

Bedbug Infestation Affects Utilization of Long-Lasting Insecticidal Nets in Kola Shara, South-West Ethiopia: A Longitudinal Study

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Abstract

Background: Despite the social and psychological influences posed by bedbugs, so far there is no pest control to aver their public health impacts in Ethiopia. In addition, bedbugs are assumed to compromise the effective utilization of chemical-based malaria vector control like mosquito nets. However, there is a paucity of evidence on the influences of bedbug infestation on long-lasting insecticidal nets (LLINs) utilization in rural settings like Kola Shara, south-west Ethiopia.

Methods: A community-based longitudinal study was conducted between April and December 2017 in 330 households who obtained new LLINs. Socio-demographic, geolocation, bedbug infestation of LLINs and utilization status of the households was documented by trained data collectors. Descriptive statistics was employed to describe the findings.

Result: Bedbug infestation and the subsequent removal net varied among each round. Although varying from month to month, there was a consistent decline in the number of nets in use. During round one and round two 11.8% (39/330) and 15.4% (51/330) nets were not in place, respectively. Moreover, the number of nets removed during round three increased to 30.6% (101/330) and a slight reduction to 27% (89/330) during round four. Both corrugated iron and thatched tukuls roof types (93.4%, 256/274 versus 92.9%, 52/56) had similar prevalence of bedbug infestation during the baseline survey, April 2017. Prevalence of bedbug infestation was similar for both types of floors, 89.4% (245/274) in mud and (89.1% (50/56) with plastic. The proportion of LLINs infested by bedbugs has shown an increasing trend (81.8%, 270/330; 93.3%, 308/330; 92.1%, 304/330; 94.5%, 312/330) during Rounds 1, 2, 3 and 4, respectively.

Conclusion: The present study demonstrated the role of LLINs infestation by bedbug that not only discouraged its persistent utilization but also discarded too early in less than six months. It is recommendable to design integrated vector control options that address pests of public health significance for a collateral benefit in malaria control. Furthermore, similar studies might emphasize on varying epidemiological settings.

Background

The extensive deployment of long-lasting insecticidal nets (LLINs), indoor residual spraying (IRS) and effective case management using malaria rapid diagnostic tests (RDT) and artemisinin-based combination (ACT), over the last decade, has been instrumental in reducing malaria burden. Obviously, in Ethiopia, vector control particularly LLINs is considered as a cornerstone of malaria prevention and control [1]. Despite the tremendous role of LLINs in reduction of malaria mortality and morbidity upon achieving appropriate coverage and effective utilization, a study has shown its poor implementation is believed to be a potential threat to malaria reduction and ultimate elimination in Ethiopia [2–4].

In order to ensure effective utilization of LLINs, the researcher need to discern factors that account for hampering household level effective utilization in malaria endemic *kebeles*.

A recent qualitative study identified that bedbug infestation as a barrier to LLINs utilization in a malaria endemic *kebele* [4]. However, no detailed information was presented its effect. Another previous study also confirmed that above three fourths of the nets were thrown away after two years as obtained from a weekly follow for two years (2014–2017), the reasons contributing for low rates of utilization not described to guide in tackling those factors accordingly [5].

The influence of infestation by public health pests such as bedbug on chemical-based malaria vector control tools calls for epidemiological studies. Bedbugs are haematobious, usually sucking blood when people are asleep mainly during the night [6]. This small insect has social and psychological disturbance on humans. Allergic reactions and erythematous or popular urticarial like dermatitis, and subsequently result secondary infections like impetigo, ecthyma and lymphangitis in some people is worth noting [7, 8].

On one hand, LLINs have additional benefit in protecting pests like bedbugs besides their targeted significant protective effect on malaria vectors upon appropriate utilization [9, 10]. Possibly, this benefit is believed to play a vital role in improving community acceptance of LLINs for malaria vector control [11]. Nevertheless, the lethal dose to mosquito vectors appears not only ineffective to kill bedbugs and managed to reproduce and multiplied rapidly on nets [12, 13], but also irritates them to come out of their hide and actively feed on human. Although the resurgence of bedbug is documented, the reason why rises in resurgence of bedbugs infestations not yet well understood [14, 15].

On the other hand, previous studies showed that community acceptance and sleeping under a bed net affected by increased distribution of bedbugs [12]. In addition, bedbug infestations are challenging the successful implementation of LLINs of malaria vector control in malaria endemic countries, which ultimately compromise the goal of elimination [16]. Thus, investigating household level invasion of bedbugs and their effect on proper utilizations of LLINs and its potential challenges in achieving malaria elimination is worth discerning [17]. So far, there is a paucity information on the influences of bedbug infestation on effective utilization of LLINs in Ethiopia. Therefore, the aim of this study was to assess the bedbug infestation rate and its influence on LLINs utilization in rural settings of south-west Ethiopia.

Methods

Study area

The present study was conducted in Kola Shara *kebele* (longitude: 060, 05.407' and latitude: 0370, 34.043'), Arba Minch Zuria District (Fig. 1), which is located south-west Ethiopia and 490 Km away from Addis Ababa. *Kebele* is the lowest administrative unit and inhabited by approximately five thousand population in about one thousand households in Ethiopia. The total population of Kola Shara *kebele* is approximately 6,615 inhabitants (Unpublished 2016 report of Arba Minch Zuria District Health Office). It lies at an elevation of 1,226 meters above sea level and categorized as lowland *kebele*. The district is estimated to obtain 850 mm to 1,057 mm total annual rainfall. The mean minimum and maximum temperature of the *kebele* is 18 °C and 31 °C, respectively [18, 19].

Kola Shara is one of the malaria endemic *kebele* in the district. The residents rely on Harri River for agricultural activities using irrigation scheme. They cultivate crops like maize and fruits including banana and mango. Abundance of the permanent water body in addition to suitable climatic conditions in the *kebele* is presumably favoring mosquito abundance and consequently malaria yearlong transmission.

Study Design, Sample Size Determination And Sampling

A community-based longitudinal study was conducted from April to December 2017. Using a single proportion formula, sample size was estimated to be 330 households with the assumption of the proportion (P) of households loss there LLINs is $P = 0.50$, $\alpha = 0.05$ at 95% confidence interval with expectation of 10% withdrawal rate. Thus, 330 households were selected from the total number of households in Kola Shara *kebele* ($N = 1350$). Simple random sampling technique was applied to sample the households (Fig. 2). In order to recruit the required sample size, the probability proportion to population size (PPS) was employed from sub-villages in the *kebele*.

From June to August 2017, the research team started setting the study that consists of taking census, obtaining consent of the selected 330 houses for joining longitudinal survey. As part of setting the study the participants were requested to be willing to refrain from renovating their houses during the longitudinal survey. A tagged new LLIN was distributed to all households ($n = 330$). The unique identification number labeled on a round plastic coin tied on the corner of each net before distribution. The identification number was used for data entry of the four rounds of survey and analysis.

The LLINs distributed for the study were with a brand name 'PermaNet_2®', 75 deniers, 30 mg/m², 160 cm width, 180 cm length and 150 cm height (manufactured by Vestergaard, group S.A with batch No: 1 029(5) 15, Vietnam: Blue rectangular shaped, released on date 05/2015). The fabric of the nets was polyester coated with 1.8 mg/kg Deltamethrin, which was supplied and distributed by the National Malaria Control Program/Federal Ministry of Health of Ethiopia.

Data Collection

Data was collected from selected households regularly for four consecutive months between September and December 2017. Household heads or their representatives were interviewed using a structured questionnaire prepared for this purpose and pretested outside the study *kebele* but in adjacent localities. The questionnaire was prepared in Amharic and data collectors administered the data collection using local languages, Gamogna. Then, the investigator (YW) translated the data collected in Amharic back to English for analysis. Trained health personnel obtained demographic information and types of roofs and floors, of the households was obtained. The data collectors also recorded the geo-location of each household and status of newly distributed LLINs and bedbug infestation in each round.

The distributed nets were inspected for the presence of bedbugs once every month consecutively for a total of four rounds and the infestation status was recorded. The data collection took almost three days in each round. The data collectors observe and record the situation of the tagged net as well as those nets thrown away/discarded or not in place due to bedbug infestation in each round. All zones and panels of the nets were carefully observed and bedbugs infestation status as well as presence and absence of the nets were documented in the coded study households data sheet. The categorization of the LLIN zones and panels recommended by WHO (WHOPES: 2013) protocol for net evaluation is illustrated [20, 21]. Ten well trained health workers from the same community did the data collection.

Data Management And Analysis

The data was collected in a spread sheet questionnaire and also entered into smart phone application Open Data Kit (ODK) version 1.17.0 designed for this purpose. Then, data transferred to computer and analyzed using SPSS IBM Version 24 (SPSS Inc. Chicago, IL, USA). Descriptive statistics was employed to summarize data and interpret findings.

Ethical Considerations

This study obtained ethical approval from the Scientific and Ethical Review Office (SERO) of the Ethiopian Public Health Institute (EPHI) (Ref: EPHI-IRB-002-2017) and Arba Minch University College of Medicine and Health Science (Ref: AMU-IRC CMHS/5380/29). The participants gave informed consent and individual data kept confidential. In addition, discussion was held with *kebele* local health authorities and obtained support letter to undertake the present study.

Result

Demographic Characteristics

The mean age (\pm SD) of the study participants was 44.5 (\pm 15.5) years and range from 18 to 64 years. Most of the participants were males (70.6%, 233/330). More than half (55.5%, 183/330) of them were below 45 years. About half (42.1%, 139/330) of the respondents have no formal education and the rest 18.2%, 18.8% and 20.9% were accounted by who attended formal education including elementary, grade 5–8 and secondary, respectively. Almost eight out of 10 and nine out of 10 of the participants were farmers and married, respectively. Some of the households had children below five years old (15%, 49/330) and a few pregnant women (3% (9/330)). Most of the roof types of the households surveyed were covered with corrugated iron (83%, 274/330) and the rest were thatched tukuls (17%, 56/330) (Table 1).

Table 1
Sociodemographic characteristics of household heads (n*=330) in Kolla Shara *kebele*, south-west Ethiopia, April, 2017.

Characteristics		Frequency (percentage)
Sex	Male	233 (70.6)
Age (years)	18–34	91 (27.6)
	35–44	92 (27.9)
	45–54	70 (21.2)
	55–64	77 (23.3)
	Mean age (\pm SD)	44.5 (15.5)
Educational Status	No formal education	139 (42.1)
	Elementary (Read and Write, Grade 1–4)	60 (18.2)
	Grade 5–8	62 (18.8)
	Secondary (Grade 9–12 and above)	69 (20.9)
Occupational Status	Farmer	263 (79.7)
	Merchant	26 (7.9)
	Daily Laborer	21 (6.4)
	Others (Student, NGO and Fishermen)	20 (6.1)
Marital status	Married	296 (89.7)
	Single	21 (6.4)
	Other (Divorce and Widowed/r)	13 (3.9)
*: Total house hold visited		

Proportion of bedbug Infestation

LLINs Utilization

Bedbug infestation and the subsequent removal net varied among each round. Although varying from month to month, there was a consistent decline in the number of nets in use. During round one and round two 11.8% (39/330) and 15.4% (51/330) nets were not in place, respectively. Moreover, the number of nets removed during round three increased to 30.6% (101/330) and a slight reduction to 27% (89/330) during round four (Fig. 3).

In addition, the frequency of absence nets during each round showed some variability. Overall, about two-thirds (62%, 204/330) of nets were not available once from four rounds, while some of them (38%, 126/330) were available throughout the four rounds of the survey period (data not shown).

More detailed information is available for 204 nets that are absent in one of or in all surveys. Most of the net (71%, 146/204) were not available in one round, while about a quarter (24%, 49/204) were not available in two rounds. Otherwise, only a net was not available throughout four rounds and eight in three rounds (data not shown).

Types of roofs and floors

Both corrugated iron and thatched tukuls roof types (93.4%, 256/274 versus 92.9%, 52/56) had similar prevalence of bedbug infestation during the baseline survey, April 2017. Prevalence of bedbug infestation was similar for both types of floors, 89.4% (245/274) in mud and (89.1% (50/56) with plastic (Table 2).

Table 2

Trend of Bedbug infestation in different house structures in Kolla Shara *kebele*, south-west Ethiopia, April – December 2017.

Characteristics		Percentage of bed bug infested houses (n = 330)				
		Baseline	Round 1	Round 2	Round 3	Round 4
		% [95%CI]	% [95%CI]	% [95%CI]	% [95%CI]	% [95%CI]
Infestation rate		94.55% [91.49, 96.55]	81.82% [77.26, 85.63]	93.64% [90.42, 95.82]	92.12% [88.66, 94.59]	94.54% [91.49, 96.54]
Roof type	Corrugated roof (n = 274)	94.89% [91.53, 96.96]	82.48% [77.48, 86.56]	94.89% [91.53, 96.90]	91.60% [87.65, 94.37]	94.89% [91.53, 96.96]
	Tukul houses (n = 56)	92.86% [81.99, 97.38]	78.57% [65.49, 87.63]	92.85% [81.99, 97.37]	94.64% [84.17, 98.32]	92.85% [81.99, 97.37]
Floor type	Mud floor (n = 267)	95.88% [82.68, 97.71]	83.89% [78.95, 87.85]	95.88% [92.68, 97.71]	92.13% [88.20, 94.83]	95.88% [92.68, 97.71]
	Cemented floor (n = 48)	87.5% [74.24, 94.44]	72.29% [58.17, 83.89]	87.50% [74.24, 94.44]	93.75% [81.69, 98.05]	87.50% [74.24, 94.44]
	Wood (n = 7)	85.71% [25.67, 99.05]	57.14% [15.04, 90.93]	85.71% [25.67, 99.04]	85.71% [25.67, 99.04]	85.71% [25.67, 99.04]
	Plastic covered floor (n = 8)	85.71% [25.67, 99.04]	87.50% [31.94, 99.05]	100%	87.50% [31.94, 99.05]	100%

Similarly, (89.1%, 244/274) corrugated roof and with thatched tukul houses were infested with bedbugs after four months (Table 3).

Table 3
Bed bugs
infestation
of LLINs
in each
round visit
in Kolla
Shara
kebele,
south-
west
Ethiopia,
April -
December
2017.

There was already high proportion of nets infested by bedbugs during the base line (80.9%, 267/330). The proportion of LLINs infested by bedbugs has shown an increasing trend (81.8%, 270/330; 93.3%, 308/330; 92.1%, 304/330; 94.5%, 312/330;) during Rounds 1, 2, 3 and 4, respectively (Table 3). In addition, bedbug infestation was not limited to LLINs during each survey. Bedbugs infested different parts of the houses like sides of the bed and chairs but with low prevalence compared to sleeping places (data not shown). Most of the bedbugs were crowded on *Zone One* (the side that touched and sewed together with the top side of net and on top of rectangular side of LLINs [20]).

Discussion

The present study made an attempt to draw attention of malaria program and public health authorities in addressing household barriers possibly threatening the effective utilization of LLINs in malaria endemic *kebeles*. This study unraveled that bedbugs, predominant public health pests, refuge themselves or trapped in the nets after feeding on human that subsequently forcing the users to discard even newly distributed nets within the first six months starting from the two months period. From the field observation held regularly, bedbugs mostly seclude themselves in certain sites of the nets particularly at each corner, i.e., where the sides of the nets join and sewed. Briefly, bedbug infestation of nets and subsequent multiplication in a certain period of time is known to provoke the community to discard their nets intended to serve longer.

The longitudinal field evaluation approach not only generated evidence on continuous declining of the proportion of nets hanging for proper utilization but also methods of estimating nets lost each month before a year. Nevertheless, an LLIN is supposed to serve for three years before it is replaced unless damaged. The present study demonstrated a need for comprehensive and integrated vector control approach that embrace pest control into account in malaria endemic *kebeles* like Kola Shara *kebele*. The present study faced some caveats similar to other observational studies. First, resistance patterns to the chemical; as performed elsewhere [22, 23], particularly for the dose recommended to impregnating LLINs was not determined for the bedbug species collected in the present study. This information would have helped us to comment on the simultaneous effect of nets in killing bedbugs to ensure community acceptance. From the field observation of the investigator, it appears that bedbugs require either another

dose for effective pest control or improving housing conditions. Second, prevalence of malaria in the study *kebele* was not simultaneously estimated during the longitudinal study, particularly the infection status for those households that discarded the nets. Finally, the types and status of walls for the houses were recorded and comparison was done. Although the type and status of the walls were documented during the survey, it was not considered in the analysis almost all type of walls had similar pattern in their appearance and cracks that favored the hiding of the bedbug. However, this study employed strong methodological approach, longitudinal study, through engaging local health workers and managed to generate monthly household level information that has never been available. Therefore, the present finding is informative to partly answer questions like 'why net utilization has never been improved' in the last decade [4, 5]; despite the blanket coverage of nets freely available to households in endemic *kebeles* through the support of global fund grants. So far, there was limited attention in exploring the household factors that compromise net utilization and high attrition rate on monthly basis [3–5]. Thus, confidently, the present finding shade light on the effects of bedbug infestation on the proper utilization of nets.

The current study revealed that a certain proportion of the nets were discarded every month with an increasing trend, reaching three-folds during the last survey compared to the first one. In harmony with this study, although household reasons for attrition of nets was obscure, high rate of net loss was documented in central-Ethiopia. Only below one out of ten (90% lost) of the nets were available at the household after two years weekly follow up [5].

The present study also reported the proportion of nets absent during one round was 21% (69/330). The absence of nets most frequently in a household is probably predisposing the family members, especially susceptible groups to malaria. Although a study mentioned that bedbug jeopardize persistent net utilization or barrier to net users [3–5, 12], another study that focused on Bedbug containment practices [9, 13], no detailed evidence available on the magnitude of the Bedbug versus net utilization.

More interestingly, therefore, the finding of the present study might contribute as a base line data for improving malaria vector control through prioritizing household barriers like Bedbugs, which are pests of public health significance worth noting.

Studies revealed the benefit of proper utilization of LLINs apart from protecting malaria vectors has also additional relevance in avoiding bedbugs bite and infestation [9–11]. The present study found that between eight and nine out of ten (87.7%, 289/330) surveyed LLINs were infested by bedbugs. A certain proportion of LLINs were observed to be discarded every month with the perceptions that nuisance effects and blood sucking of the bedbugs is more pronounced than persistent use of nets for malaria vector control. This discrepancy may be due to the differences in geographical areas [9, 11].

The findings of the present study showed that the community considered application of LLINs can cause increase bedbugs infestation in their houses. Similarly, some community members perceived bedbugs infestation can be a result of mosquito nets that LLINs tends to cause an increase in frequency of bedbugs even if in different wall and floor structures. A previous study shows that as a bedbug can

contribute on less utilization of LLINs [11, 22]. This most likely bedbug infestation makes a public health problem in the study *kebele*.

This study revealed that people are more bitten and annoyed by bedbugs rather than a mosquito. The present study found that bedbug infestation was not related with poor sanitation, but difference was observed between studies in Ethiopia [24]. Present study showed that most of the (62.20%, 205/330) invasions of bedbugs were observed in and around sleeping spaces. This finding is in agreement with a previous report from Iran [25]. On the other hand, sleeping under a bed net infested with bedbug was impeding the acceptability and use of malaria preventive measures [22, 26].

Infestations of the houses by bedbugs showed increased from (81.82%, 270/330) to (94.55%, 312/330) in this study. But it was in contrast to study in southern Ethiopia [9]. The findings of this study suggested that LLINs impregnated with Deltamethrin cannot contribute to the reduction of bedbugs in infested houses of Kola Shara Village. Similar reported were found elsewhere [22–24].

Conclusion

The present study demonstrated the role of LLINs infestation by Bedbug that not only discouraged its persistent utilization but also discarded too early in less than six months. Although further entomological investigation is required in various parts of the country and seasons of the year, maximum benefit from LLINs is obtained upon integrating pest control with public health interventions for old diseases like malaria with well-developed vector control approach. It is recommendable to design integrated vector control options that address pests of public health significance for a collateral benefit in malaria control. Furthermore, similar studies might emphasize on varying epidemiological settings.

Abbreviations

LLINs

Long Lasting Insecticidal Treated Nets, IRS:Indoor Residual Spraying, ACT:Artemisinin-based combination Therapy, ODK:Open Data Kit, SERO:Scientific and Ethical Review Office, EPHI:Ethiopian Public Health Institute.

Declarations

Authors' contributions: YW, FM and TW conceived and designed the study, YW designed data collection tools facilitated the data collection and did the data collection. YW, AW, HM and TW analyzed and interpreted the data and drafted the manuscript.

Author details: YW, AW and HM host in Ethiopian Public Health Institute (EPHI) and TW and FM host in Arba Minch University college of Natural Science.

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Competing interests: The authors declare that they have no competing interests.

Availability of data and materials: The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication: Not applicable.

Ethics approval and consent to participation: Ethical approval obtained from the Scientific and Ethical Review Office (SERO) of the Ethiopian Public Health Institute (EPHI) with protocol number: EPHI-IRB-002-2017 and in addition, ethical approval attained from Arba Minch University college of Medicine and Health Science: AMU-IRC CMHS/5380/29.

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Figures

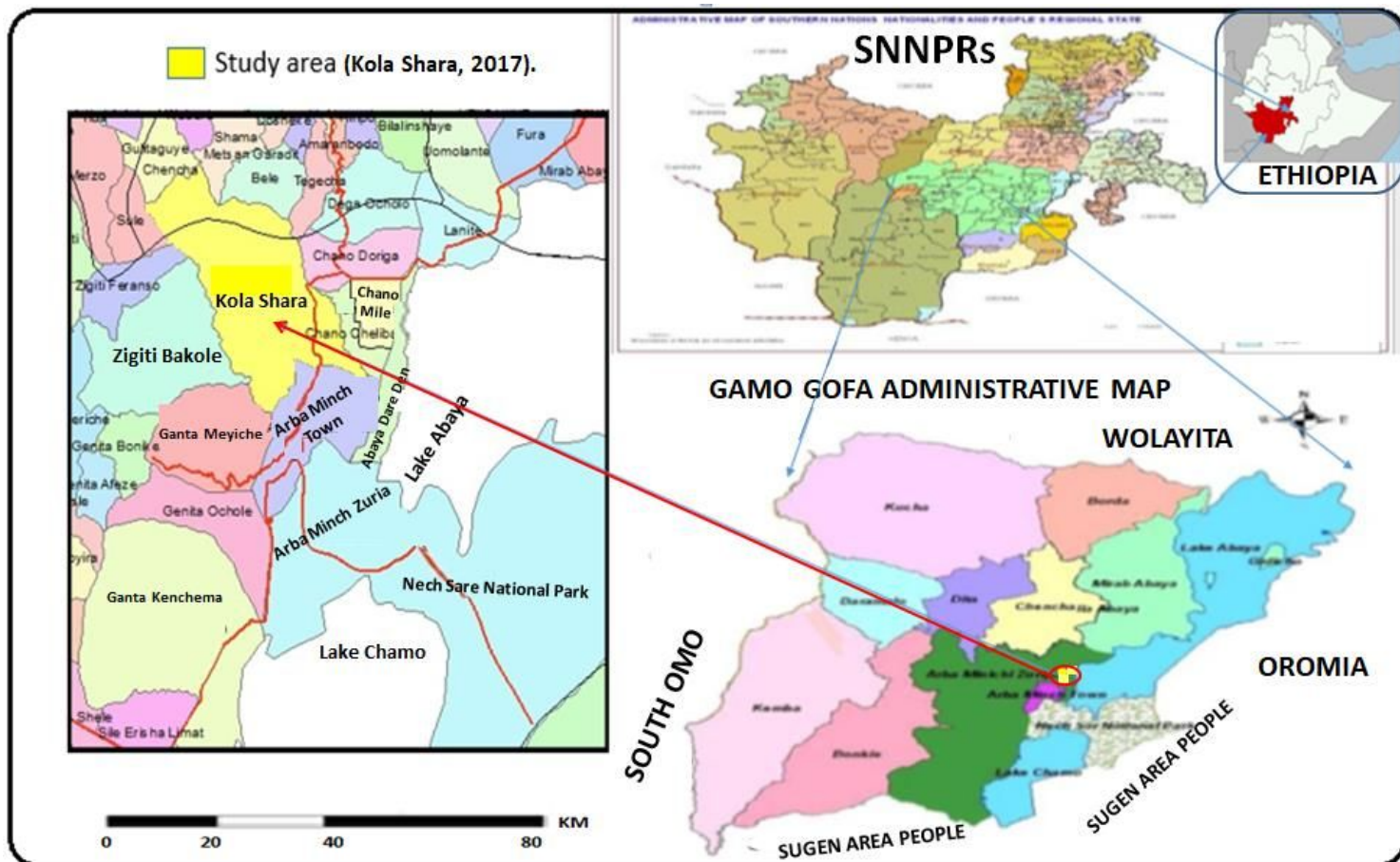


Figure 1

Map of the sample collection area, Kola Shara kebele, Gamo Zone, south-west Ethiopia.

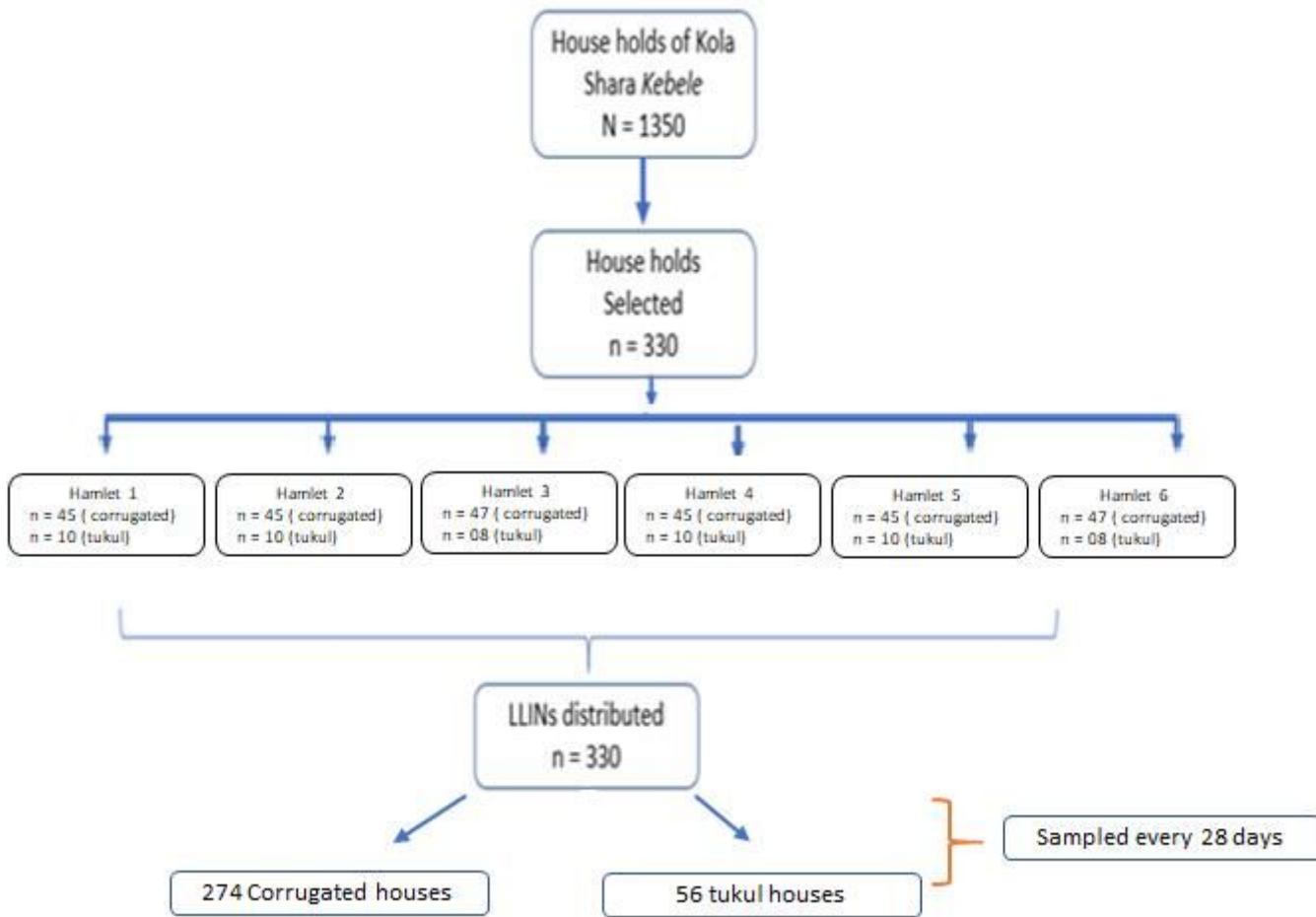


Figure 2

Data collection scheme based on proportion to population sample size, April-December 2017.

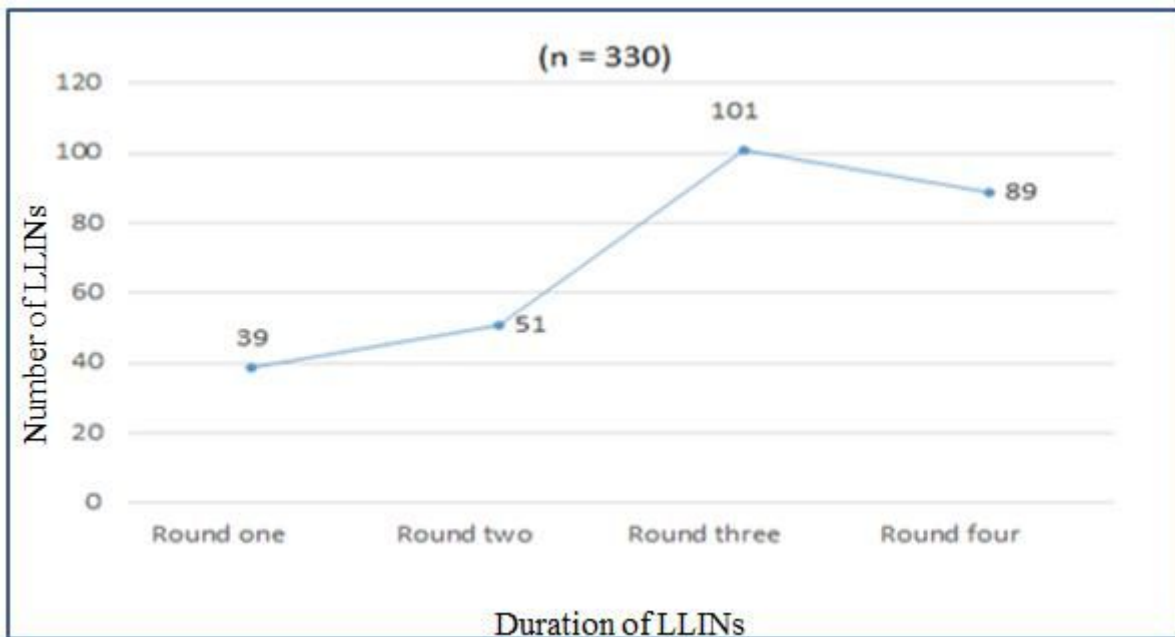


Figure 3

LLINs infested by Bedbugs and not in place during each visit at Kolla Shara kebele, south-west Ethiopia, April-December 2017.

Supplementary Files

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

- [Supplement1Uniqueidentificationnumberandtagging.docx](#)
- [Supplement3ZonesandpanelsofLLINs.docx](#)
- [Supplement4BedbugsonLLINszones.docx](#)
- [Supplement2ThatchedTukulandcorrugatedironhouses.docx](#)