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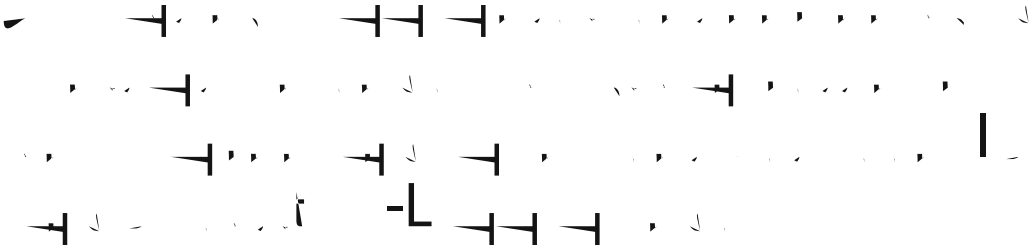

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Abstract

Background: In malaria-endemic countries, malaria prevention and treatment are critical for child health. In the context of intervention scale-up and rapid changes in endemicity, projections of intervention impact and optimized program scale-up strategies need to take into account the consequent dynamics of transmission and immunity.

Methods:

national variation in impact determinants. The WHO's national-level mortality estimates were distributed over Admin1 units by assuming a similar proportional distribution as estimated by the Malaria Atlas Project for malaria case incidence [2, 19].

For projections over 2016–2030, Spectrum applied proportional impacts predicted by regression models fitted to the average outcomes over years 1–3 after intervention scale-up from OpenMalaria simulations [13] over 2016–2021; for 2022–2030 Spectrum applied the proportional impacts from regression models fitted to average OpenMalaria simulation outcomes over years 8–10 after scale-up [13]. Spectrum applies these impact functions with a one-year time lag from intervention scale-up to start of impact, thus the projected burdens in 2016 reflected the effect of intervention coverage changes from 2014 to 2015, and onwards (Table 1).

LiST projections

LiST was used in the version Spectrum 5.43 beta 1 of May 2016. Outputs analyzed were the cause-specific deaths in children under five years (i.e. 0–59 months) of age. All-cause neonatal and post-neonatal mortality rates at 2014 and 2015 (and preceding years) were taken from estimates by the United Nations Inter-Agency Group for Child Mortality Estimation as of 2015 [20] (Table 2). The corresponding malaria mortality rates were derived by applying the proportion of post-neonatal under-5 deaths due to malaria (among eight other causes) from the WHO in the version as of October 2015 (http://www.who.int/healthinfo/global_burden_disease/estimates/en/index3.html) and [1].

Effectiveness of ITNs and/or IRS (with the coverage definitions detailed in Table 3), was estimated and implemented as children 1–59 months living in households protected by ITNs and/or IRS having a 55% lower risk of malaria-attributable death [9]. Treatment of *Plasmodium falciparum* malaria cases (without distinction between uncomplicated and severe cases) with artemisinin combination therapy (ACT) was assumed to reduce malaria mortality in children 1–23 months by 99% (range: 94–100%), and in children 24–59 months by 97% (range: 86–99%) [21].

Standardized intervention scale-up and scale-down scenarios

For the current model comparisons, baseline coverages and intervention scale-up targets for ITNs and CMU were standardized between LiST and Spectrum-Malaria (Table 3, row labeled "Coverage-standardized, DRC & Zambia"), and between the two countries, so as have a similar extent of scale-up from baseline to target level in both countries. Coverage values were set in the range of default coverage values assumed by the two models for the two countries, as explained in the following two paragraphs and with precise annual values shown in Additional file 1.

For vector control, LiST uses a combined coverage metric combining protection by ITNs and/or IRS, defined as the proportion of children under-5 who live in a household owning one or more ITNs, and/or in a house that has been sprayed with IRS within the past 12 months. Spectrum-Malaria uses as coverage metrics: for ITNs, the proportion of the population of all ages who slept under an ITN the last night; and for IRS, the proportion of the population of all ages who live in a house sprayed with IRS within the past 12 months. The standardized coverage assumptions we used for projections and comparisons were: for LiST, 70% ITN/IRS protection at 2014 and 2015 (close to the LiST default values of 70% for DRC and 74.7% for Zambia), increasing to 98% as the maximum target level (at 2016, or at 2020 with linear increase over 2016–2020); for Spectrum-Malaria, the standardized coverage assumption (judged most similar to standardized coverage in LiST) was 51% ITN usage at 2014 and 2015 (slightly below the Spectrum-Malaria default values of 55% for DRC and 68.8% for Zambia), increasing to 70% as maximum target level. We considered 51% and 70% usage to

level, several scale-down scenarios were modelled (details in Additional file 1), with each coverage change im-

DRC and Zambia, and in our coverage-standardized variants of these countries), Spectrum-Malaria predicts a similar mortality increase as LiST for DRC over the first five years after ITN scale-down (represented as a drop from 51% to 12.5% utilization, or from 77% to 18% ownership), followed by a further mortality rise compared to LiST from the 7th year following scale-down (Fig. 3). For Zambia, in the short-term (over 2016 2021) and especially the longer-term (over 2022 2030), the projected mortality rise due to ITN coverage decrease is larger in Spectrum-Malaria than in LiST.

Non-linearity in the coverage-impact relationship

We compared mortality impacts for a given coverage increase or decrease, over the full 0 100% range of possible coverages and between the countries, as comparative proportional mortality reductions relative to the mortality level under a constant-coverage scenario, at the year 2020. In LiST, the effect of a given coverage increase is calculated as a simple multiplication of (reduced) relative risks that are linear with the coverage increase, identically for all countries, as shown in Fig. 4, with identical lines for DRC and Zambia. Spectrum-Malaria, in contrast, shows

Discussion

The presented projections of impacts of ITNs and CMU on malaria mortality from two models show how

magnitudes of mortality decline associated with the increased malaria donor funding over the 2000s, which had been allocated primarily to ITN distribution programs and improved case management [31, 32].

In comparison, a recent assessment of impacts expected over 2015–2030 from scaling-up malaria control according to the WHO's Global Technical Strategy, using the Imperial College London malaria transmission model, projected a possible reduction in malaria mortality rates of 40% (across all ages) from 2010 to 2030 across 80 countries with sustained stable malaria transmission in 2010 [33]. This would seem to be a smaller impact than projected by LiST and especially Spectrum-Malaria for the combined scale-up of ITN and CMU in DRC and Zambia (Fig. 2). Strict quantitative

impacts. First, Spectrum-Malaria projects proportionally larger burden reductions for settings with lower baseline burdens. This was evident in the current projections as

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