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The Alliance for
Malaria Prevention

EXPANDING THE OWNERSHIP AND USE OF MOSQUITO NETS

Determinants of ITN durability in sub-Saharan Africa: Secondary analysis of data from 37 durability monitoring sites

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Abbreviations

aHR	Adjusted hazard ratio
ITN	Insecticide-treated net
NMP	National malaria programme
PH	Proportional hazards
pHI	Proportional hole index
SBC	Social and behaviour change
WHO	World Health Organization

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1. Introduction and purpose

The physical durability of insecticide-treated nets (ITNs) is an important component of the effectiveness of ITNs for malaria prevention. Evidence shows that ITNs have variable durability, such that the median retention time does not necessarily span the expected three-year period between distributions to households. Suboptimal ITN durability can reduce population ITN access if households discard or repurpose damaged nets before a usable replacement is available.

A standardized methodology for monitoring ITN survival was published by the World Health Organization (WHO) in 2013. Since then, national malaria programmes (NMPs) and their partners have monitored the durability of more than 15 ITN brands across sites in 23 sub-Saharan African countries. In 2021, researchers analysed durability data from 10 sites in four countries and found median survival times by site ranged from 1.6 to 5.3 years¹. Determinants of ITN survival were identified as household exposure to social and behaviour change (SBC) messaging, net care attitudes, the practice of folding nets up during the day when not in use, net exposure to cooking fires, and whether net user groups included children. The analysis also identified indirect factors as determinants of survival, such as relative household wealth and the sex of the head of household. The authors concluded that physical durability of ITNs was driven more by location-specific environmental and behavioural factors than by ITN brand.

Between 2021 and 2024, an additional 13 countries completed standard durability monitoring studies with funding from the United States President's Malaria Initiative. Data are publicly available for 27 sites in 11 of these countries. This report contains an updated secondary analysis of ITN durability monitoring data to estimate the levels of ITN physical survival and identify the most important household and behavioural determinants of ITN survival.

The results of this analysis can be used to design and target interventions such as SBC messaging, aimed to increase the length of time ITNs remain present in households in serviceable condition. Increasing ITN survival times will increase the protection provided by ITNs against malaria when nets are used correctly and consistently.

Section 2 of this report presents the methods used for this secondary analysis and Section 3 presents the results. An interpretation of the results with implications for programme design is given in Section 4. Following the list of references, an annex presents a background on durability monitoring study methods and supplementary tables and figures.

¹ The analysis used a subset of the data that is included in this expanded secondary analysis.

2. Secondary analysis approach

Research objective

The objective of this secondary analysis was to describe levels of ITN attrition due to wear and tear and ITN physical integrity from durability monitoring studies conducted since 2015 and identify household and behavioural factors predictive of physical ITN survival.

Methods

Durability monitoring data

Publicly available data sets and final reports from 37 study sites in 15 African countries covering 13 ITN brands were downloaded from www.durabilitymonitoring.org. The data represent durability monitoring of ITNs distributed through mass campaigns conducted between 2015 and 2021.

Table 1 summarizes the study countries, sites, ITN brands and the timing of primary study activities, ordered by the year of the mass campaign. Durability monitoring studies typically collect data at four survey rounds over 36 months. Four rounds of data collection occurred at 32 of the 37 sites. In Oyo, Nigeria and the two sites in Burundi, data collection ended after round three (24 months); in Fort Dauphin, Madagascar and Serenje, Zambia the first round of data collection occurred 12 months after the campaign and only three rounds of data were collected.

Table 1 Durability monitoring study details for sites included in the secondary analysis

Country	Site	ITN brand	Year of	
			Mass campaign	Endline round
Mozambique	Inhambane	Royal Sentry	2015	2018
Mozambique	Nampula	Royal Sentry	2015	2018
Mozambique	Tete	MAGNet	2015	2018
Nigeria	Ebonyi	DawaPlus 2.0	2015	2018
Nigeria	Zamfara	DawaPlus 2.0	2015	2018
Nigeria	Oyo	DawaPlus 2.0	2016	2018
DRC	Mongala	DawaPlus 2.0	2016	2019
DRC	Ubangi Sud	Duranet	2016	2019
Zanzibar	Pemba	Olyset	2016	2019
Zanzibar	Unguja	PermaNet 2.0	2016	2019
Kenya	Busia	DawaPlus 2.0	2017	2021
Kenya	Kwale	Duranet	2017	2021
Ghana	Nanuba South	Olyset	2018	2021
Ghana	Zabzugu	DawaPlus 2.0	2018	2021
Liberia	Grand Gedeh	Duranet	2018	2021
Liberia	Lofa	Duranet	2018	2021
Madagascar	Bekily	DawaPlus 2.0	2018	2021
Madagascar	Farafangana	DawaPlus 2.0	2018	2021
Madagascar	Fort Dauphin	PermaNet 2.0	2018	2021
Madagascar	Maintirano	DawaPlus 2.0	2018	2021

Country	Site	ITN brand	Year of	
			Mass campaign	Endline round
Niger	Gazaoua	Olyset	2018	2021
Niger	Madaoua	Olyset	2018	2021
Burkina Faso	Banfora	Interceptor G2	2019	2022
Burkina Faso	Gaoua	Interceptor	2019	2022
Burkina Faso	Orodara	PermaNet 3.0	2019	2022
Burundi	Kirundo	PermaNet 3.0	2019	2022
Burundi	Muyinga	Yorkool	2019	2022
Rwanda	Burera	Olyset	2020	2023
Rwanda	Karongi	Interceptor G2	2020	2023
Rwanda	Kicukiro	PermaNet 3.0	2020	2023
Rwanda	Ruhango	Yahe	2020	2023
Sierra Leone	Bo	PermaNet 3.0	2020	2023
Sierra Leone	Moyamba	Olyset Plus	2020	2023
Zambia	Serenje	Veeralin	2020	2024
Zambia	Nyimba	Olyset Plus	2021	2024
Cote d'Ivoire	Abengourou	PermaNet 3.0	2021	2024
Cote d'Ivoire	Aboisso	Interceptor G2	2021	2024

Figure 1 presents the approximate location of the 37 study sites in Africa.

Figure 1 Approximate locations of ITN durability monitoring sites included in analysis



Analyses

ITN survival was examined in two ways². First, graphical estimates of ITN median survival in years were extracted from study reports and plotted to explore the distribution of physical ITN survival. Corresponding survival curves were plotted from the data and overlaid with the hypothetical survival curve corresponding to nets with three-year median survival.

To examine the components of physical ITN survival, physical integrity results from hole assessments at each survey round were calculated and plotted in stacked bar charts. ITNs were classified as “good”, “damaged” or “torn”. Cumulative attrition due to wear and tear was estimated for each study site at each survey round and plotted as a line chart.

Preparation of explanatory variables involved aggregating responses across all surveys in which households participated (for household-level exposures) or a cohort ITN was present (for net-level exposures). Variables were categorized as “never” if the response was “no” or “never” for all surveys in which a question was asked; “at times” if the response was “sometimes” in at least one survey round or conflicting responses were recorded in different rounds; and “always” if the response was “yes” or “always” for all surveys in which the question was asked.

The approach used in the previous secondary analysis of combining SBC message exposure and net care attitudes into a composite variable with the following categories was maintained:

- A. Never exposed to SBC and never recorded a very positive net care attitude
- B. One or more SBC exposures and never recorded a very positive net care attitude
- C. Any number of SBC exposures and one or more recorded very positive net care attitude
- D. Two or more SBC exposures and two or more recorded very positive net care attitude

Physical ITN survival was analysed using survival analysis and taking two approaches. In the first, the time at risk began on the date of distribution; in the second, risk began on the date of the first observation or respondent report that the cohort ITN was hanging. For both models, failure was defined as an ITN being classified as “torn” for physical integrity or as having undergone attrition due to wear and tear. Failure time for attrition was calculated based on respondent recall of the length of time a net was in the household’s possession. In the absence of valid recall, and for nets failing due to physical integrity, the failure time was taken as the mid-point between the current and previous survey rounds.

Cox proportional hazards (PH) models were used to model physical ITN survival and investigate determinants. Two Cox PH models were developed following the two survival analysis approaches. A household-level model defined risk as starting at the distribution date and considered household-level determinants that were the same for all nets within a given household (e.g. household size, household head characteristics, household wealth tertile). A net-level model defined risk as starting on the date of the first observation that the net was hanging and considered the household-level determinants above and net-level determinants such as how nets were handled and the types of user. Model goodness of fit was assessed using plots of Cox-Snell residuals, while Schoenfeld residual plots were used to check the proportionate hazard assumption. Results for the net-level model are presented here; the household-level model provided similar results for a reduced set of explanatory variables.

² Readers should refer to the annex for details of primary study methods and an explanation of key terms.

Table A1 (annex) summarizes, for each monitoring site, the number of ITNs reportedly received from the campaign, the number of ITNs enrolled at baseline, the percentage of cohort ITNs with definite outcomes, and the percentage of cohort ITNs ever found hanging (and thus eligible for the net-level regression).

Analyses accounted for the stratified and clustered design of the primary studies. Each study site was considered as a stratum in the Cox PH models. Data were unweighted and all totals are presented as unweighted. Analysis was performed using R v4.4.2 and StataNow v18.5 (StataCorp, College Station, Texas).

Limitations

Certain durability risk factors relied on responses from household members, such as attitudes to net care and outcomes based on reported reasons for net losses. Additionally, as part of COVID-19 mitigation measures between 2000 and 2022, survey staff were unable to enter households to observe nets *in situ* (e.g. to document whether nets were folded up) and reliance on respondent recall increased. These answers are susceptible to recall bias and social desirability bias.

Some study sites experienced high levels of cohort ITNs with unknown outcomes (e.g. respondents were unsure what had happened to a net between survey rounds). The percentage of cohort nets with definite outcomes at the end of the study ranged from 55% in Tete, Mozambique to 97% in Kirundo, Burundi. Maintirano, Madagascar (60%) and Banfora, Burkina Faso (65%) also had relatively low percentages of ITNs with definite outcomes. These sites became difficult to access after the 12-month round due to local insecurity. High loss to follow-up may bias survival results if attrition or physical integrity results for ITNs with unknown outcomes are systematically different from ITNs with known outcomes. Without further investigation, the direction and scale of any difference is unknown.

Some variables found to be significant in published country-level models were omitted from this analysis due to relatively large levels of missing data for recent study countries. These variables include the head of household's age and head of household's level of education. Including these variables would have resulted in one or more countries being omitted from the multicountry analysis.

The prospective design of durability monitoring introduces the possibility of the Hawthorne effect, where repeated inquiries about net care and handling over three years could influence household member behaviour. To mitigate this, primary data collection at the sites included in this analysis limited data collection to four instances over three years, as opposed to the more frequent six-month intervals employed in some earlier research studies.

3. Results

Physical ITN survival

ITN median survival ranged from 1.6 to 6.0 years based on graphical estimates (Figure 2), with a median value of 2.7 years across all 37 sites (mean: 2.9 years). Mongala, Democratic Republic of Congo (DRC), and both sites in Burundi had the lowest survival (all under two years) and Lofa in Liberia, Zamfara in Nigeria and Abengourou in Côte d'Ivoire had the highest survival (all over 4.5 years). Of note, ITN median survival was higher than the all-site median value for all three study sites in Nigeria, both sites in Liberia and both sites in Côte d'Ivoire.

Figure 2: ITN median survival in years (graphical estimate), by country and study site

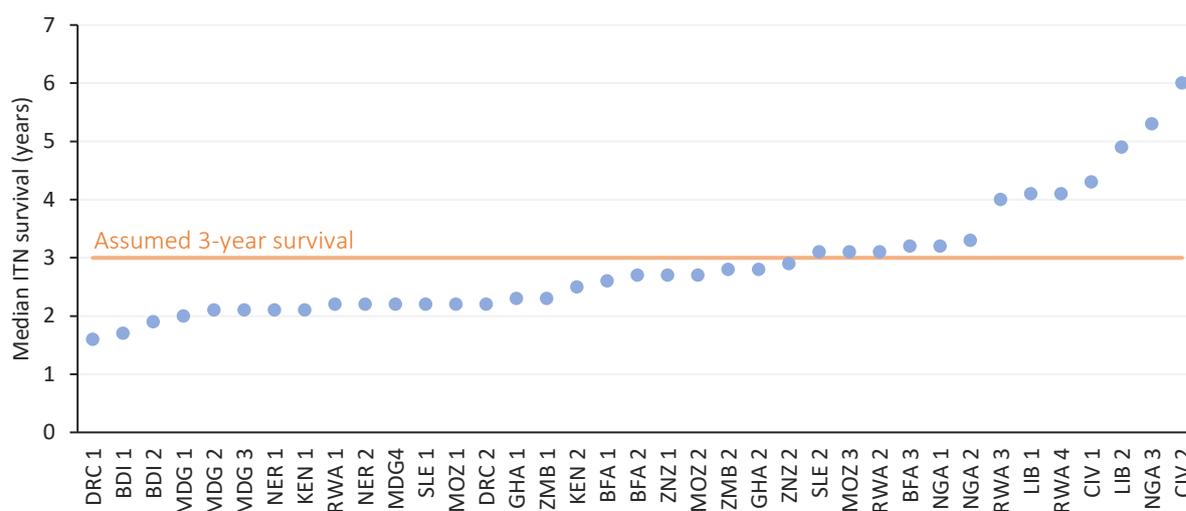
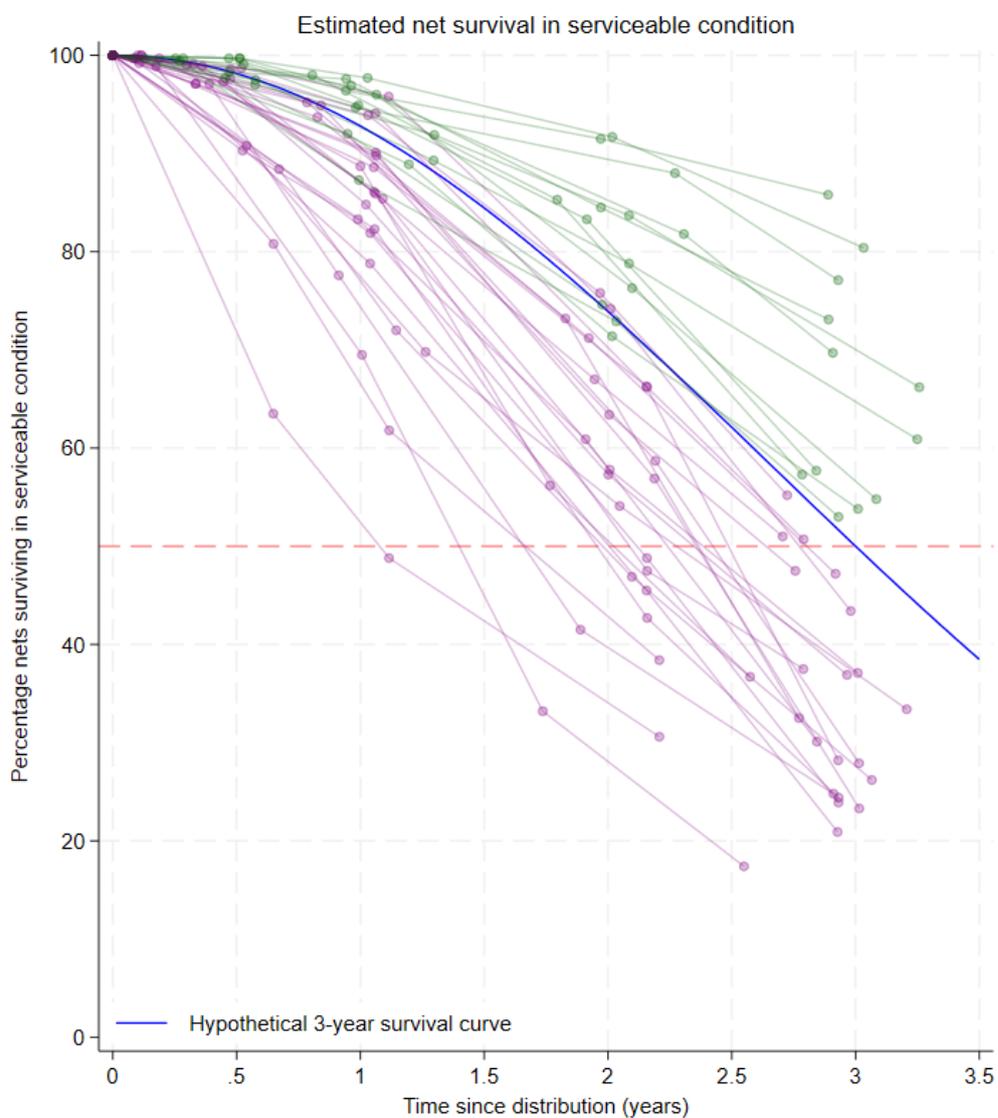


Figure 3 shows the **physical ITN survival curves plotted for each study site**, by estimating the percentage of cohort ITNs surviving in serviceable condition. The chart includes the hypothetical three-year survival curve for reference in blue³. Plots in purple lying to the left of the blue curve belong to sites with less than a three-year median survival and plots in green to the right belong to sites with greater than a three-year median survival. Corresponding to the results above, three years after the mass campaign in Gazaoua and Madaoua, Niger, only 23% and 28% of cohort ITNs remained present and in serviceable condition, respectively. In contrast, 77% of cohort ITNs remained serviceable in Lofa, Liberia, 2.9 years after the campaign and 80% of cohort ITNs remained serviceable in Zamfara, Nigeria after three years.

³ This curve presents the results we may expect to see for an ITN that last three years.

Figure 3: Variation in physical ITN survival, by study site.

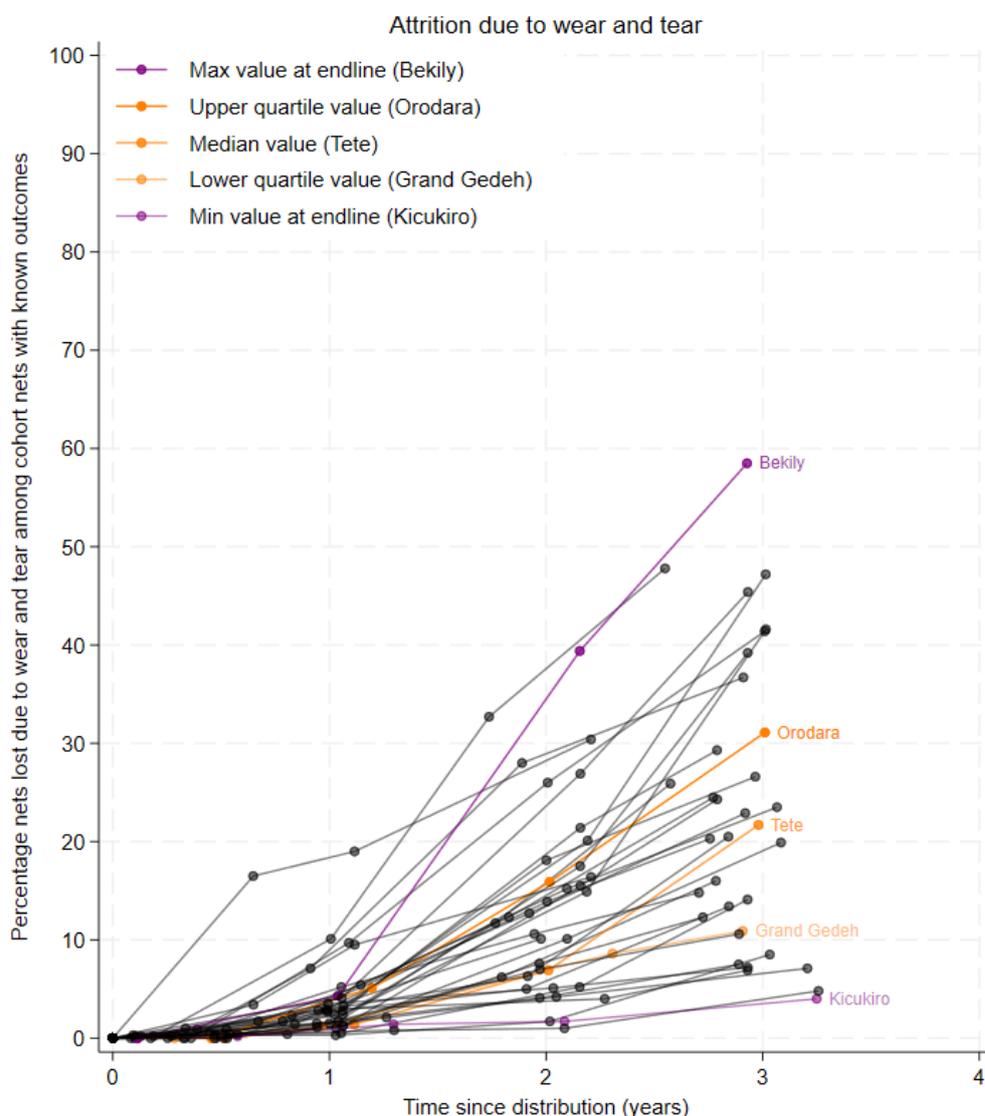
Sites with median survival less than three years are plotted in purple; sites with median survival greater than three years are plotted in green. The blue curve is the hypothetical survival curve for ITNs lasting three years. The red dotted line is at $y=50\%$, the level at which half of originally distributed ITNs have failed to survive.



Physical ITN survival reflects the combination of ITN attrition due to wear and tear and physical integrity. The variation in these measures across study sites is presented in Figure 4 (attrition) and Figure 5 (physical integrity). The percentage of cohort ITNs that had been discarded due to wear and tear at endline ranged from 4% (Kicukiro, Rwanda) to 59% (Bekily, Madagascar) with a median value of 20% (Figure 4).

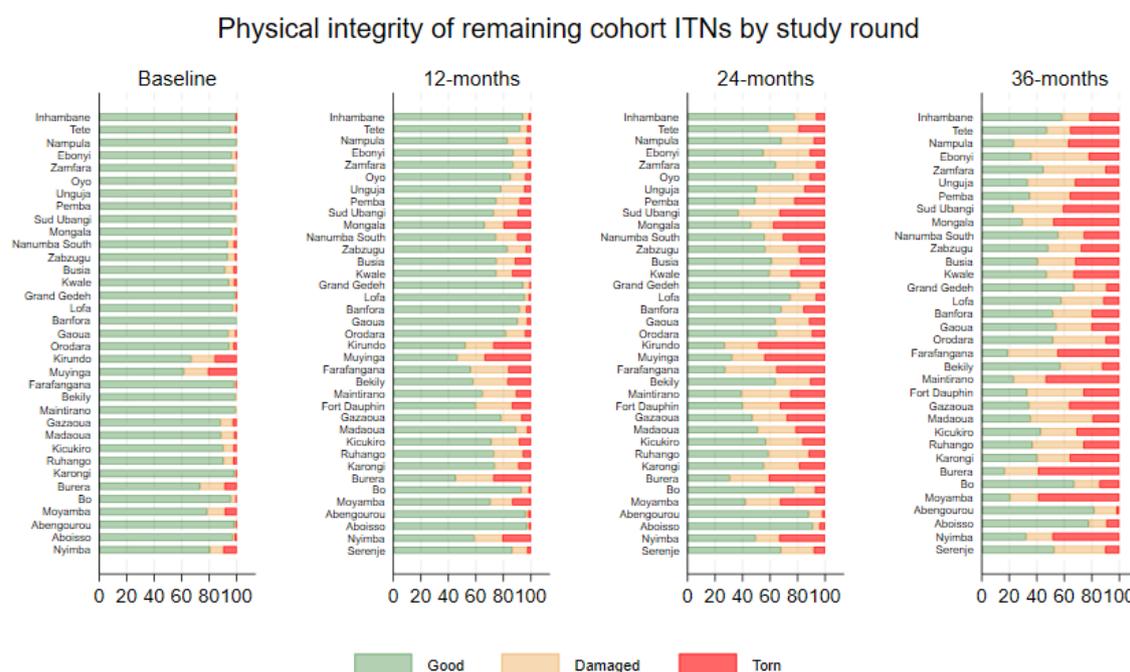
Figure 4: Attrition due to wear and tear, by study site.

Sites with the minimum (Kicukiro) and maximum (Bekily) values for attrition at endline are coloured purple; the sites with the lower quartile (Grand Gedeh), median (Tete), and upper quartile (Orodara) endline values are coloured orange.



Among cohort ITNs still in the household’s possession at endline and available for sleeping under, the percentage that were classified as “torn” ranged from 2% (Abengourou, Cote d’Ivoire) to 59% (Burera, Rwanda) with a median value of 30% (Figure 5). Study sites can be classified based on their level of attrition due to wear and tear and ITN physical integrity at endline, using the median values as reference. At the extremes of the ranges, sites such as Mongala, DRC (48%, 48%) and Farafangana, Madagascar (39%, 45%) had relatively high attrition and a high level of “torn” ITNs among those remaining in study households. Households in such sites may continue to use torn nets beyond their general ability to provide a physical barrier against mosquitos due to a lack of access to other ITNs. At the other end of the spectrum, sites such as Aboisso, Cote d’Ivoire (11%, 9%) and Lofa, Liberia (7%, 12%) have relatively low attrition and a low level of “torn” ITNs.

Figure 5 Physical integrity of remaining cohort ITNs by study site, over study rounds



Determinants of ITN physical survival from Cox PH models

The net-level regression model used 17,466 observations of 9,237 hanging cohort ITNs. There were 3,621 ITN failures during 14,218 ITN-years of analysis time at risk, with a mean analysis time per ITN of 1.54 years (18 months). Six household-level and four net-level characteristics and behaviours were identified in the model as independent predictors of survival (Table 2):

- ITNs in larger households had an increased risk of failure compared to small households (1–3 people). Risk of failure increased with increasing household size: ITNs in households with 4–6 people had an 18% increased risk of failure relative to small households ($p=0.003$) while nets in households with 7 or more people had a 47% increased risk relative to small households ($p<0.001$).
- ITNs in households with one or more children under five had an increased risk of failure compared to households with no young children. The adjusted hazard ratio (aHR) for households with children under five (1.16, $p=0.003$) indicates that ITNs in such households had a 16% increased risk of failure.
- ITNs in households in the lowest wealth tertile had an 20% greater risk of failure (aHR=1.20, $p=0.002$) compared to those in households in the highest wealth tertile. ITNs in households in the middle tertile had a 16% increased risk of failure compared to the highest tertile (aHR=1.16, $p=0.005$). The difference between the lowest and middle tertiles was not significant.
- ITNs in households that reported storing food in rooms used for sleeping had an 18% higher risk of failure than those in households that reported never storing food in such spaces (aHR=1.18, $p=0.007$).

- ITNs in households that reported cooking in rooms used for sleeping had a 25% higher risk of failure than those in households that reported never cooking in such spaces (aHR=1.25, $p<0.001$).
- The variable that coded respondents' combined SBC exposure and positive attitudes to net care showed evidence of a dose-response relationship with ITN survival. ITNs had half the risk of failure in households where respondents reported both SBC exposure and positive care attitudes at least twice compared to ITNs in households where respondents had no SBC exposure nor positive care attitudes (53%, aHR=0.47, $p<0.001$). ITNs in households with respondents that reported no SBC exposure but positive net care attitudes in some survey rounds had a 38% lower risk of failure compared to the reference group ($p<0.001$). Similarly, ITNs in households with respondents that had some SBC exposure and reported positive net care attitudes in some survey rounds had a 35% lower risk of failure compared to the reference group ($p<0.001$). There was no significant difference between the results for these two intermediate categories.
- Among net-level factors, risk of ITN survival was significantly associated with the type of ITN user (called the dominant net user group and defined as the age group(s) that most frequently reported sleeping under a given net). ITNs used by children sleeping on their own had a 31% increased risk of failure compared to ITNs with adults as the dominant users ($p<0.001$). ITNs with a mix of adults and children had a 16% greater risk of failure compared to the reference group ($p<0.001$).
- ITNs that had been used over a mat or directly over the floor had an 8% increased risk of failure compared to ITNs that had only been used over mattresses or beds, through the p-value for this factor was borderline significant (aHR=1.08, $p=0.79$).
- ITNs that were reportedly always dried on a bush after washing had a 22% increased risk of failure compared to ITNs that were never or only sometimes dried on bushes ($p=0.002$).
- ITNs that were reportedly never folded up during the day had a 61% increased risk of failure compared to ITNs that were always or sometimes folded (aHR=1.61, $p<0.001$).

Table 2 Determinants of ITN physical survival with time starting when ITNs were first hung, from Cox PH regression model

Variable	Adjusted hazard ratio (aHR)	95% confidence interval	p-value
17,466 observations of 9,237 hanging cohort nets with 3,621 failures			
Household size at baseline			
1–3 people	<i>Reference</i>		
4–6 people	1.18	1.06-1.31	0.003
7+ people	1.47	1.30-1.67	<0.001
Presence of any child under five in household			
Yes (Ref: No)	1.16	1.05-1.28	0.003
Household wealth tertile			
Highest	<i>Reference</i>		
Middle	1.16	1.05-1.29	0.005
Lowest	1.20	1.07-1.34	0.002
Store food in rooms used for sleeping			

Sometimes or Always (Ref: Never)	1.18	1.04-1.32	0.007
Cook in rooms used for sleeping			
Sometimes or Always (Ref: Never)	1.25	1.14-1.38	<0.001
Combined SBC exposure and net care attitudes			
SBC never – Attitude never	<i>Reference</i>		
Once or more – Never	0.62	0.52-0.74	<0.001
Any number – Once or more	0.65	0.57-0.75	<0.001
Twice or more – Twice or more	0.47	0.40-0.55	<0.001
Dominant net users			
Adult(s) only	<i>Reference</i>		
Child(ren) with adult(s)	1.17	1.07-1.27	<0.001
Child(ren) only	1.31	1.15-1.50	<0.001
Most rudimentary sleeping space			
Mat or floor (Ref: Mattress or Bed)	1.08	0.99-1.17	0.079
Dry net on a bush after washing			
Always (Ref: Sometimes or Never)	1.22	1.08-1.38	0.002
Folding net up during the day when hanging			
Never (Ref: Always or Sometimes)	1.61	1.48-1.75	<0.001

Other determinants examined during model building were the gender and level of education of the head of household, whether rodents had been observed around the house, whether the household members discussed net care and repair, and whether nets had been washed. These determinants were excluded from the final model as they were not significant and their inclusion did not improve model fit, or cases had a relatively large number of missing values.

Figure A1 (annex) shows plots of the adjusted survival curves for each determinant in the final model, holding other covariates at their mean values. On average, ITNs that are folded up during the day gain seven to eight months of survival compared to ITNs that are not consistently folded. Considering SBC exposure and participant net care attitudes, ITNs in households with some recall of SBC exposure and/or some positive net care attitudes gain six months' survival compared to those in "never-never" households. ITNs in households in which SBC exposure and positive attitudes were reported twice or more gain an additional three to four months' survival, bringing their total gain to nine to ten months over ITNs in "never-never" households. Other covariates for which the adjusted survival differs by six months between groups are household size (nets in 1–3 person households gain six months' survival over those in households with seven or more people) and the dominant net user group (nets used only by adults gain five to six months' survival over those used only by children).

4. Summary and interpretation

Median survival times for ITNs at each of the 37 study sites varied widely, ranging from 1.6 to 6.0 years. While the median survival time across all sites, at 2.7 years, was close to the assumed 3-year ITN life used by NMPs for planning, the high degree of heterogeneity in the results means the 3-year assumption may not accurately reflect outcomes in many settings.

ITN survival is defined by the physical integrity (i.e. the physical condition) of ITNs present in households and the level of ITN attrition due to wear and tear (i.e. the percentage of ITNs that have been discarded as they were considered too damaged to be used or were used for purposes other than sleeping under). There was no consistent pattern to physical integrity results and attrition outcomes across study sites. Three years after the campaign, attrition due to wear and tear varied from 4% to 59% of ITNs (median 20%), while the percentage of ITNs classified as “torn” ranged from 2% to 59% (median 30%).

The Cox proportional hazards model identified ten factors associated with ITN survival and each acted in the direction expected. Of these determinants, the largest detrimental effect was never folding or tying up a hanging net during the day, for which the risk of failure was 61% higher than for nets that had been folded up. This corresponds to a loss of seven to eight months in survival compared to folded nets, all other things being equal. ITNs hanging loose over sleeping spaces throughout the day may be subject to increased intentional and accidental handling, and increased risk of damage from daily household activities taking place in the same space. Considering the results of this analysis, SBC activities that promote consistently folding nets when not in use may have the most potential to reduce damage to ITNs and prolong ITN survival times substantially.

Other significant determinants of ITN survival are less amenable to immediate change but could be helpful when deciding where to target limited SBC resources. Controlling for other factors, households with more than four residents and households in the lowest and middle socioeconomic tertiles all exhibited higher risks of ITN failure (compared to smaller households and those in the highest wealth tertile, respectively). These details could be used to target SBC implementation geographies or identify households within communities for differentiated SBC activities. Similarly, while household composition and net supply will influence which residents use an ITN for sleeping under, the focus of SBC activities should draw attention to the increased risk of damage to nets that are used by children alone. Children likely use less care when handling nets, particularly when manipulating the fabric to move from under a net, which may lead to increased physical damage and eventual failure.

Model results showed the cumulative positive effect of combined SBC exposure and positive net care attitudes. Compared to ITNs in households which never reported SBC exposure or recorded positive net care attitudes, ITNs in households with some SBC exposure and/or positive net care attitudes had 35—38% better chance of survival. This survival advantage increased to 53% for ITNs in households which recorded both SBC exposure and positive care attitudes at least twice. This last result is equivalent to a survival gain of nine to ten months compared to nets in households with no SBC exposure nor positive net care attitudes. Understanding the SBC approaches and mechanisms that most effectively create and sustain positive attitudes to ITN care remains an important area of research to support impactful ITN SBC implementation and further prolong ITN survival.

Other household-level determinants that improved ITN survival were never cooking in rooms used for sleeping and never storing food in rooms used for sleeping. Consistent application of these practices avoids the direct risk of damage to nets from heat and open fires when cooking on charcoal or firewood, and the risk of damage from pests attracted by the presence of food. The practice of drying ITNs on bushes after washing was associated with poorer ITN survival, likely due to the increased risk of damage from the creation and propagation of holes when material is snagged on woody bushes. SBC messaging on net washing typically already promotes drying ITNs on washing lines but messaging related to these three determinants should be reviewed as part of future SBC design. There was some evidence that ITNs used when sleeping on mats or the floor were prone to higher risks of failure than ITNs only used over mattresses or beds. This may reflect the greater risk of netting being snagged on rough mats or other household objects at floor level, though households are likely limited in their possible response to this factor due to space limitations and/or the costs associated with purchasing mattresses and beds.

Despite the wide range in survival times presented in this secondary analysis, modelling has identified a subset of actionable determinants of survival that can be targeted by future interventions, and which could lead to improved physical survival of ITNs.

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Annex

Background on durability monitoring studies

This annex provides a brief overview of durability monitoring study methods that are relevant to this work.

Durability monitoring uses a prospective cohort study design to track ITNs for up to three years following their receipt by households during a distribution event, usually a mass campaign. ITNs tracked by the study are called cohort ITNs. Four rounds of fieldwork typically occur, with data first collected 1–6 months following the mass campaign, followed by three rounds around the campaign anniversary (i.e. 12 months, 24 months and 36 months after households received ITNs). At each round, a questionnaire captures information on the status of cohort ITNs, details on other ITNs in the household's possession, and potential risk factors for ITN durability such as:

- A. Household size and composition
- B. Household cooking and sleeping arrangements
- C. Respondent exposure to SBC activities and messages related to malaria and ITNs
- D. Respondent attitudes to net care and repair
- E. Household handling and use practices of cohort ITNs

Cohort ITNs present in the household are assessed for physical integrity using a standard hole assessment tool. Reasons for loss and related details are captured for any cohort ITN that has suffered attrition since the previous survey round (or since the mass campaign at the first round) and is no longer present in a household.

Sample size calculations are based on the number of cohort ITNs required to detect a minimum deviation of six months from the assumed three-year ITN median survival.

Durability monitoring study outcomes

The primary study outcome is physical ITN survival, defined as the percentage of cohort ITNs present and in serviceable condition at a given round. This outcome incorporates measures of ITN attrition and ITN physical integrity.

ITN attrition describes cohort nets no longer present in a study household and is defined for all campaign ITNs received by households with a known outcome, including those lost between the campaign distribution and first round. ITN attrition due to wear and tear is defined as the percentage of campaign ITNs received which are thrown away, destroyed or used for a purpose other than sleeping under.

ITN physical integrity is measured using the proportionate hole index (pHI). The pHI converts the number and size of holes in an ITN to a standard metric, allowing for comparison of physical damage (i.e. holes and tears) between nets. pHI values are used to categorize each cohort ITN as “serviceable” or “torn”, with “serviceable” ITNs further classified as either “good” or “damaged”.

Estimates of ITN survival (i.e. the percentage of cohort ITNs surviving in serviceable condition at a given time) are plotted against a set of hypothetical survival curves with defined median survival values. The ITN median survival in years for cohort nets at a study site is then read as the relative position of the empirical data point on a horizontal line between the two adjacent median survival curves.

Durability monitoring explanatory variables

As noted above, data on a wide range of potential risk factors for ITN durability are captured at each round through a standard questionnaire. Many of these factors take the form of questions with binary responses (yes/no) or categorical variables such as whether a sleeping space is a bed, a mattress, a mat or the floor.

For each study site, a household wealth index is typically calculated using the household assets and construction information recorded during the first data collection round. Analysis is by principal components with the first component taken as the wealth index and households grouped into tertiles. Other baseline household characteristics of interest are the age, sex and education level of the head of household, the number of household members, and the presence of any children under five among household members.

The standard questionnaire captures respondent attitudes towards nets and, separately, net care and repair, through two sets of Likert score questions with results recorded on a scale from -2 to +2. Attitude scores for each respondent are summed and divided by the number of statements to calculate an overall attitude score for which 0 represents a neutral result, and positive values represent a positive result. For each site, the percentage of households with a very positive attitude to net care and repair is calculated, defined as cases with a score greater than +1.

Supplementary tables and figures

Table A1: Cohort ITN cases included in secondary analysis and key sample characteristics

Country	Site	Number of ITNs reportedly received from campaign	Number of ITNs present at baseline and enrolled	Percentage of cohort ITNs with known outcomes	Percentage of cohort ITNs ever found hanging
Mozambique	Inhambane	737	726	80.3	65.2
Mozambique	Nampula	675	661	71.1	69.6
Mozambique	Tete	619	601	55.4	74.2
Nigeria	Ebonyi	415	367	88.3	85.3
Nigeria	Zamfara	373	357	92.7	99.4
Nigeria	Oyo	410	372	82.3	55.1
DRC	Mongala	400	377	74.5	54.6
DRC	Sud Ubangi	410	377	76.9	82.2
Zanzibar	Pemba	479	452	90.0	76.3
Zanzibar	Unguja	411	382	85.3	77.5
Kenya	Busia	435	364	80.8	76.6
Kenya	Kwale	436	375	84.8	69.1
Ghana	Nanumba South	360	333	77.8	62.8
Ghana	Zabzugu	295	284	92.6	83.5
Liberia	Grand Gedeh	466	389	69.9	65.3
Liberia	Lofa	406	385	74.8	67.8
Madagascar	Bekily	418	408	65.2	70.8
Madagascar	Farafangana	510	488	78.5	75.4
Madagascar	Fort Dauphin	369	312	80.4	75.6
Madagascar	Maintirano	353	335	60.3	59.4
Niger	Gazaoua	414	381	92.1	66.1
Niger	Madaoua	413	373	91.7	78.6
Burkina Faso	Banfora	307	294	65.3	68.7
Burkina Faso	Gaoua	293	282	85.1	81.6
Burkina Faso	Orodara	359	347	79.3	88.2
Burundi	Kirundo	348	300	96.7	81.3
Burundi	Muyinga	352	235	94.9	84.3
Rwanda	Burera	508	488	89.5	92.6
Rwanda	Karongi	556	534	79.6	96.8
Rwanda	Kicukiro	530	488	86.1	94.1
Rwanda	Ruhango	536	504	87.3	97.6
Sierra Leone	Bo	379	358	75.7	76.0
Sierra Leone	Moyamba	332	294	78.2	77.6
Zambia	Serenje	423	324	84.9	76.2
Zambia	Nyimba	303	236	86.0	78.8
Cote d'Ivoire	Abengourou	306	298	83.6	60.7
Cote d'Ivoire	Aboisso	396	356	86.5	55.9
	Total	15,732	14,437	80.5*	75.9*

* Unweighted averages

Figure A1: Adjusted survival curves from Cox PH regression model for each covariate, holding other values at their means

