Technical consultation on physical integrity and durability of insecticide-treated nets

Meeting report, 6 August 2025

World Health Organization

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Contents

Abbreviations

CI	confidence interval
ISO	International Organization for Standardization
ITN	insecticide-treated net
RD	resistance-to-damage
RI	risk index
WHO	World Health Organization
wRD	weighted resistance-to-damage

1. General background

Insecticide-treated nets (ITNs) are a major tool for the prevention of malaria. Each year, hundreds of millions of ITNs are distributed to people around the world, primarily in sub-Saharan Africa. Because ITN effectiveness depends on consistent nightly use, they are subject to wear and tear over time. The development of holes or tears can compromise their protective effectiveness and users may discard the nets if they perceive that the nets no longer offer adequate protection.

To ensure that those who need them the most have continuous protection, new ITNs must be redistributed to replace those that have been damaged or discarded. In general, the redistribution cycle for most national malaria programmes is every three years. However, a recent study comparing ITNs' median survival in serviceable condition found that survival times ranged from 1.6 to 5.3 years *(1)*.

While some countries have considered a shorter redistribution cycle, increased ITN durability could also offer improved protection from malaria. However, ITN durability varies considerably across locations due to ITN construction, as well as different use conditions and human behaviour. Furthermore, it remains challenging to incentivize the development of ITNs with improved longevity in the absence of reliable measures of the physical durability of the netting. To this end, a resistance-to-damage (RD) score was developed, based on methods common within the textile industry, to characterize the bursting strength, snag strength, abrasion resistance and resistance to hole enlargement of different ITN products *(2)*. This RD score was proposed as a method to predict ITN durability using standardized physical tests, instead of relying solely on operational field studies in which additional factors, such as human behaviour and net use conditions, also affect ITN longevity. If the RD score was determined to be a reliable predictor of ITN durability, it could be used to guide procurement decisions and facilitate development of ITNs with increased durability.

As noted above, the human and environmental elements associated with ITN durability should not be ignored. ITN survival varies considerably across contexts; the same product may show differences in lifespan of many months, depending on the conditions of use. Understanding the expected survival of ITNs in different locations could result in better targeting of more durable nets where they are needed the most.

A more predictive assessment of ITN durability combined with a better understanding of the contexts in which they will be deployed could result in a more rational deployment of ITNs, allowing for value-based procurement that considers the cost per year of protection.

A World Health Organization (WHO) technical consultation on the physical integrity and durability of ITNs was held virtually on 6 August 2025. The participating temporary advisors were provided with information on the RD score, an assessment of human and environmental conditions called the "risk index" (RI), and a presentation on value-based procurement, with a request that they provide feedback to WHO on these topics. The list of participants is given in Annex 1, and the meeting agenda is reproduced in Annex 2.

2. Objectives

The key objectives of the technical consultation were to:

- consider the weighted RD (wRD) score as a means of assessing the potential field durability of ITNs;
- understand the RI and consider the role it may play in ITN retention; and
- discuss how ITN performance could be better integrated into procurement decisions.

3. Proceedings

3.1 Opening

Dr Daniel Ngamije, Director of the Global Malaria Programme, opened the meeting by thanking participants for joining the technical consultation. He noted the existing challenge of ITN durability and the discrepancy between the median lifespan of ITNs and the interval between ITN distribution cycles. ITN manufacturers have the capacity to produce more durable nets; however, the potentially higher costs may pose challenges for procurement. He welcomed the discussion on the wRD score, the RI and value-based procurement. He thanked the ITN manufacturers present as observers for their major contribution to reducing malaria and wished the temporary advisors the best in their deliberations.

The declarations of interest were read by Dr Seth Irish, Technical Officer of the WHO Global Malaria Programme. Details are available in Annex 3.

Dr Emmanuel Chanda provided the context and objectives to participants. He reiterated that ITNs remain central to malaria control due to their cost-effectiveness, ease of deployment and suitability for large-scale distribution. However, durability failures – including tearing, seam failures and abrasion – reduce the proportion of the population that is protected, as mosquitoes can access people sleeping under the net and people may not use damaged nets.

3.2 Part 1: wRD score – a useful tool for linking lab performance to operational life?

In the first presentation, Professor Stephen Russell gave a presentation on the development of the original RD score for ITNs. The RD score was first developed by looking at actual sources of damage to ITNs in the field, much of which is due to snags, tears, hole enlargement and seam failure – all of which are preventable. He also noted that there are some limits to ITN durability, in that they are not meant to be resistant to cutting, flames or rodent damage. Laboratory-based textile testing of mechanical damage is important to ensure that products are fit for purpose before use. Early tests of bursting strength alone did not show sufficient correlation with ITN durability. However, when additional parameters (i.e., abrasion resistance, snag strength and resistance to hole enlargement) were evaluated, an increased correlation with ITN lifespan was found. Field work demonstrated higher survival of ITNs with an original RD score over 50. In the original RD score, each of the variables was weighted equally (see Fig. 1).

Fig. 1. Original RD score formula

$$RD = \left(\frac{\lambda_B}{\eta_B} \times \frac{100}{4}\right) + \left(\frac{\lambda_S}{\eta_S} \times \frac{100}{4}\right) + \left(\frac{\lambda_A}{\eta_A} \times \frac{100}{4}\right) + \frac{\sigma_H}{4}$$

λ_B: actual bursting strength (kPa); λ_S: actual snag strength (N); λ_A: actual abrasion resistance strength (number of rubs); σ_H: hole enlargement resistance score; η_B: aspirational bursting strength (kPa); η_S: aspirational snag strength (N); η_A: aspirational abrasion resistance (number of rubs)

An analysis of ITNs from 2013 and 2020 found that original RD scores did not change significantly between the two time periods (*3*).

Dr Frank Mechan continued the presentation, discussing the challenges of linking field data to the original RD scores. He noted that a meta-analysis found the median lifespan of ITNs to be 1.64 years – well below the expected three years between mass campaigns. A deep dive into the assumptions shaping the variables for the original RD score, combined with an analysis of field-aged ITNs, found that most mechanical damage was caused by hole enlargement and very little was caused by abrasion. Furthermore, abrasion data varied greatly, even for the same net, offering limited insight into its contribution to physical durability. To achieve better correlation between the original RD score and damage in the field, the wRD was proposed in which abrasion resistance was removed and hole enlargement was weighted at 50% (Fig. 2).

Fig. 2. wRD score formula

$$wRD = \left(\frac{\lambda_B}{\eta_B} \times \frac{100}{4}\right) + \left(\frac{\lambda_S}{\eta_S} \times \frac{100}{4}\right) + \frac{\sigma_H}{2}$$

λ_B: actual bursting strength (kPa); λ_S: actual snag strength (N); σ_H: hole enlargement resistance score; η_B: aspirational bursting strength (kPa); η_S: aspirational snag strength (N)

This simplified model was able to better predict field survival of ITNs. Interestingly, both polyethylene/tulle and polyester/traverse nets were among the top performers, indicating that wRD scores were not simply a matter of material.

Dr Matt Worges then discussed the evidence base for the development of the wRD score. The scores were collected and compared to field ITNs for 13 brands (16 819 nets). They found that the wRD score was positively associated with median lifespan ($p = 0.001$) and that a 10 point increase in wRD score was associated with a 3.5 month increase in median lifespan (95% confidence interval [CI]: 1.3–5.7). They estimated that an ITN with a wRD of 38 would have a median survival time of 1.6 years, and the survival of ITNs with a wRD of 68 would be closer to the three-year expected target, with a 2.7-year median survival time. Aspirational nets (wRD of 80–85) were also evaluated and found to correlate with a four-year survival and a 70% lower hazard of failure compared to standard nets (general wRD range of 39–65). The preliminary range found between chlorfenapyr-pyrethroid ITNs from different manufacturers was 18 points. When the same samples were sent to three different centres, the wRD scores were broadly aligned (within 1.3 points).[1]

3.3 Part 2: RI – a potential metric for quantifying the social and environmental risk for ITN lifespan?

Dr Julie-Anne Tangena and Dr Stephen Poyer presented on the behavioural aspects of ITN use and how these are related to ITN durability in the field. They described the RI as a metric to quantify the social and environmental risk to ITNs. They shared data on the same brand of ITNs, which showed significantly different median lifespans in different locations. For example, work on the ITN DawaPlus 2.0 found lifespans ranging from 1.6 years (Democratic Republic of the Congo) to 5.3 years (northern Nigeria), and similar ranges were found for other ITNs: PermaNet® 3.0 (1.9–6.0 years), Olyset™ Plus (1.2–2.3 years) and Interceptor® G2 (2.0–4.3 years). The RI helps to explain the differences in lifespan across sites. The RI can be calculated through an assessment of behaviours related to net handling (e.g., storing food in the sleeping room, cooking in sleeping room, etc.); net care attitudes (e.g., recall of key net messages); and the net use environment (e.g., wall material, cooking with firewood, rodents seen in area of use, type of sleeping space). Highly heterogeneous RIs were found in 44 sites in Africa. In some cases, high differences in RI can be found even in nearby sites (e.g., Burundi and Rwanda). In general, a 10 point decrease in RI score was associated with a 2.2 month survival gain (95% CI: 0.1–4.2). There were no interactions found between the RI and the wRD.

They proposed that careful application of the RI could lead to more effective ITN distribution strategies, as it would enable programmes to consider the specific context in which nets would be deployed.

3.4 Part 3: What are potential pathways to bring wRD into procurement decisions?

Ms Tara Seethaler presented on value-based procurement and how the wRD score might be used to deliver greater vector control impact without increasing budgets. She noted the coverage gaps that are routinely present in countries due to the mismatch between ITN durability and distribution cycles. Because the wRD score predicts real-world field performance, incorporating the wRD into procurement would enable decisions based on value rather than price alone. Increasing the wRD scores of ITNs by 10 points (a median lifespan gain of 3–4 months, as presented earlier) could result in

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1 Testing performed after the technical consultation in the remaining two centres reported results with substantially discordant values, leading to a range of wRD scores from the five laboratories of 25 points. Results obtained after the consultation included observations of very large hole enlargement (> 70 mm) and bursting strength greater than any known product (> 600 kPa). Snag strength results remained consistent across all centres. Bursting strength and hole enlargement use the same piece of equipment and are dependent on the aperture size setting. Investigation of the aperture size at one of the centres identified an incorrect setting. After correction, follow-up testing reported bursting strength and hole enlargement values that were more in line with those found in the other centres. Re-testing at the fifth centre is planned but has yet to begin.

a decrease of malaria cases by 5–6% over a three-year period in sub-Saharan Africa, which corresponds to the impact of distributing 171 million additional nets (*4*). The additional value of 10 wRD points could be worth US$ 1.35 per net.

Mr Ryan Fu continued the presentation, noting that the WHO-prequalified nets currently on the market have characteristics that result in a wide range of wRD scores, yet the wRD scores are independent of price. This suggests that countries can achieve greater impact from bed nets without necessarily increasing expenditure. There are several ways in which wRD scores could be introduced into sourcing practices, including: (i) incorporating wRD scores into procurers' sourcing algorithm; (ii) setting a minimum wRD score below which volumes are not awarded; and (iii) offering a price premium for nets with higher wRD scores. It is important to consider and mitigate the potential risks associated with developing longer lasting nets. These include environmental risks (e.g., increasing plastic density to boost wRD scores could lead to more plastic waste, or conversely could reduce plastic waste through greater longevity), user experience (e.g., changes in durability may affect fabric feel, airflow or temperature under the net) and bioefficacy (e.g., modifying the ITN denier or weave could alter insecticide bioavailability). Each of these risks has feasible mitigation strategies.

Finally, Ms Seethaler presented a vision for how the wRD and RI could be used individually or together in procurement decisions to make smarter vector control decisions and save more lives.

4. Conclusions

4.1 wRD score

In general, the temporary advisors considered the wRD score to be a useful indicator of ITN durability – one that should be used to inform procurement decisions.

There was concern noted about the insecticidal aspect of ITNs, as the duration of insecticidal efficacy is often much shorter than the physical life of the net, particularly those with higher wRD scores. Advisors noted that it is important for the insecticidal effect of the ITNs to last as long as their expected life in the field. If nets are developed that can last longer than three years, it will be essential to ensure that the insecticide also lasts that long.

There were discussions about potential barriers to implementation of the wRD score. Currently, there are International Organization for Standardization (ISO) procedures for measuring bursting strength, snag strength and resistance to hole enlargement for textiles; however, due to the nature of ITNs, the only method that can be used without adaptation is the bursting strength method. Current guidance on methods for measuring snag strength and resistance to hole enlargement have been described in the *WHO guideline for the prequalification assessment of insecticide-treated nets* (*5*). This guidance was developed based on the publications and method development of Wheldrake et al. *(2, 3)*. These methods (standardized protocols, required sample sizes, etc.) will need to be internationally validated through a multi-centre study to be employed for the envisioned purposes. WHO is not responsible for method validation and therefore further engagement among stakeholders within the sector is needed. Given the potential timelines needed to internationally validate the augmented methods, procurers may wish to integrate these attributes into their decisions, using a risk-based approach.

Another potential issue was identified in relation to mosaic ITNs, which are constructed using different fabrics for different panels, e.g., sides and roof. As the wRD score would apply to the fabric and not the constructed ITN, a mosaic net would have multiple wRD scores – one for each fabric used in constructing the ITN. Those organizations that may rely on the wRD score would need to determine which score to use to inform their decision.

Developing preferred product characteristics that specify target wRD scores could become an effective way to promote the minimum required durability of ITNs.

Finally, the weight, bulk and ease of distribution of any future ITNs with higher wRD scores will need to be assessed and considered.

4.2 RI

The temporary advisors appreciated the RI as a modifier of ITN durability. In general, most advisors saw this as a useful indicator of the important human and contextual factors affecting ITN durability, but one that needs additional work before it can be widely used in procurement decisions or ITN distribution.

There are specific questions that are currently asked in surveys to compile the RI, and these are all included in the WHO prequalification guideline for community evaluation of nets (*6*). This will enable calculation of the RI.

Temporary advisors also saw the importance of the RI as a key reminder of the importance of the human and contextual factors contributing to ITN damage.

Questions were raised about the standardization of the questionnaire and whether additional context-specific questions might be required. However, the existing questions are broadly applicable across most locations. What requires further refinement is the survey protocol and a detailed description of the required analysis to make the RI calculation simpler and more robust.

4.3 Value-based procurement

The application of the wRD score and RI to procurement procedures was discussed. If ITNs were the same price, it would be relatively straightforward to use the wRD score; however, with price differences, it is more complicated to determine the monetary value of the wRD score. Since procurement specialists routinely incorporate variables such as wRD scores in decision-making, detailed guidance – for example, on the required frequency of wRD score assessments and adjustments to procurement algorithms – can be left to their discretion.

5. Further research

- Continue to collect data to evaluate ITN durability and its relationship to the wRD score.
- Determine how to measure the wRD scores of mosaic nets (i.e., when roof and sides are different materials).
- Understand and better estimate the economic value of increased wRD scores.
- Consider how the wRD score might be incorporated into net specifications.
- Understand the stability of RI scores over time.
- Determine whether the RI should be considered in the evaluation of ITNs.
- Evaluate whether the RI (only developed from African data) is applicable to sites outside of Africa.
- Determine whether the brand of net in place during the calculation of the RI influences the RI value.

6. Proposed next steps

- Develop detailed protocols and procedures for determining wRD scores, including sample size, and conduct further inter-laboratory testing to ensure consistency of wRD score measurement across laboratories and understanding of uncertainty (i.e., CIs), so that procurers can start to use wRD scores, following a risk-based approach.
- Develop ISO methods, or other internationally recognized methods, for snag strength and resistance to hole enlargement specific to ITNs through a multi-centre study in order to further standardize these methods.
- Develop detailed protocols and procedures for determining the RI.
- Conduct additional optimization of the RI and further field evaluation.

7. References[2]

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5. WHO guideline for the prequalification assessment of insecticide-treated nets. Geneva: World Health Organization; 2024 (https://iris.who.int/handle/10665/378300).

6. Implementation guidance (Module 5): long-term community studies for ITNs. Geneva: World Health Organization; 2025 (https://extranet.who.int/prequal/node/35330).

2 All references were accessed on 19 January 2026.

Annex 1. List of participants

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Annex 2. Agenda

6 August 2025		
Open Session (TC Members & WHO Staff)		
13:00 – 13:10	Introduction	Daniel NGAMIJE
13:10 – 13:15	Declarations of interest	Seth IRISH
13:15 – 13:25	Background, objectives and expected outcomes	Emmanuel CHANDA
Part I: Weighted RD score – a useful tool for linking lab performance to operational life?		
Open Session (TC Members & WHO Staff)		
13:30 – 14:40	Presentation	Stephen RUSSELL, Frank MECHAN, Matt WORGES
14:40 – 15:00	Questions and answers	Members, WHO staff, and observers
Part II: Risk index – a potential metric for quantifying the social and environmental risk for ITN lifespan?		
15:00 – 15:40	Presentation	Steve POYER, Julie-Anne TANGENA
15:40 – 16:00	Questions and answers	Members, WHO staff, and observers
Part III: What are potential pathways to bring RD into procurement decisions?		
16:10 – 16:40	Presentation:	Tara SEETHALER, Ryan FU
16:40 – 17:00	Questions and answers	Members, WHO staff, and observers
Part IV: Conclusions		
Closed Session (TC Members, Participants & WHO Staff)		
17:00 – 18:00	Finalization of meeting conclusions	Chair

Annex 3. Declarations of interest

The WHO technical consultation on physical integrity and durability of ITNs was held virtually on 6 August 2025.

Assessment of declarations of interest (DOIs)

All temporary advisors were required to submit DOIs and confidentiality undertakings (COU) with respect to the above meeting. The observers and presenters submitted COUs only. Following a due diligence Internet search and review, DOIs were assessed by the WHO Secretariat and the review output is summarized below:

Temporary advisors

1. **Idelphonse AHOGNI,** CREC/LSHTM Collaborative Research Programme; Cotonou, Benin
2. **Roch DABIRE,** Institut de Recherche en Sciences de la Santé; Bobo Dioulasso, Burkina Faso
3. **Marcie ERSKINE,** International Federation of the Red Cross; Geneva, Switzerland
4. **Christen FORNADEL,** Innovative Vector Control Consortium; Liverpool, United Kingdom of Great Britain and Northern Ireland
5. **Lisa HARE,** Independent; Washington (DC), United States of America
6. **Albert KILIAN,** Tropical Health; Montagut, Spain
7. **Louisa MESSENGER**, University of Las Vegas, Nevada; Las Vegas, Nevada, United States of America

The temporary advisors above did not declare any relevant interests.

1. **Tim FREEMAN,** Nariah Consultancies; Port Moresby, Papua New Guinea
2. **Stephan KARL,** James Cook University; Cairns, Australia
3. **Hannah KOENKER,** PATH; Washington (DC), United States of America
4. **Emmanuel MBUBA,** Ifakara Health Institute; Bagamoyo, United Republic of Tanzania
5. **Sarah MOORE,** Ifakara Health Institute; Bagamoyo, United Republic of Tanzania
6. **Chris WARREN,** Independent; Washington (DC), United States of America

The temporary advisors above reported and explained their interests, but these interests were not deemed to result in any conflict of interest (see below).

Observers

1. **Julian AUSTIN,** Against Malaria Foundation; London, United Kingdom of Great Britain and Northern Ireland
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15. **Sam OKELLO,** A to Z Textile Mills; Arusha, United Republic of Tanzania
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17. **Anand SAMAPPIAN,** V.K.A. Polymers; Karur, India
18. **Thomas WEIS,** V.K.A. Polymers; Karur, India
19. **Chengcheng ZHANG,** Sino Africa Medical Devices Co. Ltd.; Kampala, Uganda
20. **Barnabas ZOGO,** Sumitomo Chemical (UK) Ltd; London, United Kingdom of Great Britain and Northern Ireland

The observers above were not required to fill out DOIs. They filled out COUs.

Presenters

1. **Ryan FU,** Clinton Health Access Initiative; New York City, New York, United States of America
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3. **Steve POYER,** Tropical Health; Bristol, United Kingdom of Great Britain and Northern Ireland
4. **Stephen RUSSELL,** Nonwovens Innovation and Research Institute; Leeds, United Kingdom of Great Britain and Northern Ireland
5. **Tara SEETHALER,** Clinton Health Access Initiative; Minneapolis, Minnesota, United States of America
6. **Julie-Anne TAGENA,** Liverpool School of Tropical Medicine; Liverpool, United Kingdom of Great Britain and Northern Ireland
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The presenters above were not required to fill out DOIs. They filled out COUs.

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Declared interests for temporary advisors:

Tim Freeman declared having provided expert opinion or testimony on the subject of the meeting, specifically giving public presentations and producing publications on the quality of ITNs supplied to Papua New Guinea.

Stephan Karl reported receiving funding through consulting to WHO (< US$ 5000) and research support from the Global Fund to Fight AIDS, Tuberculosis and Malaria (US$ 599 000) related to assessment of the quality of ITNs.

Hanna Koenker reported receiving research support (US$ 700 000) for a study on the durability of Interceptor G2 nets in Mozambique from BASF, as requested by the Global Fund to Fight AIDS, Tuberculosis and Malaria.

Emmanuel Mbuba reported receiving funding for salary support (US$ 4000) through employment for ITN durability studies, consulting on durability studies for manufacturers, and research support for vector control product evaluation (including ITNs) for different manufacturers.

Sarah Moore declared several sources of funding from vector control product manufacturers: A to Z and BASF (no current funding), Sumitomo Chemical (US$ 200 000), V.K.A. Polymers (US$ 200 000), Yorkool (US$ 100 000), Vegro Aps (US$ 300 000), Innovative Vector Control Consortium (US$ 500 000) and Basel Research Centre for Child Health (1 000 000 Swiss francs) for product evaluation

None of the above declarations resulted in conflicts of interest, particularly as routine monitoring of durability or product evaluation does not represent a conflict of interest.

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