**Supplemental Information for** “Impact of Vaccine Introduction on Malaria Cases and Deaths in Sub-Saharan Africa: A Modelling Study”.

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**Supplemental methods**

We utilised *malariasimulation,* an individual-based dynamic malaria transmission model developed at Imperial College London. *malariasimulation* is open-source, can be accessed on Github1, and has been described in further detail elsewhere2. Work informing this manuscript has been previously published3–5 and key methods for this manuscript are briefly described below.

* 1. **Modelling malaria transmission**

*Malariasimulation* is an individual-based transmission model with vector and human components (**Figure S1**). Briefly, individuals start as susceptible to malaria infection, and progress to infection upon a bite by an infected mosquito at a rate that is dependent upon the force of infection Λi. The force of infection is affected by the individual’s level of pre-erythrocytic immunity, the biting rate and the infectivity of the vector population. Individuals experience a level of maternal immunity within the first 6 months of life that is taken as a fixed proportion of average natural immunity acquired by individuals from 15 to 35 years of age.

Upon a bite by an infectious mosquito, individuals experience a delay *dE* before they progress to active infection, which can be either asymptomatic or symptomatic, the probability of which is dependent on the individual’s level of clinical immunity φi. The proportion of successfully treated symptomatic individuals is a fixed proportion *fT,* and treated individuals proceed to the treated category whilst 1-*fT* symptomatic individuals have untreated disease (*D).* Treated individuals recover from infection at a rate *rT,* experiencing some level of treatment-induced protection from re-infection that wanes over time. Untreated symptomatic individuals progress back to asymptomatic infection at a rate of *rD,* and eventually progress back to subpatent infection and the susceptible pool as parasites are naturally cleared over time. Superinfection is possible, as all untreated infected individuals remain susceptible to infection. Mortality from malaria is taken as a fixed proportion of severe disease (Section X). Mortality from other diseases is estimated from national life tables, and individuals are removed from the population at age-specific rates to match the age distribution. When an individual dies, they are replaced by a new individual in the simulation with similar characteristics to achieve a constant population size.

**Figure SX,** *model schematic. S = susceptibles, U= subpatent infection, A = asymptomatic infection, D= clinical disease, T= treated. Reproduced from Winksill et al. 2017*3

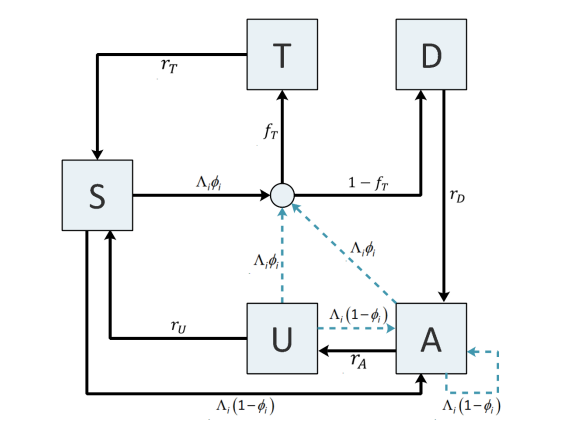


Table SX: The rates associated with transitions between infection states for the human model.

|  |  |  |
| --- | --- | --- |
| Process | Transition | Rate |
| Infection |  |  |
| Progression of untreated disease to asymptomatic infection |  |  |
| Progression of asymptomatic to subpatent infection |  |  |
| Progression of subpatent infection to susceptible |  |  |
| Progression of treated disease to susceptible\* |  |  |
| Super-infection from untreated clinical disease, asymptomatic or subpatent infection |  |  |

\* Treated individuals experience a period of drug-dependent partial protection from reinfection.

**Biting rate**

Individuals experience biting rates which is dependent upon an age-dependent biting rate (ψ(a)), where *ρ*  *a0* determine the relationship between age and biting rate.



*Ψ* normalizes biting rate over age as follows, with *g(a)* as the cross-sectional human population age distribution:



The relative biting rate is as follows:

A black and white image of a wave

AI-generated content may be incorrect.

The EIR and force of infection of an individual of age *a* at time *t* are as follows:



**Vector abundance**

Mosquito vector dynamics are modelled using a deterministic version of the stochastic model published by White et al6. Briefly, adult female mosquitoes lay eggs, which progress through larval and pupal stages. Mosquitoes experience mortality (X) that is dependent upon density, as well as a time-varying carrying capacity () which is the environmental capacity to sustain mosquito breeding sites. represents larval density in relation to carrying capacity. We assumed 50% of adult mosquitoes were female, initially as susceptible and then becoming infected as a function of a time-lag between when humans become infected and become infectious, as well as the force of infection from humans toward mosquitoes :



represents the biting rate from mosquitoes to humans, where is the level of anthropophagy and is mean time between feeds:



 normalises the biting rate across all ages as follows, where *g(a)* represents the age distribution of humans. Female mosquitoes experience a delay () between infection and infectiousness towards humans, and are assumed infectious until they die.



*Malariasimulation* incorporates data on the presence of the three dominant malaria vectors, an. gambiae*, An. arabiensis*, and *An. funestus*. Data on the relative abundance and behavior of each species is sourced from rainfall and humidity data7 and the Malaria Atas Project8 (**Table SX**).

**Table SX. Vector bionomics parameters**

|  |  |  |  |
| --- | --- | --- | --- |
| Bionomics trait | *An gambiae s.s* | *An arabiensis* | *An funestus* |
| Anthropophagy | 0.92 | 0.71 | 0.94 |
| Endophily | 0.81 | 0.42 | 0.81 |
| % bites indoors | 0.97 | 0.96 | 0.98 |
| % bites indoors and in bed | 0.89 | 0.90 | 0.90 |

Key model parameters are listed in the table below (**Table S3**).

**Seasonality**

Seasonality is implemented as a time-varying carrying-capacity as follows, where *K0* is the carrying capacity, *R* is the mean rainfall, and *R(t)* is the time varying seasonal curve.



The time-varying seasonal curve is calculated as a Fourier transform fit to daily rainfall data from the US Climate Centre for Sub-Saharan Africa9 between 2002 and 2009:



**Natural Immunity**

The model tracks several forms of immunity, including maternal immunity, pre-erythrocytic immunity (immunity to infection), blood-stage infection (immunity to clinical disease), and immunity to severe disease. Individuals retain a level of maternal immunity to clinical and severe disease ( and  respectively) at birth, which decays within the first 6 months of life. This is implemented as a fixed proportion of the acquired immunity of a randomly chosen individual between 15 to 35 years of age, which decays at a rate of .

Pre-erythrocytic immunity is boosted by one level following infection, given that the infection is at least  days following previous infection. Pre-erythrocytic immunity decays exponentially at a rate of .

Immunity to detectability of infection, clinical disease, and severe disease is boosted by one level following detectable infection, given that the infection is at least ,  or  days respectively following previous exposure. Immunity decays exponentially at a rate of rate ,and  for immunity to detectability of infection, clinical disease, and severe disease respectively.

Immunity levels are converted into individual level probabilities using Hill functions. The probability an individual *i* who is exposed to an infectious bite develops an infection is as follows, where  is the probability of infection with no immunity, is the minimum probability,  is a scale parameter, is a shape parameter, and  is the level of pre-erythrocytic immunity for an individual at time *t.*



The probability an individual *i* develops clinical disease upon infection is as follows, where  is the probability of disease with no immunity, is the minimum probability of disease, and are scale and shape parameters, is the level of acquired immunity to clinical disease, and is the level of maternally acquired immunity to clinical disease:



The probability an individual develops severe disease upon infection is as follows, where  is the probability of disease with no immunity, is the minimum probability of disease, and  are scale and shape parameters,  is the level of acquired immunity to severe disease, and is the level of maternally acquired immunity to severe disease:



Severe disease risk varies by age (*a*) as shown, where , and are parameters:



Detectability of asymptomatic infection by microscopy is as follows, where *a* is age, *t* is time,  is the minimum probability of detection,  and are scale and shape parameters, and is the level of acquired immunity to detectability of infection. Detectability of infection varies by age as follows, where , and are parameters:



**Modelling severe disease and mortality**

The incidence of severe malaria requiring hospitalization is as shown, where is the force of infection, is the probability individual *i* develops severe disease at time *t* after infection:



Mortality is taken as a fixed proportion of severe malaria (0.215). I based on verbal autopsy data10. We additionally assume that treated individuals experience a reduction in the probability of death of 50%. Baseline model parameters are shown below (**Table X).**

|  |  |  |
| --- | --- | --- |
| *Table SX, malariasimulation* key model parameters |  |  |
| Parameter | Symbol | Estimate |
| Human infection duration (days) |  |  |
| Latent period |  | 12 |
| Patent infection |  | 195 |
| Clinical disease (treated) |  | 5 |
| Clinical disease (untreated) |  | 5 |
| Sub-patent infection |  | 110 |
| Treatment Parameters |  |  |
| Probability of seeking treatment if clinically diseased |  | Variable |
| Age and heterogeneity |  |  |
| Age-dependent biting parameter |  | 0.85 |
| Age-dependent biting parameter |  | 8 years |
| Variance of the log heterogeneity in biting rates |  | 1.67 |
| Immunity reducing probability of infection |  |  |
| Maximum probability due to no immunity |  | 0.590076 |
| Maximum relative reduction due to immunity |  | 0.5 |
| Inverse of decay rate |  | 10 years |
| Scale parameter |  | 43.8787 |
| Shape parameter |  | 2.15506 |
| Duration in which immunity is not boosted |  | 7.19919 days |
| New-born immunity relative to mother’s |  | 0.774368 |
| Immunity reducing probability of clinical disease |  |  |
| Maximum probability due to no immunity |  | 0.791666 |
| Maximum relative reduction due to immunity |  | 0.000737 |
| Inverse of decay rate |  | 30 years |
| Scale parameter |  | 18.02366 |
| Shape parameter |  | 2.36949 |
| Duration in which immunity is not boosted |  | 6.06349 days |
| Inverse of decay rate of maternal immunity |  | 67.6952 days |
| Immunity reducing probability of detection |  |  |
| Minimum probability due to maximum immunity |  | 0.160527 |
| Inverse of decay rate |  | 10 years |
| Scale parameter |  | 1.577533 |
| Shape parameter |  | 0.476614 |
| Duration in which immunity is not boosted |  | 9.44512 days |
| Scale parameter relating age to immunity |  | 21.9 years |
| Time-scale at which immunity changes with age |  | 0.007055 |
| Shape parameter relating age to immunity |  | 4.8183 |
| Immunity reducing probability of severe disease and mortality |  |  |
| Maximum probability due to no immunity |  | 0.0749886 |
| Maximum relative reduction due to immunity |  | 0.0001191 |
| Scale parameter |  | 1.09629 |
| Shape parameter |  | 2.00048 |
| Inverse of decay rate |  | 30 years |
| Duration in which immunity is not boosted |  | 11.4321 days |
| Inverse of decay rate of maternal immunity |  | 76.8365 days |
| New-born immunity relative to mother’s |  | 0.195768 |
| Reduced probability of death due to treatment |  | 0.5 |
| Age-dependent severe disease risk modifier parameter |  | 0.141195 |
| Age-dependent severe disease risk modifier parameter |  | 2493.41 |
| Age-dependent severe disease risk modifier parameter |  | 2.91282 |
| Mortality scaling factor from severe disease |  | 0.065 |
| Infectiousness to mosquitoes |  |  |
| Lag from parasites to infectious gametocytes |  | 12 days |
| Untreated disease |  | 0.068 |
| Treated disease |  | 0.021896 |
| Sub-patent infection |  | 0.00062 |
| Parameter for infectiousness of state *A* |  | 1.82425 |
| Mosquito Population Model |  |  |
| Daily mortality of adults with no interventions |  | Varies by spp |
| Mean time between feeds |  | 3 days |
| Extrinsic incubation period |  | 10 days |
| Larval model |  |  |
| Average number of eggs laid per female mosquito per day |  | 21.2/day |
| Early instar larval developmental period |  | 6.64 days |
| Late instar developmental period |  | 3.72 days |
| Pupal developmental period |  | 0.643 days |
| Mortality rate of early-stage larvae (density dependent) |  | 0.0338/day |
| Mortality rate of late-stage larvae (density dependent) |  | 0.0348/day |
| Mortality rate of pupae (density independent) |  | 0.249/day |
| Effect of density dependence on late instars relative to early instars |  | 13.25 |

1. **Modelling malaria interventions**

Malaria transmission was modelled across 31 African countries at the admin-1 level, incorporating subnational data on demography, seasonality, vector abundance, transmission intensity, and intervention coverage. Included data sources are listed in the table below (**Table SX).**

*malariasimulation* models the impact of several non-vaccine malaria interventions, including indoor residual spraying (IRS), insecticide-treated bednets (ITNs), intermittent preventive chemotherapy (IPT), seasonal malaria chemoprevention (SMC), and anti-malarial treatment. The implementation of non-vaccine malaria interventions has been described in detail elsewhere3.

**Table SX,** Malariasimulation data sources

|  |  |  |
| --- | --- | --- |
| **Data type** | **Data source** | **Years used** |
| Demography | Worldpop11, “Unconstrained individual countries 2000-2020 UN adjusted (1 km resolution)” ,  UN12 | 2000-2050 |
| Seasonality (daily rainfall) | CHIRPS13 | 2019-2021 |
| Vector abundance | Malaria Atlas Project8, “Anopheles arabiensis Patton, 1905”, “Anopheles funestus”, “anopheles gambiae Giles, 1902” | 2000-2022 |
| Parasite prevalence | World Malaria Report 202114,  Malaria Atlas Project8 | 1950-2021 |
| Pyrethroid resistance | Churcher et al. (unpublished) | 2000-2050 |
| Insecticide-treated bed net (ITN) usage | Malaria Atlas Project15***,*** “Insecticide treated bednet (ITN) use version 2020” | 2000-2022 |
| ITN and IRS efficacy | Sherrard-Smith et al. 16 | -- |
| Seasonal malaria chemoprevention/ perennial malaria chemoprevention | Access SMC17, SMC alliance18 | 2000-2022 |
| Antimalarial treatment | Malaria Atlas Project8, “Effective treatment with an antimalarial drug version 2020” | 2000-2022 |
| Indoor residual spraying | Malaria Atlas Project, “Indoor residual spraying (IRS) coverage version 2020” | 2000-2022 |
| Vaccine coverage | Devised | 2023-2100 |

**Vaccine efficacy**

Vaccine efficacy models were fit to clinical trial data from children aged 5-17 months in Nanoro, Burkina Faso for R21, and to 6,537 children aged 5-17 months and 6-12 weeks from 11 trial sites for RTS,S19. Children in each study were randomized to either receive a control vaccine or the malaria vaccine of choice (R21 or RTS,S).

For the RTS,S trial, anti-circumsporozoite antibody titres were measured by ELISA in a subset of the first 200 participants in each age group at enrollment and 1 month after their third vaccine dose. Passive surveillance was conducted for clinical malaria beginning with first vaccinations. For the R21 trial, a booster dose was given to children 12 months after the primary series, and a second booster dose was delivered to a smaller subset of participants 24 months after the primary series. Control participants received control vaccines at the same time points. Antibody titres were measured in children by ELISA at baseline, 28 days after the first dose, 6 months after, and 1 year after each booster. Passive surveillance was conducted to track clinical malaria episodes in study participants over a 3-year period. For both studies, clinical malaria was defined as a history of fever in the preceding day, *p. falciparum* parasitaemia greater than 5,000 asexual forms per microliter, and a temperature of 37.5 degrees or greater. Vaccine efficacy parameters for RTS,S and R21 are shown in the table below (**Table SX).**

Vaccine efficacy against infection was translated into efficacy against clinical disease using a cohort-based malaria model published previously20.

**Table SX,** Vaccine efficacy parameters for R21 and RTS,S vaccines. *Reproduced from Schmit et al 2021*16 *and White et al. 2015*19*.*

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Description** | **R21 posterior** | **RTS, S posterior (5-17 months)** |
| ds | half-life of short-lived antibodies | 44.6 (40.8-49.0) | 45 (42-48) |
| dl | half-life of long-lived antibodies | 533.0 days (460.8-620.9) | 591 (557-632) |
| ρpeak | proportion of short-lived antibodies following first 3 doses | 0.69 (0.65- 0.72) | 0.88 (0.87-0.89) |
| ρboost | proportion of short-lived antibodies following 4th dose | 0.52 (0.48- 0.56) | 0.70 (0.68-0.72) |
| β | dose-response scale parameter | 471 EU/ mL | 99.2 EU/mL (67.6-132.6) |
| α | dose-response shape parameter | 0.91 (0.41-2.09) | 0.74 (0.62-0.93) |
| Vmax | maximum efficacy against infection | 0.87 (77-97) | 0.93 (0.83-0.99) |

**Modelling malaria vaccines**

Prior to 2026, we introduced vaccination in countries according to publicly available data on introduction, dose timing, and vaccine type (**Table SX**). Vaccine introduction and dose timing data was sourced from the WHO Malaria Vaccine Introduction [Dashboard](https://app.powerbi.com/view?r=eyJrIjoiZmZjN2RkOGYtYzM4NS00MWYxLThhYmMtYzg3YjMwYjU2ZDA4IiwidCI6ImY2MTBjMGI3LWJkMjQtNGIzOS04MTBiLTNkYzI4MGFmYjU5MCIsImMiOjh9), and data on vaccine type was sourced from the UNICEF Immunization Market [Dashboard](https://www.unicef.org/supply/immunization-market-dashboard). Data on vaccine type utilised were also sourced from Gavi and WHO press releases.

We implemented an age-based vaccination strategy, whereby the first three doses of the malaria vaccine are delivered in the first year of life and a booster dose is administered 12-15 months after the third dose (typically to children between 1 and 2 years old) 21. For the sake of consistency and given the long time horizon of the modelled scenarios, we assumed that second and third doses were delivered in the second and third month following the first dose, varying only the timing of the first dose and the time between the 3rd dose and booster. Note that an age-based vaccination strategy varies slightly from the strategy proposed by the Mali Ministry of Health, where the first 3 doses will be administered in age-based fashion, followed by seasonal administration of fourth and fifth doses in May or June of each year22. We assumed vaccine introduction would occur in January of each year for all countries.

For remaining countries where malaria vaccines have not been introduced, we assumed introduction in 2026. For countries where information on dose timing was not available, we assumed doses were delivered at 6, 7, 8, and 20 months of age. Given the greater supply of R21 relative to RTS,S, we assumed the introduction of R21 in countries where vaccine choice was not specified.

Under the Gavi investment opportunity, an estimated 50 million children will be vaccinated for malaria between 2026 and 2030 23. We devised a vaccine coverage scenario targeting children residing in moderate-to-high transmission settings in VIMC countries, aligning with the 50 million estimate through this 5-year period.

To estimate the number of children in the target age groups for vaccination, we sourced national-level VIMC data on total population, as well as population by single-year age group in each country. We used this data to calculate the proportion of 0–1-year-olds and 1–2-year-olds in the population by country. We then applied these proportions to admin-1 level estimates of total population to estimate the number of 0–1-year-olds and 1–2-year-olds residing in each admin-1 unit. In the absence of more granular data, we assumed the subnational population age distribution was equivalent to the national population age distribution.

We administered the vaccine to all moderate-to-high transmission admin-1 units in the 31 countries modelled. An admin-1 unit was considered moderate-to-high transmission if parasite prevalence exceeded 10% in 2024, according to Malaria Atlas Program estimates. When summarized over the 2026-2030 period, the target population consisted of about 100 million 0–1-year-olds residing in moderate-to-high transmission settings. If we assume a child that receives the first 3 vaccine doses is protected, 50 million protected children would translate into a coverage estimate of roughly **50%.**

In the year of vaccine introduction, we assumed malaria vaccine coverage was **40%** of DTP3 (diptheria, pertussis, and tetanus) vaccine coverage in the corresponding year. Data on national DTP3 coverage was sourced from the WHO Global Health Observatory 24. We utilized DTP3 coverage as a proxy for coverage of vaccines included in routine EPI immunization. We assumed malaria vaccine coverage scaled up to **65%** of DTP3 coverage in 2030, linearly interpolating coverage values between the introduction year and 2030. Given a vaccine coverage estimate of 50% across all countries, as well as WHO policy that no country may receive more than 20% of total vaccine supply initially 25, we assumed that countries scale up to no more than 50% vaccine coverage by 2030. We assumed coverage of the booster dose was 80% of coverage of the initial three doses in the preceding year.

From 2030 through 2100, we assumed a distribution of 80-100 million doses per year, according to Gavi demand forecasts 26. In absence of modelled data on the number of protected children, we assumed 4 doses roughly translated into one protected child, assuming 90 million doses delivered each year translated into 22.4 million protected children annually. We allocated vaccine doses to all moderate-to-high transmission admin-1 units in VIMC countries, scaling up to a 95% target coverage based on a 100 million annual dose cap.

**Table SX:** Countries modelled, vaccine choice, year of vaccine introduction, and dose timing.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Country** | **Dose 1 Timing (months)** | **Dose 2 timing (months)** | **Dose 3 timing (months)** | **Dose 4 timing (months)** | **Year of Introduction** | **Vaccine** |
| Angola | NA | NA | NA | NA | NA | R21 |
| Burundi | 6 | 7 | 9 | 19 | 2025 | RTS,S |
| Benin | 6 | 7 | 9 | 18 | 2024 | RTS,S |
| Burkina Faso | 5 | 6 | 7 | 15 | 2024 | RTS,S |
| Central African Republic | 6 | 7 | 9 | 16 | 2024 | R21 |
| Cote d’Ivoire | 6 | 8 | 9 | 15 | 2024 | R21 |
| Cameroon | 6 | 7 | 9 | 24 | 2024 | RTS,S |
| Democratic Republic of Congo | 6 | 7 | 8 | 15 | 2024 | RTS,S |
| Republic of Congo | NA | NA | NA | NA | NA | R21 |
| Ethiopia | NA | NA | NA | NA | 2025 | R21 |
| Ghana | 6 | 7 | 9 | 18 | 2019 | RTS,S |
| Guinea | NA | NA | NA | NA | 2025 | R21 |
| Guinea-Bissau | NA | NA | NA | NA | NA | R21 |
| Kenya | 6 | 7 | 9 | 24 | 2019 | RTS,S |
| Liberia | 5 | 6 | 7 | 15 | 2024 | RTS,S |
| Madagascar | NA | NA | NA | NA | 2026 | R21 |
| Mali | 5 | 6 | 7 | NA | 2025 | R21 |
| Mozambique | 6 | 7 | 9 | 18 | 2024 | R21 |
| Mauritania | NA | NA | NA | NA | 2026 | R21 |
| Malawi | 5 | 6 | 7 | 22 | 2019 | RTS,S |
| Niger | 6 | 7 | 8 | 16 | 2024 | RTS,S |
| Nigeria | 5 | 6 | 7 | 15 | 2024 | R21 |
| Sudan | 5 | 6 | 7 | 18 | 2024 | R21 |
| Sierra Leone | 6 | 7 | 8 | 18 | 2024 | RTS,S |
| Somalia | NA | NA | NA | NA | 2026 | R21 |
| South Sudan | 5 | 6 | 7 | 18 | 2024 | R21 |
| Chad | NA | NA | NA | NA | 2024 | R21 |
| Togo | NA | NA | NA | NA | 2026 | R21 |
| Tanzania | NA | NA | NA | NA | 2026 | R21 |
| Uganda | 6 | 7 | 8 | 18 | 2025 | R21 |
| Zambia | NA | NA | NA | NA | 2026 | R21 |

**Supplemental Figure X,** Map of modelled countries at the admin-1 level. Vaccines were introduced to all moderate-to-high transmission admin-1 units (highlighted in red).

A map of africa with different colored areas

Description automatically generated

**Supplemental results**

**Table SX,** Median cases and deaths per scenario, taken across 50 stochastic model runs

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Year** | | **Cases (Control)** | **Cases (Routine)** | **Deaths (Control)** | **Deaths (Routine)** |
| 2000 | 213777281 | | 213777281 | 563730 | 563730 |
| 2001 | 223593567 | | 223593567 | 568084 | 568084 |
| 2002 | 230748341 | | 230748341 | 581499 | 581499 |
| 2003 | 234330116 | | 234330116 | 575627 | 575627 |
| 2004 | 235874575 | | 235874575 | 571136 | 571136 |
| 2005 | 233066430 | | 233066430 | 560640 | 560640 |
| 2006 | 224116208 | | 224116208 | 541945 | 541945 |
| 2007 | 217780311 | | 217780311 | 535689 | 535689 |
|  |  | |  |  |  |
| 2008 | 216338564 | | 216338564 | 537228 | 537228 |
| 2009 | 213961955 | | 213961955 | 538159 | 538159 |
| 2010 | 196133496 | | 196133496 | 513015 | 513015 |
| 2011 | 193523612 | | 193523612 | 519735 | 519735 |
| 2012 | 203706758 | | 203706758 | 555171 | 555171 |
| 2013 | 207041830 | | 207041830 | 549397 | 549397 |
| 2014 | 199440153 | | 199440153 | 529418 | 529418 |
| 2015 | 200561825 | | 200561825 | 544851 | 544851 |
| 2016 | 201830407 | | 201830407 | 550792 | 550792 |
| 2017 | 193605305 | | 193605305 | 533903 | 533903 |
| 2018 | 206143010 | | 206143010 | 570333 | 570333 |
| 2019 | 230742926 | | 230742926 | 614024 | 614024 |
| 2020 | 245085431 | | 245085431 | 650027 | 650027 |
| 2021 | 262289715 | | 262289715 | 675697 | 675697 |
| 2022 | 280932052 | | 280932052 | 709134 | 709134 |
| 2023 | 286972414 | | 286964097 | 725589 | 723796 |
| 2024 | 298086801 | | 297067833 | 736882 | 727323 |
| 2025 | 312773752 | | 309322505 | 755807 | 739604 |
| 2026 | 315383149 | | 306192479 | 763698 | 718377 |
| 2027 | 323989445 | | 308877350 | 776248 | 710791 |
| 2028 | 339884035 | | 318112174 | 806071 | 716295 |
| 2029 | 340402126 | | 315668206 | 814078 | 706862 |
| 2030 | 348792572 | | 317210966 | 815008 | 711908 |
| 2031 | 365904926 | | 330060409 | 850279 | 724159 |
| 2032 | 366484932 | | 330820826 | 866771 | 738383 |
| 2033 | 372814306 | | 333990107 | 860019 | 742237 |
| 2034 | 391129444 | | 350450438 | 898972 | 776221 |
| 2035 | 390997795 | | 353109709 | 906833 | 781925 |
| 2036 | 396036458 | | 357234057 | 891588 | 781152 |
| 2037 | 413719719 | | 375555696 | 936567 | 816122 |
| 2038 | 415168737 | | 378328094 | 947321 | 826539 |
| 2039 | 417421161 | | 381981397 | 946546 | 818344 |
| 2040 | 436506367 | | 400842582 | 973148 | 849698 |
| 2041 | 436849807 | | 402831482 | 973849 | 858082 |
| 2042 | 438705875 | | 405346791 | 975230 | 860174 |
| 2043 | 458452624 | | 424432823 | 992481 | 878998 |
| 2044 | 458463702 | | 427237410 | 1004905 | 896812 |
| 2045 | 459047106 | | 427356172 | 1003329 | 886591 |
| 2046 | 478280373 | | 446603217 | 1028206 | 917498 |
| 2047 | 478419164 | | 448943058 | 1044987 | 937426 |
| 2048 | 478525597 | | 448123857 | 1031737 | 915493 |
| 2049 | 497967778 | | 468559928 | 1057536 | 951894 |
| 2050 | 498804355 | | 468609546 | 1077182 | 949155 |
| 2051 | 496583946 | | 467164986 | 1060017 | 938102 |
| 2052 | 517518215 | | 487458504 | 1082333 | 970662 |
| 2053 | 517338086 | | 488500262 | 1103866 | 987053 |
| 2054 | 514361735 | | 485871234 | 1082985 | 966837 |
| 2055 | 534241642 | | 506038319 | 1105446 | 989636 |
| 2056 | 535484350 | | 507622342 | 1114346 | 1006512 |
| 2057 | 532467004 | | 504588803 | 1103177 | 986760 |
| 2058 | 553334516 | | 524949714 | 1129682 | 1011794 |
| 2059 | 552886860 | | 524720780 | 1133438 | 1027095 |
| 2060 | 549197616 | | 521213458 | 1116632 | 1004912 |
| 2061 | 570096586 | | 541553478 | 1152932 | 1027953 |
| 2062 | 570123750 | | 541597236 | 1159331 | 1050306 |
| 2063 | 567045247 | | 536192531 | 1136704 | 1021124 |
| 2064 | 588276693 | | 557510673 | 1168124 | 1040985 |
| 2065 | 588893324 | | 558623104 | 1174283 | 1059629 |
| 2066 | 584224160 | | 554644040 | 1145711 | 1049750 |
| 2067 | 605752466 | | 574995911 | 1174605 | 1058903 |
| 2068 | 606300203 | | 575657044 | 1181104 | 1076075 |
| 2069 | 600652669 | | 570437031 | 1165986 | 1053644 |
| 2070 | 620419193 | | 591981879 | 1182062 | 1080300 |
| 2071 | 621448893 | | 592600448 | 1201262 | 1103084 |
| 2072 | 613052105 | | 585957565 | 1167759 | 1060147 |
| 2073 | 632668061 | | 607760252 | 1196227 | 1095094 |
| 2074 | 635063737 | | 608827789 | 1200808 | 1099081 |
| 2075 | 625982728 | | 601079279 | 1189146 | 1086408 |
| 2076 | 645861869 | | 621306130 | 1192251 | 1099748 |
| 2077 | 644594543 | | 620553338 | 1207780 | 1109876 |
| 2078 | 635784830 | | 612640772 | 1185967 | 1079061 |
| 2079 | 654696177 | | 631259593 | 1208180 | 1103445 |
| 2080 | 654661316 | | 632406834 | 1203536 | 1113019 |
| 2081 | 643795873 | | 621930639 | 1183677 | 1094730 |
| 2082 | 662685934 | | 641543264 | 1205117 | 1111390 |
| 2083 | 663303174 | | 642199049 | 1218624 | 1116745 |
| 2084 | 650387947 | | 630468161 | 1178475 | 1099293 |
| 2085 | 669341604 | | 649515793 | 1197580 | 1110182 |
| 2086 | 669407084 | | 648926677 | 1228785 | 1122248 |
| 2087 | 656209726 | | 637314621 | 1193049 | 1094924 |
| 2088 | 675823516 | | 656462328 | 1203509 | 1118708 |
| 2089 | 674348760 | | 655658385 | 1210193 | 1124108 |
| 2090 | 660674460 | | 643801362 | 1176816 | 1093061 |
| 2091 | 678659068 | | 660528369 | 1204598 | 1104807 |
| 2092 | 679039073 | | 661722014 | 1221410 | 1121884 |
| 2093 | 664893630 | | 649285713 | 1176898 | 1094986 |
| 2094 | 681651336 | | 667120612 | 1188326 | 1103539 |
| 2095 | 683157192 | | 667120663 | 1197755 | 1116506 |
| 2096 | 667012974 | | 651203821 | 1175840 | 1101160 |
| 2097 | 683367607 | | 667785933 | 1181896 | 1108381 |
| 2098 | 684062728 | | 668729162 | 1195752 | 1118027 |
| 2099 | 668571410 | | 653142718 | 1170721 | 1070172 |
| 2100 | 694764179 | | 678661910 | 1189119 | 1107904 |

***Figure SX***, Cases averted, deaths averted, cases averted by fully vaccinated person, and deaths averted by fully vaccinated person by country and vaccination scenario, 2000-2100. Each is ordered from smallest to largest impact. Error bars represent 90% Confidence Intervals (Cis)

***A graph of different sizes and shapes

AI-generated content may be incorrect.***

***Figure SX,*** Population cohort size by age group over simulation period, all VIMC countries

A graph of different colored lines

AI-generated content may be incorrect.

A graph of different colored bars

Description automatically generated with medium confidence

***Figure SX*,** *Cases averted by age in Angola and Sudan.*

A graph of cases with numbers and lines

Description automatically generated with medium confidence

**Figure SX,** Cumulative lifetime vaccine impact in terms of cases and deaths averted by age

A graph of a number of people

Description automatically generated with medium confidence

Other figure ideas:

Results: Cases averted per FVP and deaths averted per FVP (y axis) vs transmission intensity (x axis). Dots for each admin1 similar to Fig 4.

Results: another panel for Fig 4 looking at baseline scenarios with no vaccination (just for our own interpretation, not necessarily to include in the paper)

Supplement: maps of the PfPR, SMC / ITN / etc. coverage levels by admin1 in 2023 onward

Results: plots of three selected sites or countries (low, medium, high PfPR) showing the effects of delayed malaria broken down into smaller age groups over 50 or 100 years. Maybe a bar plot with age on the x axis and cases averted per FVP or deaths averted per FVP on the y axis. Age could be broken down into one-year groupings up until 20 and then by decade as I think you have modelled it.