DETERMINATION OF FABRIC STRENGTH OF LONG-LASTING INSECTICIDAL NETS

REPORT OF A WHO CONSULTATION
GENEVA, 20–22 AUGUST 2014

CONTROL OF NEGLECTED TROPICAL DISEASES
WHO PESTICIDE EVALUATION SCHEME

AND

GLOBAL MALARIA PROGRAMME

World Health Organization

Printed in France.

WHO/HTM/NTD/WHOPES/2015.1

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1. INTRODUCTION

A WHO consultation on assessment of the strength and durability of fabric for long-lasting insecticidal nets (LLINs) was convened at WHO headquarters, Geneva, Switzerland, on 20–22 August 2014. The meeting was convened in open and closed plenary sessions. The open meeting was attended by representatives of industry, institutional observers, including the Bill & Melinda Gates Foundation, the Global Fund to Fight AIDS, Tuberculosis and Malaria and Research for Development (R4D), in addition to members of the expert advisory group and the WHO secretariat. Annex 1 contains the agenda and Annex 2 the list of participants. The closed meeting was restricted to WHO experts and secretariat.

The consultation was opened by Dr John Reeder, Acting Director, Global Malaria Programme, who welcomed participants and noted that the WHO study on determining the fabric strength of LLINs was another successful collaboration between the WHO Global Malaria Programme and the Department of Control of Neglected Tropical Diseases. Dr Reeder thanked individual participants, countries, programmes and institutions for their contributions, noting that LLIN manufacturers had provided net samples and agreed to share the results of the study. He also thanked the Centro Tecnológico das Indústrias Têxtil e do Vestuário (Portugal) for conducting textile tests on LLINs and Dr Stephen Smith (Centers for Disease Control and Prevention, USA) for writing the study report. The Global Fund deserved special recognition for providing the resources to support this critical study on laboratory assessment of LLIN fabrics. WHO has recognized for some time that additional parameters of fabric strength should be included in WHO specifications of LLINs for quality control. A WHO position statement in 2011 noted that the cost per year of effective protection rather than the cost per LLIN should be considered. The present consultation would review the data from the two phases of the LLIN study: an initial data generation phase and a second phase on "wounded bursting strength" of LLINs, as requested by the expert group at the previous consultation in August 2013. The data will be used to improve the minimum specifications of LLINs and stimulate improvements in their quality and innovation. Dr Reeder highlighted the question to be addressed by the group: Are these data a sufficient basis for guidance on procurement? He asked the expert panel to recommend to WHO the way forward in obtaining data on the durability of LLINs under operational conditions and using the data to make recommendations, as had been done for rapid diagnostic tests for malaria. He looked forward to the conclusions and recommendations of this important consultation.

Dr Raman Velayudhan, Coordinator, Department of Control of Neglected Tropical Diseases/Vector Ecology and Management, welcomed participants and outlined the administrative arrangements for the meeting. Dr John Gimnig was appointed Chairman and Dr Stephen Smith as Rapporteur.

Dr Abraham Mnzava, Coordinator, Vector Control Unit, Global Malaria Programme, recounted the history and challenges of the project and said that field data on net performance were required at country level.

Dr Rajpal Yadav, Scientist in Charge, WHO Pesticide Evaluation Scheme (WHOPES), described the parameters already in the WHO specifications for quality control of LLINs, including denier, netting mesh size, dimensional stability to washing and bursting strength and detailed standards and criteria for technical materials and formulations. The areas of potential importance that were not yet in the specifications include data on the storage stability, flammability and mass of netting (fabric weight).

DECLARATIONS OF INTEREST

All the invited experts completed a form of declaration of interests for WHO experts, which were submitted to and assessed by the WHO Secretariat prior to the meeting. The following interests were declared:

Dr Albert Kilian's consultancy company has received a consultancy fee for a review of the literature and a grant to support a study of the durability of various brands of LLINs from Bayer CropScience Germany.

Dr Olivier Pigeon's research centre has received prescribed standard fees from eight manufacturers of pesticide products (BASF Germany, Bayer CropScience Germany, Gharda Chemicals India, NRS International United Arab Emirates, Sumitomo Chemical Japan, Syngenta Switzerland, Tagros India and Vestergaard Frandsen Switzerland) to meet the costs of physico-chemical studies of pesticide products manufactured by the respective companies.

Professor Dr Stephen Russell's institute received a research grant from R4D for a study on mechanisms of net degradation in LLINs.

The interests declared by the experts were assessed by the WHO Secretariat. With the exception of that of Dr Albert Kilian, the declared interests were determined not to be directly related to the topics being discussed at the meeting. It was therefore decided that those experts could participate in all technical sessions of the consultation, subject to public disclosure of their interests. In view of the declared interest on the part of his consultancy company, Dr Kilian did not participate in the discussions on Bayer's LifeNet LLIN.

2. LABORATORY STUDY ON FABRIC STRENGTH OF LLINS

Dr Stephen Smith (Centers for Disease Control and Prevention) gave an overview of the results of the WHO study on the fabric strength and flammability of LLINs, tested at the Centro Tecnológico das Indústrias Têxtil e do Vestuário, Portugal. The aim of the study was to subject LLINs (11 WHOPES-recommended LLINs and three that were in phase II of WHOPES evaluation) to standard tests of textile strength and flammability and to correlate the results with available data on physical durability in the field. The study was conducted in two rounds: round 1 was completed in July 2013, and the results were discussed during the WHO technical consultation on 20–22 August 2013; round 2 included several additional tests for fabric strength and additional LLIN products.

The first consultation concluded that the results of standard tearing tests were invalid because of poor reproducibility. These tests include the ballistic pendulum (Elmendorf) test (EN ISO 13937-1), the trouser tear test (ISO 13937-2), the wing tear test (ISO 13937-3) and the tongue tear test (ISO 13937-4). It was noted that knitted fabrics (such as mosquito netting) are generally considered by the textile industry to be ill suited for testing by these methods, because of poorly reproducible tearing behaviour.

Round 1 also included testing for pneumatic bursting strength (EN ISO 13938-2), grab tensile strength (ISO 13934-2) and a non-standard modification of the tensile strength test in which hooks were used instead of clamps to attach the sample to the tester (termed the "hook tensile strength test"). Nets tested for grab tensile strength failed by rupturing at the clamp ("jaw break"), which produces invalid results according to ISO guidelines. The results of hook tensile testing correlated surprisingly well with those for bursting strength, which suggests that the standard bursting strength test may be suitable for measuring resistance to damage by snagging, which the hook tensile test was designed to simulate. Round 1 testing did not cover all the WHOPES-recommended LLINs, as not all manufacturers submitted samples for testing. A second round of testing was therefore recommended, which would include these and several other nets not

tested in the first round, including three that were in WHOPES phase-II testing at that time. The recommended tests included bursting strength, grab tensile and hook tensile methods; tear testing was not recommended because of their poor reproducibility.

The first consultation also recommended that a modified bursting strength test be conducted on the complete set of nets in the study. This test, termed the "wounded bursting strength" test, involves a net sample with a small cut in it to measure how well the net retains its strength after minimal damage by, e.g. a rodent or a spark. The results could indicate that holes tend to enlarge after initial formation and therefore correlate with the hole sizes in nets recovered from the field. A study by the US Centers for Disease Control and Prevention and the North Carolina State University showed wide variation in the performance of LLINs tested in this way.

Round 1 also included flammability testing. Two methods were evaluated: a 45° angle test (16 CFR Part 1610) and a vertical test (EN 1102). All nets passed the 45° angle test, but a few nets propagated a flame in the vertical test, producing drips of flaming plastic. As the sides of LLINs are generally vertical when in use, the vertical test was considered by the consultation to be more realistic. Both tests were also included in round 2.

Much of the discussion at the first consultation was on establishing categories or tiers of performance for the tested nets. The results did not, however, show clear "break points" that would allow assignment of clear-cut performance categories without appearing to be arbitrary.

The results of round 2 testing, which included additional LLIN products, generally confirmed the conclusions of round 1 with respect to bursting strength, grab tensile, hook tensile and flammability testing. In the wounded burst strength test, polyethylene monofilament nets as a group lost more strength than multifilament polyester and polypropylene nets. Whether this is due to the polymer, the number of filaments, the knitting pattern or some other factor could not be determined.

The report of the full WHO study is contained in *Annex 3*.

DISCUSSION

The mandate of the meeting was to understand the causes of deterioration of LLINs and to determine whether they can be replicated through laboratory testing. High-quality studies of the durability of nets in the field, comparisons of field data with laboratory measures of net performance and linking the observed causes of damage with the laboratory and field measures of durability are all critical for validating the predictive value of LLIN laboratory tests. Current data on the durability of LLINs in the field are inadequate, variable and of poor quality. Direct prospective trials to compare different brands of net in in a variety of field settings will provide the necessary information. To obtain reliable data for evaluating net durability in the field, data collection methods should be standardized, taking advantage of pool procurement so that different brands are distributed to the same areas and are labelled appropriately. Netting pattern, fabric weight, type of fabric and hole location may all contribute differently to both net performance in laboratory tests and their durability in the field. Understanding the relative contributions of different factors could inform the design of more durable nets and criteria for targeting nets to appropriate settings.

Field data are also needed to determine value for money. With sufficient information on the use and misuse of nets, the causes of damage could be linked to net performance in selected laboratory tests (e.g. hook versus bursting strength), thus strengthening their predictive value. Procurement agents require means to distinguish among products and decide which nets are most suitable for different situations. The value of this information for procurement could therefore outweigh the costs of collecting it.

Changing the pricing of nets from price per unit to a pricing structure that reflects the cost over the lifetime of the net could encourage innovative products. Procurement agents enter the product life cycle too late to influence their development but could create incentives by considering pricing over a longer period, with new funding mechanisms. This could guide manufacturers and create greater cohesiveness in the LLIN product sector.

Emphasizing net durability could, however, have negative consequences. New standards may add costs to product development; increasing the strength and durability of nets could add to production time and negatively impact net acceptability and use by individuals. As recent studies show that human behaviour substantially affects the field life of LLINs, the limited resources might be better spent in encouraging compliance with the current minimum quality standards set during product development and on education and behavioural modification programmes to extend net life in the field. In addition, innovation in current techniques (e.g. modifying textile knitting) could strengthen LLINs, and better monitoring of net distribution programmes could generate data for validating new tests and evaluating the field durability and operational acceptability of new products. Strengthening WHOPES and extending other WHO mechanisms to issue stronger comparative recommendations were also discussed.

3. STUDY OF DURABILITY: RESISTANCE OF NETS TO DAMAGE[1]

Ms Kanika Bahl (R4D, USA) introduced a presentation by Dr Steve Russell on the results of tests by the Nonwovens Innovation and Research Institute on the fabric strength of LLINs. The aim of the project was to determine the fundamental mechanisms of net damage in the field, to design laboratory tests to mimic this damage and to use the tests to develop a composite measure of the resistance of LLINs to damage.

The group determined that 47% of holes in nets may be due to factors other than normal wear and tear (e.g. flames, rodents, cutting). To mimic normal wear and tear, the group identified four parameters related to the causes of holes in used LLINs retrieved from the field: tear resistance, snag strength, abrasion resistance and hole propagation.

The group designed several tests for quantifying these parameters, and used the results to calculate a composite performance value of resistance to damage. The outcomes of the project are summarized below.

STUDY OVERVIEW

A two-phase study was undertaken by collaborators from the Nonwovens Innovation and Research Institute, Tropical Health Limited Liability Partnership (led by Dr Albert Kilian) and R4D to provide a credible technical analysis of the durability of LLINs in a predictive approach, in which the results of textile tests would be correlated with parameters of durability observed in the field. The goal of the study was to facilitate adoption of forward-looking criteria for LLIN durability and innovation by manufacturers.