Efficacy of long lasting insecticidal nets compromised by insecticide resistance

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Malaria control is heavily reliant on the use of insecticides given that the two most common control tools, long lasting insecticidal nets (LLINs) and indoor residual sprays are both insecticide based. Of these, the LLINs have only one class of insecticides approved for use in net treatment, the pyrethroids. Insecticide resistance especially to pyrethroids, has emerged and now spread to many parts of sub-Saharan Africa where LLIN and IRS are central to malaria vector control and consequently threatens these vital programs.

In a study conducted in western Kenya in an area with high levels of pyrethroid resistance, live *Anopheles* mosquitoes were routinely observed resting inside nets. This may have been due to declining bioefficacy of the nets, reduced susceptibility of the mosquitoes to pyrethroid insecticides or damage to nets or all three factors. Susceptibility testing of the progeny of the mosquitoes collected in the nets confirmed very high resistance to pyrethroid insecticides. Further exposure of the progeny of the wild mosquitoes collected inside LLINs to brand new Olyset® and Permanet® 2.0 nets recorded less than 40% mortality in both cases. Evaluation of the LLINs from which these mosquitoes were collected using a lab susceptible strain however, showed that the nets were still very effective in killing susceptible mosquitoes. Several mosquitoes collected inside the nets were positive for *Plasmodium falciparum* sporozoite infection indicating their ability to transmit malaria to people sleeping even under an LLIN. A separate study conducted using the same methodology in an area of mild pyrethroid resistance, no *Anopheles* mosquitoes were observed inside the LLINs further pointing to insecticide resistance as the enabling factor for the mosquitoes resting inside LLINs.

Pyrethroid resistance has been spreading rapidly in sub-Saharan Africa and has been documented in 23 countries. This may partly be in response to agricultural application and run-off of insecticides into mosquito breeding sites, but increasingly in response to selection pressure resulting from the scale up of insecticide-treated nets and indoor residual spraying as malaria prevention tools. Regardless of the source of insecticide pressure, insecticide resistance in malaria vectors has been predicted to eventually undermine control programmes that are solely reliant on insecticides such as indoor residual spraying (IRS) and ITN programmes

Several factors associated with the number of mosquitoes inside nets were explored. Location was a strong determinant of the presence of mosquitoes inside nets, presumably due to the susceptibility of the local vector population. In the site with high pyrethroid resistance, neither net brand nor the age of the nets was associated with the number of mosquitoes inside nets. An increase in the number of mosquitoes inside nets with increasing levels of physical damage was observed. Nets with estimated hole areas of >50 cm^2 had more mosquitoes than nets with no holes. It was observed that a threshold is reached beyond which increasing damage does not lead to increasing numbers of mosquitoes. This may indicate that beyond a certain amount of damage, nets are equally likely to be penetrated by mosquitoes. Interestingly, nets with

In certain situations mosquitoes can be observed resting inside nets. This may be due to declining bioefficacy of nets, reduced susceptibility of mosquitoes to insecticides or damage to nets, or all three factors.

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