts have been successful, the prevalence of low density submicroscopic infections is particularly high [13]. The current evidences suggest that low density infections should be considered in malaria elimination strategies and require diagnostics that are more sensitive than conventional diagnostic tests (RDTs) [14]. Therefore, this study was conducted to measure the magnitude of *Plasmodium* infections (both symptomatic and asymptomatic cases) at the community level in the initial phase of malaria elimination in the targeted districts and regions in Ethiopia.

Materials And Methods

Study area and period

This study was conducted from October to December 2018 in selected districts targeted for malaria elimination in Ethiopia. Ministry of Health (MOH) launched malaria elimination in 239 districts with low annual parasites among the five regional states (Amhara, South Nations and Nationalities, Oromia, Tigray, and Harari regions) and Dire-dawa city administration. Ethiopia National Strategic Plan (NSP) 2017–2020 has stratified the country's malaria situation based on Annual Parasite Incidence (API) per 1000 population. Accordingly, four broad strata have been identified. They are malaria-free, low-, moderate-, and high-transmission strata. The current assessment was commenced in these low-to-moderate malaria transmission districts in Ethiopia as shown in Fig. 1.

The selected study districts (woreda) were from Amhara region (Berehet, Raya kobo, Bugna, Habru); from Oromia region (Merti, Sire, Zeway-dugida, Kersa, Gemechis); from South Ethiopia (Dilla-zuria, Marako, Misrak-badawacho, Damboya, Dore, Lanfaro); from Tigray region (Kolla-tembein, Hawzen, Seharti-samre), and all districts in Diriedawa city administration and Harar region.

Study participants

All residents in the study districts with or without malaria symptom, aged above 1 year and both sexes were included. Individuals having taken anti-malarial drugs in the past six weeks, non-consenting individuals, children under-the age of one-year and absentees at home during data collection were excluded.

Study design and Sampling procedure

The design of the study was cross-sectional. From among the 239 malaria elimination target districts, only 20 districts were selected as study districts proportionally considering the total size of elimination target districts per each region/city administration, intended study objective, higher malaria reports, average population per district and available budget. The sample design was framed by Ethiopian Central Statistical Agency (CSA), in collaboration with data management professionals in Ethiopian Public Health Institute (EPHI). The sampling frame used for this survey was a list of malarious kebeles in the selected 20 target districts (domains) selected for the study. In each domain (district), a sample of kebeles with a predetermined sample size was then selected independently with probability proportional to

size. A two-stage cluster sampling was used where kebele was the primary sampling unit and household was the second-stage sampling unit. The design of the survey was cross-sectional and minimum sample size required for the survey, per domain, was determined using the formula below:

$$n = Deft^2 (z\frac{a}{2})^2 \left[\frac{p(1-p)x^2}{d^2}\right]$$

Where, n: the required minimum sample size per domain; α: level of significance; p: prevalence rate; d: absolute precision (= 2*p*ε); ε: desired relative standard error; Deft: estimated design effect to account for the two-stage cluster sampling method.

The key indicator taken to determine the sample size was malaria parasite prevalence by microscopy, which was 0.5 percent, among all age groups residing in malarious areas according to the Ethiopia National Malaria indicator survey 2015. In the above formula, using a relative precision of 0.4 percent, 0.05 level of significance, design effect of 1.3, and adjusting for the 97 percent household gross response rate, and taking 20 domains (districts), the total minimum sample size was 9326 households, and 112 kebeles from a total of 406 malarious kebeles in the 20 study districts.

Households were selected with a simple random sampling using EPiSample software programmed in smart phones. To have had a domain-level estimate, precision and design effect were used at district levels. The distribution of the total sample size to the districts; therefore, used a power allocation with an appropriate power value of 0.99 to guarantee sufficient sample size in small districts.

Field data collection

During fieldwork, field teams conducted full household listings in each kebele/village using the smart phones programmed with EpiSample software and selected randomly the study households with the support of field technical assistants and guide persons. Questionnaires were programmed into Samsung I9300 S3 Neo smart phones with capacity of taking global positioning system (GPS) at each household level. After obtaining consent from the study participants, a face-to-face questionnaire interview was held by health officers/nurses. The participants were interviewed for any malaria like symptom or fever with in past 48 hrs before study commencement. Armpit digital thermometers were used to measure the axillary temperature. Laboratory technologists conducted testing of finger prick blood by Care Start™ Malaria HRP-2/pLDH Rapid Diagnostic Tests (RDTs) [15] and prepared dried blood spot (DBS) samples by filter papers for serology [16–19] and molecular analysis [20, 21]. Field data collected by EpiSample were every day sent to the central EPHI data management server and a backup was also transferred from internet server to a computer on a weekly basis.

Statistical analysis of data

Data were cleaned and analyzed using STATA 14 package. Descriptive statistics were used to describe the characteristics of the sample and calculate coverage, use and access estimates. Point estimates and confidence intervals were analyzed to adjust clustering in the sampling design, with weighting for household and cluster sampling probability [22]. The descriptive statistics and differences in distribution were evaluated using the Chi-square (χ2) test and P < 0.05 was considered statistically significant.

Results

Characteristics of the study population

This baseline assessment was conducted in twenty malaria elimination targeted districts, selected from five regions and one city administration. The regions are Harar, Oromia, Amhara, Southern Nations Nationalities and Peoples (SNNP), and Tigray regions; and Dire Dawa city administration.

At the total study households, 35900 participants were initially registered into the ODK program installed into Smartphone; of which, 29993 gave axillary temperature for temperature measurement. Out of those who gave axillary temperature, 28983 participants tested for malaria with RDTs, and 29085 gave DBS (Fig. 2 and Table 1).

The mean age of participants was 25 years. Age category 18–59 years held the highest proportion (44.8%-61.8%) in all the study regions; while, the age category of >60 yrs covered the lowest proportion in all regions. The other age groups covered almost similar proportion in all settings. Gender data shows almost equal proportion in all study settings, despite slight increase by female participants in some areas (Table 1).

Table 1
Characteristics of study sites and population by regions in Ethiopia, Oct-Dec 2018.

Characteristics		Amhara, n(%)	Dire dawa N (%)	Harari N (%)	Oromia, N (%)	SNNPR, N (%)	Tigray, N (%)	Total , N (%)
Age in yrs	< 5	609(9.6)	145(12)	65(6.1)	1245(13.2)	1533(12.1)	461(9.7)	4058(11.4)
	5−11	940(14.7)	213(17.7)	174(16.4)	1726(18.3)	3126(24.7)	903(19)	7082(20)
	12−17	679(10.6)	112(9.3)	102(9.6)	1049(11.1)	1884(14.9)	569(12)	4395(12.4)
	18−59	3699(58)	667(55.3)	656(61.8)	4697(49.7)	5659(44.8)	2317(48.8)	17695(49.9)
	>60	449(7)	69(5.7)	64(6)	729(7.7)	439(3.5)	499(10.5)	2249(6.3)
Sex	Female	3277(50.6)	673(53.5)	525(48.4)	4684(49.3)	6582(51.5)	2360(49.5)	18101(50.4)
	Male	3203(49.4)	586(46.5)	558(51.5)	4821(50.7)	6208(48.5)	2407(50.5)	17783(49.6)
Fever	No	5563(98.2)	917(99.2)	997(96.1)	7861(99.3)	7798(76.1)	4091(97.5)	27227(90.8)
	Yes	102(1.8)	7(0.8)	41(3.9)	58(0.7)	2453(23.9)	105(2.5)	2766(9.2)

Malaria prevalence per Regions

The overall prevalence of malaria as detected by RDTs in this survey was 1.17% (339/28983) among the total study participants. A high proportion of malaria infection was reported from Harari 46(4.7%) followed by 87(3.7%) in Kersa, 81(2.7%) in Misrak Badawacho, 27(1.7%) in Kolla Tembien, 32(1.4%) in Habru and 22(1.07%) in Raya Kobo districts. Whereas, in half (50%) of the surveyed districts, the prevalence of malaria infection was less than 1% by RDTs. Interestingly, four districts namely Berehet, Sire, Gemechis and Damboya reported zero prevalence of malaria by the RDT test (Table 2).

Table 2

Prevalence of malaria infections using RDTs by regions and districts in Ethiopia, Oct-Dec 2018.

Regions	Name of districts	RDT Results		
		Negative, n(%)	Positive, n(%)	Total, n (%)
Amhara	Berehet	531(100)	0	531(100))
	Bugina	625(99.84)	1(0.16)	626(100
	Raya kobo	2033(98.93)	22(1.07)	2055(100)
	Habru	2249(98.6)	32(1.4)	2281(100)
	Total	**5438(99)**	**55(1)**	**5493(100)**
Dire dawa		882(99.55)	4(0.45)	886(100)
Harari		933(95.3)	46(4.7)	979(100)
Oromia	Merti	863(99.08)	8(0.92)	871(100)
	Sire	729(100)	0	729(100)
	Zeway-dugida	2423(99.6)	10(0.4)	2433(100)
	Kersa	2271(96.3)	87(3.7)	2358(100)
	Gemechis	1447(100)	0	1447(100)
	Total	**7733(98.66)**	**105(1.34)**	**7838(100)**
SNNPR	Dilla-zuria	501(99.6)	2(0.4)	503(100)
	Marako	1815(99.9)	1(0.1)	1816(100)
	Misrak-badawacho	2918(97.3)	81(2.7)	2999(100)
	Damboya	816(100)	0	816(100)
	Dore (Hawassa-zuria)	1402(99.9)	1(0.1)	1403(100)
	Lanfaro	2128(99.95)	1(0.05)	2129(100)
	Total	**9580(99.1)**	**86(0.9)**	**9666(100)**
Tigray	Kolla-Tembein	1570(98.3)	27(1.7)	1597(100)
	Hawzen	1230(99.6)	5(0.4)	1235(100)
	Seharti-Samre	1278(99.1)	11(0.9)	1289(100)
	Total	**4078(98.95)**	**43(1.05)**	**4121(100)**
Total		28644(98.83)	339(1.17)	28983(100)

Malaria and sociodemography

From a total of 28983 survey participants who were grouped in to five age groups, malaria RDT positivity was higher among age group 5–11years (1.8%) followed by 12-17years (1.4%), while positivity rate was low among the age group of 18–59 years (0.9%). RDT positivity rate among males (1.4%) was higher than females (1%). Malaria positivity among

pregnant women (1.9%) was higher compared to non-pregnant women (*P-value: 0.023*) and those did not know their pregnancy status (*p-value: 0.988*) (Table 3).

Among the 2,510 febrile individuals having axillary temperature > 37.5°C, only 84(3.35%) were malaria positive while 2,426 (96.65%) were malaria negative. Statistics showed significant association between febrile cases and malaria positivity (*P-value*: <0.001) (Table 3). Among the total study participants, malaria prevalence in afebrile individuals was 0.88% (255/28973) and in febrile individuals was 0.29% (84/28973). Among all malaria positives, 75.2% (255/339) were afebrile and 24.8% (84/339) were febrile (Table 3).

High malaria prevalence (59%: 167/283) was seen at an altitude of 1501-2000m ASL, while 23% at 1000-1500m and 18% at > 2000m. Yet, there was observed a statistically significant relationship between lower altitude and malaria positivity (*P-value*: <0.001) (Table 3). The assessment showed travel history had no association (*P-value*: 0.274) with malaria positivity. Most of the malaria positives had no travel history; from those having travel history, 98.3% (418) were malaria negative while 1.7% were malaria positive (Table 3).

Table 3
Malaria prevalence and sociodemographic characteristics in Ethiopia, Oct-Dec 2018.

Characteristics	RDT results			P-value
	Negative	Positive	Total	
Age group (in years)				
< 5	2850(98.75)	36(1.25)	2886(100)	0.677
5−11	5856(98.2)	107(1.8)	5963(100)	0.044
12−17	3485(98.6)	50(1.4)	3535(100)	0.354
18−59	14578(99.1)	125(0.9)	14703(100)	0.251
> 60(Reference)	1865(98.9)	21(1.1)	1886(100)	
Total	28634(98.83)	339(1.17)	28973(100)	
Sex				
Female (Reference)	15417(99)	149(1)	15566(100)	
Male	13217(98.6)	190(1.4)	13407(100)	< 0.001
Total	28634(98.83)	339(1.17)	28973(100)	
Pregnant Women				
Yes	504(98.1)	10(1.9)	514(100)	0.023
No(Reference)	7532(99.2)	58(0.8)	7590(100)	
Don't Know	36(100)	0	36(100)	0.988
Total	8072(99.2)	68(0.8)	8140(100)	
Travel History, n(%)				
Yes	411(98.3)	7(1.7)	418(100)	0.274
No	25334(98.9)	283(1.1)	25617(100)	Ref
Total	25745(98.9)	290(1.1)	26035(100)	
Fever status, n(%)				
Febrile(axillary temp > 37.5oC)	2426(96.65)	84(3.35)	2510(100)	< 0.001
Non-febrile(axillary temp ≤ 37.5oC)	26208(99)	255(1)	26463(100)	Ref
Total	28634(98.83)	339(1.17)	28973(100)	
Altitude of the study area (M), n(%)				
1000−1500	3030(97.9)	65(2.1)	3095(100)	< 0.001
1501−2000	18665(99.1)	167(0.9)	18834(100)	
> 2000	3402(98.5)	51(1.5)	3453(100)	Ref
Total	25099(98.9)	283(1.1)	25382(100)	

Among the afebrile malaria patients (255), the highest proportion was observed in 18–59 yrs of age, which was 38.4% (98); followed by 29.4%(75) in 5–11 yrs, 16.1%(41) in 12–17 yrs, 10.5%(26) in under 5 years, and 5.9%(15) in >60 yrs of age. This means afebrile malaria prevalence was 10.2% (26/255) in under-five children and 89.8% (229/255) in age groups above 5 years (Table 4).

Table 4
Confirmed malaria cases in varying age category using Care Start RDTs, Oct-Dec 2018, Ethiopia.

Variables		Age category in yrs					Total
		< 5	5–11	12–17	18–59	≥ 60	
Malaria RDT positives	No fever	26(10.2%)	75(29.4%)	41(16.1%)	98(38.4%)	15(5.9%)	255(100.0%)
	Fever (> 37.5ºc)	10(11.9%)	32(38.1%)	9(10.7%)	27(32.1%)	6(7.1%)	84(100.0%)
	Total	36(10.6%)	107(31.6%)	50(14.7%)	125(36.9%)	21(6.2%)	339(100.0%)

Discussion

The study provided baseline information for malaria elimination program in the targeted low transmission districts of Ethiopia. The overall prevalence of malaria by RDTs in this survey was 1.17% (339/28983). In this survey, malaria prevalence ranged from zero to 4.7% at district level by malaria RDTs. In half (50%) of the surveyed districts, the prevalence of malaria was less than 1% by RDTs. The difference in malaria prevalence among the districts was supported by the findings reported from baseline malaria surveys conducted elsewhere in Asia [1–4, 23].

The large scale deployment of RDTs for malaria diagnosis has greatly improved access to confirmatory diagnosis in malaria endemic countries, contributing to the success of malaria control programs in recent years [24]. RDTs are convenient tests for the screening of large number of samples in national surveillance studies or other large-scale malaria elimination programs such as mass screening and treatment programs. However, population surveys using traditional diagnostic techniques including microscopy or RDTs may miss low-grade infections that are below the detection limit of these tools. Studies in high transmission areas have shown that as many as two-thirds of microscopy-negative patients may have low grade parasites [25].

False-negative RDT results commonly occur because of professional errors, inconvenient storage situations, histidine rich proteine deletions, low parasitaemia and RDT types with poor performance. The detection capacity of malaria RDTs varies in different transmission settings and false negative RDT results are common in lower malaria transmission settings [26]. Therefore, highly sensitive and specific malaria diagnostics such as PCR or highly sensitive RDTs are critically needed in community surveys, particularly in low transmission and elimination target settings to explore more precise prevalence estimates [27].

In this study, among the 2,510 febrile individuals having axillary temperature > 37.5ºC, only 84(3.35%) were malaria positive while 2,426 (96.65%) were negative. This may be so because fever is not specific to malaria and it might have been caused by other illnesses. Fever was not fully explained by malaria as reported by other studies in low-resource areas [28]. Although the proportion of infection positivity is lower among febrile cases, statistics shows significant association between fever and malaria positivity (*P-value*: <0.001).

In our study, afebrile malaria cases were 'cases tested positive by RDTs but were with axillary temperature of < 37.5ºC as measured by a digital thermometer or/and those who had reported no fever history or no malaria like symptoms within 48 hrs before field data collection. Afebrile malaria cases accounted for 0.88% (255/28973) among the total tested

study participants and 75.2% (255/339) among all malaria positives. The afebrile or asymptomatic malaria cases in low transmission and elimination-targeted areas are potential reservoirs sustaining uninterrupted malaria transmission in the area [13]. With regard to the elimination strategy, WHO remarks that asymptomatic malaria infections should be confirmed by standard diagnostic tests. WHO states that any case confirmed by a diagnostic test is malaria infection whether it is symptomatic or asymptomatic. Active monitoring of malaria infections is necessary in settings where malaria transmission has currently declined, and national efforts are under way to achieve malaria elimination.

In Zambia [29], among 3,863 household members tested in the elimination target areas, 2.6% of individuals were found positive by either of RDTs, microscopy or PCR. Of all positives, 47% (48) had sub-patent parasitemia and 85% of sub-patent parasitemia cases were asymptomatic. The study recommended further need of active or reactive case detection approaches to identify more asymptomatic individuals at the community levels during declining malaria. Most countries with low transmission settings and striving to eliminate malaria demonstrated a large proportion of asymptomatic *Plasmodial* infections, particularly submicroscopic parasitemia cases [30–32]. Asymptomatic and subpatent malaria reservoirs can maintain continuous transmission even in low transmission settings unless they are strictly monitored and detected by a highly sensitive diagnostic method, and immediately treated by an effective antimalarial drug [12]. The current study findings forward the necessity of use of more sensitive molecular diagnostic tools to give up more accurate prevalence of infections in community surveys occurring at low-transmission settings.

Malaria RDT positivity was higher among the age group 5–11years (1.8%) followed by 12-17years (1.4%), while the positivity rate was low among the age group of 18–59 years (0.9%). However, the difference in malaria prevalence among age groups was not significant. Among the total afebrile malaria patients (255), the highest proportion was observed in 18–59 yrs of age, which was 38.4% (98). This means afebrile or asymptomatic malaria prevalence was 10.2% (26/255) in under-five children and 89.8% (229/255) in age groups above 5 years. This may be so because the older ages might have developed acquired immunity from repeated previous exposures that could block malaria symptom development as reported by other studies [33].

Malaria prevalence among males (1.4%) is significantly higher than among females (1%). Males usually stay in outdoor activities more frequently than females and hence more exposed to mosquito bites. Currently studies reported that mosquitoes change their behavior from indoor biting to outdoor or probably new mosquitoes with outdoor-biting may have arrived at the study areas. The current malaria prevention and control intervention program gives higher priority for pregnant women and children; however, malaria prevalence among pregnant women (1.9%) was higher when compared to non-pregnant women and those who did not know their pregnancy status. A possible reason for this may be immune suppression and loss of acquired immunity among the pregnant, and the hormonal, immunological and hematological changes during pregnancy period. High malaria prevalence (59% of all positives) was seen at an altitude of 1501-2000m ASL, while 23% at 1000-1500m and 18% at >2000m. Statistically significant relationship was observed between lower altitude and malaria positivity (*P-value*: <0.001). Finally, because of lacking reagents, we are unable to produce molecular and sero-prevalence (ELISA) prevalence despite a large number of dried blood spots (29,085 DBS samples) collected in this baseline assessment.

Conclusion

The total malaria prevalence by RDTs in this survey was 1.17%; of which, 0.29% positives had fever and 0.88% were afebrile. These infections in low transmission and elimination-targeted areas are very considerable since they still prolong uninterrupted malaria transmission in the area. Although RDTs may be convenient serological tests for the screening of large number of samples in national surveillance studies or other large-scale malaria elimination programs such as mass screening and treatment programs, population surveys using traditional diagnostic techniques including microscopy and/or RDTs may miss low-grade infections that are below the detection limit of these tools. Therefore,

molecular techniques, such as PCR (and may be other serological tests), are more sensitive, and thus are more likely to detect infectious reservoirs in the elimination settings.

Abbreviations

ACT: Artemisinin Based Combination Therapy; **API:** Annual Parasite Incidence; **EPHI:** Ethiopian Public Health Institute; **FMOH:** Federal Ministry of Health; **HH:** Household; **HMIS:** Health Management Information System; **IRS:** Indoor Residual Spraying; **ITN:** Insecticidal Treated Net; **LLIN:** Long Lasting Insecticidal Treated Net; **MIS:** Malaria Indicator Survey; **NSP:** National Strategic Plan; **ODK:** Open Data Kit; **PCR:** Polymerase chain reaction; **RDT**: Rapid Diagnostic Test

Declarations

Ethics approval and informed consent

This study was ethically cleared by the Institutional Review Board of the Ethiopian Public Health Institute (EPHI). Official cooperation letters were written by the EPHI to the study districts. Individual informed consents/assents were obtained from participants before administering the questionnaires and collecting blood samples. To keep confidentiality, study participants' data were coded separately and were accessed by the principal investigator (with permission of PI) only. All individuals found positive on RDTs at the field were treated according to the national malaria treatment guidelines [34,35]. People declared negative by RDT but who were febrile or otherwise ill were referred to the nearest health facilities for further investigation.

Consent for publication

Not applicable, the manuscript does not contain data from any individual person.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request or are available in the EPHI data repository

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

D_sN and A_dA: Conceptualization, designing, data collection, analysis, write-ups & coordination. BG, SM, A_bA, DD, and DM: Conceptualization, designing, data collection & analysis. GA, SH, MH, KE, AY, and AG: Designing & data collection.

HN, SA, D$_n$N, ZD and BS: Sampling procedure, ODK programming & data analysis. HT, G$_z$T, BT, HR, WB, AZ, A$_s$A and AW: Designing. HS, G$_r$T, G$_t$T and EA: Designing & survey management. D$_s$N wrote the final manuscript. All authors read and approved the final manuscript.

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Acknowledgements

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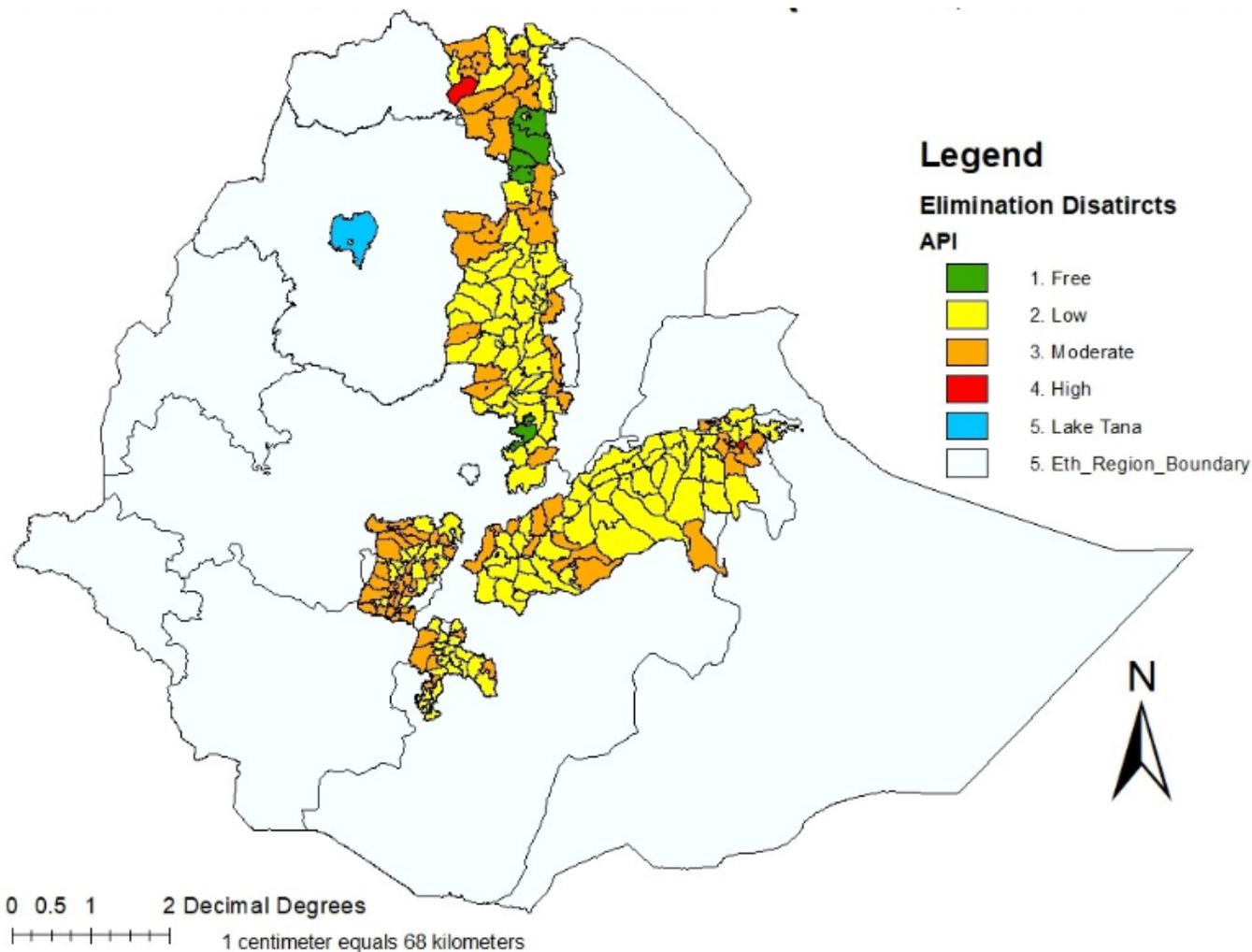
Figures

Figure 1

Risk map of districts by annual parasite incidence, Ethiopia, 2017 (Source FMOH NSP: 2017-2020). Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.
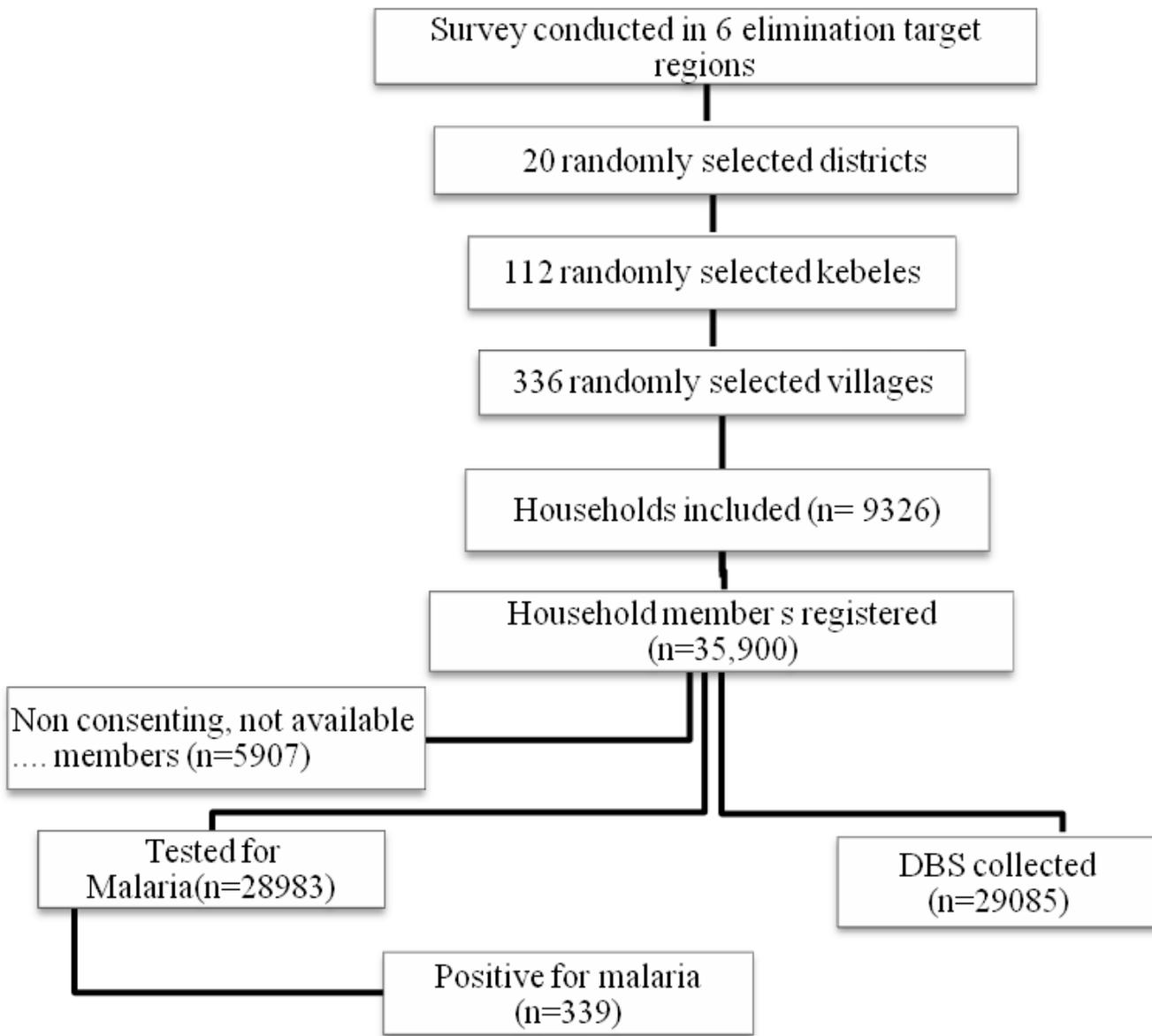
Figure 2

Framework of study participants. Malaria baseline survey in elimination targeted districts in Ethiopia, Oct-Dec 2018.