THE PMI VECTORLINK MALI ITN DURABILITY MONITORING 36-MONTH REPORT FOR YORKOOL AND PERMANET 2.0 DISTRIBUTED IN 2017

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Abt Associates Inc. | 6130 Executive Blvd | Rockville, Maryland 20814
T. 301.347.5000 | F. 301.913.9061 | abtassociates.com

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ACRONYMS

ACT	Artemisinin-based Combination Therapy
CDC	Centers for Disease Control and Prevention
CI	Confidence Interval
HPLC	High Performance Liquid Chromatography
IPC	Interpersonal Communication
IQR	Interquartile Range
ITN	Insecticide-treated Net
KD	Knockdown
KD60	60-minute knock-down rate
LBMA	*Laboratoire de Biologie Moléculaire Appliquée* (Laboratory of Applied Molecular Biology)
NMCP	National Malaria Control Program
OMVS	*Organisation pour la Mise en Valeur du Fleuve Sénégal* (Senegal River Basin Development Organization)
PCA	Principal Component Analysis
pHI	Proportionate Hole Index
PMI	President's Malaria Initiative
PCA	Principal Component Analysis
SL	Surface Levels (of insecticide)
TL	Total Levels (of insecticide)
USAID	United States Agency for International Development
WHO	World Health Organization
WHOPES	World Health Organization Pesticide Evaluation Scheme

EXECUTIVE SUMMARY

In 2018, 85% of households in Mali owned at least one insecticide treated net (ITN) and the mean number of ITNs per house was two (INSTAT, 2019). In Mali, ITNs are distributed through mass distribution campaigns and through routine health services to pregnant women and infants. ~~In this context~~ The importance of net durability and the "average useful life" of a bednet is one of the critical factors a Malaria National Control Program needs to know as it determines the frequency at which nets need to be replaced and the type of nets to be procured. The objectives of this ITN Durability Monitoring study were to 1) assess the physical durability of Yorkool and PermaNet 2.0 ITNs in 2 sites, 2) identify major determinants of net durability, 3) determine net bioefficacy and 4) monitor chemical decay. The ITN universal coverage campaign in Kayes Region was conducted in December 2017 and data collection was conducted at an average of 6 months post-distribution as baseline between March and May 2018, at 12 months (December 2018), 24 months (November-December 2019) and at 36 months (November-December 2020). The study was carried out in the districts of Kenieba (Yorkool) and Kita (PermaNet 2.0) located in Kayes Region in sites with similar malaria epidemiological, climatic and socio-ecological profiles.

Household and ITN Follow-Up

The number of households recruited at baseline per cluster was 120 for Kenieba and 90 for Kita and the number of active households (defined as either a household that still has nets, nobody at home, or unknown) were 89 in Kenieba and 78 in Kita at the 36-month survey. The cumulative follow-up status of households after 36 months showed a large increase of households that lost all cohort nets. A total of 976 (461 in Kenieba and 515 in Kita) nets were recruited at baseline and the number of cohort nets active (nets present, used elsewhere and unknown/owner absent) at 36 months was 245 in Kenieba and 250 in Kita.

Durability Risk Factors

The most common household risk factors related to net damage were storing food in sleeping room and the perceived presence of rodents (>60.0%) in both sites, also few households always cooked in the sleeping room (<5.0%) in both sites during the survey period (baseline, 12-, 24- and 36 month). The main type of sleeping place for campaign nets was a mat or the ground in both sites at baseline (dry season when a lot of people were sleeping outside) and it was a bed or mattress at 12-, 24- and 36 months survey (end of rainy season). Throughout the survey period, more than half of all nets (>50%) in both sites were found hanging loose over the sleeping place during the day, which exposes the nets to an increased risk of damage. In addition, the risk of damaging nets by drying them over bushes or fences varied from 1.0% to 78.0% in Kenieba and from 1.0% to 36.0% in Kita. There was a significant difference between sites ($p<0.0001$) at baseline, 12- and 24 months. The median number of times a net was washed in the last 6 months ranged from 1 to 3 in both sites. The use of detergent/bleach for washing nets was the same in both sites (>45.0%) at baseline, 12– and 24 months. In contrast at 36 months it was significantly higher ($p=0.0258$) in Kenieba (71.8%) than Kita (37.8%). The respondent exposure to messages on net usage in the last six months was significantly lower in Kenieba (8.9% to 27.4%) than in Kita (29.2 to 43.8%). Exposure to messages about nets dramatically declined in Kenieba over time, suggesting there was very little ongoing behavior change communication activity after the initial distribution. But it increased in Kita, suggesting there was ongoing behavior change communication activity. The households were mainly exposed to messages on net usage (>50.0%) from interpersonal communication (IPC) (e.g. health workers, friends/family, and community leaders or events) and media only in both sites. The proportion of respondents with a very positive attitude/capacity to keep nets in a good condition and repair net damage (net care and repair attitude score above 1.0) ranged from 13.6% to 56.1% in Kenieba and from 4.4% to 50.0% in Kita. Additional social behavior change communication (SBC) is recommended to improve net care attitudes, which are associated with improved ITN lifespan. As expected, with increasing time since distribution the proportion of households experiencing any holes in their campaign nets increased over survey periods in Kenieba (25.0% to 78.0%) and in Kita (20.2% to 81.9%). It was higher in Kenieba than Kita at 12- and 24 months ($p<0.05$). The proportion of households that never discussed care and repair remained lower ($p<0.05$) in Kenieba (7.1% to 44.4%) than in Kita (23.6% to 78.6%). The proportion of households that ever repaired nets (if the net had holes) was similar in both sites, although there was fluctuation over time (42.5-63.3% in Kenieba, 44.4-74.5% in Kita).

ITN Ownership and Use

The proportion of campaign nets found hanging was low in both sites (<20.0%) at baseline (6 months), with most nets still stored in the original package (82.3% in Kenieba and 73.3% in Kita). The proportion found hanging steadily increased but there was a difference between Kenieba (59.7%) and Kita (76.8%) (*p = 0.01*) at 24 months. The proportion of cohort nets that were taken down or stored was also significantly (*p<0.05*) lower in Kenieba (4.8-28.8%) than in Kita (7.5-21.7%) at baseline, 12 and 24 months. The proportion of cohort nets still in the package was low (<5.0%) in both sites at 36 months. The proportion of cohort nets used the previous night was significantly (*p<0.05*) lower in Kenieba (38.6% to 64.7%) than in Kita (53.5% to 76.1%). The proportion of cohort nets used every night (in the previous week) was lower in Kenieba (36.2% to 57.9%) than in Kita (48.8% to 72.2%). The proportion of households which have any other non-cohort nets was >40% in both sites during the survey. The non-campaign nets came mainly from public sector through other campaigns. The users of campaign cohort nets were mainly adults only in Kenieba (>50.0%) and in Kita (>40.0%).

ITN Survivorship (Attrition and Physical Integrity)
The proportion of ITNs in the surveyed households with any sign of damage increased over time, as expected, from baseline to 36 months. The proportion of nets with holes was significantly (*p<0.05*) higher for Yorkool nets in Kenieba (48.1% to 88.9%) than for PermaNet 2.0 in Kita (14.4% to 65.6%) during the survey periods. Of those nets remaining, the proportion of serviceable nets (pHI≤642) was significantly (*p<0.05*) lower for Yorkool nets in Kenieba (48.8%) than PermaNet 2.0 in Kita (77.7%) after 36 months. This suggest that there is a significant difference between the two brands. The main type of damage on campaign nets was tears in Kenieba and tears/other in Kita. The nets still in serviceable condition were 23.1% for Yorkool nets in Kita, but higher at 58.8% for PermaNet 2.0 in Kenieba. The median survival of Yorkool nets was 2.1 years (1.82-2.61) in Kenieba and 3.4 years (2.67-5.04) for PermaNet 2.0 in Kita at 36 months. This difference may be related to the denier (fabric thickness) of the nets, with the more durable PermaNet 2.0 nets being 100 denier compared to the thinner 75 denier Yorkool nets, which were less durable.

Insecticidal Effectiveness
Mosquito Bio-Assay
The proportion of ITNs that meet optimal effectiveness (at least 95% KD or 80% mortality) at 36 months was 31% for Yorkool from Kenieba and 20% for PermaNet 2.0 from Kita. At 36 months, the proportion of ITNs that met minimal effectiveness (75% KD or 50% 24h mortality) criteria was 51,7% for Yorkool from Kenieba and 60%% for PermaNet 2.0 from Kita. Based on WHO criteria there is a potential problem with low bio efficacy of both ITN brands after 36 months.

Chemical Analysis
The deltamethrin surface content, as measured by the C-Vue HPLC method, in both brands (Yorkool and PermaNet 2.0) decreased significantly over the study to <90.0% (<0.10 mg/m^2) in both sites at 36 months. Washing practices can influence chemical loss but the mean number of net washes in last 6 months (if washed) was 3 in both sites, so that was not likely the cause of this observation. The main product used to wash them was detergent, bleach or regular bar soap in both sites.

A summary of key results from the baseline, 12-, 24 and 36-month rounds is presented below.

TABLE ES-1: 6, 12, 24 AND 36 MONTH KEY RESULTS

Site/Net	Survey and time since distribution	Attrition wear and tear (%)	% Remaining nets in serviceable condition (n)	Remaining nets hanging over sleeping space (%)		Optimal insecticidal effectiveness in bioassay (%)	Mean surface Insecticide concentration (mg/m^2) +/- (add IC or range)	% Insecticide decrease compared with baseline
				Campaign	Other			
Kenieba/Yorkool	6m (baseline)	0.0	99.1 (N=461)	11.4	39.8	66.6	0.69	
	12m	1.7	84.9 (N=245)	52.6	49.3	70.0	0.20	71.0%
	24m	10.7	70.3 (N=144)	59.7	74.3	70.0	0.19	72.4%
	36m	45.3	48.8 (N=45)	46.6	61.5	31.0	0.08	88.4%
Kita/PermaNet 2.0	6m (baseline)	0.0	100.0 (N=515)	15.9	59.5	66.6	0.46	
	12m	0.0	95.4 (N=305)	73.4	71.0	76.6	0.24	47.8%
	24m	17.2	91.8 (N=147)	76.8	79.2	56.6	0.17	63.0%
	36m	22.4	77.7 (N=99)	67.6	74.2	20.0	0.06	86.9%

Conclusion

At the 36-month follow-up period, the proportion of Yorkool nets surviving in serviceable condition in Kenieba was lower than PermaNet 2.0 nets in Kita, mostly because of high attrition due to wear and tear and lower physical integrity. The estimated median survival time of Yorkool nets was 2.1 years in Kenieba and 3.4 years for PermaNet 2.0 in Kita. It should also be noted that 82.8% (Kenieba) and 73.3% (Kita) of cohort nets were unused and still in the package 6 months after distribution, hence, it could be argued that the median 'in use' survival is even shorter. The reasons for the lower performance of Yorkool nets in Kenieba could be associated with product specifications, with PermaNet 2.0 having a thicker fabric of 100 denier polyester compared to 75 denier of Yorkool, or factors associated to ITN durability risk factors and use (e.g. not properly storing during the day, washing and drying ourdoors etc). The C-Vue portable chromatographic device was used successfully for the first time in Mali to measure the surface insecticide concentration of ITNs and produced results that were consistent with cone bioassays. This new technology allows for an affordable and locally available method to perform ITN durability monitoring in malaria endemic countries.

1. BACKGROUND

Insecticide-treated nets (ITNs) are a key component of malaria vector control in Mali (West Africa), where donors such as the President's Malaria Initiative (PMI) and Global Fund (GF) have distributed millions of nets. The ITN distribution strategies in Mali are based on providing access through mass distribution campaigns to the entire target population, routine distribution to pregnant women and children under one year of age, and during prenatal consultations for women and the Expanded Program on Immunization for children. These strategies are reinforced by educational communication at the community level. Progress has been particularly impressive in increasing ITN coverage as 82% of households in Mali have at least one ITN, and the average is two ITN per house (SILS, 2014).

According to WHO nets should be replaced approximately every three years, but field studies have shown that the durability of ITNs varies within and among countries, and that the durability of different types of nets also varies (WHO, 2017). This variation is attributed to behavioral, social, physical, and chemical elements, so country-specific information is useful for guiding procurement and programmatic decisions made by the National Malaria Control Program (NMCP) Mali, PMI, the Global Fund, and the Senegal River Basin Development Authority/*Organisation pour la Mise en Valeur du Fleuve Sénégal* (OMVS). In this context, the importance of net durability and the "average useful life" of a net are increasingly recognized as critical factors a malaria control program needs to know to determine the frequency at which nets should be replaced and the type of nets to be procured. This is reflected in the World Health Organization (WHO) guidelines for the monitoring of ITNs in the field, which recommends that countries routinely monitor net durability (WHO, 2013). In 2014-2016, the PMI Africa Indoor Spraying Project in Mali conducted a three-year durability study on four types of ITN (PermaNet 2.0, PermaNet 3.0, Olyset Net, and OlysetPlus Net). This study assessed the impact of new combination ITN products on entomological measures of malaria transmission in southern parts of Mali (Selingue and Bougouni). Among the results of that study, the proportion of hole index 36 months after net distribution was much lower in PermaNet 2.0 and PermaNet 3.0 arms than in Olyset Net and OlysetPlus Net arms (PMI/ PBO ITN Durability Report 2017).

In December 2017, Mali's NMCP and stakeholders including Population Services International Mali conducted an ITN universal coverage campaign in Kayes Region, southern Mali. The universal coverage campaign was supported by the Global Fund in Kenieba and by OMVS in Kita. Through PMI, the Laboratory of Applied Molecular Biology (LBMA) implemented ITN durability monitoring from 2018 to 2020. The first year of monitoring was conducted in collaboration with USAID Global Health Supply Chain Program in 2018, and the second- and the third-year monitoring was conducting in collaboration with the PMI VectorLink Project in Mali in 2019-2020. This report describes results from the survey after 36 months.

The primary objectives of the study were:

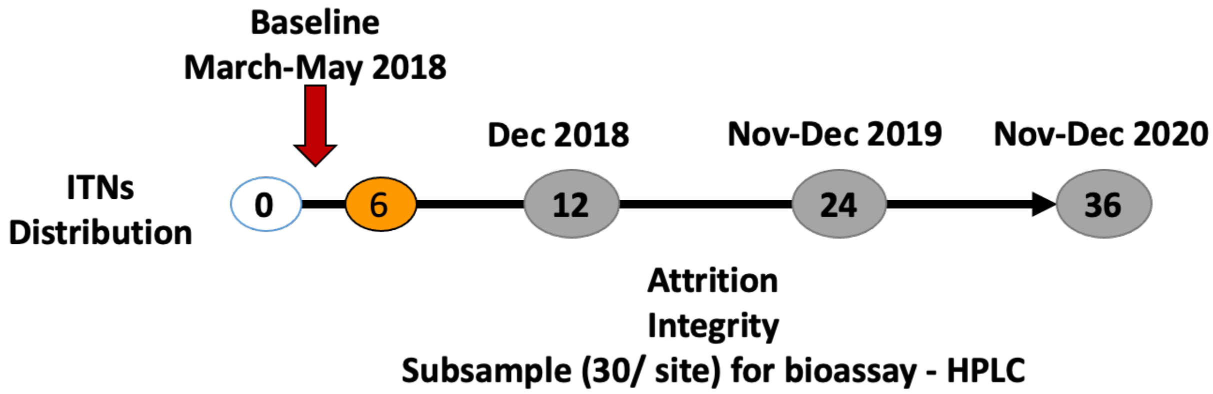
- To assess the physical durability of Yorkool and PermaNet 2.0 ITNs in two sites (Kenieba and Kita) at baseline, 12 months and 36 months after ITN distribution,
- To compare the durability of ITNs across the two sites (Kenieba and Kita) and identify major determinants of field performance.

The secondary objectives were:

- To describe major behavioral aspects of net care and repair and their impact on physical durability during the 36 months of field use,
- To assess the insecticidal effectiveness (residue and bioassay) at 6 (baseline), 12, 24, and 36 months of field use.

Following distribution of nets in December 2017, LBMA conducted the baseline survey (at approximately 6 months post distribution) between March and May 2018, the 12-month survey in December 2018, the 24-month survey in November–December 2019, and the 36-month survey in November–December 2020. Figure 1 shows the assessment objectives and subsamples assessed over this timeline.

FIGURE 1: DURABILITY MONITORING TIMELINE

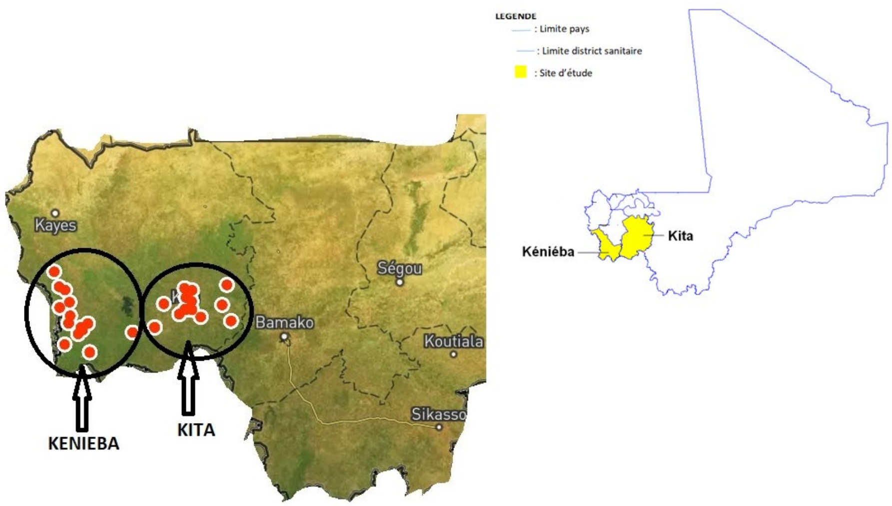


2. METHODS

2.1 STUDY SITES

The study was carried out in Kenieba and Kita districts, both located in Kayes Region in western Mali; Figure 2 plots the 30 study clusters (15 in Kenieba, 15 in Kita). The two districts have similar malaria epidemiology, climatic, and socio-ecological profiles. The economic activities are based on agriculture, livestock, small-scale trading, small crafts, logging, gold extraction, and fishing. Agriculture is the dominant activity, and the products resulting from this activity are sold in markets.

FIGURE 2: MAP OF THE STUDY SITES AND SAMPLING CLUSTERS IN KITA AND KENIEBA DISTRICTS, KAYES REGION, WESTERN MALI



Malaria control interventions in the Region:
From 2012 to 2013 in Kayes Region, the proportion of children under 5 years old receiving malaria tests was 31.3%, with 10.0% positive by malaria microscopy and 4.1% of febrile under-fives treated with Artemisinin-based Combination Therapy (ACT) (Table 1). In 2018, the prevalence of malaria in children <5 years old was 13% in Kayes Region (District Health Information System 2018). The proportion of households with at least one ITN was 77.6%, the proportion of population with access to an ITN was 58.0%, and the proportion of the population using an ITN the night before was 52.3%.

TABLE 1: SOCIO-DEMOGRAPHIC AND MALARIA SITUATION IN KAYES REGION (2013)

Under-fives with fever receiving malaria test	Under-fives positive for malaria (microscopy)	Febrile children treated with ACT	Household with at least one ITN	Population access to ITN	Population using ITN last night
31.3% (n=77)	10.0% (n=77)	4.1% (n=77)	77.6% (n=1,398)	58.0%	52.3% (n=5,848)

n= number of people surveyed.

2.2 ITN Brands Monitored

The Yorkool net was monitored in Kenieba and the PermaNet 2.0 net was monitored in Kita. The technical specifications of the ITNs (material, textile specifics, insecticide with concentration) are the same for the two brands, with the exception being Yorkool nets are 75-denier and PermaNet 2.0 are 100-denier (measure of fabric thickness).

More specifics about the two brands of ITN monitored:

(a) **Yorkool** (distributed in Kenieba District): The net is a 75-denier polyester ITN. Apart from the netting denier, this net has the same specifications as PermaNet 2.0.

(b) **PermaNet 2.0** (distributed in Kita District): The net is made of knitted poly-filament polyester fibers and is treated with deltamethrin to a target concentration of 55 mg/m2 = 1.4 g/kg for a 100-denier net. PermaNet 2.0 has been widely distributed and used in many countries since 2004.

2.3 Study Design Summary

This is a prospective longitudinal study of a cohort of nets distributed in December 2017 as part of a universal coverage net campaign. Within a few months following distribution (from March to May 2017), a representative sample of campaign nets from the study sites were identified through a cluster household survey. All campaign nets from consenting households were selected to constitute the cohort of nets for the three years of the study. These nets were then labeled with a unique code to assess the presence and physical condition at baseline (within 6 months post-distribution) and in three additional annual surveys together with household characteristics, and use, care, and repair behaviors for the net. At each assessment (baseline, 12, 24, and 36 months), subsamples of campaign nets were selected for insecticide effectiveness testing (bioassays and chemical residue).

The following assumptions are underlying the calculations of sample size and precision using standard formulas:

- Confidence interval (CI) (alpha-error) 95%
- Power (beta-error) 80%
- Design effect of 2.50
- Household loss to follow-up 5%
- Campaign ITN per household at baseline (assuming an average household size of 7) and a loss of 0.2 nets/household between campaign and baseline survey
- Total attrition rate for campaign nets of 35% over three years and an attrition rate due to wear and tear of 20% with loss due to giving away nets to others of 15% over three years.
- Estimated median net survival of three years, i.e., survival of 50% after three years.

For the selection of clusters, the campaign ITN distribution registers were used in both sites. A cluster was defined as a community and the selection was done with Probability Proportionate to Size (PPS) with the number of ITNs distributed per community as the measure of size. Within each selected community, 10 households were selected using the following methodology:

If the community was small (fewer than 200 households[1]), the field team mapped the whole village (i.e., listed all inhabited houses where people live); from the compiled list of eligible households, the supervisor randomly selected 10 households with equal probability for each household using random number lists. These random number lists provide 10 random numbers for each possible total of listed households.

If the community was larger than 200 households, the equal size section-approach was used. With the help of local authorities, the community was divided into sections of approximately equal size (40–60 compounds each). One of these sections was randomly selected by the supervisor using a pre-prepared random number sheet, and within this section all households were mapped and households selected as above. The number of sections used in such clusters was recorded by the supervisor.

[1] In accordance with the household definition used in the ITN distribution campaign, the definition of a household was "people eating from the same pot."

Field teams visited the sampled households and initially screened them to determine if they had participated in the ITN distribution campaign. If a household had not participated, it was dropped and a replacement household was visited. If a household confirmed participation in the campaign, it was given information on the study and its oral consent was sought, using the consent script in the local language. If the household did not give consent, it was dropped, and replacement households were visited until the total of 10 households was reached. For each consenting household, the GPS coordinates were recorded and the name of the head of household was entered into the household master list, which was used to identify the household for the annual assessment visits.

Within each household, the field team identified all campaign nets based on the label of the net and on the interview with the household respondents. Each campaign net was labeled in the baseline? with a unique identifying number that was used to create a master net list.

At baseline, a separate cohort of six nets per cluster was tagged for eventual follow-up and removal at the 12- and 24-month assessments. Using a separate group of two-digit tags (A1-A6; B1-B6, etc.), households were selected randomly from outside the main net cohort. One net in each of these household was tagged for follow-up at 6, 12, and 24 months, GPS location was recorded, and a one-page questionnaire (confirming the net was the campaign net and obtaining basic information on its use and washing patterns) was administered at baseline. At the 12- and 24-month assessments, two nets per cluster were selected for a bioassay from the master list of bioassay households using simple random sampling, using replacement households as needed. For the 36-month sample, 30 nets were selected from the main cohort master list using simple random sampling. Households were given a new ITN as a replacement. The collected nets were labeled and stored in separate plastic bags for transportation. The one-page questionnaire was administered and packed with each net.

As soon as clusters were selected, the local authorities and chiefs were informed of the purpose and expected period of the survey and then their support was sought. Then communities were sensitized and mobilized in order to obtain maximum cooperation for each survey.

Based on calculations using the sampsi command of Stata and the assumptions above, a sample of 15 clusters with 10 households was considered to be sufficient per study location. This resulted in an initial cohort of 345 campaign nets from 150 households per site or 790 nets from 300 households for two sites. After three years, considering loss to follow-up and attrition rates as outlined above, we expected there would be 279 nets with complete data for evaluation per location (557 nets in total). This sample size with the assumed design effect will allow detection of a 10–11%-point difference between locations if the assumed median survival is three years: for example, 39% or less or 61% or more estimated survival compared to 50%. This translates into approximately a 0.5 median survival difference that can be detected as statistically significant.

Following the WHO recommendation for phase III testing of ITNs, random samples of 30 campaign nets per site (total 60) were selected at each annual assessment (from outside the main cohort at 6, 12, and 24 months) for insecticidal effectiveness (bioassay) analysis. The same samples (bioassay samples) of ITNs were used for chemical residue analysis using High Performance Liquid Chromatography (HPLC). A portable field-adapted liquid chromatographic system (C-Vue machine) for measurement of residual insecticide levels on ITN surfaces (a non-destructive sampling technique) was used. A subsample of ITNs tested at LBMA were sent to the Centers for Disease Control and Prevention (CDC), Atlanta, for quality control and method validation.

2.4 Training and Fieldwork

ITN durability monitoring activities were coordinated by the Principal Investigator. One Co-investigator, three Assistant Entomologists, and one Data Manager were hired to assist the Principal Investigator in monitoring, analysis, and reporting activities. An Insectary Manager was hired for the maintenance of the insectary throughout the year to raise a colony of mosquitoes for net bioassays. Each site had its own implementation team, consisting of an Investigator, two Assistant Entomologists, and four interviewers/local guides. The duration of the fieldwork for the 15 clusters of each site was 15 working days, so that each assessment round was completed within four weeks.

Investigators, assistants, and interviewers/local guides had a good knowledge of local dialects and experience in household surveys. Just prior to each fieldwork cycle, the team completed a five-day training, which included:

- Understanding the study design and sampling procedures
- General approach to ethics of field work (consent and interview)
- Detailed study of interview with role play

- Introduction to and practice of use of the data entry device
- Physical assessment of holes and repairs in nets with practical exercises

The Principal Investigator trained staff to conduct ITN durability monitoring according to PMI, WHO Malaria Policy Advisory Committee, and Roll Back Malaria Vector Control Working Group guidelines and in the development of progress reports. The NMCP and VectorLink Mali participated in this training in order to build their capacity. The PMI Mali team also participated in the training.

For each field work mission, the supervision was conducted by the team of LBMA and NMCP Mali.

A mission was conducted to mobilize and sensitize the health regional director in Kayes, selected communities' health authorities in Kenieba and Kita districts, and local leaders in order to obtain permission to use the community as a study site and to inform the community members about the study's objectives and methods.

The challenges encountered were:

- The site accessibly was very difficult for some clusters.
- Some ITNs owners were absent, doing agricultural field work.

2.5 DATA MANAGEMENT

For data collection, electronic devices (Samsung Galaxy Tab A with ODK questionnaires) were used that allowed a detailed programming of skip patterns and internal controls to ensure that all necessary data are collected and consistent. Data from each interviewer were collected on a local storage device (laptop) by the supervisor until it could be transferred.

From the data three types of data files were created and updated after each assessment round:

- The household master list
- The net master list
- The annual household and net data files
- The master bioassay household list

As noted above, the household master list includes the GPS coordinates and name of the head of household as this information was needed to track the household in subsequent surveys. Between surveys, this list has been safely kept on a fixed and secure data server with adequate protection (encryption and password) and accessed only by the Principal Investigator and Co-investigator. Following approval of the final report, this information (GPS coordinates and names) will be deleted.

Other personal identifiers are the first names of household members needed to identify the net users in the household surveys. Following data cleaning, household member names will be removed so that analytical data files will have no household or personal identifiers remaining.

At the end of each day, the investigators reviewed all collected data and discussed with the team the performance in the field with respect to strengths and weaknesses. Daily reports were made to the location coordinator and any problems were reported to the co-investigators or Principal Investigator for discussion and finding solutions. For technical issues with the electronic data collection devices, consultants were on stand-by for field support throughout the field activities.

2.6 ANALYSIS

Once data collection for 6-, 12-, 24-, and 36-month assessment rounds were completed and the data verified, the data sets were transferred to a statistical software package (STATA for Windows, Version 14.0) for further consistency checks and preparation for analysis. The data analysis was conducted by using Stata do-files (macros).

For calculation of CIs around estimates, the intra-cluster correlation were taken into account (design effect). In addition to descriptive uni-variable analysis, multi-variable analysis was performed to assess determinants of physical durability. Data on household attitudes toward care and repair from the Likert score questions were summarized by recoding the four-level Likert scale to have a value of -2 for "strongly disagree," -1 for "disagree," +1 for "agree," and +2 for "strongly agree." These attitude scores for each respondent were summed and divided by the number of statements to calculate an overall attitude score.

A wealth index was computed at the household level using principal component analysis (PCA). The variables for household amenities, assets, livestock, and other characteristics that are related to a household's socioeconomic status were used for the computation. All variables were dichotomized except those of animal ownership where the total number owned were used. The first component of the PCA was used as the wealth index. Households were then classified according to their index value into quintiles within each study location and time point.

The physical integrity of campaign ITNs was assessed in accordance with WHO guidelines, with the number of holes of size 0.5-2 cm diameter (size 1), 2-10 cm diameter (size 2), 10-25 cm diameter (size 3), and >25 cm diameter (size 4) recorded for each net following examination by the team in a well-lit location. Data from the ITN hole assessment was transformed into the proportionate hole index (pHI) for each ITN using the following standard equation:

pHI = Number of size 1 holes + (No. of size 2 holes x 23) + (No. of size 3 holes x 196) + (No. of size 4 holes x 576)

Based on the pHI value, ITNs were categorized as "good," "serviceable," or "torn" as defined below. Note that "good" is a subset of all "serviceable" ITNs.

- Good: pHI<64 (corresponding to a total hole surface area <0.01m^2)
- Serviceable: pHI<=642 (total hole surface area <=0.1 m^2)
- Torn: pHI>642 (total hole surface area >0.1m^2)

According to the World Health Organization Pesticide Evaluation Scheme (WHOPES) Phase III evaluation criteria, at least 80% of recommended ITN brand should achieve optimal effectiveness 36 months post distribution. For the PMI durability monitoring, this means that at all time points, ≥80% of ITNs should meet optimal effectiveness criteria (at least 95% knockdown (KD) or 80% mortality). However, this may not be realistic under real-world conditions nor necessary from an epidemiological standpoint. Therefore, if less than 80% of nets meet these criteria, PMI recommends checking whether at least 80% of nets meet minimal effectiveness criteria. This is not an official WHOPES threshold but will give a good assessment by how much the nets are failing:

If greater than 80% of ITNs meet minimal effectiveness evaluation criteria (75% KD or 50% 24h mortality), this is a potential problem with bioefficacy of ITNs and further investigation of likely causes should be done.

If less than 80% of nets meet minimal effectiveness evaluation criteria, a significant problem with the bioefficacy of the nets is very likely and urgent investigation into likely causes should be done.

If the proportion of nets with at least minimal insecticidal effectiveness in the bioassay is around 80% after three years, the overall sample under the assumptions mentioned above will provide a precision of ±10.0%-points in a one-sided analysis.

The same ITN samples were used for bioassay and for chemical surface residue analysis method (C-Vue chromatography system). Outcome measures from these tests present the mean and median level of active ingredient across the net brand samples in mg/m2 and compare these averages with manufacturer specifications for the insecticides used on the netting. Values generated by C-Vue chromatography are surface levels (SL) of deltamethrin obtained by rubbing the net with a filter paper and analyzing the residue with the portable C-Vue HPLC. A comparison of SL and total levels (TL) using the standard CIPAC methods was conducted at CDC on the 6 and 12-month Mali nets. From the relationship equation (TL =(Log(SL)+1.37)/ 0.0232) an estimate of TL can be made.

2.7 COVID-19 ADAPTATIONS

To ensure the safety of study participants, trainers, and fieldwork staff, COVID-19 mitigations measures were implemented throughout the 36-month survey round. During in-person fieldworker training, staff were instructed not to enter households, trained on how to examine nets with minimal contact, and trained on how to obtain oral consent. In the field and during training, staff were required to wear a mask at all times, to maintain high levels of hand washing, and to use a new pair of gloves when examining nets at each new study household.

2.8 ETHICAL CLEARANCE

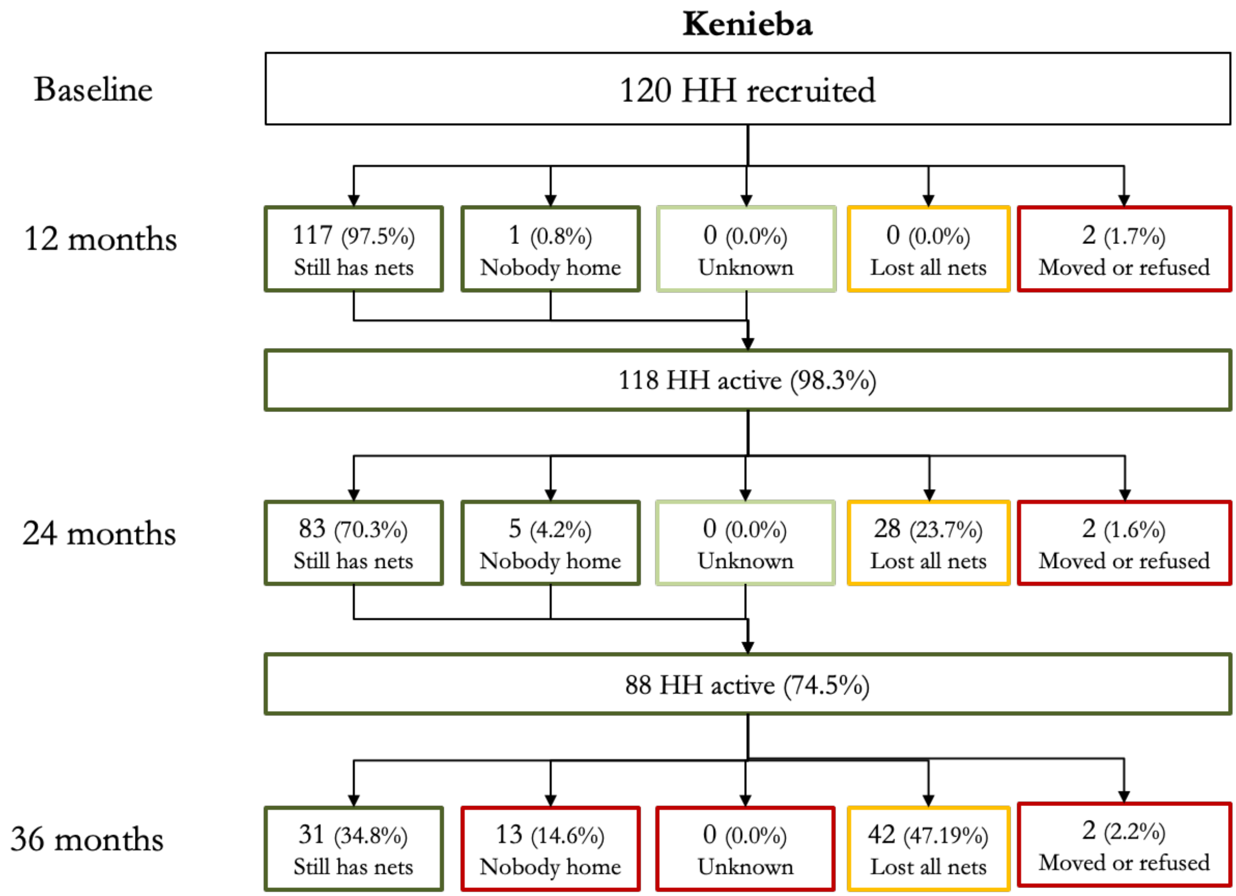
The protocol of the study was translated into French and presented to the Mali National Institute of Public Health Research ethical committee for review. Clearance was obtained on January 22, 2018 under reference number 02/2018/CE-INRSP. Staff implementing this study complied with all policies and procedures of both PMI and the local ethics board. Informed oral consent was sought for all participants in this study prior to conducting the interview.

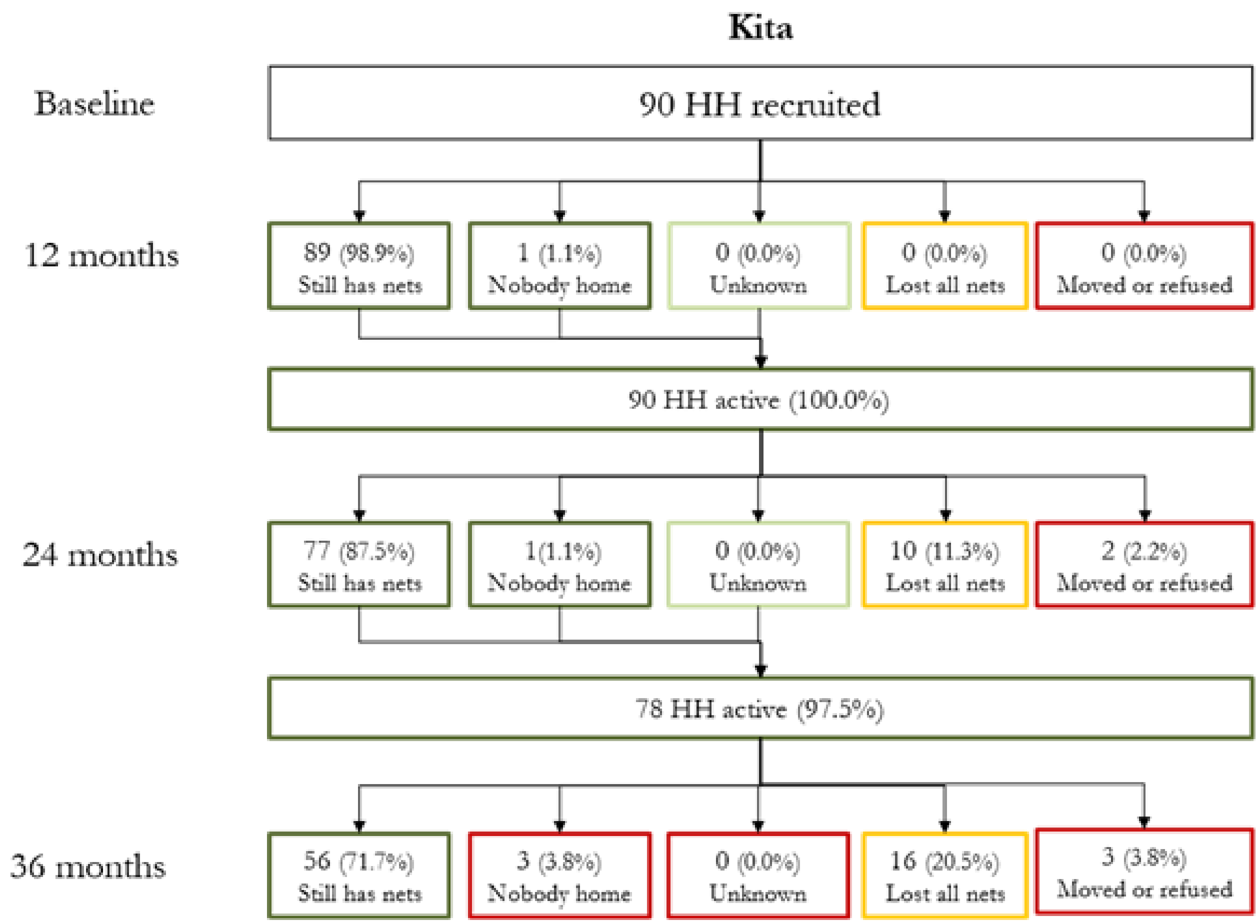
3. RESULTS

3.1 SAMPLE

The follow-up was good with 210 households recruited (120 in Kenieba and 90 in Kita) in the baseline survey (6 months post ITN distribution) (Figure 3). Overall, the number of active households in Kenieba in the 12-, 24-, and 36-month surveys were 118, 88 and 44, respectively. In Kita there were 90, 78, and 59 active households in the respective surveys.

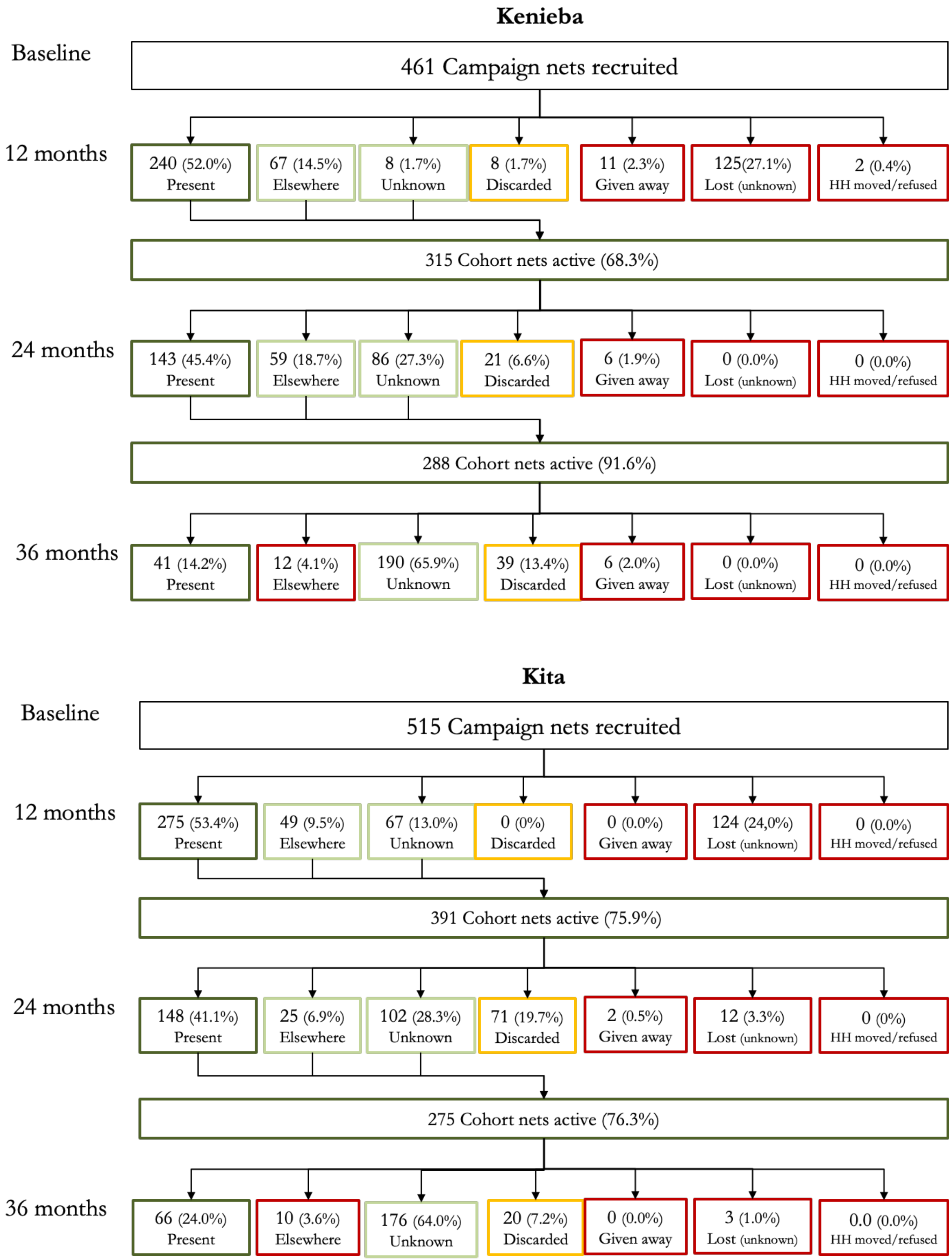
FIGURE 3: 36-MONTH FOLLOW-UP STATUS OF HOUSEHOLDS RECRUITED AT BASELINE





A total of 976 nets (461 in Kenieba and 515 in Kita) were recruited at baseline (6 months) and were tagged for follow-up (Figure 4). The status of active cohorts (nets present, used elsewhere and unknown/owner absent) was 315, 288, and 243, respectively, at 12, 24, and 36 months in Kenieba and 391, 275 and 252 respectively, at 12, 24, and 36 months in Kita. Strikingly, at the 36-month survey around 60% of nets in both cohorts were not available for sampling for unknown reasons (house owner was absent).

FIGURE 4: FOLLOW-UP STATUS OF COHORT ITNS RECRUITED AT BASELINE



3.2 DETERMINANTS OF DURABILITY

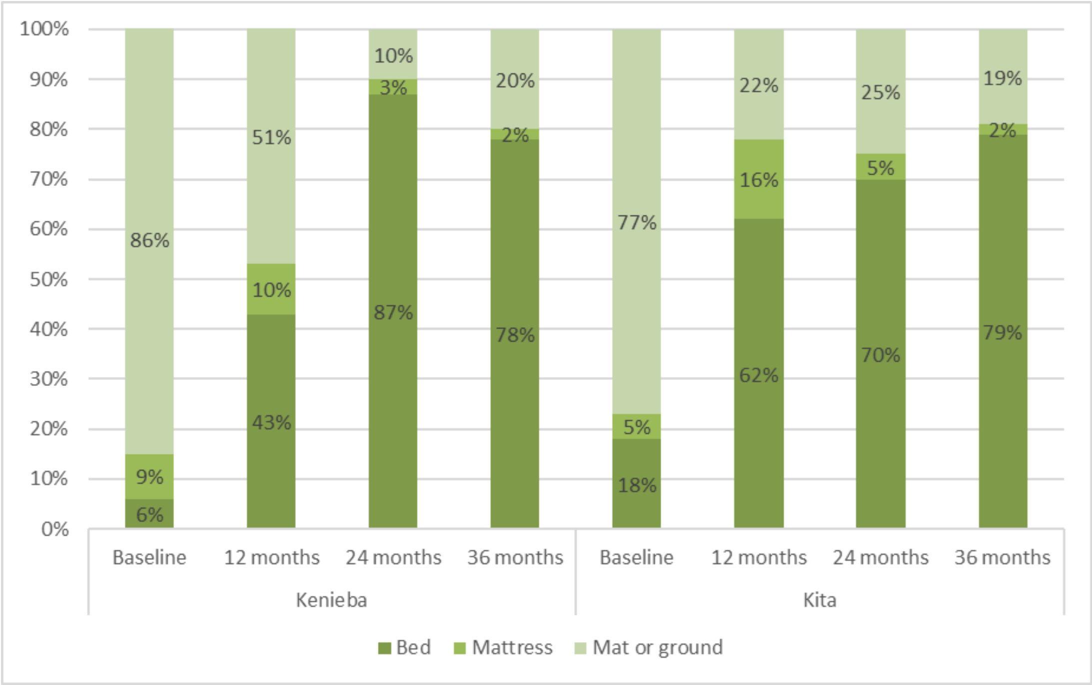
The household risk factor determinants of ITN durability (presence of rodents and food in the household and practice of cooking near sleeping areas) were identified. Storing food in the sleeping room is thought to attract rodents, which increases the potential damage of nets by rodents. During all the surveys (at 6, 12, 24, and 36 months), this practice was reported in more than half (>60.0%) of the households in both sites (Table 2). Cooking in the sleeping room where nets are hanging can potentially cause a fire, especially if the cooking fuel is firewood. However, doing this always was not common in either site, and <5% households said they always used firewood. The perceived presence of rodents was generally high (>60.0%) in both sites during all surveys. It was significantly ($p=0.0009$) higher in Kenieba (97.2%) than in Kita (75.0%) at 36 months (Table 2).

TABLE 2: PREVALENCE OF HOUSEHOLD RISK FACTORS FOR DAMAGE

Variable and site	Baseline (6 months)	12 months	24 months	36 months
Kenieba	N=120	N=117	N=112	N=73
Ever store food in sleeping room	61.7%	78.6%	76.7%	76.7%
Cook in sleeping room				
never	26.7%	64.9%	94.6%	75.3%
sometimes	68.3%	35.0%	5.3%	24.6%
always	5.0%	0.0%	0.0%	0.0%
Rodents observed (last 6 m)	79.2%	80.3%	91.9%	97.2%
Kita	N=90	N=89	N=89	N=72
Ever store food in sleeping room	66.6%	65.1%	69.6%	76.3%
Cook in sleeping room				
never	41.2%	93.3%	92.1%	69.4%
sometimes	56.7%	6.7%	7.8%	30.5%
always	2.2%	0.0%	0.0%	0.0%
Rodents observed (last 6 m)	62.2%	64.0%	80.9%	75.0%

The sleeping place risk factor determinant of ITN durability was identified. Generally, nets used when sleeping on mats or the ground are more prone to wear and tear than those used over mattresses and bed frames. The main type of sleeping place for the campaign nets if used was bed and mattress (>60.0%) at 24 and 36 months in Kenieba and at 12, 24, and 36 months in Kita. In contrast, at baseline (6 months), it was mat or ground (>75.0%) (Figure 5). The baseline was conducted in the hot dry season in May, when many people slept outdoors on mats or on the ground. The 12-, 24-, and 36-month surveys were conducted at the end of rainy season (November-December), when people tended to sleep indoors on a bed or mattress.

FIGURE 5: TYPE OF SLEEPING PLACE FOR CAMPAIGN ITNS WHEN USED



The following risk factor determinants were identified in relation to hanging of campaign nets risk and net durability. Throughout the study period (baseline, 12, 24, and 36 months), more than half of all nets (range of 50.0% to 77.6%) were found hanging loose over the sleeping place during the day—if they were hanging—exposing them to an increased risk of damage. This was the case in both sites (Table 3). In contrast, the risk of damaging washed nets by drying them over bushes or fences varied between 1.0% and 78.0% of washed nets in Kenieba and between 1.0% and 36.0% of washed nets in Kita and there was a major difference between sites ($p<0.0001$) at 6, 12, and 24 months. As expected, the proportion of households with cohort nets ever washed started out low and increased over time, reaching 71.8% in Kenieba and 74.7% in Kita at 36 months. However, the difference of the proportion of nets ever washed? between the sites at the final timepoint was not statistically or programmatically significant. The washing frequency every six months showed little variation; it was about one to three washes in both sites. Excessive washing, particularly with cleaning products like detergent or bleach, can diminish insecticide effectiveness. The proportion of households reporting washes with a detergent was comparable between the two sites at baseline, 12, and 24 months (45.0% to 75.0%, $p>0.05$). In contrast at 36 months, the proportion of households reporting washes with a detergent was significantly higher ($p=0.0258$) in Kenieba (71.8%) than in Kita (37.8%).

TABLE 3: PREVALENCE OF HANDLING RISK FACTORS FOR CAMPAIGN ITNS

Variable and site	Baseline (6 months)	12 months	24 months	36 months
Kenieba	% (n)	% (n)	% (n)	% (n)
Hanging nets NOT folded or tied	76.9% (52)	72.0% (129)	75.5% (86)	71.4% (21)
Net dried on fence or bush	11.5% (26)	0.8% (115)	77.6% (103)	68.7 (32)
Net ever washed	5.5% (471)	46.9% (245)	73.6% (144)	71.8 (45)
Median washed last 6 m (IQR)	2 (2-1)	1 (1-1)	2 (1-4)	3 (2-5)
Used detergent/bleach for wash	65.3% (26)	67.8% (115)	56.6% (106)	71.8% (32)
Kita	% (n)	% (n)	% (n)	% (n)
Hanging nets NOT folded or tied	50.0% (82)	67.4% (224)	57.5% (113)	77.6% (67)
Net dried on fence or bush	13.4% (52)	2.9% (206)	0.9% (110)	36.4% (74)
Net ever washed	10.1% (514)	67.5% (305)	76.1% (147)	74.7% (99)
Median washed last 6 m (IQR)	1 (1-2)	1 (1-1)	3 (2-4)	3 (2-4)
Used detergent/bleach for wash	75.0% (52)	66.8% (206)	49.1% (112)	37.8% (74)

IQR=interquartile range

The exposure of respondents to messages about nets in the previous six months was examined. In general, a low proportion of respondents were exposed to messages about nets (<45.0%) in both sites throughout the survey. The highest proportions were observed at baseline (20.8%) (just after the net distribution campaign) and at 36 months (27.4%) in Kenieba, and at 24 months (43.8%) in Kita (Table 4). Exposure to net messaging dramatically declined in Kenieba from 6 to 24 months, suggesting there was very little ongoing behavior change communication activity. But it increased in Kita, suggesting there was ongoing behavior change communication activity. However, the difference between the sites was statistically or programmatically significant ($p=0.0009$) only at 24 months. The mean information sources were the same in both sites, mainly interpersonal communication (IPC) (e.g., health workers, friends/family, and community leaders or events) and media.

TABLE 4: RESPONDENT EXPOSURE TO MESSAGES ABOUT NETS IN THE PAST SIX MONTHS

Variable and site	Baseline (6 months)	12 months	24 months	36 months
Kenieba				
Any exposure last 6 months	20.8%	16.2%	8.9%	27.4%
Mean info sources (if exposed)	1.5	1.0	1.3	1.6
Type of media				
media only	8.0%	21.0%	70.0%	30.0%
both	20.0%	15.7%	10.0%	10.0%
IPC only	72.0%	63.1%	20.0%	60.0%
Kita				
Any exposure last 6 months	30.0%	29.2%	43.8%	34.7%
Mean info sources (if exposed)	1.5	1.0	1.5	1.6
Type of media				
media only	25.9%	46.1%	39.4%	32.0%
both	11.1%	0.0%	5.2%	4.0%
IPC only	62.9%	53.8%	55.2%	66.0%

The study also explored the recall of messages on net and attitude towards net care and repair (based on all surveyed households). Messages on net care were recalled by a low proportion of respondents in both sites, which reflects the low exposure to messages (Table 5). The proportion of respondents that recalled messages to "use a net every night" and that "nets prevent malaria" was significantly ($p<0.05$) lower at 24 months in Kenieba (1.7% and 4.4%) than at Kita (34.8% and 42.7%). The proportion of respondents that recalled messages on net care and repair was low in both sites (<30.0%) at baseline, 12, 24, and 36 months. It was significantly ($p<0.05$) lower at 24 months in Kenieba (0.0% and 3.5%) than at Kita (3.3% and 13.4%). The net care and repair attitude score above 1.0 (very positive attitude/capacity to keep nets in a good condition and repair net damage) were:

- Higher in Kenieba (39.1%) than in Kita (27.7%) ($p=0.031$) at baseline,
- Higher in Kenieba (13.6%) than in Kita (4.4%) ($p=0.019$) at 12 months,

- Lower in Kenieba (36.6%) than in Kita (61.8%) (*p=0.004*) at 24 months, and
- Similar in Kenieba (56.1%) and in Kita (50.0%) (*p=0.676*) at 36 months.

This is one of the most significant differences between the two sites from baseline to 24 months. Additional social behavior change communication is recommended to improve net care attitudes, which has been demonstrated to be associated with improved ITN lifespan. The net care and repair attitude increased from baseline to 36 months.

TABLE 5: RESPONDENT ATTITUDES TOWARD NETS AND NET CARE AND REPAIR

Variable and site	Baseline (6 months)	12 months	24 months	36 months
Kenieba	N=120	N=117	N=112	N=73
Recalled "use net (every) night"	20.0%	15.3%	1.7%	26.0%
Recalled "nets prevent malaria"	40.0%	42.1%	4.4%	6.8%
Recalled "care for net"	16.0%	5.6%	3.5%	10.0%
Recalled "repair net"	8.0%	5.2%	0.0%	0.0%
Attitude score care and repair mean (95% CI) % with score > 1.0	 0.6 (0.51-0.80) 39.1%	 0.4 (0.37-0.54) 13.6%	 0.6 (0.51-0.78) 36.6%	 0.9 (0.86-1.10) 56.1%
Kita	N=90	N=89	N=89	N=72
Recalled "use net (every) night"	30.0%	28.0%	42.7%	29.1%
Recalled "nets prevent malaria"	59.2%	38.4%	34.8%	22.2%
Recalled "care for net"	18.5%	26.9%	13.4%	13.8%
Recalled "repair net"	7.4%	3.8%	3.3%	1.3%
Attitude score care and repair mean (95% CI) % with score > 1.0	 0.7(0.60-0.83) 27.7%	 0.4 (0.36-0.51) 4.4%	 0.9 (0.85-1.10) 61.8%	 0.8 (0.75-1.03) 50.0%

The household experience with care and repair of nets and actual repairs made in damaged campaign nets were explored (Table 6). As expected, with increasing time since distribution, the proportion of households experiencing any holes in their campaign nets increased, reaching 78.0% in Kenieba and 81.9% in Kita by 36 months. It was:

- Similar in Kenieba (25.0%) and in Kita (22.2%) (*p = 0.6892*) at baseline,
- Higher in Kenieba (64.9%) than in Kita (20.2%) (*p<0.0001*) at 12 months,
- Higher in Kenieba (77.6%) than in Kita (56.1%) (*p=0.01*) at 24 months, and
- Similar in Kenieba (78.0%) and in Kita (81.9%) (*p = 0.6401*) at 36 months.

The households that never discussed care and repairs remained low in Kenieba (7.1% to 44.4%) and high in Kita (30.0% to 78.6%): It was:

- Lower in Kenieba (9.1%) than in Kita (30.0%) (*p=0.002*) at baseline (6 months),
- Lower in Kenieba (44.4%) than in Kita (78.6%) (*p=0.001*) at 12 months,
- Lower in Kenieba (7.1%) than in Kita (70.7%) (*p<0.0001*) at 24 months, and
- Similar in Kenieba (34.2%) and in Kita (23.6%) (*p= 0.2536*) 36 months.

The proportions of households that never repaired nets (if they had holes) were the same in both sites. Proportions were between 42.5% and 63.3% in Kenieba and between 44.4% and 74.5% in Kita. The proportion of households with damaged campaign nets repaired was low overall in both sites (<30.0%), between 12.7% and 27.5% in Kenieba and between 15.7% and 26.1% in Kita.

TABLE 6: HOUSEHOLD NET CARE AND REPAIR EXPERIENCE

Variable and site	Baseline (6 months)	12 months	24 months	36 months
Kenieba				
Ever experienced holes in net	25.0% (120)	64.9% (117)	77.6% (n=112)	78.0% (n=73)
Ever discussed care and repair	9.1% (120)	44.4% (117)	7.1% (n=112)	34.2% (n=73)
Ever repaired (if had holes)	63.3% (30)	44.7% (76)	42.5% (n=87)	59.6% (n=57)
Damaged campaign nets repaired	n.a.	12.7% (109)	19.4% (n=113)	27.5% (n=40)
Kita				
Ever experienced holes in net	22.2% (90)	20.2% (89)	56.1% (n=89)	81.9% (n=72)
Ever discussed care and repair	30.0% (90)	78.6% (89)	70.7% (n=89)	23.6% (n=72)
Ever repaired (if had holes)	60.0% (20)	44.4% (18)	50.0% (n=50)	74.5% (n=59)
Damaged campaign nets repaired	n.a.	15.7% (89)	23.8% (n=105)	26.1% (n=65)

3.3 NET OWNERSHIP AND NET USE

This section looks at the use and ownership of the campaign ITNs, as well as other nets in the sampled households, including where they were obtained and used, who used them, and what the level of ownership coverage was. The hanging and use of cohort nets were explored (Table 7). The proportion of campaign nets found hanging was low in both sites (<20.0%) at baseline. This proportion steadily increased during the study, but the difference between the sites, 59.7% in Kenieba and 76.8% in Kita (76.8%), was significantly different (*$p=0.01$*) at 24 months. The proportion of nets taken down or stored was low in both sites (<30.0%) during all surveys. It was:

- Lower in Kenieba (5.4%) than in Kita (7.5%) (*$p=0.031$*) at baseline (6 months),
- Lower in Kenieba (4.8%) than in Kita (21.7%) (*$p < 0.0001$*) at 24 months.

The proportion of nets still in their packaging was higher in Kenieba (82.8%) than in Kita (73.3%) (*$p=0.031$*) at baseline (6 months) (Table 7). This high proportion observed in both sites can be attributed to the period of this survey (dry season with low density of mosquitoes) and the use of existing non-cohort nets. The proportion in packaging decreased over the study (<3.0%) at both sites at 36 months. The proportion of nets "used last night" and "every night (last week)" was low (<20.0%) in both sites at baseline (6 months) but increased over the study (12 and 24 months). At 24 months, the proportion of "nets used last night" was lower in Kenieba (60.4%) than in Kita (79.3%) (*$p=0.004$*). The proportion of nets used "every night (last week)" was lower in Kenieba (53.3%) than in Kita (76.3%) (*$p=0.01$*). At 36 months, the proportions of nets "used last night" and "every night (last week)" was lower (*$p=0.0006$* and *$p<0.0001$*) in Kenieba compared to Kita. Generally, if a net was hanging, it was also being used.

TABLE 7: STATUS AND REPORTED USE OF COHORT NETS IN THE HOUSEHOLD

Variable	Baseline (6 months)	12 months	24 months	36 months
Kenieba	N=471	N=245	N=144	N=45
Hanging	11.4%	52.6%	59.7%	46.6%
Taken down or stored	5.4%	6.1%	4.8%	28.8%
Still in package	82.8%	13.0%	2.7%	2.2%
Used last night	11.4%	50.2%	60.4%	31.1%
Used every night (last week)	8.9%	49.8%	58.3%	4.6%
Kita	N=514	N=305	N=147	N=91
Hanging	15.9%	73.4%	76.8%	67.6%
Taken down or stored	7.5%	18.6%	21.7%	16.1%
Still in package	73.3%	5.9%	0.6%	1.0%
Used last night	16.5%	75.4%	79.3%	67.6%
Used every night (last week)	15.5%	74.1%	76.3%	22.4%

The hanging and use of non-cohort nets was explored (Table 8). The proportion of non-cohort nets found hanging was the same in Kenieba (39.8%) and in Kita (59.5%) at baseline (6 months). It increased over the study to 74.3% at 24 months and 61.5% at 36 months in Kenieba. The proportion also increased to 79.2% at 24 months and to 74.2% at 36 months in Kita. We observed a statistically significant difference (*$p=0.006$*) between Kenieba (49.3%) and Kita (71.0%)

at 12 months. The same situation was observed at 36 months (*p=0.030*). From the beginning, and throughout the study, households owned many other nets and new ones kept coming in.

The proportion of nets taken down or stored was low in both sites (<30.0%). It was:

- Lower in Kenieba (18.7%) than in Kita (27.3%) (*p=0.001*) at baseline (6 months),
- Lower in Kenieba (1.8%) than in Kita (14.0%) (*p=0.0003*) at 12 months, and
- Lower in Kenieba (4.6%) than in Kita (16.0%) (*p=0.0003*) at 24 months.
- Similar in Kenieba (28.8%) and Kita (16.1%) (*p = 0.3705*) at 36 months.

The proportion of nets still in package was low in both sites (<20.0%) over the study periods. But it was:

- Higher in Kenieba (10.4%) than in Kita (8.3%) (*p=0.001*) at baseline (6 months),
- Higher in Kenieba (20.2%) than in Kita (11.0%) (*p=0.0003*) at 12 months,
- Lower in Kenieba (3.2%) than in Kita (3.8%) (*p=0.0003*) at 24 months, and
- Similar in Kenieba (8.6%) and Kita (5.8%) (*p = 0.0577*) at 36 months.

The proportions of nets "used last night" and "every night (last week)" was low (<50.0%) in both sites at baseline, but increased over the study periods. The proportion of nets "used last night" was lower in Kenieba (38.6%) than in Kita (74.0%) (*p=0.002*) and the proportion of nets "used every night (last week)" was also lower in Kenieba (36.2%) than in Kita (72.0%) (*p=0.002*) at 12 months. The proportion of nets "used last night" was lower in Kenieba (64.7%) than in Kita (76.1%) (*p=0.004*) and the proportion of nets "used every night (last week)" was approximatively the same in Kenieba (57.9%) and in Kita (70.7%) at 24 months. The proportion of nets "used last night" was lower in Kenieba (59.0%) than in Kita (74.2%) (*p= 0.0027*) and the proportion of nets "used every night (last week)" was lower in Kenieba (57.0%) than in Kita (71.5%)(*p= 0.0212*) at 36 months.

TABLE 8: OWNERSHIP AND SOURCE OF NON-COHORT NETS

Variable	Baseline (6 months)	12 months	24 months	36 months
Kenieba	N=143	N=158	N=214	N=242
Hanging	39.8%	49.3%	74.3%	61.5%
Taken down or stored	18.7%	1.8%	4.6%	26.4%
Still in package	10.4%	20.2%	3.2%	8.6%
Used last night	40.5%	38.6%	64.7%	59.0%
Used every night (last week)	38.4%	36.2%	57.9%	57.0%
Kita	N=84	N=100	N=130	N=190
Hanging	59.5%	71.0%	79.2%	74.2%
Taken down or stored	27.3%	14.0%	16.0%	13.7%
Still in package	8.3%	11.0%	3.8%	5.8%
Used last night	53.5%	74.0%	76.1%	74.2%
Used every night (last week)	48.8%	72.2%	70.7%	71.5%

The ownership of non-cohort nets and the source of obtaining them were identified (Table 9). The proportion of households with any other nets was high (>55.5%) in both sites at 6, 12, and 36 months. But it was higher in Kenieba (99.1%) than in Kita (41.5%) (*p<0.0001*) at 24 months. The main source of non-campaign nets was other campaign (but only at 24 and 36 months of the current study) and the public sector in both sites. The proportion of nets that came from the public sector was high (>48%) in both sites at 6, 12, and 36 months. But it was higher in Kenieba (75.8%) than in Kita (33.7%) (p=0.002) at 24 months. The proportion of nets that came from the private sector was low (>25.0%) over the study. It was higher in Kenieba (15.8%) than in Kita (5.5%) (*p=0.034*) only at baseline (6 months). The proportion of nets that came from family or friends fluctuated from 6.6% to 60.3% in Kenieba and from 14.4% to 53.9% in Kita over the study period.

TABLE 9: STATUS AND REPORTED USE OF NON-COHORT NETS IN THE HOUSEHOLD

Variable	Baseline (6 months)	12 months	24 months	36 months
Kenieba	N=120	N=117	N=112	N=89
Household has any other nets	79.1%	61.1%	99.1%	79.7%
Source public sector	65.0%	58.1%	75.8%	70.6%
Source other campaign*	0.0%	0.0%	75.8%	59.9%
Source private sector	15.8%	12.8%	23.2%	6.6%
Source family or friends	6.6%	60.3%	24.1%	22.7%
Kita	N=90	N=89	N=80	N=78
Household has any other nets	65.5%	58.4%	41.5%	84.6%
Source public sector	56.6%	48.3%	33.7%	68.4%
Source other campaign*	0.0%	0.0%	88.7%	48.9%
Source private sector	5.5%	12.3%	4.4%	1.0%
Source family or friends	14.4%	53.9%	24.7%	30.5%

*Previous or subsequent to cohort campaign

The users of campaign cohort nets were identified (Table 10). The nets were mainly used by adults only (>50.0%) in Kenieba over the study period, and adults only (>45.0%) in Kita at 6, 24, and 36 months. They were mainly used by children only (45.2%) at 12 months. The significant differences in use patterns were observed between sites at 24 months only (*p=0.027*).

TABLE 10: USE OF COHORT NETS BY HOUSEHOLD MEMBERS AMONG NETS USED THE PREVIOUS NIGHT

Variable	Baseline (6 months)	12 months	24 months	34 months
Kenieba	N=52	N=123	N=87	N=14
Children only*	7.6%	12.2%	9.1%	14.2%
Children + adults**	38.4%	37.4%	16.0%	0.0%
Adults only**	53.8%	50.4%	74.7%	85.7%
Kita	N=85	N=230	N=115	N=67
Children only*	8.2%	13.9%	13.0%	8.9%
Children + adults**	45.8%	45.2%	33.0%	29.8%
Adults only**	45.8%	40.8%	53.9%	61.1%

* Age 0-9 years; ** includes adolescents 10-19

The users of non-cohort nets were identified (Table 11). The nets were mainly used by adults only (>40.0%) in Kenieba over the study periods, children + adults (>45.0%) in Kita at baseline (6 months) and 12 months, and adults only (>35.0%) in Kita at 24 and 36 months. A significant difference in use patterns was observed between sites at 24 months (*p=0.0024*).

TABLE 11: USE OF NON-COHORT NETS BY HOUSEHOLD MEMBERS AMONG NETS USED THE PREVIOUS NIGHT

Variable	Baseline (6 months)	12 months	24 months	36 months
Kenieba	N=58	N=61	N=138	N=143
Children only*	6.8%	19.6%	13.0%	16.0%
Children + adults**	32.7%	36.0%	20.2%	25.8%
Adults only**	60.3%	44.2%	66.6%	58.0%
Kita	N=45	N=74	N=99	N=141
Children only*	13.3%	21.6%	24.2%	19.1%
Children + adults**	48.8%	45.9%	37.3%	31.2%
Adults only**	37.7%	32.4%	38.3%	49.6%

* Age 0-9 years; ** includes adolescents 10-19

3.4 DURABILITY OF CAMPAIGN ITNS

Attrition (including nets lost between campaign and baseline) was estimated in Table 12. It was:

- Higher in Kenieba (40.0%) than in Kita (20.1%) (*p<0.0001*) at baseline (6 months),
- Lower in Kenieba (30.6%) and in Kita (30.9%) (*p=0.025*) at 12 months,
- Similar in Kenieba (14.2%) and in Kita (24.2%) (*p=0.2715*) at 24 months and,
- Similar in Kenieba (52.2%) and in Kita (25.7%) at 36 months.

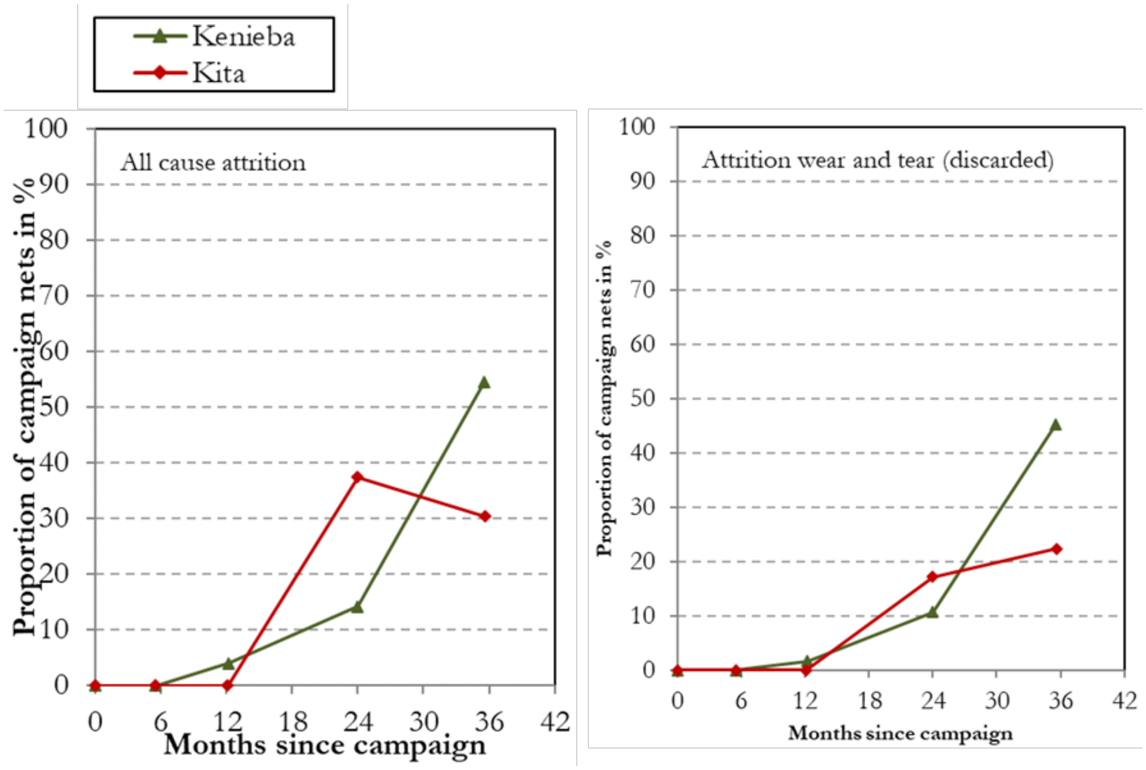
Attrition was significantly different between Kenieba and Kita at baseline (6 months) and 12 months.

TABLE 12: CAMPAIGN COHORT ITN ATTRITION

Variable	Campaign – Baseline (6 months)	Campaign – 12 months	Campaign – 24 months	Campaign – 36 months
Kenieba	N=785	N=465	N=168	N=86
Given away	40.0%	2.3%	3.5%	6.9%
Discarded (wear and tear)	0.0%	1.7%	10.7%	45.3%
Unknown	0.0%	26.6%	0.0%	0.0%
Total	**40.0%**	**30.6%**	**14.2%**	**52.2%**
Kita	N=644	N=511	N=197	N=89
Given away	5.4%	0.0%	0.5%	0.0%
Discarded (wear and tear)	0.0%	0.0%	17.2%	22.4%
Unknown	14.7%	30.9%	6.5%	3.3%
Total	**20.1%**	**30.9%**	**24.2%**	**25.7%**

All-cause attrition observed was higher in Kenieba (4.8%) than in Kita (0.0%) (*p=0.0029*) at 12 months, but similar in Kenieba (14.2%) and in Kita (37.4%) (*p=0.0617*) at 24 months, and similar in Kenieba (54.6%) and in Kita (30.3%) (*p=0.0514*) at 36 months (Figure 6). It is common that 5-20% of campaign nets were given away between the campaign and the baseline (6 months) survey. This was due to 1) redistribution of nets primarily among family members and 2) the mobility of some family members, who travelled to other localities with the nets. It also depended on the scope and scale of previous ITN distributions in the area. All-cause attrition was between 5% and 40% at 12, and 24 months in Kenieba and at 12-, 24- and 36 months in Kita. Attrition due to wear and tear (discarded) was observed (1.7%) at 12 months, (10.7%) at 24 months and (45.5%) at 36 months in Kenieba. In contrast, it was observed only at 24 months (17.2%) and at 36 months (22.4%) in Kita (Figure 6). The attrition due to wear and tear was higher than expected in both sites at 24 months Normally it varies between 0-1% at baseline (6 months) and 1-5% at 12 months and 3-12% at 24 months (https://www.durabilitymonitoring.org/).

FIGURE 6: TRENDS IN TOTAL ATTRITION AND ATTRITION DUE TO WEAR AND TEAR (DISCARDED NETS)



The physical condition (integrity) of surviving cohort nets was explored (Table 13). The proportion of net with any holes was:

- Higher in Kenieba (48.1%) than in Kita (14.4%) (*p<0.0001*) at 12 months,
- Higher in Kenieba (78.4%) than in Kita (48.9%) (*p=0.0001*) at 24 months, and
- Higher in Kenieba (88.9%) than in Kita (65.6%) (*p=0.012*) at 36 months.

The proportion of net serviceable (pHI≤642) was:

- Lower in Kenieba (84.9%) than in Kita (95.4%) (*p=0.004*) at 12 months,
- Lower in Kenieba (70.3%) than in Kita (91.8%) (*p=0.005*) at 24 months, and
- Lower in Kenieba (48.8%) than in Kita (77.7%) (*p=0.005*) at 36 months.

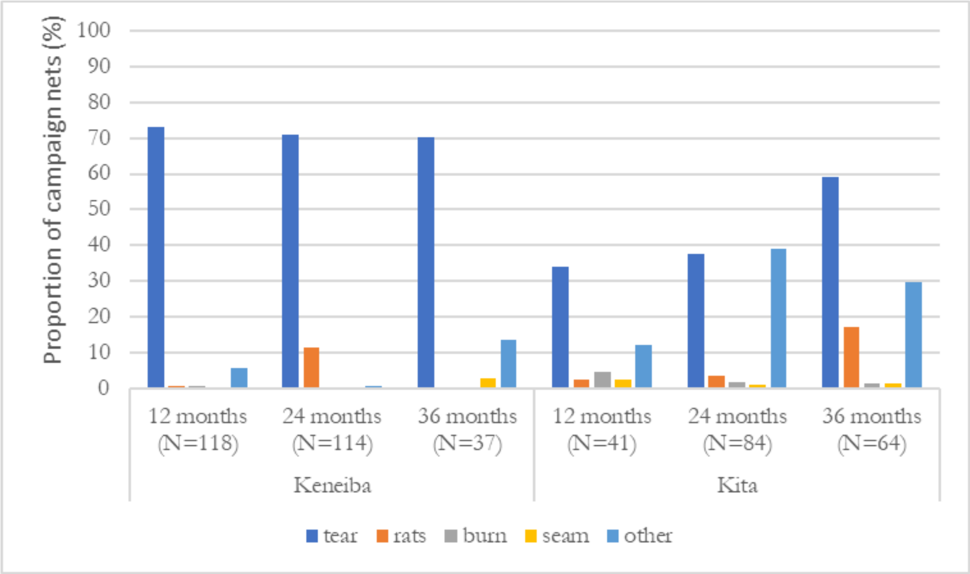
As expected, the proportion of ITNs present in the surveyed households with any sign of damage initially increased rapidly, but then leveled off a bit, as older nets were increasingly discarded. Generally, the expected proportion of nets in serviceable condition at 24 months was greater than 74% and for 36 months greater than 50%. This situation was observed in Kita, but in Kenieba the proportion of nets in serviceable condition was lower than expected. This suggests that there is a significant difference between the two brands. Further investigation may be useful to determine whether the product specifications or socio-cultural factors are driving the improved durability.

TABLE 13: PHYSICAL INTEGRITY OF OBSERVED CAMPAIGN COHORT ITNS

Variable	Baseline (6 months)	12 months	24 months	36 months
Kenieba	N=461	N=245	N=144	N=45
Any holes	1.9%	48.1%	78.4%	88.9%
Median pHI (if any hole)	623	301.5	296	917.5
Good (pHI<64)	98.3%	65.7%	47.2%	33.3%
Too torn (pHI>642)	0.8%	15.1%	29.1%	51.1%
Serviceable (pHI≤642)	**99.1%**	**84.9%**	**70.3%**	**48.8%**
Kita	N=515	N=305	N=147	N=99
Any holes	3.3%	14.4%	48.9%	65.6%
Median pHI (if any hole)	1	111.5	90.5	198
Good (pHI<64)	100.0%	92.7%	71.4%	63.6%
Too torn (pHI>642)	0.0%	4.5%	8.1%	22.2%
Serviceable (pHI≤642)	**100.0%**	**95.4%**	**91.8%**	**77.7%**

The type of net damage that was reported by the households for each campaign ITN with any holes was identified. The general damage pattern was dominated by mechanical damage and was similar within each site. At 12, 24 and 36 months, the main type of damage reported in Kenieba was tear (>70%); in Kita, it was tear and other causes (>30%) (Figure 7).

FIGURE 7: TYPES OF DAMAGE MECHANISMS REPORTED FOR DAMAGED CAMPAIGN ITNS



The nets surviving in serviceable condition (including nets discarded before baseline) was estimated (Table 14). Of the cohort nets found in households, the proportion of nets surviving in serviceable condition was:

- Lower in Kenieba (99.1%) than in Kita (100.0%) (*p=0.037*) at baseline (6 months),
- Lower in Kenieba (84.9%) than in Kita (95.4%) (*p=0.004*) at 12 months,
- Similar in Kenieba (62.9%) and in Kita (73.6%) (*p=0.359*) at 24 months, and
- Lower in Kenieba (25.0%) than Kita (58.8%) (*p=0.004*) at 36 months

Of the cohort nets found in households, the proportion of only net surviving in serviceable condition was:

- Lower in Kenieba (94.8%) than in Kita (100.0%) (*p=0.008*) at baseline (6 months),
- Lower in Kenieba (82.4%) than in Kita (94.9%) (*p=0.0025*) at 12 months,
- Similar in Kenieba (62.0%) and in Kita (73.4%) (*p=0.335*) at 24 months, and
- Lower in Kenieba (23.1%) than Kita (58.8%) (*p=0.002*) at 36 months.

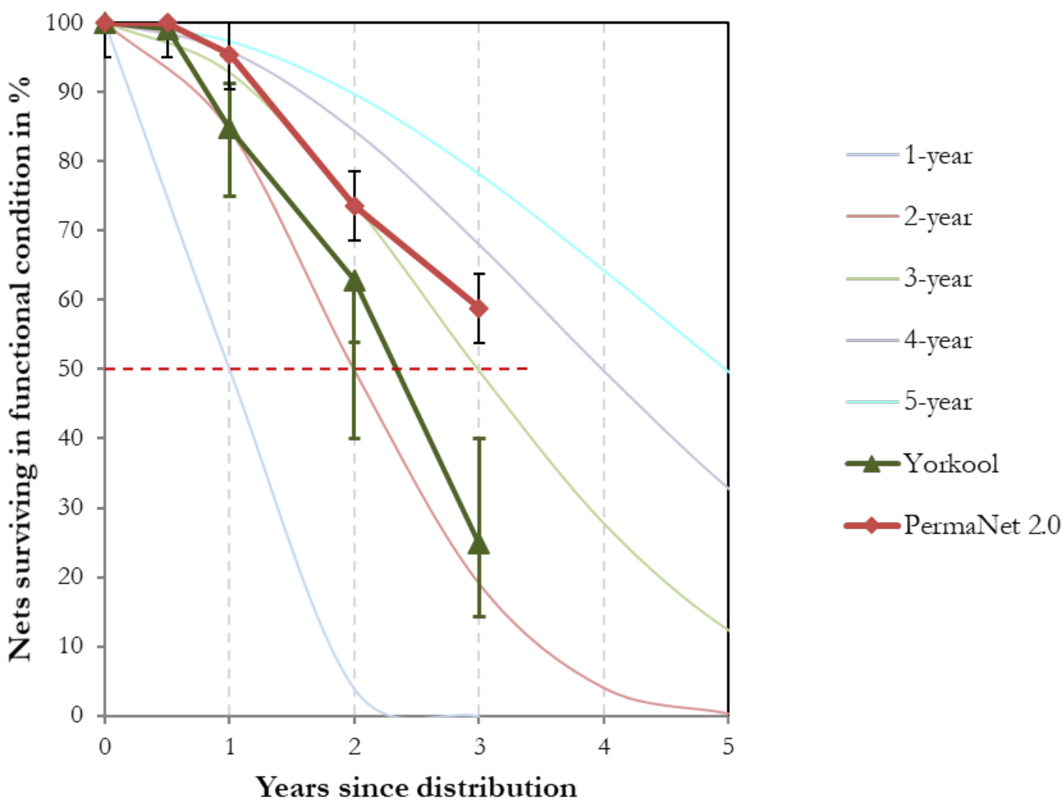
TABLE 14: CAMPAIGN COHORT ITNS SURVIVING IN SERVICEABLE CONDITION

Variable	Baseline (6 months)	12 months	24 months	36 months
Kenieba	N=471	N=245	N=162	N=80
Survival estimate	99.1%	84.9%	62.9%	25.0%
95% CI	97.86-99.67	74.98-91.34	46.04-53.96	14.34-39.9
Only nets ever used	N=77	N=211	N=158	N=69
Survival estimate	94.8%	82.4%	62.0%	23.1%
95% CI	87.82-97.88	71.56-89.78	54.24-86.63	13.13-37.61
Kita	N=514	N=305	N=181	N=85
Survival estimate	100.0%	95.4%	73.6%	58.8%
95% CI		91.58-97.55	54.38-86.73	41.71-74.04
Only nets ever used	N=127	N=276	N=254	N=85
Survival estimate	100.0%	94.9%	73.4%	58.8%
95% CI		90.71-97.29	55.34-78.69	41.71-74.04

* Among present nets observed and discarded nets at each round.

To standardize the analysis and facilitate comparisons with other durability data, the results were plotted against the hypothetical survival curves with defined median survival (Figure 8). The survival estimates roughly follow the hypothetical curves, and the relationship between the two sites was different throughout the follow-up. The median survival was 2.1 years (1.82-2.61) in Kenieba (Yorkool) and 3.4 years (2.67-5.04) in Kita (PermaNet 2.0).

FIGURE 8: ESTIMATED ITN SURVIVAL



Error bars show 95% CIs.

3.5 INSECTICIDAL EFFECTIVENESS AND CONTENT OF CAMPAIGN NETS

The outcomes of insecticidal effectiveness were based on bioassay results using the standard WHO cone test, where the 60-minute knock-down (KD60) and the 24-hour mortality rate (functional mortality) were measured using a susceptible colony of *An. coluzzii* Ngousso. The two variables from these tests were combined into the following outcome measures:

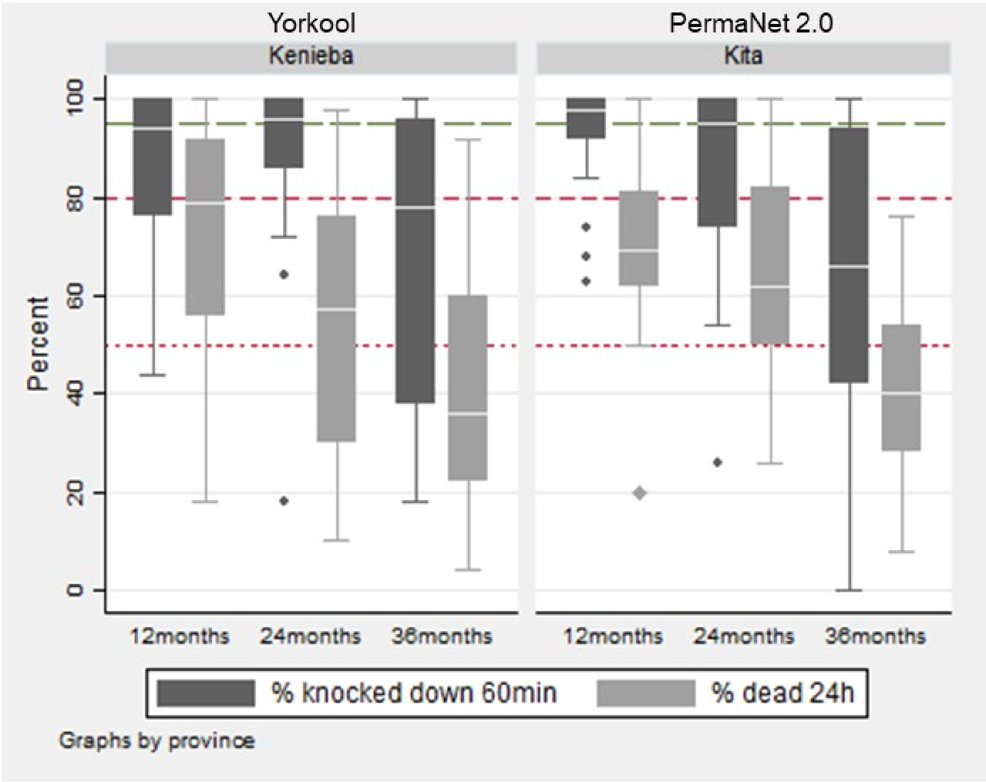
- Optimal effectiveness: KD60 ≥ 95% or mortality ≥ 80%
- Minimal effectiveness: KD60 ≥ 75% or mortality ≥ 50%

Bioassay results from 6, 12, 24 and 36 months are shown in Table 15 and Figure 9. The determination of insecticide bioefficacy for Yorkool nets collected in Kenieba and PermaNet 2.0 nets collected in Kita 6, 12, 24 and 36 months were conducted. At each point in time, the proportion of nets with optimal effectiveness (at least 95% KD or 80% mortality) was <80%. The proportion of nets reaching minimal effectiveness (75% KD or 50% 24h mortality) was >80% at 6, 12, and 24 months, but at 36 months was reduced. The proportion of nets with optimal and minimal effectiveness was similar (*p>0.05*) in both type of nets during the 36 months survey.

TABLE 15: CONE BIOASSAY RESULTS USING A SUSCEPTIBLE COLONY OF *AN. COLUZZII* ON YORKOOL AND PERMANENT 2.0 ITNS

Site/Net	6 months (Baseline)	12 months	24 months	36 months
Kenieba/Yorkool	**N=30**	**N=30**	**N=30**	**N=29**
KD60				
Mean (95% CI)	94.6% (90.5-98.6)	85.6% (78.2-93.5)	90.5% (83.5-97.5)	67.3% (55.2-79.5)
Median (IQR)	98% (94.0-99.7)	94% (82-99.7)	96% (96.0-100.0)	78.0% (38.0-96.0)
Mortality 24 hours				
Mean (95% CI)	54.4% (47.8-60.9)	74.1% (63.5-84.7)	54.2% (44.3-64.2)	42.4% (29.7-55.1)
Median (IQR)	54.0% (42.0-66.0)	79% (72-89.7)	57.0% (44.2-72.4)	36.0% (22.0-60.0)
Optimal effectiveness				
Estimate (95% CI)	66.6% (45.8-82.5)	70.0% (47.9-85.5)	70.0% (47.9-85.5)	31.0% (15.1-53.1)
Minimal effectiveness				
Estimate (95% CI)	96.6% (77.7-99.5)	100%	93.3% (75.8-98.4)	51.7%(32.7-70.1)
Kita/PermaNet 2.0	**N=30**	**N=30**	**N=30**	**N=30**
KD60	94.9% (92.8-96.9)			
Mean (95% CI)	97.0% (94.0-	93.7% (89.4-98.1)	84.2% (76.5-91.8)	64.5% (53.7-75.3)
Median (IQR)	100.0)	98% (94.2-100)	95% (78.0-99.7)	66.0% (42.0-94.0)
Mortality 24 hours				
Mean (95% CI)	62.0% (53.6-70.5)	71.2% (63.8-78.6)	65.2% (57.2-73.3)	39.8% (33.8-45.8)
Median (IQR)	59.0% (48.0-72.0)	69% (64.2-77.7)	62.0% (58.2-74.0)	40.0% (28.0-54.0)
Optimal effectiveness				
Estimate (95% CI)	66.6% (53.1-77.8)	76.6% (48.9-91.8)	56.6% (37.0-74.3)	20.0% (8.0-41.5)
Minimal effectiveness				
Estimate (95% CI)	100.0%	100%	96.6% (77.7-99.5)	60.0% (38.9-77.8)

FIGURE 9: BOX PLOT OF CONE BIOASSAY USING A SUSCEPTIBLE COLONY OF *AN. COLUZZII* NGOUSO ON YORKOOL AND PERMANET 2.0 ITNS



The box plots in Figure 9 show the median (horizontal line), IQR (box), adjacent values (whiskers), and outliers (circles).

The conditions in which the nets were handled in the households and selected for the bioassay were identified (Table 16). The location of nets (hanging loose and folded/tied) was the same in both sites (>20.0%) at 12 and 36 months, and different between Kenieba and Kita (p=0.0012) at 24 months. The main type of sleeping place was a bed in both sites at 12, 24 and 36 months. The nets were mainly used by older child (>13 years old), adults only in Kenieba, and by all users group in Kita at 12, 24 and 36 months.

TABLE 16: VARIABLES RELATED TO HANDLING OF BIO-ASSAY TEST NETS

Variable	12 months	24 months	36 months
Kenieba/Yorkool	N=30	N=30	N=29
Location found			
hanging loose	30.0%	16.6%	10.3%
hanging folded/tied	36.6%	16.6%	34.4%
Type of sleeping place			
bed	63.3%	63.3%	72.4%
mattress	20.0%	0.0%	3.4%
mat/ground	3.3%	6.6%	10.3%
Net users			
young child only	26.6%	7.1%	0.0%
young child + adult	0.0%	28.5%	0.0%
older child, adult only	73.3%	64.2%	100%

Variable	12 months	24 months	36 months
Kita/PermaNet 2.0	N=30	N=30	N=30
Location found			
hanging loose	60.0%	70.0%	6.6%
hanging folded/tied	30.0%	23.3%	56.6%
Type of sleeping place			
bed	86.6%	83.3%	73.3%
mattress	0.0%	10.0%	0.0%
mat/ground	0.0%	6.6%	26.6%
Net users			
young child only	50.0%	5.0%	8.3%
young child + adult	50.0%	20.0%	16.6%
older child, adult only	0.0%	75.5%	75.0%

The variables related to net use for nets selected for bioassay is shown in Table 17. The proportion of nets used last night was:

- Lower in Kenieba (56.6%) than in Kita (90.0%) (*p=0.0068*) at 12 months,
- Lower in Kenieba (53.3%) than in Kita (93.3%) (*p=0.0012*) at 24 months and
- Similar in Kenieba (31,0%) and in Kita (53,3%) (*p=0.0959*) at 36 months.

The proportion of nets used the previous week every night was:

- Lower in Kenieba (56.6%) than in Kita (83.3%) (*p=0.008*) at 12 months,
- Lower in Kenieba (56.6%) than in Kita (93.3%) (*p=0.0029*) at 24 months and
- Similar in Kenieba (27.5%) and in Kita (50.0%) (*p=0.055*) at 36 months.

TABLE 17: VARIABLES RELATED TO USE OF BIO-ASSAY TEST NETS

Variable	12 months	24 months	36 months
Kenieba	N=30	N=30	N=29
Used last night	56.6%	53.3%	31.0%
Use last week			
every night	56.6%	50.0%	27.5%
most (5-6)	0.0%	10.0%	3.4%
some (1-4)	6.6%	10.0%	0.0%
not used	36.6%	30.0%	68.9%
don't know	0.0%	0.0%	0.0%
Seasonal use			
equally rain and dry	53.3%	56.6%	44.8%
mainly rain	36.6%	10.0%	37.9%
rain only	10.0%	33.3%	17.2%
Kita	N=30	N=30	N=30
Used last night	90.0%	93.3%	53.3%
Use last week			
every night	83.3%	93.3%	50.0%
most (5-6)	6.6%	0.0%	3.3%
some (1-4)	6.6%	3.3%	6.6%
not used	3.3%	3.3%	30.0%
don't know	0.0%	0.0%	10.0%
Seasonal use			
equally rain and dry	73.3%	100.0%	86.6%
mainly rain	23.3%	0.0%	6.6%
rain only	3.3%	0.0%	6.6%

The variables related to washing of selected nets for bioassay was determined. The proportion of nets washed was high (>70%) in both sites at 12, 24 and 36 months (Table 18). The mean washes in the last six months (all/if washed) was approximatively 3.0 in both sites at 12, 24 and 36 months. The main soap used was country soap bar/ detergent or bleach in both sites at 12, 24 and 36 months.

TABLE 18: VARIABLES RELATED TO WASHING OF BIO-ASSAY TEST NETS

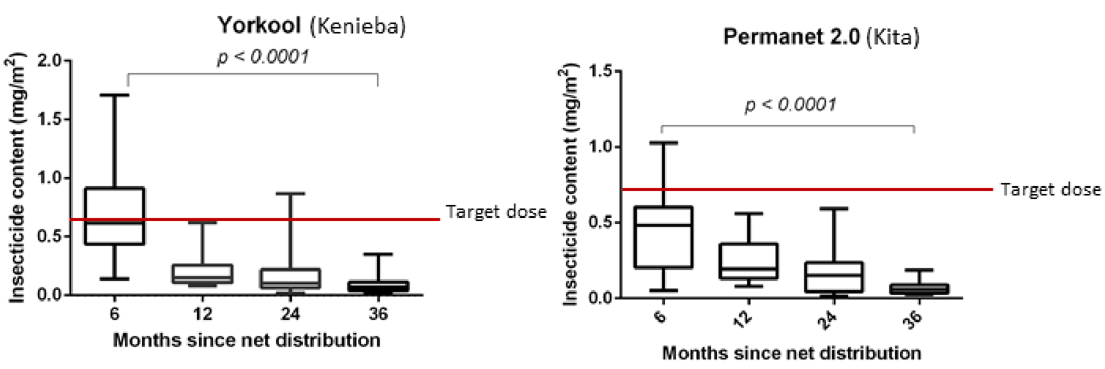
Variable	12 months	24 months	36 months*
Kenieba	N=30	N=30	N=29
Ever washed	70.0%	93.3%	79.3%
Washes last 6 months (all)			
Mean	3.2	2.8	2.0
Median	1	2	2
Washes last 6 months (if washed)			
Mean	4.5	3	2.6
Median	2	2	2
Soap used			
country soap bar	38.1%	32.1%	21.7%
detergent or bleach	52.3%	57.1%	43.4%
mix	9.5%	10.7%	26.0%
Kita	N=30	N=30	N=30
Ever washed	83.3%	96.6%	93.3%
Washes last 6 months (all)			
Mean	2.4	3.1	3.0
Median	2	2	3
Washes last 6 months (if washed)			
Mean	2.9	3.2	3.2
Median	2	2	3
Soap used			
country soap bar	36.0%	37.9%	25.0%
detergent or bleach	64.0%	27.5%	50.0%
mix	0.0%	34.4%	3.5%

The surface concentration of insecticide residue on ITNs collected at 6, 12, 24 and 36 months is presented on Table 19 and Figure 10. The deltamethrin surface content decreased significantly over the study period. The concentration of insecticide residue was higher in Yorkool nets (0.69 mg/m^2) than in PermaNet 2.0 nets (0.46 mg/m^2) (p=0.0211) at 6 months. It was approximately the same in Yorkool nets (0.20 mg/m^2) and in PermaNet 2.0 nets (0.24 mg/m^2) (p=0.1907) at 12 months. The content was also similar for Yorkool nets (0.19 mg/m^2) and PermaNet 2.0 nets (0.17 mg/m^2) (p=*0.7901*) at 24 months. It was same in Yorkool (0.08 mg/m^2) and in PermaNet 2.0 (0.06 mg/m^2) (p=*0.1808*) at 36 months. Compared to baseline the insecticide concentration decreased by 71.0%, 72.5% and 88.6% respectively at 12-, 24- and 36 months for Yorkool nets (Table 19). The insecticide concentration decreased by 47.8%, 63.0% and 87.0% respectively at 12-, 24- and 36 months for PermaNet 2.0 (Table 19). Based on a study at CDC and LBMA using Mali 6 and 12-month nets, a conversion formula was determined to convert surface levels to total levels of deltamethrin (TL =(Log(SL)+1.37)/0.0232) which after 36 months decreased the total level mean of Yorkool nets to 14mg/m^2 and PermaNet 2.0 to 6mg/m^2, compared to the factory total level of 55mg/m^2 (Table 19).

TABLE 19: CHEMICAL CONTENT RESULTS

Variable	6 months (Baseline)	12 months	24 months	36 months
Kenieba/Yorkool	**N=30**	**N=30**	**N=30**	**N=29**
Mean surface insecticide concentration mg/m² Mean (95% CI)	0.69 (0.5-0.8%)	0.20 (0.1-0.2%)	0.19 (0.1-0.2%)	0.08 (0.06-0.11%)
% Decrease compared to baseline	-	71.0%	72.5%	88.4%
Converted total levels of insecticide (mg/m²)	55	29	28	14
Kita/PermaNet 2.0	**N=30**	**N=30**	**N=30**	**N=30**
Mean surface insecticide concentration mg/m² (95% CI)	0.46 (0.3-0.5%)	0.24 (0.1-0.2%)	0.17 (0.1-0.2%)	0.06 (0.05-0.08%)
% Decrease compared to baseline	-	47.8%	63.0%	87.0%
Converted total levels of insecticide (mg/m²)	45	32	26	6

FIGURE 10: BOX PLOT OF ITNS CHEMICAL SURFACE LEVEL RESULTS USING A PORTABLE HPLC C-VUE



4. CONCLUSIONS

This report presents the findings of a three-year durability monitoring study that compared two ITN brands (Yorkool and PermaNet 2.0) in two locations in Mali with similar malaria epidemiology, climatic, and socio-ecological profiles. At the 36-month follow-up period, the proportion of Yorkool nets surviving in serviceable condition was lower than PermaNet 2.0 nets, because of high attrition due to wear and tear and lower physical integrity. Of those nets remaining after 36 months, the proportion of serviceable nets (pHI≤642) was significantly ($p<0.05$) lower for Yorkool nets in Kenieba (48.8%) than PermaNet 2.0 in Kita (77.7%). The nets still available and surviving in serviceable condition were 23.1% for Yorkool nets in Kenieba, but it was significantly higher at 58.8% for PermaNet 2.0 in Kita. The proportion of ITNs that meet optimal effectiveness through bioassay of *An. gambiae* (at least 95% KD or 80% mortality) after 36 months was 31% for Yorkool from Kenieba and 20% for PermaNet 2.0 from Kita. The proportion of ITNs that met minimal effectiveness (75% KD or 50% 24h mortality) criteria after 36 months was 51.7% for Yorkool from Kenieba and 60.0% for PermaNet 2.0 from Kita. The median survival of Yorkool nets was 2.1 years in Kenieba and 3.4 years for PermaNet 2.0 in Kita. It should also be noted that 82.8% (Kenieba) and 73.3% (Kita) of cohort nets were unused and still in the package 6 months after distribution. Therefore, it could be argued that the median 'in use' survival is even shorter. The reasons for the lower performance of Yorkool nets in Kenieba could be associated with product specifications, with PermaNet 2.0 having a thicker fabric of 100 denier polyester compared to 75 denier of Yorkool, or factors associated to ITN durability risk factors and use such as not properly storing nets during the day and washing and drying nets ourdoors. The C-Vue portable chromatographic device was used successfully for the first time in Mali to measure the surface level insecticide concentration of ITNs and produced results that were consistent with cone bioassays. This new technology allows for an affordable and locally available, non-destructive method to perform ITN insecticide content monitoring in malaria endemic countries.

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