

Assessing longevity of long lasting insecticidal nets in some selected sentinel sites of Ethiopia

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Abstract

Introduction: Long-lasting insecticidal nets are conventional tools in the prevention and control of malaria. Survey information on monitoring longevity of long-lasting insecticidal nets under field conditions is important for insecticide resistance monitoring and management in the country.

Objective: The current study aimed at evaluating the effective life time of long lasting insecticidal treated nets under operational conditions.

Materials and Methods: A cross-sectional study was conducted from January 2016 to December 2017 in Oromia, Amhara, Tigray and Southern Ethiopia regions on a total of 1416 randomly selected households owning Magnet, PermaNet 2.0 and Interceptor nets. Two years old long-lasting insecticide nets were examined for their physical status, bio-efficacy and chemical analysis.

Results: Community net utilization was 75.7% and the proportional hole index of Magnet, PermaNet 2.0 and Interceptor nets were 24.2, 21.7 and 21.6, respectively. The mean mosquito knock down and mortality rates for Magnet net were 93.5% and 95.1% respectively. Mean knock down and mortality rates for PermaNet 2.0 were 85% with 87% while mean mosquito knock down and mortality rates for Interceptor were found to be 96% with 92.3%, respectively. The mean knockdown for all different type of net was 91.8% and the mortality rate was 91.75%. The mean concentrations of deltamethrin on Magnet and PermaNet 2.0 were 362.41 mg/m² and 377.2mg/m² respectively. Concentration of Alphacypermethrine in the Interceptor was 2627 mg/m².

Conclusion: The current study revealed that, community net utilization was low while, the physical integrity and insecticidal activities of all net types were found to have acceptable protection after two years of use. Additional study should be required after two years on durability of long-lasting insecticidal nets.

Key words: Net integrity, net utilization, durability, long lasting insecticidal nets, proportional hole index.

Introduction

Long-lasting insecticidal nets (LLINs) are important tools in the prevention and control of vector-borne diseases, especially malaria and recommended to be used by all population at risk of vector borne diseases (Massue et al. 2016). LLINs are designed to provide physical and chemical protection for those who sleep under it (Dutta et al. 2018). Personal protection is one of the good strategies in malaria control using bed nets and other vector control methods targeting adult mosquitoes. Though the mosquitoes find entry into the nets through holes, endemic areas with malaria need to use such preventive measures without interruption (Acharya and Acharya 2015). This physical barrier of the net was supplemented with modern synthetic pyrethroids lasting long deposits (Eng et al. 2015). In malaria endemic regions, especially in several African settings, malaria incidence and death has been reduced by ITN (Dutta et al. 2018). Large scale distribution of LLINs to achieve universal coverage has been associated with highly successful malaria control outcomes (Hakizimana et al. 2014). LLINs have a relatively uniform life span of about 3 years and retain its effective biological activity without retreatment. The link between the physical condition of an LLIN

and the malaria protection provided by the tool is complex, not well understood because of many reasons (ALMA 2016). As to current WHO recommendation, the replacement cycles of LLINs should be planned every 3 years. Information on durability of LLINs is an important tool to understand whether they are functional in terms of physical integrity and biological activities as this will help for further net procurement decisions and replacement cycle. This confirms that the service life span of LLINs for national malaria control programs through improving available information. Thus, information is required to ensure the quality maintained with better informed decision about the most appropriate products for different settings, supporting more accurate planning for universal coverage and to increase the cost effectiveness. In Ethiopia, various studies have been conducted with respect to coverage and utilization of LLINs in different parts of the country (EPHI 2016). However, there is a scarcity of data on evaluation of the effective duration, retention and efficacy of LLINs which enables programs to optimize LLINs operations. Information is also needed to formulate a desired strategic framework for

further scaling up the coverage and for evidence-based decision on replacement cycle/period of LLINs. Thus, this study was conducted on three products of nets, alpha-cypermethrin incorporated into polyethylene, alpha-cypermethrin and deltamethrin coated on polyester under field and laboratory condition at different socio-demographic settings in Ethiopia.

Materials and Methods

Study setting: The study was conducted from January 2016 to December 2017 during major and minor malaria transmission seasons in four districts (Wondo Genet, Jabitehnan, Medebay Zana and Mirab Abaya) of Ethiopia. The study regions were Oromia, Amhara, Tigray and Southern Ethiopia (SNNPRs) which represents different environmental and cultural settings in the LLINs mass distributions. The study sites were selected based on epidemiology of malaria, LLIN distributed to local households and accessibility. Households or the study units and sampling frame in the four sentinel sites (districts) were mapped with the number of households per sentinel sites ranging from higher region to lower kebele. List of households with LLIN aged between 24 and 36 months were received. Systematic random sampling method was used to select the study units, households. The sample size was determined using 95% confidence interval which yielded 354 households for each region, totally 1416 households for all. Sample size calculation was based on the proportion of households in malaria endemic areas in Ethiopia who had at least one insecticide treated mosquito net (64%), ($p = 0.64$), according to the 2015 Ethiopia malaria indicator survey (EPHI 2016).

Procedures

Questionnaire: A total of 1416 heads of households willing to participate in the study were interviewed. A semi-structured questionnaire was administered to collect information on the household demographics, history of the net, use and care of LLINs, type of sleeping materials they used under the net and housing condition.

LLINs collection: LLINs were collected from selected households of each sentinel site in four regions for physical status inspection, bioassay and chemical analysis. During collection, new LLIN was provided to each selected household in exchange of the LLINs used for the study. The age and types of the net was recorded at the time of collection based on the information gained from the Health Center in the specific district.

LLINs physical status /Integrity Evaluation: The physical status inspection of LLINs was undertaken according to the WHO Guidelines (WHO 2011). Of

the LLINs found in the selected households, a single net was randomly selected to count and measure the size of holes at each position. Each LLIN sampled was hung up from the four corner points and examined for the hole appearance and size. Hole categories were designed to be easily and accurately measured under field conditions and were weighted as 1, 23, 196 and 578 respectively. The number of holes in each category were multiplied by the category weight and expressed as a proportionate hole index (PHI) following the WHO hole category (WHO 2013). The measurements of hole or tear height and width on the net were recorded in centimeters at different parts or location (upper, middle, lower and seams) of the net.

Cone bioassay: Cone bioassays were performed according to World Health Organization guidelines (WHO 2011). 30 nets were randomly selected from each sentinel sites. From each type of LLINs collected, four pieces 25cm by 25 cm in size with two replicates were cut from four sides of the net using sharp scissors. The test was conducted using susceptible *Anopheles arabiensis* strain. Five non-blood fed 2–5-day old female *An. arabiensis* were exposed to each net section for 3 minutes at temperature of $25 \pm 2^\circ\text{C}$ and relative humidity of $70 \pm 10\%$. Testing was conducted over a series of days. Untreated net obtained from the local market was used as a control (FMHACA or market). The mosquitoes, from both the test and the control, were then transferred to holding cups for a period of 24 hours and mosquitoes were provided with 10% sugar solution in the form of soaked cotton. Mosquitoes knocked down and mortality was recorded at 60-minutes and 24h post exposure respectively.

Chemical analysis: Following the cone bioassay, sixteen subsamples per LLIN type were cut 30cm by 30 cm according to WHO guideline (WHO 2011). The nets were rolled up with aluminium foil; labeled and stored at 4°C prior to chemical analysis. Chemical analysis was conducted in Adami Tulu pesticides processing share Company's laboratory. The data were calculated for each insecticide that shows the chemical concentration available within 2 years of service period.

Data Analysis: Generalized Linear Model with a negative binomial distribution was employed to analyze the differences in the physical condition of nets over time. The net damages were compared through calculating Proportional Hole index (PHI). Hole size category was estimated at 1–4 and holes were counted from the roof, upper, middle and seam of each net. Total mean hole size was calculated to compare which position more vulnerable to tear or hole. LLIN condition was classified as “good” condition ($\text{PHI} = 0-64$), “acceptable” condition ($\text{PHI} = 65-642$), and “torn”

(PHI= 643+). The bio-efficacy of nets was determined by cone test. All distributed nets in all districts were the same age category, i.e. two years. So that the comparison was done between the regions considering different insecticide class and community settings. According to WHOPES guidelines, LLINs should remain effective if knock down is >95% after 60 minutes or if mortality is >80% 24h post exposure for a minimum of three years under field condition (WHO 2005). All analyses were carried out using Statistical package for social sciences (SPSS) software (version 20) with 0.05 level of significance. The study protocol was reviewed and approved by the Ethiopian Public health Institute (EPHI) Institutional Review Board (IRB) and verbal or written consent was obtained from the study participants before the commencement of the study.

Results

Physical or integrity status: A total of 1416 LLINs with different ages confirmed by batch numbers and

date of hanging were evaluated about their physical status and integrity. Of the LLINs samples, 120 LLINs were analyzed for residual concentration. Since the ages of all nets were the same, the median age was 2 years. The majority of LLINs (75.7 %) were used for sleeping and 22.6% of LLINs had holes from all assessed.

From all physically evaluated, the total numbers of holes at each size with respective positions were calculated and presented in Figure 1. For all physical status evaluated nets, the summed holes count at size 1 ($p < 0.001$) were 37 on roof, 37 on upper and 34 on lower; at size 2 ($p > 0.001$) were 21 on roof, 38 on upper and 26 on lower; at size 3 ($p > 0.01$) were 15 on roof, 16 on upper and 24 on lower and at size 4 ($p > 0.01$) were 10, 8 and 16 on roof, upper and lower position respectively. From all inspected physical status of the LLINs for the presence of hole, seams positions were found to be free of any hole/tears.

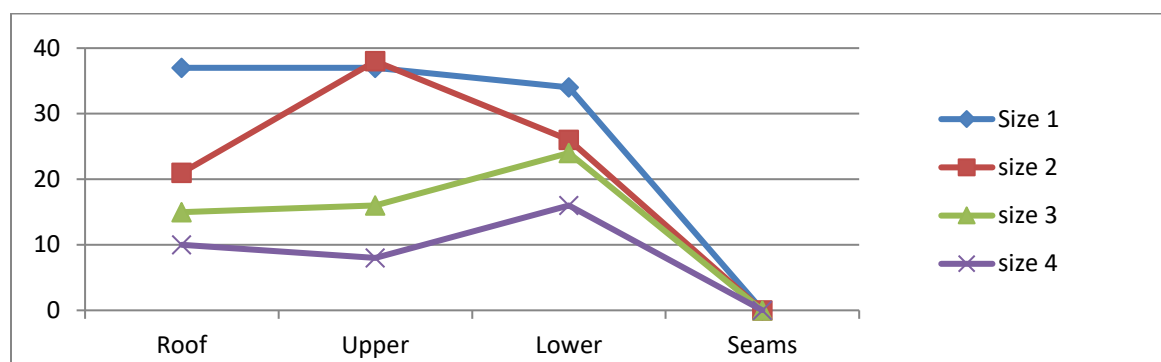


Figure 1: Physical condition/status of the long lasting insecticide nets (LLINs)

The summed physical status result of the nets by insecticide classes was presented. There was no significant difference of percentage at size category of all nets in different community settings (Table 1). The percent values of holes at each size category were found to be below 10% and had been decreased from size 1 to size 4 after two years of services. The total

number of holes and median number at size 1, size 2, size 3 and size 4 (WHO size category) were 108 (7.8), 85 (7.22), 55 (7.52) and 34 (12) respectively. The number of holes counted in different brands of nets were summed with their proportional hole index (pHI) weighed according to WHO guideline hole size category (WHO 2011) (Table 1).

Table 1: Number and percentage of hole by net type

Net type	Measurement	Size 1 n (%)	Size 2 n (%)	Size 3 n (%)	Size 4 n (%)	Total (%)
Magnet® Net	n (%)	49 (6.92)	37 (5.22)	24 (3.39)	20 (2.82)	130 (18.36)
	Weighed	49	851	4704	11560	17164
	pHI	0.07	1.202	6.64	16.33	24.242
Permanet® 2.0	n (%)	51 (14.41)	28 (7.91)	15 (4.44)	7 (1.98)	101 (28.53)
	Weighed	51	644	2940	4046	7681
	pHI	0.14	1.82	8.30	11.43	21.69
Interceptor®	n (%)	8 (2.26)	20 (5.65)	16 (4.52)	7 (1.98)	51 (14.41)
	Weighed	8	460	3136	4046	7650
	pHI	0.023	1.3	8.86	11.43	21.61

WHO pHI formula is = (size 1 hole's x 1) + (size 2 holes x 23) + (size 3 holes x 196) + (size 4 holes x 578) to categorize the physical integrity of nets. Based on pHI value, LLINs were assigned to one of the following WHO categories: "good" (pHI ≤ 64), "damaged" (pHI = 65–642) and "too torn" (pHI ≥ 643). The pHI calculated for Magnet, PermaNet 2.0 and interceptor were 24.24, 21.7, and 21.6 respectively (Table 5). The medians of each net class, Magnet, PermaNet 2.0 and Interceptor were 7, 5.5 and 3.5 respectively. The comparisons for each type of nets were also measured according to their size category

(Figure 2). The numbers of holes for Magnet were 49, 40, 29 and 22; PermaNet 2.0, 51, 29, 21 and 8; Interceptor, 7, 19, 19 and 24 at size 1, 2, 3 and 4, respectively. The overall number of holes for Magnet, PermaNet 2.0 and Interceptor net appeared at any size was 141, 109 and 69, respectively. The significance and values difference interaction at each hole size category (Table 2) was significantly varied for overall LLINs. The most reasons for appeared hole on the net were torn or split when caught on an object, burning and animals (Table 5).

Table 2: Characterizations of hole interaction values with LLINs respective size category

	df	Mean Difference	P value
Number of Holes at size 1	25	11.25	>.0001
Number of Holes at size 2	25	8.71	>.001
Number of Holes at size 3	15	5.98	>.01
Number of Holes at size 4	12	6.42	>.01

Cone bioassay: Three LLIN types: Magnet, PermaNet 2.0 and Interceptor were subjected to WHO cone bio-assay against the primary malaria vectors (*Anopheles arabienesis*). The minimal residual bio-efficacy was observed by mosquito knock down and mortalities of the nets. The pooled bio-efficacy of all net types was observed in each position with two replicates. Knock down rate (KDR) after 1hour at position 2 was found to be 91% with 94.3% mortality rate after 24hour post exposure. Regarding position 3, the knock down result after 1hr was 93% and 94.5% mortality after 24hr post exposure. Position 4 and 5 knock down rates were found to be 94.33% and 95.67% respectively with the mortality rate 96.5% at position 4 and 94.83% at position 5. Knock down and mortality rate (MR) of each individual nets were tested

at their respective position (P), 2, 3, 4 and 5 were 84.33%, 83.7%, 87% and 85% and 86.7%, 84%, 88.3% and 89% for PermaNet 2.0, 94%, 94.7%, 98.33% and 96.33% and 90%, 91.67%, 93.7% and 94% for interceptor net and the magnet net result of knock down and mortality were above 90% and 95% respectively at each position (Figure 3). Though the insecticide classes in each position indicated different results, the knock down and mortality rate of the different nets were not varied significantly ($p < 0.001$) when compared by regions. Bio-efficacy observation was not observed at position 1 (P1), because it is not used for protection rather than tacking under the bed and contagious because of contact while it is found at the lower part of the net.

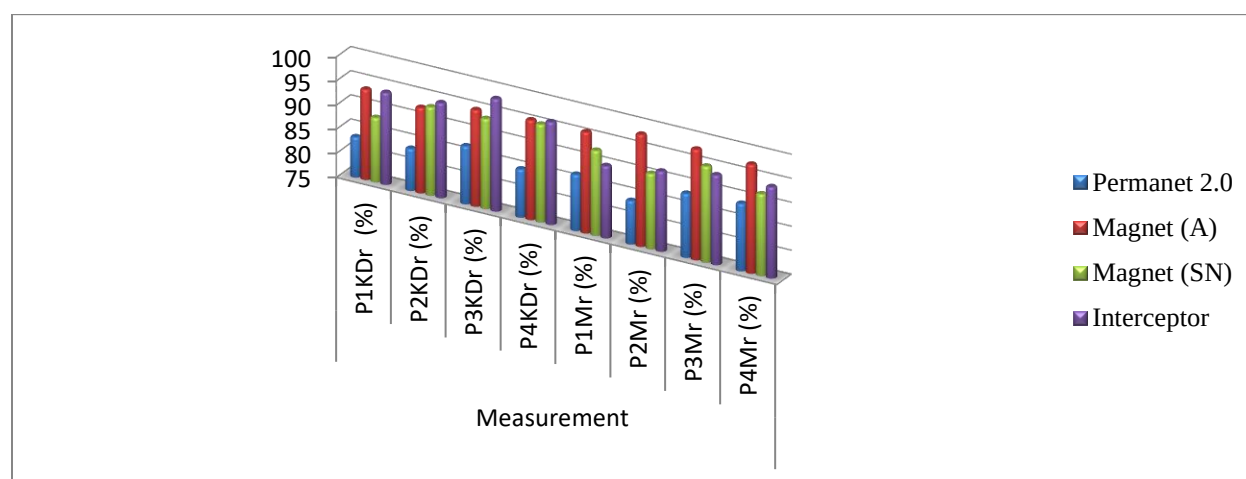


Figure 2: Pooled results at each position with two replicate for each types

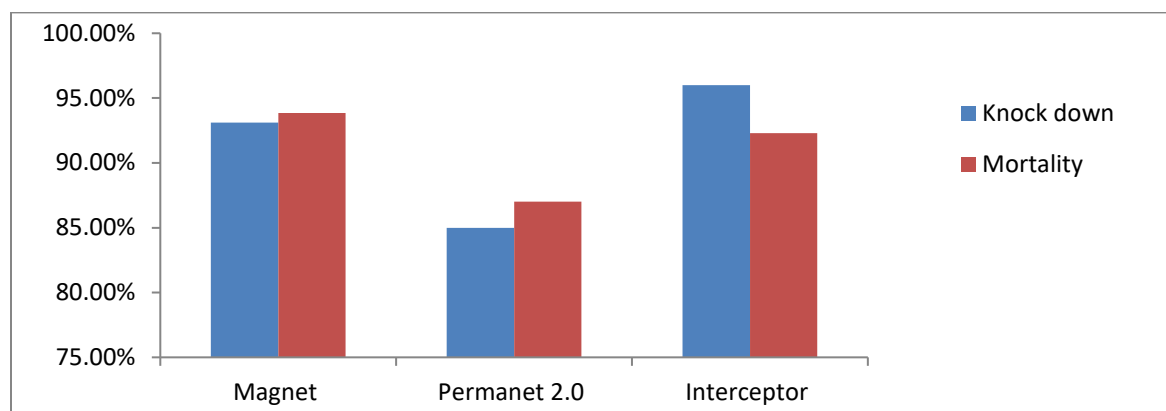


Figure 3: Pooled results in percent for Cone Bioassay for both Knockdown and mortality of each net type

The overall results of the insecticidal activity of all nets regarding knockdown after 60 min and mortality after 24 hours from the cone bio-assays against *An. arabiensis* (Figure 1) were observed. Mortality for the magnet was 95.1% while the mortality for PermaNet 2.0 was 87%, and for interceptor net was 92.3%. According to the result of two years used nets, the risk of mosquito death was increased significantly when compared to mosquito exposed in untreated nets as

control. The knock down and mortality percent of PermaNet 2.0 was found to be less than other LLINs. PermaNet 2.0 passed WHO cut off point with mortality but, the knock result was less than 90% which was fail to pass the criteria of WHO with all significance values (Table 3). The overall mean (df = 15, *P value* = 0.000) difference knock down and mortality rates for all nets were 275.763 (91.825%) and 277.013 (92.304%) respectively.

Table 3: Bioactivity of insecticide on each net on the *An. arebiensis*

	df	Mean Difference	F	P value
Knock down rate	15	275.76	22.054	<.001
Mortality rate	15	277.01	22.990	<.001
Knock down %	15	91.82	22.251	<.001
Mortality %	15	92.30	22.990	<.001

Chemical Analysis: Insecticide concentration of 2 years old 64 different nets from all study sites were measured using HPLC. The product types measured were alpha-cypermethrin incorporated into polyethylene and alpha-cypermethrin and Deltamethrin coated on polyester. The average

insecticide concentration of Magnet net in Amhara region and SNNPRs was 202.41 mg/m² and Permanet 2.0 from Oromia was 377.2mg/m² at two replicate each position designation of the Piece net. An available chemical on interceptor net from Tigray region was 2627 mg/m² (Table 4)).

Table 4: Concentration of insecticides on each LLINs surface area

Net Type	Area of sample in (m ²)	Available chemicals in mg/m ²	Number of nets
Magnet	1 *10 ⁻²	202.41	32
Permanet 2.0	1*10 ⁻²	377.2	16
Interceptor	1*10 ⁻²	2627	16

Of tested net classes, only interceptor nets showed concentrations more than the 1000 mg/m², indicating that the decrease of these other net's chemicals were

due not a lack of sufficient insecticide, but rather to other different factors with bio-availability of theinsecticide on the surface of the net fibre.

Table 5: Characterizations of factor associated with net durability by net type and use status by the community

N = (1416).		Magnet N = 708, Permanet 2.0 and interceptor = 354		N (%)
Characteristics		Net type		
		Magnet	Permanet2.0	Interceptor
House type	House with separate bedroom and kitchen	671(94.8%)	297(83.9%)	249(70.3%)
	Tukul with kitchen /bedroom together	37(5.2%)	57(16.1%)	105(29.7%)
Total		708 (100.0%)	354 (100.0%)	354 (100.0%)
Use of the net in the House		570 (80.5)	253 (71.5)	274 (77.4)
Reason why the net is not ever being used	Net was damaged and thrown away	101 (14.3)	82 (23.2)	53 (15)
	Net was given away to others	6 (0.8)	1(0.3)	7 (2)
	Net was stolen	1 (0.1)	0	1 (0.3)
	Net was old	0	0	4 (1.1)
	Net was being used in other location	11 (1.6)	9 (2.5)	2 (0.6)
	Net was being used for other purposes	17 (2.4)	7 (2)	13 (3.7)
	Total	136 (19.4)	99 (28)	80 (22.7)
The time duration of the net not available for sleeping	0-6 months	55 (7.8)	42 (11.9)	31 (8.8)
	Full 6 months	82 (11.6)	59 (16.7)	49 (13.8)
Total		137 (19.4)	101 (28.6)	80 (22.8)
Last night used net for sleeping		569 (80.4)	254 (71.8)	273 (77.1)
Reason why the net used last night	The net is Too hot because of the smell	66 (9.3)	47 (13.3)	23 (6.5)
	Feel closed in	7 (1)	2 (0.6)	1 (0.3)
	Absence of malaria	8 (1.1)	0	3 (0.8)
	Absence of mosquito	9 (1.3)	9 (2.5)	8 (2.3)
	The net is too torn/old	14 (2)	5 (1.4)	13 (3.7)
	The net is not available	6 (0.8)	3 (0.8)	5 (1.4)
	Total	38 (5.4)	27 (7.6)	26 (7.3)
	Duration of the net used to sleep under	148 (20.9)	93 (26.7)	79 (22.3)
	All the year	437 (61.7)	272 (76.8)	230 (65)
Other places used for sleeping from the main hoses	Only the rainy season	266 (37.6)	78 (22)	95 (26.8)
	Only the dry season	5 (0.7)	4 (1.1)	29 (8.2)
Type of sleeping place with the net cover	Field	12 (1.7)	5 (1.4)	1 (0.3)
	Beach	6 (0.8)	6 (1.7)	4 (1.1)
	Forest	55 (7.8)	36 (10.2)	10 (2.8)
	Farm hut	2 (0.3)	0	0
Type of washing soap	Reed mat	232 (32.8)	116 (32.8)	116 (32.8)
	Cut bamboo	23 (3.2)	13 (3.7)	12 (3.4)
	Grass	72 (10.2)	34 (9.6)	34 (9.6)
	Foam mattress	217 (30.6)	106 (29.9)	108 (30.5)
	Wooden bed frame finished	48 (6.8)	29 (8.2)	26 (7.3)
	Wooden bed frame sticks	23 (3.2)	12 (3.4)	12 (3.4)
	Metal bed frame	23 (3.2)	11(3.1)	12 (3.4)
	Bare floor or ground	70 (9.9)	33 (9.3)	34 (9.6)
	Water only	59 (8.3)	19 (5.4)	24 (6.8)
Scrubbing the net on the hard surface during wash	Local bar soap	246 (34.7)	126 (35.6)	155 (43.8)
	Detergent powder	232 (32.8)	113 (31.9)	93 (26.3)
	Detergent powder with mix bar	154 (21.8)	88 (24.9)	80 (22.6)
	Bleach	17 (2.4)	8 (2.3)	2 (0.6)
Place of the net dried after wash	Outside in the sun	289 (42.1)	137 (38.7)	104 (29.4)
	Outside in the shade	379 (53.5)	212 (59.9)	121 (34.2)
	Inside	319 (45.1)	137 (38.7)	226 (63.8)
Water condition for wash	Cold	8 (1.1)	5 (1.4)	7 (2)
	Warm	499 (70.5)	245 (69.2)	308 (87)
	Hot	181 (25.6)	97 (27.4)	42 (11.9)
	Total	28 (4)	12 (3.4)	4 (1.1)
Any hole appeared on the net		133 (18.8)	97 (27.4)	52 (14.7)
Cause of the hole on the net	Tore or split	111 (15.7)	46 (13)	70 (19.8)
	Burnt	23 (3.2)	9 (2.5)	3 (0.8)
	Animals	11 (1.6)	4 (1.1)	4 (1.1)

Discussion

In Ethiopia, focusing malaria endemic area, LLINs distribution/coverage was seems to be the same. The net durability is not clearly known after distribution. In the study communities, the nets were being used differently in different periods: all the years, only during rainy and dry seasons. All sampled households were owned at least one LLINs with two years old

since the campaign net distribution is commonly in the same time. Net usage was found to be low with 76.5% of all the communities used a net every night in their house. This contradicted to the study conducted in Tafea Province, Vanuatu (Dutta et al. 2018). The reasons related to this were early net attrition, community perception (adverse effects) to ward

chemicals on the nets, absence or presence of mosquitoes and are either discarded, given away or used for something other than preventing mosquito bites at night (Table 5) which is in line with the study conducted in Zambia (Dev et al. 2016; Tan et al. 2016). The current study found that, about 24% of the nets hadn't been used by the households which were distributed by the MoH before 24 months. It was because of associated factors; given away to others for use, stolen, being used in another location and other purpose, hotness, smell, feel closed in, absence of malaria and mosquitoes at the time (Table 5). LLIN loss, measured by survivorship/attrition was incomparable with the study conducted in Benin after three years use (Gnanguenon et al. 2014).

The physical status of all nets was found in a good condition in line with the study in Tanzania (Massue et al. 2016). There was no significant difference in the different types of LLINs regarding attrition rate. A low number of the used nets had holes (<20%), which contradicted/opposed previously published studies (Craig et al. 2015). Factors assessed in the current study could explain in a holistic manner net use by individuals in households owning at least a net are less contributed for the hole distribution. Factors that affect LLIN durability, act to a lesser extent, in different settings. The rate at which holes appear (loss of fabric integrity) in nets found to be lower in Ethiopia is compared to published studies in different countries (Hakizimana et al. 2014; Tan et al. 2016). The number of washed bed nets was high, almost all nets used in the study communities were found to be washed frequently with similar proportion in contrast of published studies (Dutta et al. 2018) which dried outside in the sun. The total hole number were also found to be changed depending on the position at different size category: roof, upper, lower and seams. The numbers of tears and holes was relatively high in PermaNet®2.0 when compared with the left LLINs. Contrary to other studies, the observed holes were in the roof and upper parts of the nets in all LLIN types (Dutta et al. 2018). This is because of a sleeping materials and house type in which the net is used and materials the net hanged over may affects at any time during its lifetime (Tan et al. 2016). The proportional hole index (PHI) that calculated for overall is 22.5 (Table 1) which indicated that the nets to be classified as "Good" according to WHO criteria or cut off. This is because, LLIN based intervention technology is appropriate if, the respondents appreciated and used their nets, adapting to the needs of their specific context for greater community acceptance, compliance and retention in malaria control are considered. According to the current study observation, the two-year service able life'

assumption, currently used in Ethiopia did not subject to program distribution/replacement of LLINs while the nets being used were found in a good condition regarding with physical integrity.

In current study based on WHO measures of optimal effectiveness and minimal effectiveness criteria, the insecticidal effectiveness of the LLINs in the study were evaluated. Bio-efficacy tests for each chemical class were compared based upon the results as a confirmed 24-hour mortality of susceptible *An. arabiensis* exposed to the nets for 3 min. We found that, the Magnet and Interceptor nets performed significantly better than PermaNets 2.0 nets. Approximately 2 years after nets were distributed, 95.1% of Magnet and 92.3% of interceptor in the field remained effective in killing susceptible Anophelines. The PermaNet 2.0 performed significantly worse (87% mortality), with no nets remaining effective after 2 years but, effectively passed the WHO criteria with knock down percent (Figure 4). This may be because of the wider range of mortalities produced by nets 2 years probably reflects difference in human related behavior with regard to net usage: general handling, amount of use, storage, washing, and attempts at insecticide regeneration (Lindblade et al. 2005). The Magnet and Interceptor net were observed to be more durable and robust than the PermaNet®2.0 LLINs in terms of Mortality rate (Bio-efficacy). In line with published studies, the residual bio-efficacies of nets varied between locations ($P < 0.05$) which suggest that the community practices for net care and maintenance varied (Dev et al. 2016). The presented mortality and knockdown results indicated that the efficacy of permaNet 2.0 begins to decrease during the second year of use under programmatic conditions; even though the nets were designed to last for 3 years. The available residual chemicals after two years in all nets were above 360 mg/m². High insecticidal concentration was found on Interceptor and PermaNet 2.0 where, low insecticidal concentration was found on magnet net (Table 4). Surprisingly, high concentration insecticide on permanent and low concentration insecticide on Magnet net was not associated with percent mortality. This is similar with study conducted on durability of LLINs in Zambia (Tan et al. 2016). There are some limitations of the current study that should be noted. In this study, the following possible limitations were considered: LLINs available may be a biased sample, as worn-out LLINs may no longer be present; a significant and unknown portion of the local population has moved into or out of the study area; the number of opportunities for follow-up are limited and labels on LLINs fade or are lost over time, making identification difficult.

Conclusions and Recommendations

The current study revealed that, the community net utilization is low while, the physical status and insecticidal activities of all nets are in a good condition to give acceptable protection after two years services. Results of the current study using bed nets collected over two years in Ethiopia indicated some of the potential strength of the PHI including: underestimating the contribution of really large holes, overestimating the contribution of smaller holes and ignoring extra small holes and hole location. This information should be used to 'inform' decisions on replacing LLINs through avoiding compromised efficacy of LLINs earlier than what expected. Though, the LLINs condition in Ethiopia is found to be in a good condition, special focus for some households in the communities need replacement before three years net use which could be important to achieve universal coverage standing from the current. Longitudinal studies are needed to determine the attrition rate, understand the reasons, utilization and insecticidal activities of LLINs.

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Competing interests

The authors declare that they have no competing interests.

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