Malaria Journal

RESEARCH

Open Access

Overcoming practical challenges to pilot Sierra Leone's first school-based distribution of piperonyl butoxide-synergist ITNs: findings from a 2023 assessment in Kono district

Keith Esch[1*], Fredrick Yamba[2], Kevin Opondo[3], Musa Sillah-Kanu[2], David Schnabel[4], Prince Owusu[5], Raymond Sudoi[6], Malia Skjefte[7], Wani Lahai[2], Mohamed G. Sheku[8], Mariama Kabba Jibatteh[8], Augustine Ngegbe[9], Jenny Carlson[10], Temitayo Labor[4], Djenam Jacob[11], Charlene Youseff[12], Elisabeth Tyler[1], Prince Nallo[12], Dennis Marke[2] and Stephen Poyer[13]

Abstract

Background Continuous distribution of insecticide treated nets (ITNs) through schools is increasingly utilized by National Malaria Programmes across sub-Saharan Africa to maintain coverage between three-year mass distribution campaigns. In March 2023, the Sierra Leone National Malaria Control Programme (NMCP) piloted its first school-based distribution (SBD) in Kono district, reaching 88,605 pupils in 531 schools with piperonyl butoxide-synergist (PBO) ITNs. The pilot was assessed to determine changes in household and population ITN access and use, and to identify areas where future widescale SBD campaigns in Sierra Leone can be improved.

Methods This was a mixed methods assessment. A cluster, multi-stage sampled household survey was conducted across 950 households, stratified post-hoc by presence (or not) of children eligible for SBD and powered to determine significant differences in ITN access among 'intervention' households (those with at least one eligible child) and 'control' households (those with no eligible children). Key informant interviews (KIIs) were conducted with 26 SBD stakeholders representing government, donors, third party logistics agencies and implementing partners.

Results One- to two-months post SBD, a significantly higher proportion of households in the intervention group owned at least one ITN (93% versus 69%, $p < 0.001$) and at least one ITN per two people (42% versus 24%, $p < 0.001$). Population ITN access was significantly higher in the intervention group than the control group (69% versus 46%, $p < 0.001$). A higher proportion of the population also reported using an ITN the previous night in the intervention group (71%) than the control group (49%) ($p < 0.001$). KIIs highlighted resolvable challenges, particularly those related to untimely or insufficient funding, which led to subsequent issues for coordination, storage, transportation, quantification, distribution, training, microplanning and supervision.

Conclusion Sierra Leone's SBD pilot significantly improved key ITN ownership, use and access indicators at the household and population levels in Kono district one- to two-months post-SBD. However, intervention population ITN use, and access were still below the NMCP's 80% target. Gaps should be addressed for SBD scale-up.

*Correspondence:
Keith Esch
kesch@psi.org
Full list of author information is available at the end of the article

Research on costing, sustained levels of ITN use and access, and the effect of SBD ITNs on malaria parasitaemia may be considered by the NMCP.

Keywords Insecticide treated nets, School-based distribution, Sierra Leone, Continuous distribution, Piperonyl butoxide-synergist

Background

In 2023, there were 263 million cases and 597,000 deaths from malaria in sub-Saharan Africa [1]. Despite the gains made in malaria prevention and control in recent decades with tools such as insecticide-treated nets (ITNs) and indoor residual spraying (IRS), the development and spread of insecticide resistance threatens progress [1–3]. Due to high pyrethroid resistance reported in Sierra Leone in 2019 [4], the National Malaria Control Programme (NMCP) procured ITNs treated with pyrethroid plus piperonyl-butoxide (PBO), a synergist that recovers susceptibility in resistant mosquitoes, and became the first country to distribute PBO ITNs nationally during the 2020 mass ITN distribution campaign. In 2021, the country also implemented IRS with clothianidin-based insecticide (SumiShield™ 50 WG) in Bo and Bombali districts. These two interventions contributed, in part, to the reduction of the national malaria burden with parasite prevalence falling from 40% in 2016 to 22% in 2021 [5].

Sierra Leone has distributed 22.1 million ITNs cumulatively through national ITN mass campaigns in 2006, 2010, 2014, 2017, 2020, and 2024. Antenatal care (ANC) and expanded program on immunization (EPI) channels have been functioning nationally since 2005, through which approximately 2.2 million ITNs have been distributed since 2019. Still, national population ITN use was only 45% in 2021 (ranging from 36% in urban and 50% in rural areas) and population access remains at 43% nationally (ranging from 36% in urban and 48% in rural areas), both measures falling well below the recommended 80% in Sierra Leone [5, 6]. While population use and access are low, the ITN use:access ratio (calculated as population ITN use divided by population ITN access) is high (1.08), demonstrating that nets are used when they are available [5, 7]. Therefore, the NMCP strives for universal population use and access between mass campaigns by intensifying ITN distribution through continuous distribution channels.

Nationally, malaria prevalence in children aged five to nine years (50.1% by rapid diagnostic test [RDT] and 26.8% by microscopy) is higher than children aged under five years (39.3% by RDT and 21.6% by microscopy) [5], suggesting that targeting school-aged children for receipt of ITNs, supported by appropriate messages on ITN use and care, could reduce the burden in this age group.

Globally, schools are increasingly being used as a continuous ITN distribution channel to achieve and sustain optimal ITN coverage, and school-based distribution (SBD) of ITNs has been shown to be effective in increasing and maintaining population-level ITN access and use between mass campaigns [8–12]. This is particularly important in Sierra Leone, where PBO ITNs distributed in 2020 did not consistently last the recommended three years [13]. In 2022, the Sierra Leone NMCP, through its Integrated Vector Management Technical Working Group, recommended SBD with PBO ITNs be piloted in Sierra Leone to complement mass campaigns and routine distributions through ANC and EPI channels. Kono district was selected for its high malaria prevalence among school-aged children (34.1% by microscopy) [5], the number of PBO ITNs available for distribution matching the number of pupils in the target classes (another term for which is 'grades'), and because Kono was not receiving other malaria prevention interventions like IRS.

The NMCP led the SBD pilot in March and April 2023, with support from the U.S. President's Malaria Initiative (PMI) VectorLink Project (and later, the PMI Evolve Project). Three weeks prior to the SBD, a social behaviour change (SBC) campaign was launched across media and interpersonal channels to spread awareness for the pilot, clarify campaign-eligible classes (classes 1, 3, and 5), and reinforce malaria/ITN knowledge among school-aged children, their parents, and community members. In March and April 2023, ITNs were transported from the capital to pre-established holding points throughout Kono. ITNs were then brought to all registered public and private primary schools and distributed directly to all present students in classes 1, 3 and 5, reaching 86,605 pupils across 531 schools in Kono. Digital data collection tools were used by implementers to monitor distribution progress in real time. Typically, SBDs, a form of continuous distribution, are conducted in the two years between triennial mass campaigns. However, due to funding and timing constraints, this pilot was conducted in the third year post-2020 mass campaign and targeted at half of primary school-aged students (classes 1,3 and 5). In 2024, a mass ITN campaign was conducted across Sierra Leone, rendering it unnecessary to reach the other half of eligible students through SBD that year.

This assessment used mixed methods, employing a household survey and key informant interviews (KIIs). Its aims were to describe the strengths and weaknesses of the pilot's implementation in Kono to identify areas for future improvement, and to determine levels of ITN access and ITN use following the pilot.

Methods

Household survey

Assessment location and design

A clustered household survey was conducted across Kono district, stratified posthoc by the presence (or not) of a child in class 1, 3, and/or 5. Households with one or more eligible children are termed 'intervention' households, while other households are called 'control' households.

Sample size and sampling procedures

The household survey sample was designed to be able to detect a statistically significant difference in the level of population ITN access among intervention and control households. The sample size calculation was based on several assumptions, including: 55% ITN access among control households (population ITN access from the Sierra Leone Malaria Indicator Survey [MIS] 2021) and 77% ITN access among intervention households (estimated by considering the number of ITNs present in households enumerated for the 2021 MIS, conducted shortly after the 2020 mass campaign and mean household size during the MIS) [5], a design effect of 2.5, 5% non-response or refusal rate, 5% two-sided alpha error and 80% power. The mean number of children eligible for SBD in Kono per household was estimated as 0.4 (calculated using data from the 2021 MIS). Therefore, an assumed 2.7 households would need to be visited to reach an intervention household. A total of 350 intervention households and 600 control households were sampled to detect an estimated 16 percentage point difference between groups.

Two-stage cluster household survey sampling was employed. First, 50 enumeration areas (EAs) of approximately 100 households were selected with probability proportionate to size, with population as the measure of size, from a district-wide sampling frame that included all EAs. At stage two, all households were listed, and 19 households were sampled by simple random sampling for inclusion in the study. To participate, respondents were at least 18 years old, the head of the household or their representative, had resided in the household since the SBD campaign, and were a member of the household who had slept there the previous night.

Training and data collection procedures

Prior to data collection, a three-day training was led by the staff from the PMI Evolve team with support from Nest Builders International, a locally contracted research agency. Selected data collectors had prior experience with household surveys and spoke both English and Krio. Data collection was conducted two to three months after the SBD (June-July 2023) to allow time for households to adapt to the availability of one or more new ITNs. This is a similar period of pause between intervention and data collection used for ITN durability monitoring (DM) [14].

The questionnaire was produced in both English and Krio and adapted from those validated and used for MIS [15] and DM surveys in Sierra Leone [14]. It captured information on household members, household construction and household assets; ITNs owned by the household for sleeping under (including their source); and ITNs lost, discarded, or given away in the past two months (covering the period between the SBD and the interview). Interviews lasted between 30 and 60 min each, depending on household size, the number of ITNs owned, and data collector experience.

Data management

Data was collected electronically in the Open Data Kit-based software, SurveyCTO (Dobility, Inc.). Data temporarily stored on the devices were automatically deleted following a successful upload to the server, which occurred daily or when a stable internet connection became available. Data was remotely assessed by the study team each day to ensure quality.

Outcome measures

Analysis followed standard ITN indicator definitions from household surveys. The primary comparison was across two analytical groups of intervention and control households. The primary outcome indicator was population-level access to ITNs (proportion of the household population that could use an ITN if each ITN can be used by two people). Also examined were household-level ITN ownership (proportion of households owning at least one ITN), household levels of possession of one ITN per two people, population-level ITN use (proportion of population that reported using an ITN the previous night), and population-level use given ITN access. SBC exposure and ITN source were also explored. Household wealth index tertiles were generated using principal component analysis based on amenities, assets, livestock, and other characteristics that are related to a household's socioeconomic status.

Analysis

Quantitative data were analyzed in Stata (Version 15, College Station, Texas). Using standard Stata do files adapted by PMI Evolve from previous ITN studies, data were reviewed, cleaned, and prepared for analysis. Final analysis followed defined outcome measures. Given the sampling design, the study was considered self-weighted and no weights were applied. Chi squared tests were used to assess the level of significance of differences between groups. T-tests were used to determine statistical differences in means across groups. Calculation of confidence intervals around estimates accounted for the sampling design effect. Given the posthoc stratification approach, multivariate regression analysis checks were performed to control for potential variation in household and population sample characteristics between the arms when assessing population ITN access and population ITN use. This assessment reports non-model (unadjusted) values.

Key informant interviews

Sample size and procedures

In-depth KIIs were conducted with 26 key informants, purposefully sampled from the national and sub-national levels. Interviewees represented a broad range of SBD stakeholders and included staff from donor agencies, Ministry of Health and Sanitation (MOHS), NMCP, Ministry of Basic and Senior Secondary Education (MBSSE), head teachers, peripheral health units (PHUs), third party logistics agencies, and implementing partners (IPs). A modular discussion guide was used, which focused on informants' perceptions of the strengths, weaknesses, opportunities, and threats of the SBD implementation. Core activities discussed were ITN quantification, transportation, training, reverse logistics, community sensitization and mobilization, distribution, and reporting. Additional discussion topics included leadership, coordination, personnel, and financing. Verbal informed consent was sought prior to each interview. Interviews were conducted in June 2023, between two and three months after the pilot and lasted approximately 60 min each.

Data collection instrument and procedures

The discussion guide drew on a validated tool developed for the assessment of ITN routine distribution through ANC and EPI channels, and used in Burkina Faso, Niger, Senegal, Cameroon, Côte d'Ivoire, and Zambia [15]. The core distribution activities and supporting topics on continuous distribution through ANC and EPI were closely aligned to those required for SBD. The discussion guide was produced in English and Krio and participants were able to specify their language preference. Hard copy discussion guides were printed, and soft copies were made available to facilitate data collection depending on whether written or typed notes were taken to support audio recordings.

Data management and analysis

Data were processed and analyzed using Dedoose software (Version 9.0.107, 2023, Los Angeles, California). An inductive-deductive content analysis was used to identify the study results. A codebook was created using the interview guides and study objectives, with additional codes added throughout the process. Code reports were then created based on major code groupings and compared between team members to identify emerging themes.

Results

Household survey findings

A total of 950 households were approached and surveyed (Table 1). No households refused to participate. Intervention households comprised 57% of the sample, which was higher than the sampling assumption of 37%. Results showed no difference in statistical tests between control and intervention households for mean number of persons per sleeping space ($p = 0.4476$), mean age of head of household ($p = 0.5228$), percent of female-headed households ($p = 0.777$), and percent of households who recalled receiving ITNs from the 2020 mass campaign ($p = 0.601$). Across arms, approximately 57% of households recalled receiving at least one PBO ITN from the 2020 mass campaign. Intervention households reported having received significantly more PBO ITNs (mean = 2.2) from the 2020 mass campaign than control households (mean = 2.0, $p < 0.0186$) and had a higher percentage of children under five ($p < 0.001$). There was a lower percentage of intervention households in the highest wealth tertile (27%) compared to the distribution of control households (42%, $p < 0.001$).

All assessed key ITN ownership, ITN access and ITN use indicators at the household and population levels were significantly higher in the intervention group than the control group (Table 2). A significantly higher proportion of households in the intervention group owned at least one ITN (93% versus 69%, $p < 0.001$) and at least one ITN per two people (42% versus 24%, $p < 0.001$). Among households that owned at least one ITN, significantly more in the intervention group owned ITNs from the SBD ($p < 0.001$) as expected, while significantly more in the control group owned ITNs from previous mass campaigns ($p < 0.001$) and other distribution channels ($p < 0.001$).

Population ITN access was significantly higher in the intervention group than the control group (69% versus

Table 1 Household and population sample characteristics

	Control	Intervention	P-value	Total
	N = 408	*N = 542*		*N = 950*
Mean number of persons per sleeping space	2.2	2.2	0.4476	2.2
	N = 408	*N = 524*		*N = 950*
Percentage of households with any children under five	38.2%	49.6%	< 0.001	44.7%
Percentage of households with a female head of household	28.8%	29.7%	0.777	29.3%
Mean age of household head	46.6	47.2	0.5228	47.0
Highest level of education achieved by household head	*N = 408*	*N = 542*		*N = 950*
No formal education	51.5%	60.7%	0.0047	56.7%
Primary	13.5%	14.9%	0.5255	14.3%
Secondary	27.7%	20.1%	0.0065	23.4%
Higher	7.4%	4.2%	0.0397	5.6%
Household wealth index	*N = 408*	*N = 542*		*N = 950*
Lowest	28.9%	36.5%	0.013	33.3%
Middle	28.9%	36.7%	0.011	33.4%
Highest	42.2%	26.8%	< 0.001	33.4%
Percentage of households that recall receiving any ITNs from the mass campaign in 2020	56.4%	57.9%	0.601	57.3%
Mean number of mass campaign ITNs reportedly received	2.0	2.2	0.0186	2.1

Table 2 ITN access and use

	Control	Intervention	P-value	Total
Household level	*N = 408*	*N = 542*	*P-value*	*N = 950*
Owns at least one ITN	69.4%	93.4%	< 0.001	83.1%
Owns at least one ITN per two people	23.5%	42.1%	< 0.001	34.1%
Owns at least one ITN from:	N = 283	N = 506	P-value	N = 789
Previous mass campaign	69.3%	47.0%	< 0.001	55.0%
School	0.0%	89.1%	< 0.001	57.3%
ANC visit	17.0%	12.1%	0.054	13.8%
Other channels (e.g., other public source, private sector, and other/doesn't recall)	21.9%	9.5%	< 0.001	13.9%
Population level	*N = 1,746*	*N = 3090*	*P-value*	*N = 4,854*
Population access to ITN	46.1%	68.7%	< 0.001	60.5%
ITN use previous night	49.0%	70.5%	< 0.001	62.7%
	N = 814	*N = 2122*	*P-value*	*2,936*
ITN use:access ratio	1.06	1.03		1.04

46%, p < 0.001). However, population access in the intervention group was below the NMCP's 80% target. A higher proportion of the population also reported using an ITN the previous night in the intervention group (71%) than the control group (49%) (p < 0.001). As with population access, population use in the intervention population did not achieve the NMCP target of 80%. Across groups, use:access was high and did not significantly differ. The differences between ITN access and use indicators in intervention and control groups maintained their significance when multivariate regressions were performed to control for potential variation in measured household and population sample characteristics between the groups.

A significantly higher proportion of respondents from intervention households were exposed to ITN SBC messaging than control households in the six months preceding the survey (71% versus 43%, p < 0.001) (Table 3). Amongst the exposed, interpersonal communication was the primary source of messaging received by both groups, although a significantly higher proportion of intervention households received

Table 3 SBC exposure

	Control	Intervention	P-value	Total
	N = 408	*N = 542*		*N = 950*
Any exposure to ITN SBC in the last six months	43.1%	70.8%	< 0.001	58.9%
Among those exposed (N)	*N = 176*	*N = 384*		*N = 560*
Mean number of sources among exposed	2.5	1.8	0.471	2.0
Proportion of households that received SBC from SBD-related activities	18.2%	79.2%	< 0.001	60.0%
Types of media source among exposed				
Media only	1.7%	2.0%	0.761	2.0%
Interpersonal communication only	64.8%	78.3%	0.001	74.1%
Both	33.5%	19.6%	< 0.001	24.0%
Messages recalled among exposed				
Use your net	68.2%	81.8%	< 0.001	77.5%
Care for your net	66.5%	77.3%	0.005	73.9%
Hang up your net	83.0%	87.8%	0.105	86.3%
Sleep under your net every night	86.9%	86.5%	0.936	86.6%
Nets prevent malaria	67.0%	63.3%	0.407	64.5%
Repair your net	27.8%	35.4%	0.072	33.0%

interpersonal communication only ($p = 0.001$), while a significantly higher proportion of control households received a combination of both media and interpersonal communication ($p < 0.001$). While respondents from both groups recalled several SBC messages, a significantly higher proportion from the intervention groups cited messages on ITN use ($p < 0.001$) and caring for ITNs ($p = 0.005$).

On average, among households with any nets there were 2.5 ITNs per household in the intervention group, compared with 1.7 ITNs in control group households ($p < 0.001$) (Table 4). Over half (55%) of intervention group ITNs were reported as being received from SBD, with another 35% received from a previous mass campaign. In the control group, nearly three quarters (72%) of ITNs were reported as being received from a previous mass campaign with an additional 11% coming from an ANC visit. Across both groups, 77% of ITNs were slept under the night before the survey.

With 88,605 ITNs distributed, the SBD achieved 96.8% of its target ITN coverage. Approximately one month following the SBD, 99% of SBD ITNs were still in the possession of receiving households (Table 5). Only six SBD ITNs from the intervention households were reported as being missing, of which, one was stolen, one was given away to relatives, two were given away to non-relatives, and the location of two were unknown. All three ITNs that were given away were determined to be unneeded at the time by SBD households.

Table 4 ITN source(s) and use

	Control	Intervention	P-value	Total
	N = 283	*N = 506*		*N = 789*
Mean number of nets per household with at least one net	1.7	2.5	< 0.001	2.2
Net sources	*N = 495*	*N = 1247*		*N = 1742*
School	0.0%	54.6%	< 0.001	39.2%
Previous mass campaign	71.5%	35.4%		45.6%
ANC visit	10.9%	5.2%		6.8%
Other public source	3.2%	2.3%		2.6%
Private sector	9.3%	1.8%		3.9%
Other/doesn't recall	4.8%	0.7%		1.9%
Percentage of nets that were slept under the night before the survey	79.8%	75.6%	0.149	76.8%

Table 5 Lost nets from the SBD in intervention group

	N = 458 households
Households with all SBD nets still in possession	98.9%
	N = 695 nets
Proportion of SBD nets still in possession of household	99.1%
For missing nets, what happened to the missing SBD nets[a]	*N = 6*
Net was stolen	16.7% (n = 1)
Net was given away to relatives	16.7% (n = 1)
Net was given away to others	33.3% (n = 2)
Don't know	33.3% (n = 2)
Why were the SBD nets not kept?[b]	*N = 3*
Net was not needed at the time	100.0% (n = 3)

[a] No responses for ITNs accidentally destroyed, sold, thrown away, used for other purposes, used by family elsewhere, or other

[b] No responses for ITNs being too torn, too dirty, unliked, sold because money was needed, other, or don't know

In the intervention group, 17% of households discarded at least one non-SBD ITN after receiving at least one SBD ITN (Table 6). Half of discarded ITNs were thrown away because the ITNs were reportedly too torn or had too many holes. If these households had not received an SBD ITN, they reported that 57% of discarded ITNs would have been kept, despite the tears and holes.

Key informant interview findings

Coordination

A 20-member task force was created prior to the SBD, which was led by the NMCP in coordination with the Kono District Health Management Team. Participants included MBSSE, as well as PMI and its IPs. The task force met weekly to review progress and address issues. WhatsApp was noted as the most effective and widely used communication tool among participants for coordinating during the SBD process.

Timeliness of funding dispersal from the MOHS financial unit, Integrated Health Project Administration Unit, was highlighted as a key coordination challenge. Untimely dispersal of funding delayed meetings and prohibited key personnel from attending meetings.

> *"A task force can only operate based on the availability of resources. If you don't have resources, you cannot conduct meetings as you would have to cater for people's welfare like providing them with food and refreshments, transport reimbursement, and the like when you host them." (Key informant from the national level)*

A common theme that arose during the key informant interviewing was the need for improved coordination between logistics partners and the NMCP to facilitate timely delivery of ITNs. For example, participants noted gaps in coordination and communication related to transportation and ITN delivery during the pilot.

SBC communication

An SBC communication campaign was organized approximately three weeks before the distribution campaign to create awareness for the SBD and increase knowledge of malaria and ITNs. Messages, designed during stakeholder meetings, addressed topics including ITN care and use, which students were to receive ITNs (classes 1, 3, and 5), general malaria prevention, and the role of the NMCP in the community. Multiple communication channels were used during the SBC campaign (radio jingles, megaphones, meetings, and community demonstrations), and messaging was also shared through posters, flashcards, banners, and drawings. Paramount Chiefs (traditional leaders of

Table 6 Other nets discarded since the SBD in the intervention group

	N = 458
Households that discarded one or more non-SBD net since receiving an SBD net	17.0%
Of households that discarded one or more non-SBD nets since receiving an SBD net	
Mean number discarded nets per household	2.1
What happened to the nets[a]	*N = 134*
Net was destroyed accidentally	25.0%
Net was thrown away	50.0%
Material used for other purpose	25.0%
Why were the non-SBD nets thrown away?[b]	*N = 76*
Net was too torn, too many holes	100.0%
Proportion of nets for which the respondent reported that would have been kept if an SBD net was not received	56.6%

[a] No responses ITNs being stolen, sold, given away to relatives/others, used by other family members elsewhere, other or don't know

[b] No responses for ITNs being too dirty, not needed, unliked, sold because money was needed, other, or don't know

Chiefdoms) and chiefdom opinion leaders were also engaged to increase buy-in. The main audience for the campaign were beneficiaries from classes 1, 3, and 5, although parents and community members were also targeted.

> *"The jingle is still being aired every day, and I listen to it regularly... The nurses too have been consistent in passing out the message regarding the ITNs daily through their megaphones." (Key informant from the chiefdom level)*

Participants generally had positive feelings towards the SBC campaign and felt that it was an effective form of educating the community about the SBD. However, some school children and parents were displeased that all children were not eligible to receive an ITN through SBD and said that future SBDs might not be successful unless this issue was addressed.

> *"Some children were feeling isolated and some were even crying [asking] why they were not given one... some parents as well. We had to explain to the parents again...even though there was a meeting already with them where we explained the process and the grades for the distribution. But sometimes some people will not believe until when they actually see the reality. Some even remarked that they will not send their children to school again because when benefits come their children are not part of the ones that benefit from it." (Key informant from the national level)*

Net storage

During the SBD, a checklist was reviewed and signed at each level to confirm ITN receipt and count. Participants shared that this was an effective way to document ITN transportation and added accountability to the process. However, there were concerns with the storage and transportation process. Key challenges included delayed funding, poor communication, and low quality of the storage locations. Whereas ITNs should be stored in a shaded, secure, well-ventilated environment off the ground on pallets, pilot storage locations were often too small to fit all the ITNs, and did not have adequate ventilation, security and/or available pallets. Most participants interviewed shared that they were required to play the role of security at the storage locations.

> *"So basically, I have to transform myself into security personnel just to make sure [the nets] were protected." (Key informant from the district level)*

Additionally, participants shared experiences such as having to pay out of pocket to get the ITNs transported to the PHUs and schools, not having funds available to pay for proper storage locations and not receiving reimbursement for these out-of-pocket expenses.

While some were optimistic about the ITN transport process, others shared challenges with lack of labour/personnel for transportation and distribution (especially at PHUs/schools), poor road conditions, and confusion with roles when transporting ITNs from the district to the PHUs/schools such as who was responsible for transporting and distributing the nets, when the delivery would happen, and where the nets would be delivered.

Net quantification and distribution

Participants shared that the register data was readily available, and in some cases, additional register sheets were provided. Waybill receipts were used to confirm that the ITNs were distributed. While a 10% buffer was used to quantify the number of ITNs that needed to be distributed to schools, there were cases where school enrollment had increased after the quantification had been completed and some pupils did not receive an ITN as planned.

Other challenges shared by participants included having no funding available to transport leftover and excess ITNs, having inconsistent network connectivity, which prevented the digital monitoring tool from being used, delays or changes in distribution dates, and insufficient fuel to conduct the distribution.

> *"How would I conduct monitoring at a particular school when I was not supplied with fuel to the said school? I think that was a huge gap in the monitoring chain of the distribution process." (Key informant from the chiefdom level)*

Training and microplanning

Trainings on SBD ITN distribution processes were reported by key informants to be received positively. However, there were challenges with using the digital tools, reimbursement, and training timelines. After training, many trainees had an incomplete understanding of the digital tool impacting proficiency, which was perpetuated by weak internet access. Additionally, some trainees used personal funds to travel to the training and were not reimbursed. One key informant shared:

> *"... training of these nurses was just for one day... the nurses found it very difficult to use the tablets that were given to them." (Key informant from the chiefdom level)*

Supervision and monitoring

Supervision was overseen by the NMCP and MBSSE. Supervision teams assessed registration, documentation, distribution, and stock. Supervisors reported having a clear understanding of their role and objectives. Commonly reported issues with the digital data collection equipment and supplies, such as faulty or absent power banks or no internet connection, led to the use of personal devices. Participants shared that increasing the number of days of training and spending more time training on the digital tool would strengthen subsequent supervisions.

Discussion

The SBD pilot in Kono district achieved 96.2% of its target distribution coverage by delivering PBO ITNs to 88,605 pupils across 531 schools, improving ITN access for children attending school. Population-level ITN access, the primary assessment indicator of interest, was significantly higher amongst the intervention population than that of the control (69% vs 46%, $p < 0.001$). However, even amongst the intervention population, access was below the 80% target set by the NMCP. Low levels of ITN access, even post-SBD, are unsurprising, given that SBD was first implemented in 2023, rather than on an on-going basis after the 2020 mass campaign. This assessment provides evidence to support the expansion of SBD in Sierra Leone, as the pilot demonstrated a significant increase in household and population level use and access indicators in intervention households, including household ownership of at least one ITN, household ownership of one ITN per two people, population ITN access, and population ITN use. However, like population access, use amongst the population intervention (71%), while significantly higher than the control population (46%, $p < 0.001$), did not meet the NMCP target of 80%. Fewer than 1% of SBD nets received by children from eligible households in the study sample were recorded as missing two to three months after the distribution.

Challenges with the rollout of the pilot SBD offered valuable learnings that can be applied both in-country and externally, with the main issue related to the disbursement of funds. Insufficient or untimely funding hindered SBD coordination and planning, delayed ITN transportation, led to a shortage of desired transportation assets and sub-standard ITN storage practices, reduced training quality, and hampered supervision through lack of access to functional tablets and sufficient data bundles. To ensure the timely release of all approved funds, clear written guidance should be developed in coordination with all stakeholders to clarify key aspects of disbursement processes, including procedures, timelines, and required documentation.

Beyond funding-related findings, KIIs identified key gaps to be addressed during future SBD efforts. One quarter of study households that reported receiving SBC messaging were exposed to a media channel (2% by media only and 24% by both interpersonal communication and media). While key informants highlighted the reach of media channels, SBC stakeholders should prioritize interpersonal communication channels, which have been demonstrated here to reach more beneficiaries. Critically, a communication plan should be developed that includes a greater emphasis on how SBD is rolled out, who is targeted, and why. Doing so will assuage concerns that those who did not receive an ITN and to guide those who are ineligible to receive an SBD ITN to an alternative channel.

The roles and responsibilities matrix developed by the task force should be updated based on the results of this pilot to alleviate any confusion, particularly around ITN transportation and storage responsibilities. Though census data was relatively accurate, fluctuations in school enrollment were not picked up during microplanning. Prior to future SBD efforts, a comparison between census and school register data is necessary to ensure maximum quantification accuracy and implementation efficiency. During training, a greater focus should be paid on digital tool use to improve user proficiency. Finally, prior to ITN arrival at the chiefdom level, suitable storage locations and security plans must be identified and established.

While the KIIs highlighted operational challenges, they also uncovered individual and collective acts of determined professionalism that quietly propelled the SBD's success. Future efforts should fill the identified gaps so that intervention success does not rely upon instances of PHU staff guarding ITNs overnight or supervisors buying their own cellphone bundles to upload data. Nonetheless, this commitment should be recognized and lauded.

The assessment highlighted a latent need for replacement ITNs between mass campaigns, with households reporting that they keep and utilize torn or worn-out ITNs in the absence of new ones.

It also reaffirmed that in Sierra Leone, those with access to ITNs use them irrespective of demographic differences. The use:access ratio was 1.06 in control households and 1.03 in intervention households, which is consistent with the national use:access ratio of 1.08 [5]. In both intervention and control households, use:access was above 0.8, the NMCP [6] and nominal minimum target [16].

Before investing in new distribution channels, the NMCP must ensure that their ANC and EPI channels are well-functioning to ensure that the most biologically vulnerable groups are reached. Sierra Leone has been

distributing ITNs to pregnant women through ANC and children under one though EPI for nearly 20 years. Since 2019, approximately 1.2 million ITNs were distributed through ANC, and another 1 million were distributed through EPI. In 2021, ITN coverage for pregnant women and children in Sierra Leone was 50% and 52%, respectively [5]. Formally assessing these channels may identify gaps, the rectification of which would further solidify their utility.

Findings from this assessment contribute to the existing body of literature on the benefits of SBD as a routine ITN distribution channel [8–12]. However, it was conducted between just two and three months after the SBD making it impossible to know if gains made in ITN use and access will be maintained throughout the life of the SBD ITNs. Further, conducting an SBD three years post-mass campaign, when ITN coverage is low, could exaggerate intervention efficacy compared to if it was conducted per best practice (in years one and two post-mass campaign). A costing analysis and at least one subsequent follow-up survey round, two or three years after the pilot, would be beneficial both to understand SBD ITN use and access over time in Sierra Leone, and to be more comparable to similar studies conducted elsewhere [11, 17–21]. Finally, this assessment did not investigate the impact of SBD on parasitaemia. While it is expected that improved ITN access will contribute to reduction in parasitaemia, especially given that school-going children between ages five and nine are known to be a major driver of malaria transmission [22–24], a formal epidemiological analysis could be useful in Sierra Leone.

Conclusion

This assessment demonstrates that the SBD pilot in Kono district, Sierra Leone improved household and population levels of ITN access and population levels of ITN use. Findings support the Sierra Leone NMCP's decision to incorporate SBD into their continuous ITN distribution strategy to improve ITN access and use. However, one- to two-months post-SBD, intervention population use and access, did not achieve the 80% NMCP target. When scaling up SBD, the NMCP and other stakeholders must improve financial and logistical coordination, which will facilitate agreement on roll out approach and ensure a clear communication plan is produced to bolster the intervention and community support.

Abbreviations

ANC	Antenatal care
DM	Durability monitoring
EA	Enumeration areas
EPI	Expanded Programme on Immunization
IP	Implementing partner
IRS	Indoor residual spraying
ITN	Insecticide-treated net
KII	Key informant interview
MBSSE	Ministry of Basic and Senior Secondary Education
MIS	Malaria Indicator Survey
MOHS	Ministry of Health and Sanitation
NMCP	National Malaria Control Programme
PBO	Piperonyl-butoxide
PHU	Peripheral Health Units
PMI	US President's Malaria Initiative
PSI	Population Services International
RDT	Rapid diagnostic test
REB	Research Ethics Board
SBC	Social behaviour change
SBD	School-based distribution
SLESRC	Sierra Leone Ethics and Scientific Review Committee

Acknowledgements

The authors sincerely thank the Government of Sierra Leone, including the MOHS and the MBSSE, for their guidance and leadership. A hearty thanks is extended posthumously to Dr. Samuel Smith, former Sierra Leone NMCP Program Manager, for his enthusiasm for implementing SBDs in Sierra Leone. The authors would like to give deep gratitude to all those participating in this pilot at district, chiefdom, PHU, and school levels, for their commitment to its successful execution. Thanks to PMI Evolve's Chief of Party, Laurent Iyikirenga for his leadership and Allieu Mansaray from Nest Builders International for heading data collection. A special thanks to Dr. Janee Miller for helping to conceive of this assessment. Finally, the authors thank PMI and CDC, especially Kristen George, Lilia Gerberg, Rebecca Levine, and Tony Hughes for their thought leadership and support.

Disclaimer

The findings and conclusions expressed herein are those of the authors and do not necessarily represent the official position of USAID, PMI, or the U.S. Centers for Disease Control and Prevention.

Author contributions

SP designed the study and quantitative tools and contributed to drafting and critically revising the manuscript. KE reviewed the protocol, led implementation of the study, and drafted the manuscript abstract and quantitative analysis portions of the methods and results sections. The drafting of qualitative portions of these sections was led by MS with support from KE. Writing of the discussion section was led by KE with major inputs from KO, DS, SP, PO, and JC. KO drafted the manuscript introduction and conclusion sections. CY and PN led both quantitative and qualitative data collection. RS provided in-person data collector training and conducted quantitative data analysis. MS and ET conducted qualitative data analysis. ET led internal manuscript copy editing and version control. All co-authors reviewed the manuscript and provided feedback.

Funding

Financial support for this study was provided by the U.S. President's Malaria Initiative.

Data availability

Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate

This study was determined to be research with human subjects and received written approval from the Sierra Leone Ethics and Scientific Review Committee (SLESRC) within the MOHS on April 14, 2023, under reference number 022/04/2023. The Population Services International (PSI) Research Ethics Board (REB) granted authorization on March 15, 2023. Staff implementing this study complied with all policies and procedures of both PSI REB and SLESRC. Informed consent was also obtained from the head of household or their representative prior to the household interview. Oral consent was obtained for KIIs at the site of the interview.

Consent for publication
All authors have read and approved the final version of the manuscript and consent to its publication.

Competing interests
The authors declare no competing interests.

Author details
[1]PMI Evolve Project, Population Services International, Washington, DC, USA. [2]National Malaria Control Programme, Freetown, Sierra Leone. [3]PMI Evolve Project, Abt Global, Freetown, Sierra Leone. [4]U.S. President's Malaria Initiative, U.S. Centers for Disease Control and Prevention, Freetown, Sierra Leone. [5]PMI Evolve Project, Population Services International, Accra, Ghana. [6]PMI Evolve Project, Population Services International, Nairobi, Kenya. [7]Population Services International, Washington, DC, USA. [8]District Health Management Team, Kono, Sierra Leone. [9]Ministry of Basic and Senior Secondary Education, Kono, Sierra Leone. [10]U.S. President's Malaria Initiative, USAID, Washington, DC, USA. [11]PMI Evolve Project, Abt Global, Rockville, MD, USA. [12]Nest Builders International, Freetown, Sierra Leone. [13]PMI Evolve Project, Tropical Health LLP, Bristol, UK.

Received: 16 January 2025 Accepted: 9 April 2025
Published online: 09 May 2025

References

1. WHO. World malaria report 2024. Geneva: World Health Organization, 2024. https://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2024. Accessed 17 Dec 2024.
2. Bhatt S, Weiss DJ, Cameron E, Bisanzio D, Mappin B, Dalrymple U, et al. The effect of malaria control on *Plasmodium falciparum* in Africa between 2000 and 2015. Nature. 2015;526:207–11.
3. Ranson H, Lissenden N. Insecticide resistance in African *Anopheles* mosquitoes: a worsening situation that needs urgent action to maintain malaria control. Trends Parasitol. 2016;32:187–96.
4. VectorLink PMI. PMI VectorLink Sierra Leone Annual Entomological Monitoring Report, May 1, 2018–February 28, 2019. Rockville: PMI VectorLink Project; 2019. https://d1u4sg1s9ptc4z.cloudfront.net/uploads/2021/03/sierra-leone-2019-entomological-monitoring-final-report.pdf. Accessed 3 June 2024.
5. Program NMC, Leone SS, Leone U of S, Services CR, International U. Sierra Leone Malaria IndicatorSurvey 2021. Sierra Leone National Malaria Control Programme; 2021.https://malariasurveys.org/documents/SL%20MIS%20final%20report-4.3.2022.pdf. Accessed 3 June2024.
6. National Malaria Control Programme. Sierra Leone National Malaria Elimination Strategic Plan 2021–2025. Sierra Leone: Freetown, 2021.
7. Sierra Leone. Breakthrough ACTION and RESEARCH. https://breakthroughactionandresearch.org/resources/itn-use-and-access-report/sierra-leone/. Accessed 17 June 2024.
8. Stuck L, Chacky F, Festo C, Lutambi A, Abdul R, Greer G, et al. Evaluation of long-lasting insecticidal net distribution through schools in Southern Tanzania. Health Policy Plan. 2022;37:243–54.
9. Koenker H, Worges M, Kamala B, Gitanya P, Chacky F, Lazaro S, et al. Annual distributions of insecticide-treated nets to schoolchildren and other key populations to maintain higher ITN access than with mass campaigns: a modelling study for mainland Tanzania. Malar J. 2022;21:246.
10. Acosta A, Obi E, Ato Selby R, Ugot I, Lynch M, Maire M, et al. Design, implementation, and evaluation of a school insecticide-treated net distribution program in Cross River State, Nigeria. Glob Health Sci Pract. 2018;6:272–87.
11. Yukich J, Stuck L, Scates S, Wisniewski J, Chacky F, Festo C, et al. Sustaining LLIN coverage with continuous distribution: the school net programme in Tanzania. Malar J. 2020;19:158.
12. President's Malaria Initiative. PMI Technical Guidance FY 2025: External. 2025. https://d1u4sg1s9ptc4z.cloudfront.net/uploads/2024/04/EXTERNAL-VERSION-PMI-FY2025-Technical-Guidance-1.pdf. Accessed 31 May 2024.
13. President's Malaria Initiative Sierra Leone. Durability Monitoring Snapshot: 36 Months (March–April 2023). Sierra Leone, Freetown. 2024. https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.durabilitymonitoring.org%2Fwp-content%2Fuploads%2F2024%2F05%2FPMI-VectorLink-Sierra-Leone-36-Month-DM-Snapshot-with-Bioassays-and-Chemical-Results-clean.docx&wdOrigin=BROWSELINK. Accessed 31 May 2024.
14. President's Malaria Initiative. LLIN Durability Monitoring. Toolkit and Data Repository for PMI-funded LLIN durability monitoring studies. https://www.durabilitymonitoring.org/. Accessed 17 Dec 2024.
15. The DHS Program-MIS Model Questionnaires. https://dhsprogram.com/Methodology/Survey-Types/MIS-Model-Questionnaires.cfm. Accessed 17 Dec 2024.
16. Koenker H, Kilian A. Recalculating the net use gap: a multi-country comparison of ITN use versus ITN access. PLoS ONE. 2014;9: e97496.
17. Scates SS, Finn TP, Wisniewski J, Dadi D, Mandike R, Khamis M, et al. Costs of insecticide-treated bed net distribution systems in sub-Saharan Africa. Malar J. 2020;19:105.
18. Koenker HM, Yukich JO, Mkindi A, Mandike R, Brown N, Kilian A, et al. Analysing and recommending options for maintaining universal coverage with long-lasting insecticidal nets: the case of Tanzania in 2011. Malar J. 2013;12:150.
19. Yukich J, Sternberg E, Miller J. PMI VectorLink 2020 School and Community-based ITN Distribution Cost Study Report. 2022 https://www.continuousdistribution.org/wp-content/uploads/2023/01/PMI-VectorLink-School-and-Community-Based-Distribution-Cost-Study.pdf. Accessed 12 Dec 2024.
20. Scates S, Yukich J. PMI VectorWorks cost analysis series 4: health facility and school distribution in Ghana 2015–16. PMI VectorWorks. https://pdf.usaid.gov/pdf_docs/PA00TQN7.pdf. Accessed 12 Dec 2024.
21. ITN Quantification. https://allianceformalariaprevention.com/itn-quantification/index.html. Accessed 12 Dec 2024.
22. Cohee LM, Goupeyou-Youmsi J, Seydel KB, Mangani C, Ntenda P, Sixpence A, et al. Understanding the intransigence of malaria in Malawi. Am J Trop Med Hyg. 2022;107(4_Suppl):40–8.
23. Coalson JE, Cohee LM, Buchwald AG, Nyambalo A, Kubale J, Seydel KB, et al. Simulation models predict that school-age children are responsible for most human-to-mosquito *Plasmodium falciparum* transmission in southern Malawi. Malar J. 2018;17:147.
24. Koenker H, Yukich J, Erskine M, Opoku R, Sternberg E, Kilian A. How many mosquito nets are needed to maintain universal coverage: an update. Malar J. 2023;22:200.

Publisher's Note