



Malaria: Trend of Burden and Impact of Control Strategies

**Emmanuel Ikechukwu Nnamonu^{1*}, Pamela Amarachi Ndukwe-Ani²,
Cyril Ali Imakwu³, Clara Ifeoma Okenyi¹, Felix Joel Ugwu¹,
Maduabuchi Isaac Aniekwe³, Solomon Ikechukwu Odo¹
and Samuel Uchechukwu Ezenwosu¹**

¹Department of Biology, Federal College of Education, Eha-Amufu, Enugu State, Nigeria.

²Department of Economics, Ebonyi State University, Abakaliki, Ebonyi State, Nigeria.

³Department of Parasitology and Entomology, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.

Authors' contributions

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ABSTRACT

Since antiquity, malaria had plagued humans claiming millions of lives annually around the world. In addition to its health toll, billions of dollars are lost every year to the exorbitant cost of treatment, premature death, loss of opportunities, capital intensive public health and government interventions to curb the menace. This had intensified global malaria eradication efforts over the last few decades leading to the successful elimination of the disease from most developed countries drastically reducing global malaria mortality to hundreds of thousands yearly. Still, developing countries of the world especially those in tropical Africa remain the worst hit and children are the most vulnerable group generally accounting for > 50% of all malaria mortality. The world actually experienced a giant leap forward between 2000 and 2015 when global malaria mortality rate declined by a remarkable 25% and by a significant 69% in children less than five. Also, during this period a

*Corresponding author: Email: nnamonue@gmail.com, emmanuel.nnamonu@fceehamufu.edu.ng;

staggering 70% of malaria cases were averted due to strengthened malaria intervention. Some of this step forward was also attributed to increasing urbanization and overall economic development across the nation's leading to improved housing and nutrition. However, years later, progress has been relatively slower and seemed to have stalled. Nonetheless, the impacts of control strategies have saved millions of lives universally. But to save more lives and eliminate malaria from highest risk countries like in tropical Africa, more efforts are required at both international and national capacity through the funding of research and malaria projects, effective surveillance and response, strengthened health system and mosquito vector control strategies, and development of new, improved antimalarial intervention tools like diagnostics, prophylactics, therapeutics and vaccines. Also, the role of human activity and lifestyle in the fight against malaria cannot be overemphasized.

Keywords: Malaria; burden; control strategies; *plasmodium falciparum*.

1. INTRODUCTION

The fight against malaria has lasted for centuries. Although some countries of the world have successfully eliminated this life-threatening disease; others most especially in Africa have adapted and accepted to live with it. Though preventable and treatable, malaria has remained one of the most severe public health problems worldwide. Currently, it occurs mostly in poor tropical and subtropical regions of the world where it is the leading cause of death and disease with young children and pregnant women been the most vulnerable group [1].

Notable factors that increase its prevalence in the aforementioned areas include the abundance of very efficient mosquito species (*Anopheles gambiae* complex) responsible for high transmission; the presence of the predominant parasite species (*Plasmodium falciparum*) which are most likely to cause severe malaria and death; and local weather conditions which favours transmission to occur year-round [2]. Other location-based causes of malaria in Africa include management of irrigation in rice farms (which contributes to environmental problems like water adoption, water quality reduction and waterlogging that encourages the breeding of mosquitoes) [3], grown bushes around residence, high involvement in farming activities, residing close to water bodies, staying late night outdoors, poor health care system [4], scarce resources and other socioeconomic problems that have hindered efficient malaria control activities [5].

Malaria is a vector-borne disease caused by a single-celled protozoan parasite called *Plasmodium*, transmitted by female *Anopheles* mosquitoes. Hence, it is otherwise called *Plasmodium* infection. The four different species of *Plasmodium* commonly associated with

human malaria include: *P. falciparum*, *P. malariae*, *P. ovale* and *P. vivax*. Humans occasionally become infected with a *Plasmodium* species that normally infect animals known as *P. knowlesi* but there are yet to be reports of animal-mosquito-human transmission otherwise known as "zoonotic" forms of malaria. *Plasmodium falciparum* which is the most dominant species in Africa has remained the deadliest amongst all human *Plasmodium* species responsible for approximately 90% of malaria deaths per year. On the other hand, there is fear that more people worldwide live at risk from *P. vivax* than *P. falciparum* and as a result suffer increased morbidity from *P. vivax*

Infected female mosquitoes transmit *Plasmodium* into humans as they feed on blood. Male mosquitoes do not transmit the disease as they feed only on plant juices. There are more than 400 different species of *Anopheles* mosquito; around 30 are malaria vectors of major importance. All of the important vector species bite between dusk and dawn. The intensity of transmission depends on factors related to the parasite, the vector, the human host, and the environment [6]. Basically, transmission becomes more intense in places where the mosquito lifespan is longer thereby giving the parasite more time to complete its development inside the mosquito. Also, the transmission is severe where mosquito prefers to bite humans rather than other animals. Long lifespan and strong human-biting habit are the major characteristics of the African mosquito species that favours their high vectoral capacity and transmission; consequently, leading to the approximately 90% of the world's malaria cases accrued to Africa. Similarly, transmission equally depends on climatic conditions that may affect the number and survival of mosquitoes such as rainfall patterns, temperature and humidity. For instance, in some places the peak falls during

and just after the rainy season. Certainly, when climate and other conditions suddenly favour transmission in areas where people have little or no immunity to malaria, malaria epidemics can occur. Additionally, it can also occur when people with low immunity move into areas with intense malaria transmission. Human immunity is a vital factor, especially among adults in areas of moderate or intense transmission conditions. Partial immunity is developed over years of exposure, and while it never provides complete protection, it does reduce the risk that malaria infection will cause severe disease. This is a reason behind malaria deaths in young children in Africa. In areas with less transmission and low immunity, all age groups are at risk.

The severity of malaria varies based on the species of plasmodium. Malaria is an acute febrile illness with an incubation period of 7 days or longer. Thus, a febrile illness developing less than 1 week after the first possible exposure is not malaria. The most severe form is caused by *P. falciparum*; variable clinical features include fever, chills, headache, muscular aching and weakness, vomiting, cough, diarrhoea and abdominal pain. Other symptoms related to organ failure may supervene, such as acute renal failure, pulmonary oedema, generalized convulsions, circulatory collapse, followed by coma and death [1].

Young children, pregnant women, people who are immunosuppressed and elderly travellers are particularly at risk of severe disease. Malaria, particularly *P. falciparum*, in non-immune pregnant travellers increases the risk of maternal death, miscarriage, stillbirth and neonatal death. Other forms of human malaria caused by other *Plasmodium* species can result in significant morbidity but are rarely life-threatening. Cases of severe *P. vivax* malaria have recently been reported among populations living in subtropical countries or areas at risk. *P. vivax* and *P. ovale* can remain dormant in the liver. Relapses caused by these persistent liver forms (hypnozoites) may appear months, and rarely several years, after exposure. Relapses are not prevented by current chemoprophylactic regimens, with the exception of primaquine. Latent blood infection with *P. malariae* may be present for many years, but it is very rarely life-threatening.

In recent years, sporadic cases of travellers' malaria due to *P. knowlesi* have been reported.

Humans can be infected with this "monkey malaria" parasite while staying in rainforests and/or their fringe areas in South-East Asia, within the range of the natural monkey hosts and mosquito vector of this infection. These areas include parts of Cambodia, China, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam. The parasite has a life-cycle of 24 hours and can give rise to daily fever spikes occurring 9–12 days after infection. Symptoms may be atypical. Severe *P. knowlesi* malaria with organ failure may occur, and sporadic fatal outcomes have been described. *P. knowlesi* has no persistent liver forms and relapses do not occur. Travellers to forested areas of South-East Asia where human *P. knowlesi* infections have been reported should protect themselves against mosquito bites between dusk and dawn to prevent infection and take the usual chemoprophylaxis revealed that malaria though preventable and curable has remained a life-threatening disease caused by parasites that are transmitted to people through the bites of infected female *Anopheles* mosquitoes. In 2018, there were an estimated 228 million cases of malaria worldwide. The estimated number of malaria deaths stood at 405000 in 2018. Children aged under 5 years are the most vulnerable group affected by malaria; in 2018, they accounted for 67% (272000) of all malaria deaths worldwide. The WHO African Region carries a disproportionately high share of the global malaria burden. In 2018, the region was home to 93% of malaria cases and 94% of malaria deaths. 6 countries accounted for more than half of all malaria cases worldwide: Nigeria (25%), the Democratic Republic of the Congo (12%), Uganda (5%), and Côte d'Ivoire, Mozambique and Niger (4% each). In 2018, *P. falciparum* accounted for 99.7% of estimated malaria cases in the WHO African Region 50% of cases in the WHO South-East Asia Region, 71% of cases in the Eastern Mediterranean and 65% in the Western Pacific. *P. vivax* is the predominant parasite in the WHO Region of the Americas, representing 75% of malaria cases. Total funding for malaria control and elimination reached an estimated US\$ 2.7 billion in 2018. Contributions from governments of endemic countries amounted to US\$ 900 million, representing 30% of total funding [1].

Despite all efforts, policies, resources, strategies and technology invested towards the elimination of malaria globally, the latest incidence report still shows high prevalence, especially in Africa. However, there is evidence of the positive impact

of various malaria control programmes. For instance, there were 228 million cases of malaria in 2018 compared to 231 million cases in 2017. The estimated number of malaria deaths stood at 405000 in 2018, compared with 416000 deaths in 2017.

Similarly, [7] reported in a study titled “Global malaria mortality between 1980 and 2010: a systematic analysis,” that researchers found that global malaria deaths increased from 995,000 in 1980 to a peak of 1.8 million in 2004, then decreased to 1.2 million malaria deaths in 2010; a 32% decrease compared with 2004. Their report also revealed that these results are largely driven by the pattern seen in sub-Saharan Africa, where deaths increased from 493,000 in 1980 to 1.6 million in 2004 and then decreased by about 30% to 1.1 million in 2010. According to their report, the trend was much different, with deaths steadily decreasing from 502,000 in 1980 to 104,000 in 2010.

The present review is focused on analysing the malaria burden, impact of control strategies – past and present.

2. THE TREND OF MALARIA BURDEN (FROM EARLY 2000’S TILL DATE)

At the end of 2004, 107 countries and territories had areas at risk of malaria transmission, 3.2 billion people lived in areas at risk of malaria transmission; an estimated 350–500 million clinical malaria episodes occurred (most were caused by infection with *P. falciparum* and *P. vivax*); *Falciparum* malaria causes more than 1 million deaths each year which also contributed indirectly to many additional deaths mainly in young children through synergy with other infections and illnesses [8]. There were about 60% of the cases of malaria worldwide, about 75% of global falciparum malaria cases and more than 80% of malaria deaths occur in Africa south of the Sahara. Plasmodium *falciparum* championed the vast majority of malaria infections in the African region and about 18% of deaths in children under 5 years of age. Malaria was also a major cause of anaemia in children and pregnant women, low birth weight, premature birth and infant mortality. In endemic African countries, malaria accounted for 25–35% of all outpatient visits, 20–45% of hospital admissions and 15–35% of hospital deaths, imposing a great burden on already fragile health-care systems [8].

In 2009 there was an estimated 225 million cases of malaria down from an estimated 244 million cases in 2005. The vast majority of cases in 2009 (78%) were in the African Region, followed by South-East Asia (15%) and Eastern Mediterranean Regions (5%). The global number of cases was estimated to have increased between 2000 and 2005 in line with population growth and however, decreased subsequently due to the impact of malaria control. The largest percentage reductions since 2005 were estimated to have occurred in the European Region (86%) followed by the Region of the Americas (42%) [9].

The global number of malaria deaths was estimated to have decreased from 985000 in 2000 to 781000 in 2009. It is estimated that 91% of deaths in 2009 were in the African Region, followed by the South-East Asia (6%) (The number of deaths in the South-East Asian Region is higher than previously estimated owing to increased estimates in India and Indonesia) and Eastern Mediterranean Regions (2%). About 85% of deaths globally were in children under 5 years of age. The largest percentage decreases were seen in the Region of the Americas (48%) [9].

In 2010, an estimated 216 million cases of malaria were recorded worldwide (increased from 223 million in 2000, to 237 million cases in 2005), 91% were caused by *P. falciparum*. The vast majority of cases (81%) were in the African Region followed by the South-East Asia (13%) and Eastern Mediterranean Regions (5%). The estimated number of malaria cases per 1000 persons at risk, which takes into account population growth over time, reduced in case incidence of 17% globally between 2000 and 2010. There were cases of declines in case incidence in every Region: European (100%), American (60%) and Western Pacific Regions (38%). An estimated 655 000 malaria deaths occurred in 2010, estimated that 91% of deaths in 2010 were in the African Region, followed by the South-East Asian Region (6%), and Eastern Mediterranean Regions (3%). About 86% of deaths globally were in children. In the African Region, the number of deaths is estimated to have risen from 682000 in 2000 to 748000 in 2004 before decreasing to 596 000 in 2010 following a scale-up of control activities. Malaria mortality rates decreased by 25% worldwide between 2000 and 2010 and by 33% in the WHO African Region [9].

An estimated 3.3 billion people were at risk of malaria in 2011 with approximately 80% of cases and 90% of deaths are estimated occur in the WHO African Region, children under five years of age and pregnant women most severely affected. Populations living in Sub-Saharan Africa had the highest risk of acquiring malaria. A 75% reduction in malaria case incidence was equivalent to an 8.83% reduction per year (compounded) between 2000 and 2015 [10].

There were an estimated 207 million cases of malaria in 2012 (from 226 million in 2000 to 244 million in 2005, before decreasing to 207 million in 2012), 80% in the African Region, 13% in Asia Region and 6% in Eastern Mediterranean Region. Approximately 9% of the estimated cases globally were due to *P. vivax*. There was a 25% globally reduction in incidence cases between 2000 and 2012 (31% in the African Region, 100% in the European Region, 70% in American Region 56% in Western Pacific Region). It was projected in 2012 that if the annual rate of decrease in malaria incidence that occurred between 2000 and 2012 was maintained, malaria case incidence would have decreased by 31% globally and 39% in the African Region by 2015 [11].

There were an estimated 627000 malaria deaths worldwide in 2012, with an estimated 90% of death in the African Region, 7% in the South-East Asia Region and 3% in the Eastern Mediterranean Region. About 482000 malaria deaths were estimated to occur in children under 5 years of age (77% of the global total). An estimated 462000 deaths occurred in children under 5 years of age in the African Region. Despite the fact that most of the deaths were due to *P. falciparum*, *P. vivax* was increasingly recognized as a cause of severe malaria and death. Between 2000 and 2012, the population at risk for malaria increased by 23% globally and by 29% in sub-Saharan Africa. Malaria mortality rates were estimated to have decreased by 42% globally across all age groups between 2000 and 2012, and by 48% in children under 5 years of age. In the African Region, malaria death rates decreased by 49% across all age groups and by 54% in children under 5 years of age. It was projected in 2013 that If the annual rate of decrease that has occurred over the past 12 years (2000-2012) was maintained, then malaria mortality rates would have decreased by 52% globally across all age groups, and by 60% in children under 5 years of age by 2015 in the African Region they were projected to have

decreased by 62% in all age groups and by 68% in children under 5 by 2015. Notably, the decrease in malaria mortality rates was slower between 2011 and 2012 [11].

With regards to geographical locations, about 80% of malaria deaths in 2012 were estimated to occur in just 17 countries, and 80% of cases in 18 countries. Four countries accounted for more than 80% of *P. vivax* cases estimated cases (Ethiopia, India, Indonesia and Pakistan). The global burden of mortality was dominated by countries in Sub-Saharan Africa: The Democratic Republic of the Congo and Nigeria together account for 40% of the global total of estimated malaria deaths and 32% of cases [11].

Average malaria infection prevalence declined 48% in children aged 2–10 years, from 26% to 14% in 2013. The number of malaria infections at any one time dropped 26%, from 173 million to 128 million in 2013. Malaria mortality rates have decreased by 47% worldwide and by 54% in the WHO Africa Region. The World Malaria Report 2014 revealed that malaria transmission occurred in all six WHO regions. 3.2 billion people were estimated to be at risk of being infected with malaria and developing the disease. 1.2 billion were at high risk (>1 in 1000 chance of getting malaria in a year), 198 million cases of malaria occurred globally in 2013, 584000 deaths occurred and the burden was heaviest in the WHO African Region (where an estimated 90% of all malaria deaths occur, and deaths of children aged under 5 years accounted for 78% of all deaths) [12].

The number of malaria cases globally fell from an estimated 262 million in 2000 to 214 million in 2014 - a decline of 18%. The 88% incidence cases in 2014 occurred in the WHO African Region, 10% in the WHO South-East Asia Region while 2% occurred in the WHO Eastern Mediterranean Region. The incidence of malaria, which takes into account population growth, is estimated to have decreased by 37% between 2000 and 2014. 57 of 106 countries that had the ongoing transmission in 2000 reduced malaria incidence by >75% in 2014; A further 18 countries were estimated to have reduced malaria incidence by 50–75% [13].

The number of malaria deaths globally decreased from an estimated 839000 in 2000, to 438000 in 2014, a decline of 48%. Most deaths in 2014 were in the WHO African Region (90%), followed by the WHO South-East Asia Region

(7%) and the WHO Eastern Mediterranean Region (2%). The malaria mortality rate, which takes into account population growth, is estimated to have decreased by 60% globally between 2000 and 2014. The number of malaria deaths in children aged under 5 years was estimated to have decreased from 723000 globally in 2000 to 306000 in 2014. The bulk of this decrease occurred in the WHO African Region, where the estimated number of deaths fell from 694000 in 2000 to 292000 in 2014 [13]. In 2014, malaria was the fourth highest cause of death, accounting for 10% of child deaths in Sub-Saharan Africa. Malaria remained a major killer of children, particularly in Sub-Saharan Africa, taking the life of a child every 2 minutes. The proportion of children infected with malaria parasites halved in endemic areas of Africa since 2000. Infection prevalence among children aged 2–10 years was estimated to have declined from 33% in 2000 to 16% in 2014, with three-quarters of this change occurring after 2005.

It was estimated that a cumulative 1.2 billion fewer malaria cases and 6.2 million fewer malaria deaths occurred globally between 2001 and 2014 than would have been the case had incidence and mortality rates remained unchanged since 2000. In Sub-Saharan Africa, it is estimated that malaria control interventions accounted for 70% of the 943 million fewer malaria cases occurring between 2001 and 2014, averting 663 million malaria cases. Of the 663 million cases averted due to malaria control interventions, it was estimated that 69% were averted due to use of insecticide-treated mosquito nets (ITNs), 21% due to artemisinin-based combination therapy (ACT) and 10% due to indoor residual spraying [13]. In 2015, an estimated 212 million cases of malaria occurred worldwide, a fall of 22% since 2000 and 14% since 2010. Most of the cases in 2015 were in the WHO African Region (90%), followed by the WHO South-East Asia Region (7%) and the WHO Eastern Mediterranean Region (2%). About 4% of estimated cases globally are caused by *P. vivax*, but outside the African continent, this proportion increases to 41%. Most cases of malaria caused by *P. vivax* occur in the WHO South-East Asia Region (58%), followed by the WHO Eastern Mediterranean Region (16%) and the WHO African Region (12%). About 76% of estimated malaria cases in 2015 occurred in just 13 countries [14].

It was estimated that 429000 deaths from malaria occurred globally in 2015, a decrease of

50% since 2000 and of 22% since 2010. Most deaths in 2015 were estimated to have occurred in the WHO African Region (92%), followed by the WHO South-East Asia Region (6%) and the WHO Eastern Mediterranean Region (2%). Almost all deaths (99%) resulted from *P. falciparum* malaria. *Plasmodium vivax* is estimated to have been responsible for 3100 deaths in 2015 (range: 1800–4900), with most (86%) occurring outside Africa. 2015 recorded 303000 malaria deaths in children aged under 5 years, equivalent to 70% of the global total. The number of malaria deaths in children less than 5 years was estimated to have decreased by 60% since 2000 and by 29% since 2010. Malaria was estimated to take the life of a child every 2 minutes. 13 countries accounted for 75% of malaria deaths in 2015. Sadly, the global burden of mortality was dominated by countries in Sub-Saharan Africa, with the Democratic Republic of the Congo and Nigeria together accounting for more than 36% of the global total of estimated malaria deaths. Four countries accounted for 81% of estimated deaths due to *P. vivax* malaria (Ethiopia, India, Indonesia and Pakistan) [14].

The proportion of the population at risk in Sub-Saharan Africa who were infected with malaria parasites was estimated to have declined from 22% in 2005 to 17% in 2010 and to 13% in 2015. The number of people infected in Sub-Saharan Africa was also estimated to have decreased, from 146 million in 2005 to 131 million in 2010, and to 114 million in 2015. Infection rates were higher in children aged 2–10 years but the majority of infected people were in other age groups. In 2015, it was estimated that 7 of the 43 countries in Sub-Saharan Africa with malaria transmission had more than 25% of their population infected with malaria parasites (Burkina Faso, Cameroon, Equatorial Guinea, Guinea, Mali, Sierra Leone and Togo). This number decreased from 12 countries in 2010.

Malaria mortality rates were estimated to have declined by 62% globally between 2000 and 2015, and by 29% between 2010 and 2015. The rate of decline between 2010 and 2015 was fastest in the WHO Western Pacific Region (58%) and the WHO South-East Asia Region (46%). In children aged under 5 years, malaria mortality rates were estimated to have fallen by 69% globally between 2000 and 2015 and by 35% globally between 2010 and 2015. They fell by 38% in the WHO African Region between 2010 and 2015. Of 91 countries and territories with malaria transmission in 2015, 39 are

estimated to have achieved a reduction of 40% or more in mortality rates between 2010 and 2015, 14 had reductions of 20–40% and 8 experienced increases in mortality rates of >20%. A further 10 countries reported no deaths in 2010 and in 2015 (the remaining 20 countries experienced changes <20%) [14].

It was estimated that a cumulative 1.3 billion fewer malaria cases and 6.8 million fewer malaria deaths occurred globally between 2001 and 2015 than would have occurred had incidence and mortality rates remained unchanged since 2000. The highest proportion of cases and deaths were averted in the WHO African Region (94%). Of the estimated 6.8 million fewer malaria deaths between 2001 and 2015, about 6.6 million (97%) were for children aged under 5 years. Not all of the cases and deaths averted can be attributed to malaria control efforts. Some progress was probably related to increased urbanization and overall economic development, which has led to improved housing and nutrition. However, it had previously been estimated that 70% of the cases averted between 2001 and 2015 were due to malaria interventions. In the WHO African Region, reduced malaria mortality rates, particularly among children aged under 5 years, have led to a rise in life expectancy at birth of 1.2 years, accounting for 12% of the total increase in life expectancy of 9.4 years from 50.6 years in 2000 to 60 years in 2015. Across all malaria-endemic countries, the contribution of malaria mortality reduction was 0.26 years or 5% of the total increase in life expectancy between 2000 and 2015, from 66.4 years to 71.4 years [14].

In 2016, an estimated 216 million cases of malaria occurred worldwide compared with 237 million cases in 2010. Compared with 2015, 5 million more malaria cases were estimated to have occurred globally in 2016. Of the 91 countries that had an indigenous malaria case in 2016, a decrease in malaria cases of more than 20% compared with 2015 was estimated in 16 countries, while an increase of a similar magnitude was estimated in 25 countries. The WHO regions of the Americas and Africa accounted for nearly 70% of the countries that had increases of more than 20% in 2016 compared with 2015. Twenty-nine high-burden countries that accounted for 85% of malaria cases in 2016 had a change of more than 50000 cases compared with 2015. Twenty-four had estimated increases of between 50500 (Chad) and over one million (Nigeria and Rwanda)

cases, while five had decreases of between 151000 (Gambia) and 856000 (Madagascar) [15].

The incidence rate of malaria globally declined steadily from 76 to 63 cases per 1000 population at risk from 2010 to 2016, amounting to 18% decline. In the WHO African Region, malaria incidence reduced from 256 to 206 cases per 1000 population at risk from 2010 to 2016, representing a 20% reduction in case incidence. Among other regions, the WHO South-East Asia Region registered the largest decline (48%), followed by the WHO Region of the Americas (22%) and the WHO Western Pacific Region (12%). Between 2014 and 2016, however, the malaria case incidence rate remained unchanged globally and increased in all WHO regions except in the WHO European Region. The highest percentage increase was in the WHO Region of the Americas (36%) where malaria incidence began rising in 2013, largely due to increases in Brazil and Venezuela (Bolivarian Republic) [15].

Estimates of malaria mortality rate per 100000 population at risk show that, compared with 2010, all regions where an indigenous malaria death was reported or estimated had recorded reductions by 2016. The largest decline in mortality rate occurred in the WHO regions of South-East Asia (44%), Africa (37%) and the Americas (27%). Between 2015 and 2016, however, there was no significant change in mortality rate in the WHO African Region, while a slight increase was reported in all other WHO regions [15].

An estimated 219 million cases of malaria occurred worldwide in 2017 compared with 239 million cases in 2010 and 217 million cases in 2016. Although there were 20 million fewer cases in 2017 than in 2010 globally, the period 2015 to 2017 registered only a minimal slightly upward change in trend, despite a dip in cases in 2015, suggesting that progress had generally stalled. The WHO African Region still bears the largest burden of malaria morbidity with 200 million cases (92%) in 2017 followed by the WHO South-East Asia Region (5%) and the WHO Eastern Mediterranean Region (2%). Globally, 3.4% of all estimated cases were caused by *P. vivax*, with 56% of the *vivax* cases being in the WHO South-East Asia Region. *P. vivax* is the predominant parasite in the WHO Region of the Americas (74%) and is responsible for 37% of cases in the WHO South-East Asia Region and 31% in the WHO Eastern Mediterranean Region [16].

Almost 80% of all malaria cases globally were in 15 African countries and in India. Nearly 50% of all cases globally were accounted for by Nigeria (25%), the Democratic Republic of the Congo (11%), Mozambique (5%), India (4%) and Uganda (4%). About 82% of estimated vivax malaria cases in 2017 occurred in just five countries (India, Pakistan, Ethiopia, Afghanistan and Indonesia). Of the 87 countries that had an indigenous malaria case in 2017, a decrease in malaria cases of more than 20% compared with 2016 was estimated in 20 countries, and an increase of a similar magnitude was estimated in 20 countries. Most of these changes occurred in countries with low to very low malaria burden, and in several countries the absolute difference was small. Countries with an estimated decrease of more than 20% were as follows: WHO African Region (Gambia and Mauritania); WHO Region of the Americas (Colombia, Dominican Republic, El Salvador, Guatemala, Honduras and Suriname); WHO Eastern Mediterranean Region (Iran, Islamic Republic of Pakistan and Saudi Arabia). WHO South-East Asia Region (Bhutan, India, Myanmar and Timor-Leste); and WHO Western Pacific Region (China, Lao People's Democratic Republic, Malaysia, Republic of Korea and Vanuatu). Countries and areas with an estimated increase of more than 20% were as follows: WHO African Region (Botswana, Cabo Verde, Comoros, Eritrea, Eswatini, Madagascar, Namibia, Senegal, South Africa and Zimbabwe); WHO Region of the Americas (Belize, Brazil, Costa Rica, French Guiana, Mexico, Nicaragua and Venezuela (Bolivarian Republic of ?)); WHO South-East Asia Region (Nepal); and WHO Western Pacific Region (Cambodia and Solomon Islands). In the WHO Region of the Americas, Venezuela (Bolivarian Republic of) accounted for 84% of the increase in cases [17].

Among the moderate to high burden countries with overall case numbers exceeding 300000 indigenous cases in 2017, a change of greater than 100000 cases between 2016 and 2017 occurred in 21 countries. Of these, Nigeria, Madagascar and the Democratic Republic of the Congo had the highest estimated increases, all being greater than half a million cases. In contrast, India reported more than 3 million fewer cases (24%) in the same period. For the first time since 2011, Rwanda reported a reduction in cases, with slightly more than 430000 fewer cases in 2017 compared with 2016, although cases in 2017 still represent a more than 10-fold increase compared with 2011 [17].

The incidence rate (i.e. the number of cases per 1000 population) of malaria globally reduced between 2010 and 2017. It fell from 72 in 2010 to 59 in 2017. However, from 2014 to 2017, the rate of change slowed dramatically, reducing from 61 in 2014 to 59 in 2015, and remaining at this level in 2016 and 2017. Except in the WHO South-East Asia Region, change in incidence rate has either remained flat or, in the case with the WHO Region of the Americas, increased; this increase was largely due to increases in Brazil, Nicaragua and Venezuela (Bolivarian Republic). Within the WHO African Region, incidence rate changed from 278 in 2010, to 219 in both 2016 and 2017 [17].

Between 2010 and 2017, estimated deaths due to malaria globally declined from 607000 to 435000 cases. Estimates of malaria mortality rate (deaths per 100000 population at risk) showed that, compared with 2010, all regions had recorded reductions by 2017, except the WHO Region of the Americas, mainly due to a rapid increase in malaria in Venezuela (Bolivarian Republic of ?). Globally, 266000 (61%) malaria deaths were estimated to be in children aged under 5 years. Although the WHO African Region accounted for 93% of all deaths in 2017, it also accounted for 88% of the 172000 fewer cases reported in 2017 relative to 2010. Despite these gains, the rate of reduction of malaria mortality has also slowed since 2015, somewhat similar to the estimated trends in malaria case incidence. Almost 80% of all malaria deaths in 2017 occurred in 17 countries in the WHO African Region and India, and about 53% of all malaria deaths globally were accounted for by Nigeria, Democratic Republic of the Congo, Burkina Faso, United Republic of Tanzania, Sierra Leone, Niger and India [17].

3. PROGRESS IN MALARIA CONTROL

The progress made so far on malaria control wouldn't have to be possible without the huge annual financial investment involved. An estimated US\$ 2.7 billion invested in malaria control and elimination in 2018 suffered a reduction of US\$ 3.2 billion compared with US\$ 5.0 billion spent in 2017. Nearly three-quarters of investments in 2018 were spent in the WHO African Region, followed by the WHO Region of the Americas (7%), the WHO South-East Asia Region (6%), and the WHO Eastern Mediterranean Region and the WHO Western Pacific Region (5% each). In 2018, 47% of total funding for malaria was invested in low-income

countries, 43% in lower-middle-income countries and 11% in upper-middle-income countries. International funding represented the major source of funding in low-income and lower-middle-income countries, at 85% and 61%, respectively. Domestic funding has remained stable since 2010. Of the US\$ 2.7 billion invested in 2018, US\$ 1.8 billion came from international funders. Governments of malaria-endemic countries contributed 30% of total funding (US\$ 900 million) in 2018, a figure unchanged from 2017. Two-thirds of domestically sourced funds were invested in malaria control activities carried out by national malaria programmes (NMPs), with the remaining share estimated as the cost of patient care. As in previous years, the United States of America (USA) was the largest international source of malaria financing, providing US\$ 1.0 billion (37%) in 2018. Country members of the Development Assistance Committee together accounted for US\$ 300 million (11%). The United Kingdom of Great Britain and Northern Ireland contributed around US\$ 200 million (7%). Of the US\$ 2.7 billion invested in 2018, US\$ 1.0 billion was channelled through the Global Fund to Fight AIDS, Tuberculosis and Malaria. Although funding for malaria has remained relatively stable since 2010, the level of investment in 2018 is far from what is required to reach the first two milestones

of the GTS that is, a reduction of at least 40% in malaria case incidence and mortality rates globally by 2020, compared with 2015 levels. US\$ 663 million was invested in basic research and product development for malaria in 2018, an increase of US\$ 18 million compared with 2017. Funding for drug research and development (R&D) increased to the highest level ever recorded, from US\$ 228 million in 2017 to US\$ 252 million in 2018. This increase was a result of private sector industry investment in several Phase II trials of new chemical entities with the potential for single-exposure radical cure [1].

The mentioned financial investment has led to significant progress in malaria control. Between 2016 and 2018, a total of 578 million insecticide-treated mosquito nets (ITNs), mainly LLINs, were reported by manufacturers as having been delivered globally, with 50% going to Côte d'Ivoire, the Democratic Republic of the Congo, Ethiopia, Ghana, India, Nigeria, Uganda and the United Republic of Tanzania. In 2018 about 197 million ITNs were delivered by manufacturers, of which more than 87% were delivered to countries in sub-Saharan Africa. Globally, 80% of ITNs were distributed through mass distribution campaigns, 10% in antenatal care facilities and 6% as part of immunization programmes. An estimated 412 million rapid diagnostic tests kits

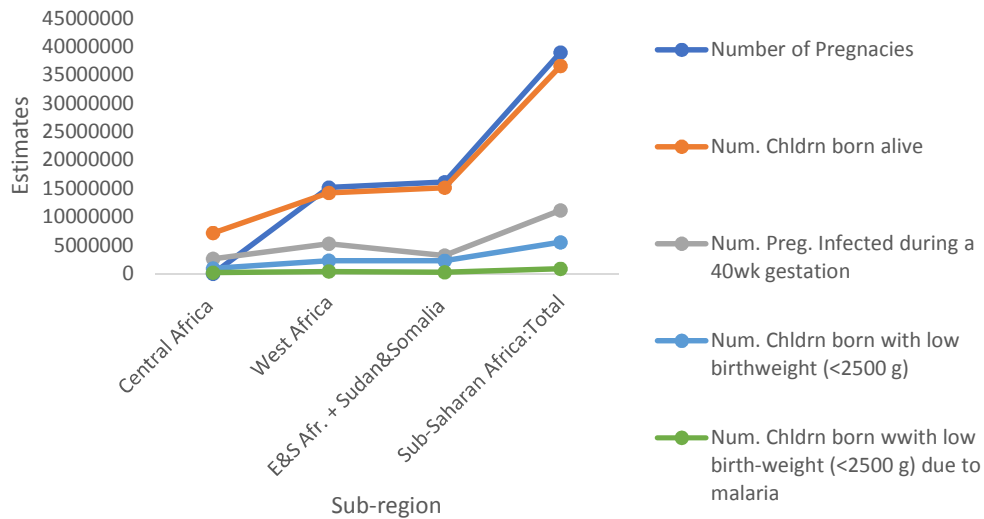


Fig. 1. Estimates of pregnancies, live birth, low birth weights, exposure to malaria infection in pregnancy and malaria-attributable low birthweights in 2018 in moderate to high transmission Sub-Saharan Africa.

Source: Imperial College, WHO estimates (WHO, 2019)

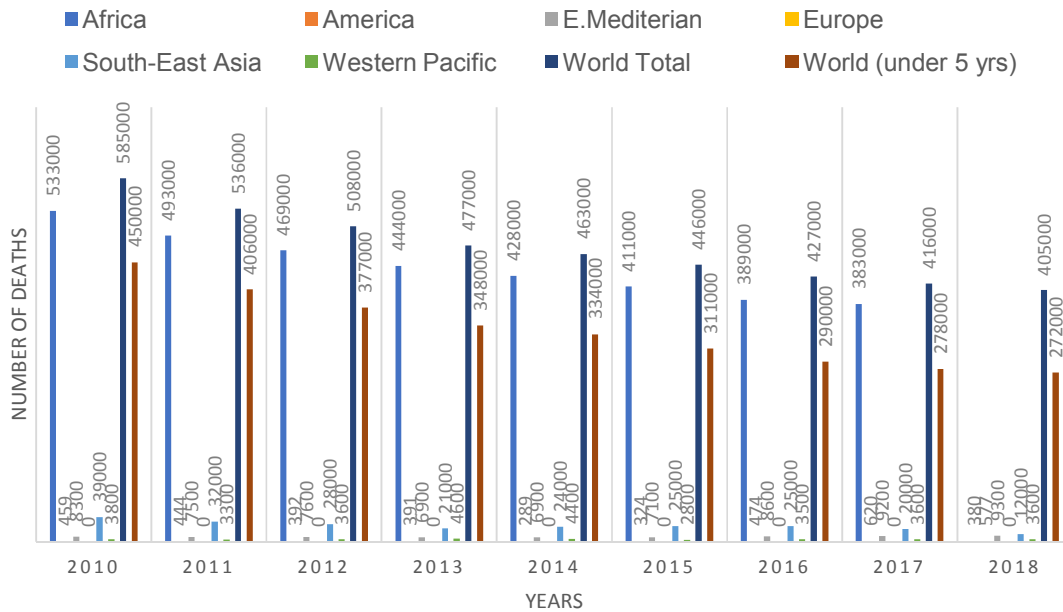


Fig. 2. Estimated number of malaria deaths by WHO regions, 2010-2018
 Source: WHO, 2019

(RDTs) were sold globally in 2018. In 2018, 259 million RDTs were distributed by National Malaria Programmes (NMPs). Most RDTs (64%) were tests that detected *P. falciparum* only and were supplied to Sub-Saharan Africa. Similarly, an estimated 3 billion treatment courses of artemisinin-based combination therapy (ACT) were procured by countries over the period 2010–2018. An estimated 63% of these procurements were reported to have been made for the public sector. In 2018, 214 million ACT treatment courses were delivered by NMPs, of which 98% were in the WHO African Region [1].

Consequently, half of the people at risk of malaria in Sub-Saharan Africa are sleeping under an ITN; in 2018, 50% of the population was protected by this intervention, an increase from 29% in 2010. The percentage of the population with access to an ITN increased from 33% in 2010 to 57% in 2018. However, coverage has improved only marginally since 2015 and has been at a standstill since 2016. Households with at least one ITN for every two people increased to 72% in 2018, from 47% in 2010. However, this figure represents only a modest increase over the past 3 years and remains far from the target of universal coverage. Fewer people at risk of malaria are being protected by indoor residual spraying (IRS), a prevention method that involves spraying the inside walls of

dwellings with insecticides. Globally, IRS protection declined from a peak of 5% in 2010 to 2% in 2018, with declining trends seen across all WHO regions apart from the WHO Eastern Mediterranean Region where IRS protection increased between 2016 and 2018. Although IRS coverage dropped from 180 million people at risk protected globally in 2010 to 93 million in 2018, the 2018 figure was a decrease of 13 million compared with 2017. The declines in IRS coverage may be due to the switch from pyrethroids to more expensive insecticides in response to increasing pyrethroid resistance, or changes in operational strategies (e.g. at-risk populations decreasing in countries aiming for the elimination of malaria) [1].

On the other hand, there were reports on insecticides resistance from 81 countries in WHO Regions between 2010 and 2018. Out of the 81 malaria-endemic countries that provided data for 2010–2018, there were resistance to at least one of the four insecticide classes in 73 countries, an increase of five countries compared with the previous reporting period 2010–2017. In 26 countries, resistance was reported to all main insecticide classes. Resistance to pyrethroids (the only insecticide class currently used in ITNs) was widespread and was detected in at least one malaria vector in more than two-thirds of the sites tested (highest in the WHO African Region and in

the WHO Eastern Mediterranean Region). Resistance to organochlorines was detected for at least one malaria vector in almost two-thirds of the sites. Resistance to carbamates and organophosphates was less prevalent and was detected in 31% and 26% of the tested sites, respectively. Prevalence was highest for carbamates in the WHO South-East Asia Region and for organophosphates in the WHO South-East Asia Region and in the WHO Western Pacific Region. More countries are moving towards zero indigenous cases. In 2018, 49 countries reported fewer than 10000 such cases, up from 46 countries in 2017 and 40 countries in 2010. The number of countries with fewer than 100 indigenous cases (a strong indicator that elimination is within reach) increased from 17 countries in 2010 to 25 countries in 2017 and 27 countries in 2018 [1].

Some researchers have resorted less economic ways of controlling and managing malaria vectors such as use of plant extracts as larvicides for malaria vector control [18,16,19,20]. Poor housing quality (with regards to walls, roofs, doors, and window materials) [21,22,23] has been reported as one of the major factors that enhances malaria prevalence. Therefore, house improvement has been considered as one of the methods of controlling malaria. Several researchers have reported on this [24,25,26,27]. Other reported methods include: Attractive toxic sugar bait, mass drug administration (treatment of the entire population in a geographic area with a curative dose of a drug without first testing for infection and regardless of the presence of symptoms) [28,29]; Swarm sprays [30,31], Targeting livestock – treating livestock with insecticides [32,33,34,35] and Genetically modified mosquitoes - genetically modify a mosquito that hinders or eliminates the *Plasmodium* during series of development in the body of the mosquito[36,37].

4. CONCLUSION

Over the years, malaria control strategies have shown significant impact in reducing the burden of malaria. But to win the raging war against malaria, a multifaceted approach requiring the utilization of all available arsenal and resources within our reach is crucial. Also, there is a need to focus on and scale-up intervention in highly malarial endemic countries like tropical Africa as well as ensuring sustained progress in countries that have achieved elimination to prevent malaria resurgence. All hands must be on deck for

development of new, improved antimalarial interventions, and to replace current drugs and pesticides that had succumbed to parasite susceptibility and mosquito vector resistance with more effective ones.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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