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ORIGINAL ARTICLE

Geographical distribution of falciparum malaria in the world and its relationship with the human development index (HDI): countries based on the WHO report in 2017

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Abstract

Aim Malaria is one of the most serious public health issues worldwide and is still responsible for the deaths of nearly half a million individuals every year worldwide. The aim of this study is to investigate the epidemiology of the incidence of and mortality from malaria and its association with the human development index (HDI).

Subjects and methods The present research is an ecological study conducted in 2017 that explored the association between the HDI and incidence of and mortality from malaria in WHO regions based on data extracted from the World Bank. In this study, the two-variable correlation method was adopted to analyze the data extracted to investigate the correlation between malaria incidence and HDI. A significance level of $P < 0.05$ was considered. The analyses were performed using Stata14 software.

Results The highest incidence of malaria in the world was reported in 2001 (80.73 per 1000 people) and the lowest in 2017 (59.12 per 1000). The results revealed a significant reverse correlation between malaria incidence ($r = -0.640$, $P < 0.0001$) and the HDI index in 2017. The analysis of HDI decomposites with malaria incidence in 2017 demonstrated a reverse and significant correlation between malaria incidence and gross national income per 1000 capita ($r = -0.365$, $P < 0.0001$), mean years of schooling ($r = -0.477$, $P < 0.0001$), life expectancy at birth ($r = -0.694$, $P < 0.0001$) and expected years of schooling ($r = -0.458$, $P < 0.0001$).

Conclusion Given the reverse correlation between malaria incidence and HDI, a greater emphasis on factors associated with the disease in these countries, effective prevention and awareness raising about the means of transmission can be effective in curbing the incidence of this disease.

Keywords Incidence · Malaria · Human development index

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Introduction

Malaria is a disease caused by protozoan parasites of the genus Plasmodium, which has five different species: falciparum, *Plasmodium vivax*, *Plasmodium malaria*, *Plasmodium ovale* and Plasmodium (Shapiro) infection, with different Plasmodium species producing various clinical outcomes in patients (Yang et al. 2018). The most viral and lethal species of malaria worldwide is *P. falciparum*, although other Plasmodium species can also cause serious illness in humans (Kasetsirikul et al. 2016).

In light of extensive worldwide efforts, the global burden of malaria has declined dramatically since 2000. The incidence rate has dropped by 37% and the mortality rate by 60% (Eperon et al. 2017). This decrease, which is evident worldwide, is chiefly the outcome of interventions such as the control of malaria-carrying mosquitoes (the use of

insecticides, spraying indoor spaces), treatment of patients and improved diagnosis (rapid diagnostic tests) (Bhatt et al. 2015).

In 2015, malaria was still endemic in 91 countries, of which 43 were located in sub-Saharan Africa, and 212 million new cases and 429,000 deaths were reported in this year. In addition, 90% of malaria cases and 92% of deaths were reported in sub-Saharan Africa (Qin et al. 2017). Globally, > 90% of deaths are caused by *Plasmodium falciparum* (99% in Africa) and 7.2% by *Plasmodium vivax* (Thellier et al. 2019).

Malaria is an example of a disease that reflects widening social inequalities (Franco-Herrera et al. 2018). Among the several parameters associated with malaria, social factors have gained widespread recognition, and the socio-economic indicators related to these social factors can be explored at different levels (micro- and macro-social). In this regard, the human development index (HDI) is a key indicator that explores dimensions such a long and healthy life (life expectancy), access to knowledge (education) and a decent standard of living (income) (Franco-Herrera et al. 2018).

In many countries, lack of preventive education programs and access to medical services, coupled with other social determinants such as unemployment, political instability, low level of education, malnutrition and lack of access to adequate health services, further complicates the problem, affecting the incidence of and mortality from the disease (Bhutta et al. 2014). Given the above, the goal of the present study is to evaluate the epidemiology of the incidence of and mortality from malaria and its association with the 2017 Human Development Index.

Method

This is an ecological study that investigates the relationship between malaria incidence and the World Development Index. The study data including HDI values and incidence of and mortality from malaria in WHO regions were extracted from the World Bank.

Human development index (HDI)

With numerical values of 0 and 1, the HDI reflects the extent of a country's progress toward the highest possible value, 1, which allows a comparison of countries in this regard. The HDI is an abstract human development measure. It measures the average success of a country according to three main dimensions of human development: a long and healthy life, access to knowledge and decent standards of living. The first dimension is measured by life expectancy at birth. Knowledge is measured by a combination of adult literacy and the specific enrollment ratio in primary, secondary and university education (mean years of schooling) and the standards of living according to the gross national income (GNI) (Bray et al. 2012; Khazaei et al. 2019a, b).

Statistical analysis

In this study, the two-variable correlation method was used to analyze the data extracted to study the correlation between malaria incidence and HDI. The significance level was $P < 0.05$. The analyses were made using Stata software version 12 (Stata Corp, College Station, TX, USA).

Results

Malaria cases

In 2017, an estimated 219 million cases of malaria were reported worldwide (95% CI: 203–262 million) compared with 239 million cases in 2010 (95% CI: 219–285 million). Most of the 2017 cases were in the WHO African Region (92%), followed by the WHO South-East Asia Region (5%) and the WHO Eastern Mediterranean Region (2%). Fifteen countries in sub-Saharan Africa and India carried about 80% of the global malaria burden. Five countries accounted for nearly half of all malaria cases worldwide: Nigeria (25%), Democratic Republic of the Congo (11%), Mozambique (5%), India (4%) and Uganda (4%). The ten counties that carried the highest burden of Malaria in Africa reported growth in the number of malaria cases in 2017 compared to 2016. Of these, Nigeria, Madagascar and the Democratic Republic of the Congo reported the highest estimated increase, all greater than half a million cases. In contrast, India reported 3 million fewer cases in the same period, indicating a 24% decrease compared to 2016. The incidence rate of malaria declined globally between 2010 and 2017, from 72 to 59 cases per 1000 population at risk. Although this figure represents an 18% reduction over this period, the number of cases per 1000 population at risk has remained at 59 over the past 3 years (Figs. 1 and 2).

Figure 3 shows the trend of malaria incidence in the world and in WHO regions in the 2010–2017 period (Fig. 3).

According to the results, the highest global incidence of malaria was reported in 2005 (80.73 per 1000 people) and the lowest in 2017 (59.12 per 1000 persons). The highest incidence was reported in Africa between 2000 and 2017 and the lowest in Europe (Table 1).

Plasmodium falciparum is the most prevalent species of malaria parasite in the WHO African Region, accounting for 99.7% of estimated malaria cases in 2017 as well as in the WHO regions of South-East Asia (62.8%), the Eastern Mediterranean (69%) and the Western Pacific (71.9%). *P. vivax* is the predominant parasite in the WHO Region of the Americas, representing 74.1% of malaria cases (Fig. 4).

Figure 5 shows the trend of malaria mortality in the Global and in WHO regions 2010-2017 period (Fig. 5).

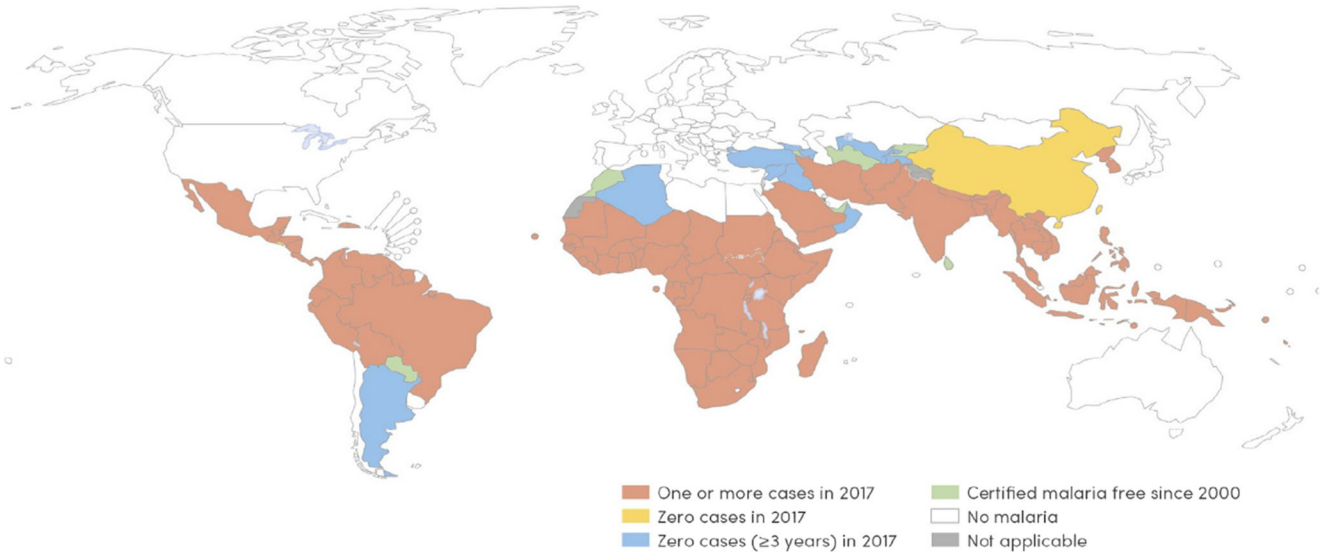


Fig. 1 Countries with indigenous cases of malaria in 2000 and their status in 2017 compared to countries with zero indigenous cases over at least the consecutive years, which are considered malaria free. All countries in the WHO European region reported zero indigenous cases in 2016 and 2017. In 2017, both China and El Salvador reported zero indigenous cases. WHO: World Health Organization (source WHO database)

Malaria deaths

In 2017, there were an estimated 435,000 malaria-induced deaths globally compared with 451,000 estimated deaths in 2016 and 607,000 in 2010.

The WHO African Region accounted for 93% of all malaria deaths in 2017. Although the WHO African Region had the highest rate of malaria deaths in 2017, it also accounted for 88% of the reduction (172,000 cases) in global malaria deaths reported in 2017 compared to 2010.

Nearly 80% of global malaria deaths in 2017 were concentrated in 17 countries in the WHO African Region and India, of which 7 countries accounted for 53% of all global malaria deaths: Nigeria (19%), Democratic Republic of the Congo (11%), Burkina Faso (6%), United Republic of Tanzania (5%), Sierra Leone (4%), Niger (4%) and India (4%).

All WHO regions except the WHO Region of the Americas reported diminished mortality in 2017 compared with 2010. The largest decline was registered in the WHO regions of South-East Asia (54%), Africa (40%) and the Eastern Mediterranean (10%). There has been a continuous decline in global malaria deaths over time.

Table 2 shows malaria deaths in WHO regions and worldwide. As can be seen, the highest rate of malaria

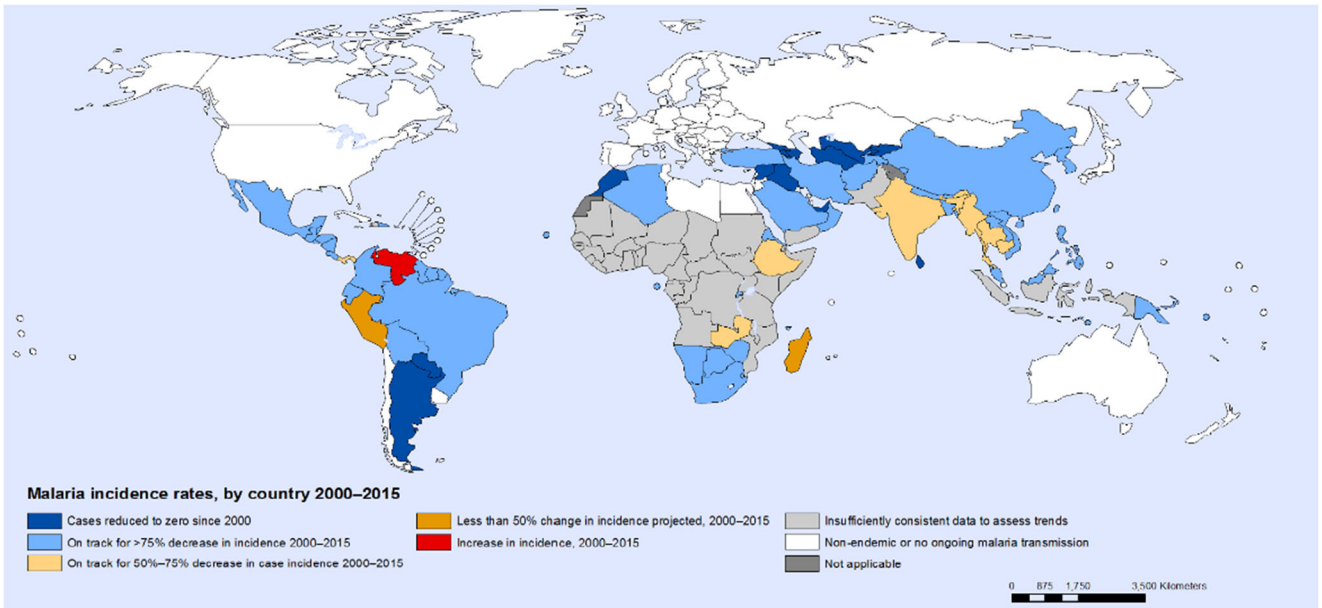


Fig. 2 Projected change in malaria incidence rate in countries, 2000–2015 (source WHO database)

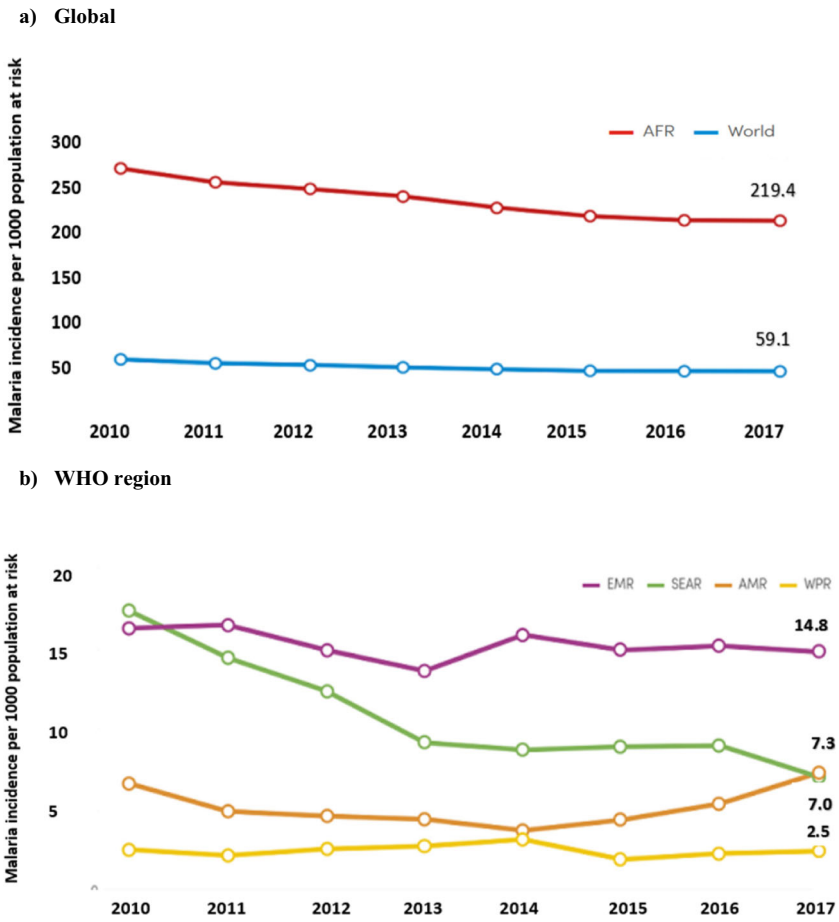


Fig. 3 Trends in malaria incidence rate (cases per 1000 population at risk): **a** globally and **b** by WHO region, 2010–2017 periods. Source: WHO estimates. AFR: WHO African Region; AMR: WHO Region of the Americas; EMR: WHO Eastern Mediterranean Region; SEAR: WHO South-East Asia Region; WPR: WHO Western Pacific Region, WHO: World Health Organization

deaths in the world was reported in 2010 with 607,000 cases and the lowest in 2017 with 435,000 cases. The highest mortality rate was reported in Africa and the lowest in the Region of the Americas. The European region did not report any cases of malaria deaths in these years.

The following diagrams show the trend of malaria deaths worldwide and in WHO regions during 2010–2017.

Table 3 summarizes the epidemiology, reported cases and estimated malaria deaths in the 2017–2010 periods.

Malaria and HDI

Results showed a significant reverse correlation between malaria incidence ($r = -0.640$, $P < 0.0001$) and HDI in 2017 (Fig. 6).

The analysis of HDI decomposites with malaria incidence in 2017 demonstrated a significant negative correlation between malaria incidence and GNI ($r = -0.365$, $P < 0.0001$), MYS ($r = -0.477$, $P < 0.0001$), LEB ($r = -0.694$, $P < 0.0001$) and EYS ($r = 00.458$, $P < 0.0001$) (Table 4).

Table 1 Malaria incidence from 2010 to 2017 by WHO region

WHO region	Malaria incidence (per 1000 population at risk)									
	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
Africa	327.69	323.47	275.13	260.38	253.35	245.42	233.43	224.20	219.92	219.38
Americas	14.58	11.15	6.65	4.93	4.63	4.44	3.74	4.40	5.40	7.31
South-East Asia	20.56	20.92	17.32	14.42	12.37	9.17	8.72	8.92	8.98	7.05
Europe	13.84	1.99	0.06	0.02	0.01	0.00	0.00	0	0	0
Eastern Mediterranean	28.19	21.23	16.23	16.44	14.89	13.60	15.83	14.88	15.14	14.77
Western Pacific	4.80	3.45	2.56	2.19	2.59	2.77	3.19	1.95	2.32	2.47
(WHO) Global	78.87	80.73	71.73	67.72	65.88	63.27	61.20	59.45	59.29	59.12

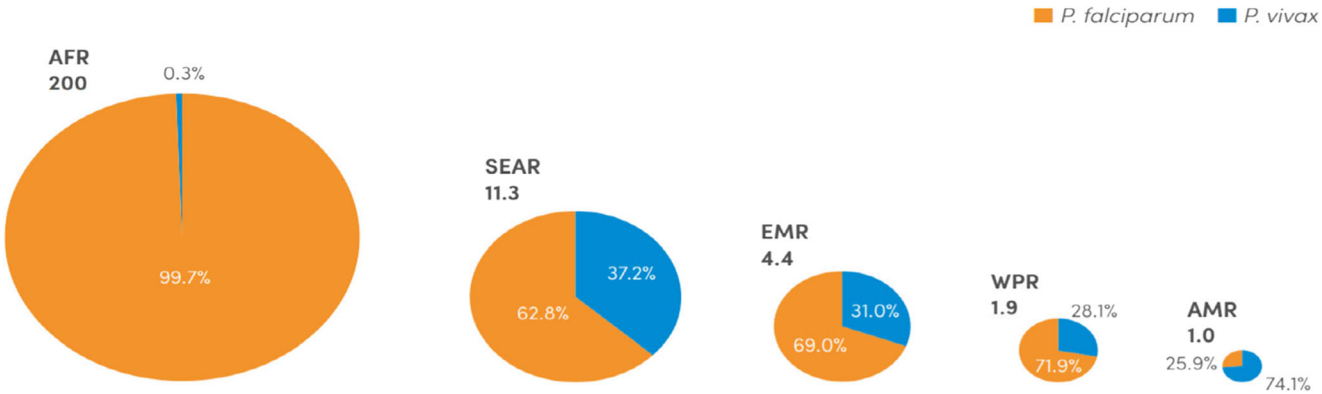


Fig. 4 Estimated malaria cases (millions) by WHO region in 2017. The area of the circles shows the percentage of the estimated number of cases in each region. Source: WHO Estimate. AFR: WHO African Region; AMR: WHO Region of the Americas; EMR: WHO Eastern Mediterranean Region; SEAR: WHO South-East Asia Region; WHO: World Health Organization; WPR: WHO Western Pacific Region (source WHO database)

Discussion

Malaria is one of the most epidemic diseases in the world and is endemic to tropical and subtropical regions. Malaria is an example of diseases that manifest widening socio-economic inequalities (Ahmad et al. 2011; Franco-Herrera et al. 2018). In addition to mortality, malaria infection can cause anemia, low birth weight and abortion. Malaria plagues about 500 million people a year, leading to the death of about million people a year (de Deus Vieira et al. 2014).

The results of our study showed that the highest incidence of malaria in the world is in Africa and the lowest in Europe. In the tropical and subtropical regions of Latin America, there are still several endemic malarial regions that impose a significant burden on the local population. Most cases of malaria in South America occur in the Amazon region. In 2015, the four countries surveyed accounted for 83% of malaria cases in the Americas: Brazil (24%), the Bolivarian Republic of Venezuela (30%), Colombia (10%) and Peru (19%) (WHO 2013).

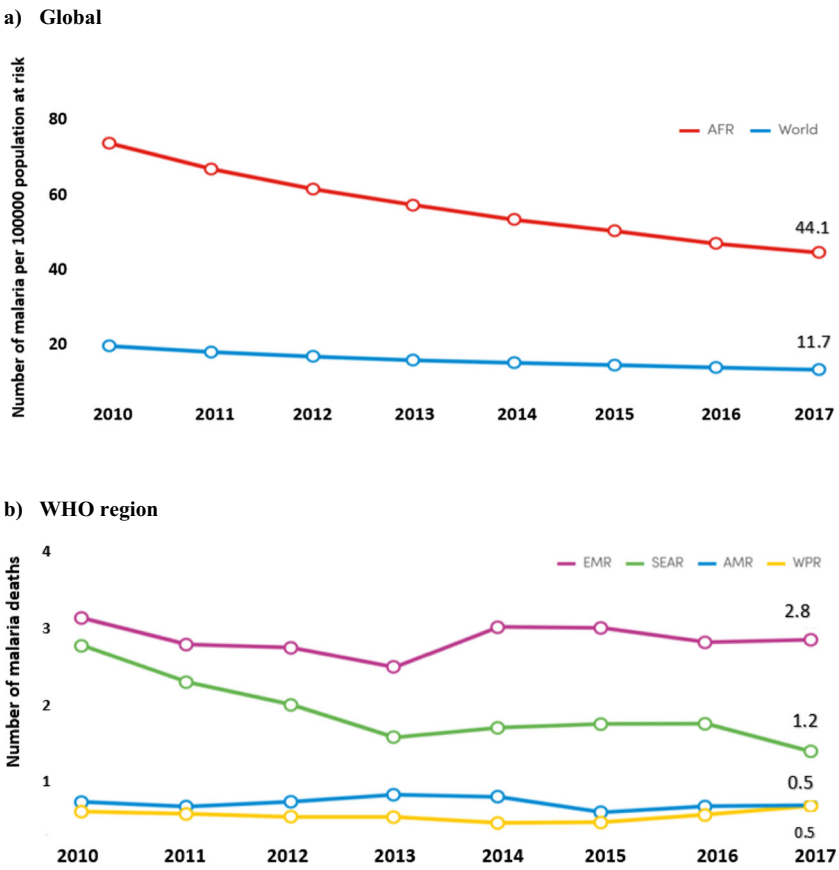


Fig. 5 Trend of malaria mortality rate (deaths per 1000 population at risk), globally and in WHO regions in 2010–2017 periods. Source: WHO estimates. AFR: WHO African Region; AMR: WHO Region of the Americas; EMR: WHO Eastern Mediterranean Region; SEAR: WHO South-East Asia Region; WPR: WHO Western Pacific Region

Table 2 Estimated number of malaria deaths by WHO region, 2010–2017 sources: WHO Estimates

WHO region	Number of deaths							
	2010	2011	2012	2013	2014	2015	2016	2017
African	555000	517000	489000	467000	446000	432000	413000	403000
Americas	480	450	400	400	300	320	460	630
Eastern Mediterranean	8070	7280	7340	6750	8520	8660	8160	8300
European	0	0	0	0	0	0	0	0
South-East Asia	39800	32800	28400	21800	24100	25200	25600	19700
Western Pacific	3770	3340	3850	4600	4420	2860	3510	3620
World	607000	561000	529000	500000	483000	469000	451000	435000

In developed countries, the incidence of HDI-related malaria is low. In recent years, malaria has reappeared in temperate regions such as Greece, the Korean Peninsula and Australia (Brachman 1998; Danis et al. 2011; Hanna et al. 2004). In the region of the Americas, malaria transmission was reported in 21 countries, where 203 million people live in areas at high risk of infection (Renault et al. 2007).

Differences in the incidence and mortality rate of malaria in people of different social strata may indicate the role of socio-economic status, rapid and convenient access to health services, unemployment, low education, malnutrition and lack of access to primary health care in this regard (Bhutta et al. 2014).

The results of this study suggest that there was a significant negative correlation between malaria incidence ($R = -0.640$, $P < 0.0001$) and HDI in 2017. The higher incidence of malaria in countries with lower HDIs can be explained by delayed use of diagnostic methods, poor economic status and geographical conditions.

The highest incidence of HDI-related malaria in the world is in countries with low HDI values. The highest mortality rate for HDI-related malaria is reported in African countries. In the past decade, countries in the Latin American region (except for Venezuela) have witnessed a decrease in the incidence of the disease (Medina-Morales et al. 2016). It is estimated that about 1 million lives have been taken by the disease in Africa (Murray et al. 2012).

Malaria is more prevalent in countries with low HDI values, especially in sub-Saharan Africa, where poverty is widespread and there is low economic growth (Sachs and Malaney 2002; Teklehaimanot and Mejia 2008). Twenty percent of the world's poorest populations comprise 58% of malaria deaths. An increase of macro-level evidence indicates that there is a causal link between malaria and low socio-economic levels (Gallup and Sachs 2001; Sachs and Malaney 2002).

A review of micro-level analyses (family and population) on the relationship between malaria and socio-economic status obtained different results (Worrall et al. 2005).

In Ghana, the social class did not indicate the malaria risk. In Tanzania, there was no reported association between malaria and and socio-economic status (SES), but the prevalence of malaria was significantly higher among lower SES individuals (Somi et al. 2008).

In Sonko et al.'s study, the prevalence of malaria, even after adjusting for age, sex and health area, regardless of age group, was strongly associated with the level of development (Sonko et al. 2014). In studies conducted in the African desert, employment and housing were associated with malarial infection (Ayele et al. 2012, 2014; Clarke et al. 2001; De Beaudrap et al. 2011; Gahutu et al. 2011; Winskill et al. 2011; Worrall et al. 2005).

Historically, malaria has been eradicated in the USA, Italy, Greece and Spain through socio-economic development and intensive anti-malarial interventions such as housing improvement. In Gambia, a randomized controlled trial showed that controlling doors and windows and proper housing related to contact with malaria pistachios reduced the risk of malaria among children by 50% (Kirby et al. 2009).

This randomized controlled trial has proven that advances in housing quality can greatly reduce malaria transmission and its occurrence.

In Mozambique (Temu et al. 2012), Eritrea (Ghebreyesus et al. 2000; Sintasath et al. 2005) and the Democratic Republic of Laos, living in grass-roofed houses increased the probability of contracting malaria (Hiscox et al. 2013). Similarly, houses built with bamboo walls, windows and doors, and often inhabited by people of lower SES, allow mosquitoes to enter the house (Hiscox et al. 2013). The mud used as a wall material was associated with a high prevalence of malaria (Bousema et al. 2010).

Franco-Herrera et al.'s (2018) study did not reveal any significant association between malaria and HDI incidence in five of the six countries studied (except for Venezuela) during 2005–2015 (Franco-Herrera et al. 2018). A 2014 study by de Deus Vieira et al. showed that there was a significant positive correlation between malaria incidence and HDI. This correlation was stronger in people from lower socio-economic backgrounds (de Deus Vieira et al. 2014).

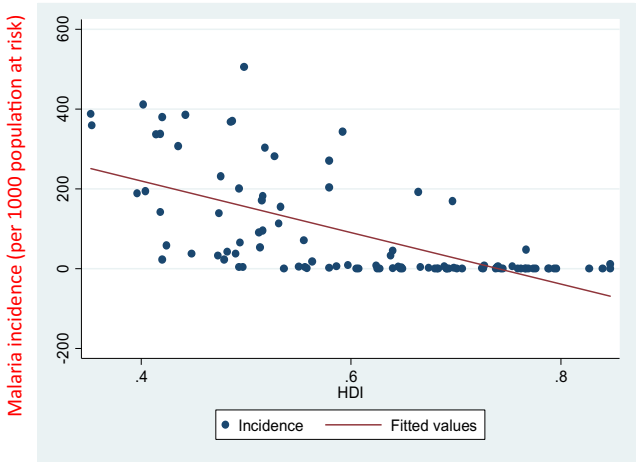
A 2004 study by Jean et al. did not exhibit a significant relationship between the incidence of malaria in newborns and

Table 3 Summary of epidemiology and malaria status in the WHO regions (sources: WHO Estimates)

Continents of the world	Epidemiology	Reported cases and deaths, 2010–2017	Estimated cases and deaths, 2010–2017
West Africa	Population at risk: 374 million Parasites: P. falciparum (almost 100%) Vectors: An. arabiensis, An. funestus, An. gambiae, An. hispaniola, An. labranchiae, An. melas, An. moucheti, An. multicolor, An. nili, An. pharoensis and An. sergentii	Total presumed and confirmed cases: 29.1 million (2010), 52.0 million (2015), 57.9 million (2017); increase 2010–2017: 99%; increase 2015–2017: 11% Total confirmed cases: 6.9 million (2010), 32.7 million (2015), 41.1 million (2017); increase 2010–2017: 495%; increase 2015–2017: 26% Total deaths: 39 000 (2010), 21 600 (2015), 18 400 (2017); decrease 2010–2017: 53%; increase 2015–2017: 15%	Cases: 116.1 million (2010), 102.0 million (2015), 104.2 million (2017); decrease 2010–2017: 10% Deaths: 320 000 (2010), 231 000 (2015), 205 000 (2017); decrease 2010–2017: 36%
Central Africa	Population at risk: 174 million Parasites: P. falciparum (100%) Vectors: An. arabiensis, An. funestus, An. gambiae, An. hancocki, An. melas, An. moucheti, An. nili and An. pharoensis	Total presumed and confirmed cases: 20.4 million (2010), 25.4 million (2015), 34.1 million (2017); increase 2010–2017: 67%; increase 2015–2017: 34% Total confirmed cases: 6.3 million (2010), 22.2 million (2015), 30.4 million (2017); increase 2010–2017: 383%; increase 2015–2017: 37% Total deaths: 40 400 (2010), 58 200 (2015), 55 300 (2017); increase 2010–2017: 37%; decrease 2015–2017: 5%	Cases: 41.0 million (2010), 43.9 million (2015), 45.5 million (2017); increase 2010–2017: 11% Deaths: 117 700 (2010), 94 100 (2015), 92 300 (2017); decrease 2010–2017: 22%
East and Southern Africa	Population at risk: 350 million Parasites: P. falciparum (89%) and P. vivax (11%) Vectors: An. arabiensis, An. funestus, An. gambiae, An. merus, An. nili and An. pharoensis	Total presumed and confirmed cases: 53.2 million (2010), 56.2 million (2015), 58.9 million (2017); increase 2010–2017: 11%; increase 2015–2017: 5% Total confirmed cases: 13.5 million (2010), 34.0 million (2015), 45.6 million (2017); increase 2010–2017: 238%; increase 2015–2017: 34% Total deaths: 70 700 (2010), 38 300 (2015), 20 100 (2017); decrease 2010–2017: 72%; decrease 2015–2017: 48%	Cases: 49.1 million (2010), 47.8 million (2015), 50.6 million (2017); increase 2010–2017: 3% Deaths: 116 000 (2010), 105 400 (2015), 103 600 (2017); decrease 2010–2017: 11%
East and Southern Africa	Population at risk: 15 million Parasites: P. falciparum (98%) and P. vivax (2%) Vectors: An. funestus, An.gambiae s.s. and An. gambiae	Total presumed and confirmed cases: 205 300 (2010), 48 000 (2015), 132 500 (2017); decrease 2010–2017: 35%; increase 2015–2017: 176% Total confirmed cases: 82 400 (2010), 33 900 (2015), 112 700 (2017); increase 2010–2017: 37%; increase 2015–2017: 233% Total deaths: 242 (2010), 178 (2015), 453 (2017); increase 2010–2017: 87%; increase 2015–2017: 154%	Cases: 134 000 (2010), 87 400 (2015), 235 000 (2017); increase 2010–2017: 75% Deaths: 347 (2010), 294 (2015), 741 (2017); increase 2010–2017: 114%
Region of the Americas	Population at risk: 138 million Parasites: P. vivax (75.6%), P. falciparum and mixed (24.3%), and other	Total presumed and confirmed cases: 677 200 (2010), 450 100 (2015), 773 500 (2017); increase 2010–2017: 14%; increase 2015–2017: 72% Total confirmed cases: 677 200 (2010), 450 100 (2015), 773 500 (2017); increase 2010–2017: 14%; increase 2015–2017: 72% Total deaths: 190 (2010), 98 (2015), 87 (2017); decrease 2010–2017: 54%; decrease 2015–2017: 11%	Cases: 813 500 (2010), 573 200 (2015), 975 700 (2017); increase 2010–2017: 20% Deaths: 475 (2010), 316 (2015), 625 (2017); increase 2010–2017: 32%
Eastern Mediterranean Region	Population at risk: 299 million Parasites: P. falciparum and mixed (64%) and P. vivax (36%) Vectors: An. arabiensis, An. culicifacies, An. d'thali, An. fluviatilis, An. funestus, An. hyrcanus, An. labranchiae, An. maculipennis s.s., An. pulcherrimus, An. sacharovi, An. sergentii, An. stephensi, An. subpictus and An. superpictus	Total presumed and confirmed cases: 6.369 million (2010), 5.402 million (2015), 4.113 million (2017); decrease 2010–2017: 35%; decrease 2015–2017: 24% Total confirmed cases: 1.165 million (2010), 999 200 (2015), 1.462 million (2017); increase 2010–2017: 25%; increase 2015–2017: 46% Total deaths: 1143 (2010), 1016 (2015), 1627 (2017); increase 2010–2017: 42%; increase 2015–2017: 60%	Cases: 4.255 million (2010), 4.377 million (2015), 4.410 million (2017); increase 2010–2017: 4% Deaths: 8070 (2010), 8660 (2015), 8300 (2017); increase 2010–2017: 3%
South-East Asia Region	Population at risk: 1.6 billion Parasites: P. falciparum and mixed (62%), P. vivax (37%)	Total presumed and confirmed cases: 4.887 million (2010), 1.651 million (2015), 1.244 million (2017); decrease 2010–2017: 75%; decrease 2015–2017: 25% Total confirmed cases: 2.676 million (2010), 1.618 million (2015), 1.233 million (2017); decrease 2010–2017: 54%; decrease 2015–2017: 24% Total deaths: 2421 (2010), 620 (2015), 299 (2017); decrease 2010–2017: 88%; decrease 2015–2017: 52%	Cases: 25.5 million (2010), 14.0 million (2015), 11.3 million (2017); decrease 2010–2017: 56% Deaths: 39 800 (2010), 25 200 (2015), 19 700 (2017); decrease 2010–2017: 50%
Western Pacific Region	Population at risk: 753 million Parasites: P. falciparum and mixed (71%), P. vivax (28%)	Total presumed and confirmed cases: 1.654 million (2010), 708 400 (2015), 1.032 million (2017); decrease 2010–2017: 38%; increase 2015–2017: 46% Total confirmed cases: 259 500 (2010), 410 700 (2015), 602 100 (2017); increase 2010–2017: 132%; increase 2015–2017: 47% Total deaths: 910 (2010), 235 (2015), 335 (2017); decrease 2010–2017: 63%; increase 2015–2017: 43%	Cases: 1.838 million (2010), 1.451 million (2015), 1.857 million (2017); increase 2010–2017: 1% Deaths: 3769 (2010), 2853 (2015), 3617 (2017); decrease 2010–2017: 4%

HDI. The observed difference in the incidence and mortality rate of malaria related to other contributing factors could be attributed to distinctions in individuals' social classes (Van Geertruyden et al. 2004).

Social and economic developments have had a major impact on the incidence of and mortality from malaria. Malaria risk is on the rise in low- and middle-income countries. Adverse economic conditions, population density and environmental temperature conducive to mosquito growth and proliferation are among the HDI-related malaria risk factors. The incidence of and mortality from malaria have been linked to the economic growth of societies, with the majority of malaria-related deaths being reported in poor and low-income countries (Were et al. 2018, 2019).



R Sq. linear=-0.640, P<0.0001

Fig. 6 Correlation between HDI and malaria incidence in 2017 worldwide

The goals of the HDI, other than income and material prosperity, are concerned with long-term life satisfaction of individuals in different societies. They also focus on human development, indicating that the real purpose of development programs is to ultimately create favorable conditions for healthy, creative and happy living (Bhutta et al. 2014). An important factor that affects the high rate of malaria incidence in most countries is poor socio-economic status, and therefore an effective step to reduce the incidence of this disease and many other chronic diseases could be improving the economic status of households (Franco-Herrera et al. 2018). The incidence and mortality rate of HDI-related malaria has declined in many countries. Early prevention and conducting epidemiological studies, timely treatment and follow-up of malaria patients, especially those in less developed countries, can also contribute to decreasing the incidence of this disease.

Our study showed that there is a significant relationship between the incidence of malaria and the level of education, so that the higher the level of education is, the lower the incidence of malaria.

Various studies have shown an association between increased levels of education and reduced mortality and mortality from malaria (Fairlie 2005; Vikram et al. 2012).

Previous studies have shown that parental education increases knowledge related to health and increases their acceptance of health messages. Health messages are provided to individuals through a variety of sources, including health infrastructure, mass media and other social networks. In the Philippines, one study found that with every 1 year of maternal education, the likelihood of using preventive services increased by 4% (Basu and Stephenson 2005).

Educated people are also more likely to live in communities with better access to health care and better infrastructure, including water and sewage services, which reduces the risk of malaria. Educated people may have broader social networks that improve their knowledge of health, health behaviors and prevention techniques.

In the study by Njau et al. (2014), the results showed that even after controlling these background characteristics, children of educated mothers are less likely to develop malaria than mothers with low levels of education.

Conclusion

The results suggest that a low HDI in countries is associated with a higher incidence of malaria. Hence, more attention must be paid to factors associated with the incidence of the disease in these countries. By taking effective preventive measures and raising awareness about the transmission paths of the disease, its incidence worldwide, including in African countries and countries with lower income levels, can be reduced.

Study limitations

Given that this article is the result of data recorded in the World Bank, and given that the registration system in countries has different sensitivities and characteristics, some countries may have more accurate reports on diagnosis and registration due to a better registry. Disease reporting varies from country to country, so the differences in the reported incidence of this disease could partly indicate the differences in the systems of registration and reporting, which can be considered a limitation of this study.

Table 4 Pearson correlation between HDI dimensions and malaria incidence in 2017

Components HDI	Malaria incidence (per 1000 population at risk)	
	r	P-value
Gross national income per 1000 capita (GNI)	-0.365	P<0.0001
Mean years of schooling (MYS)	-0.477	P<0.0001
Life expectancy at birth (LEB)	-0.694	P<0.0001
Expected years of schooling (EYS)	-0.458	P<0.0001

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Compliance with ethical standards

Conflict of interest There are no conflicts of interest.

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References

Ahmad R, Ali WN, Nor ZM, Ismail Z, Hadi AA, Ibrahim MN, Lim LH (2011) Mapping of mosquito breeding sites in malaria endemic areas in Pos Lenjang, Kuala Lipis, Pahang, Malaysia. Malar J 10(1):361. https://doi.org/10.1186/1475-2875-10-361

Ayele DG, Zewotir TT, Mwambi HG (2012) Prevalence and risk factors of malaria in Ethiopia. Malar J 11(1):195. https://doi.org/10.1186/1475-2875-11-195

Ayele DG, Zewotir TT, Mwambi HG (2014) Semiparametric models for malaria rapid diagnosis test result. BMC Public Health 14(1):31. https://doi.org/10.1186/1471-2458-14-31

Basu AM, Stephenson R (2005) Low levels of maternal education and the proximate determinants of childhood mortality: a little learning is not a dangerous thing. Soc Sci Med 60(9):20. https://doi.org/10.1016/j.socscimed.2004.08.057

Beaudrap D, Pierre CN, Grandesso F, Turyakira E, Schramm B, Boum Y, Etard J-F (2011) Heterogeneous decrease in malaria prevalence in children over a six-year period in South-Western Uganda. Malar J 10(1):132. https://doi.org/10.1186/1475-2875-10-132

Bhatt S, Weiss D, Cameron E, Bisanzio D, Mappin B, Dalrymple U, Eckhoff P (2015) The effect of malaria control on Plasmodium falciparum in Africa between 2000 and 2015. Nature 526(7572):207–211. https://doi.org/10.1038/nature15535

Bhutta ZA, Sommerfeld J, Lassi ZS, Salam RA, Das JK (2014) Global burden, distribution, and interventions for infectious diseases of poverty. Infectious diseases of poverty 3(1):21. https://doi.org/10.1186/2049-9957-3-21

Bousema T, Drakeley C, Gesase S, Hashim R, Magesa S, Mosha F, Otieno S, Carneiro I, Cox J, Msuya E (2010) Identification of hot spots of malaria transmission for targeted malaria control. J Infect Dis 201(11):1764–1774. https://doi.org/10.1086/652456

Brachman PS (1998) Reemergence of Plasmodium vivax malaria in the Republic of Korea. Emerg Infect Dis 4(4):707. https://doi.org/10.3201/eid0404.980432

Bray F, Jemal A, Grey N, Ferlay J, Forman D (2012) Global cancer transitions according to the human development index (2008–2030): a population-based study. Lancet Oncol 13(8):790–801. https://doi.org/10.1016/S1470-2045(12)70211-5

Clarke SE, Bøgh C, Brown RC, Pinder M, Walraven GEL, Lindsay SW (2001) Do untreated Bednets protect against malaria? Trans R Soc Trop Med Hyg 95(5):457–462. https://doi.org/10.1016/S0035-9203(01)90001-X

Danis K, Baka A, Lenglet A, Van Bortel W, Terzaki I, Tseroni M, Gewehr S (2011) Autochthonous Plasmodium vivax malaria in Greece, 2011. Eurosurveillance 16(42):19993

de Deus Vieira G, Gim KNM, Zaqueo GM, da Cunha AT, Katsuragawa TH, de Almeida BS, de Sousa CM (2014) Reduction of incidence and relapse or recrudescence cases of malaria in the western region of the Brazilian Amazon. The Journal of Infection in Developing Countries 8(09):1181–1187. https://doi.org/10.3855/jidc.4422

Eperon G, Durieux-Paillard S, Mauris A, Chappuis F, Gysin N (2017) Malaria cases in Switzerland from 2005 to 2015 and recent rise of imported Plasmodium vivax malaria. Swiss Med Wkly 147(41):142. https://doi.org/10.4414/smw.2017.14510

Fairlie RW (2005) An extension of the blinder-Oaxaca decomposition technique to logit and Probit models. J Econ Soc Meas 30(4):305–316. https://doi.org/10.3233/JEM-2005-0259

Franco-Herrera D, González-Ocampo D, Restrepo-Montoya V, Gómez-Guevara JE, Alvear-Villacorte N, Rodíguez-Morales AJ (2018) Relationship between malaria epidemiology and the human development index in Colombia and Latin America. Le infezioni in medicina 26(3):255–262

Gahutu J-B, Steininger C, Shyirambere C, Zeile I, Cwinya-Ay N, Danquah I, Larsen CH, Eggelte TA, Aline Uwimana and Corine Karema (2011) Prevalence and risk factors of malaria among children in southern Highland Rwanda. Malar J 10(1):134. https://doi.org/10.1186/1475-2875-10-134

Gallup JL, Sachs JD (2001) The economic burden of malaria. Am J Trop Med Hyg 64(1_suppl):85–96. https://doi.org/10.4269/ajtmh.2001.64.85

Ghebreyesus TA, Haile M, Witten KH, Getachew A, Yohannes M, Lindsay SW, Byass P (2000) Household risk factors for malaria among children in the Ethiopian highlands. Trans R Soc Trop Med Hyg 94(1):17–21. https://doi.org/10.1016/S0035-9203(00)90424-3

Hanna JN, Ritchie SA, Brookes DL, Montgomery BL, Eisen DP, Cooper RD (2004) An outbreak of Plasmodium vivax malaria in far North Queensland, 2002. Med J Aust 180(1):24–28. https://doi.org/10.5694/j.1326-5377.2004.tb05769.x

Hiscox A, Khammanithong P, Kaul S, Sananikhom P, Luthi R, Hill N, Brey PT, Lindsay SW (2013) Risk factors for mosquito house entry in the Lao Pdr. PLoS One 8(5):132. https://doi.org/10.1371/journal.pone.0062769

Kasetsirikul S, Buranapong J, Srituravanich W, Kaewthamasorn M, Pimpin A (2016) The development of malaria diagnostic techniques: a review of the approaches with focus on dielectrophoretic and magnetophoretic methods. Malar J 15(1):358. https://doi.org/10.1186/s12936-016-1400-9

Khazaei Z, Sohrabivafa M, Mansori K, Naemi H, Goodarzi E (2019a) Incidence and mortality of cervix cancer and their relationship with the human development index in 185 countries in the world: an ecology study in 2018. Advances in Human Biology 9(3):222. https://doi.org/10.4103/AIHB.AIHB_15_19

Khazaei Z, Jarrahi AM, Momenabadi V, Ghorat F, Adineh H, Sohrabivafa M, Goodarzi E (2019b) Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide stomach cancers and their relationship with the human development index (HDI). World Cancer Research Journal 6:9

Kirby MJ, Ameh D, Bottomley C, Green C, Jawara M, Milligan PJ, Snell PC, Conway DJ, Lindsay SW (2009) Effect of two different house screening interventions on exposure to malaria vectors and on Anaemia in children in the Gambia: a randomised controlled trial. Lancet 374(9694):998–1009. https://doi.org/10.1016/S0140-6736(09)60871-0

Medina-Morales DA, Montoya-Franco E, Sanchez-Aristizabal V, Machado-Alba JE, Rodríguez-Morales AJ (2016) Severe and benign Plasmodium vivax malaria in Embera (Amerindian) children and adolescents from an endemic municipality in Western Colombia. Journal of infection and public health 9(2):172–180. https://doi.org/10.1016/j.jiph.2015.09.001

Murray CJ, Rosenfeld LC, Lim SS, Andrews KG, Foreman KJ, Haring D, Lopez AD (2012) Global malaria mortality between 1980 and 2010: a systematic analysis. Lancet 379(9814):413–431. https://doi.org/10.1016/S0140-6736(12)60034-8

Njau JD, Stephenson R, Menon MP, Kachur SP, McFarland DA (2014) Investigating the important correlates of maternal education and

childhood malaria infections. Am J Trop Med Hyg 91(3):509–519. https://doi.org/10.4269/ajtmh.13-0713

Qin L, Chen C, Chen L, Xue R, Ou-Yang M, Zhou C, He J (2017) Worldwide malaria incidence and cancer mortality are inversely associated. Infectious agents and cancer 12(1):14. https://doi.org/10.1186/s13027-017-0117-x

Renault CS, Bastos FA, Filgueira JPPS, Homma TK (2007) Epidemiologia da malária no município de Belém-Pará. Revista Paraense de Medicina 21(3):19–24

Sachs J, Malaney P (2002) The economic and social burden of malaria. Nature 415(6872):680–685. https://doi.org/10.1038/415680a

Sintasath DM, Ghebremeskel T, Lynch M, Kleinau E, Bretas G, Shililu J, Brantly E, Graves PM, Beier JC (2005) Malaria prevalence and associated risk factors in Eritrea. Am J Trop Med Hyg 72(6):682–687. https://doi.org/10.4269/ajtmh.2005.72.682

Somi MF, Butler JR, Vahid F, Njau JD, Kachur SP, Abdulla S (2008) Use of proxy measures in estimating socioeconomic inequalities in malaria prevalence. Tropical Med Int Health 13(3):354–364. https://doi.org/10.1111/j.1365-3156.2008.02009.x

Sonko ST, Jaiteh M, Jafali J, Jarju LBS, D'Alessandro U, Camara A, Komma-Bah M, Saho A (2014) Does socio-economic status explain the differentials in malaria parasite prevalence? Evidence from the Gambia. Malar J 13(1):449. https://doi.org/10.1186/1475-2875-13-449

Teklehaimanot A, Mejia P (2008) Malaria and poverty. Ann N Y Acad Sci 1136(1):32–37

Temu EA, Coleman M, Abilio AP, Kleinschmidt I (2012) High prevalence of malaria in Zambezia, Mozambique: the protective effect of Irs versus increased risks due to pig-keeping and house construction. PLoS One 7(2):238. https://doi.org/10.1371/journal.pone.0031409

Thellier M, Simard F, Musset L, Cot M, Velut G, Kendjo E, Pradines B (2019) Changes in malaria epidemiology in France and worldwide, 2000–2015. Medecine et maladies infectieuses 50(2):99–112. https://doi.org/10.1016/j.medmal.2019.06.002

Van Geertruyden JP, Thomas F, Erhart A, D'Alessandro U (2004) The contribution of malaria in pregnancy to perinatal mortality. Am J Trop Med Hyg 71(2_suppl):35–40. https://doi.org/10.4269/ajtmh.2004.71.35

Vikram K, Vanneman R, Desai S (2012) Linkages between maternal education and childhood immunization in India. Soc Sci Med 75(2):331–339. https://doi.org/10.1016/j.socscimed.2012.02.043

Were V, Buff AM, Desai M, Kariuki S, Samuels A, Ter Kuile FO, Niessen L (2018) Socioeconomic health inequality in malaria indicators in rural western Kenya: evidence from a household malaria survey on burden and care-seeking behaviour. Malar J 17(1):166. https://doi.org/10.1186/s12936-018-2319-0

Were V, Buff AM, Desai M, Kariuki S, Samuels A, Phillips-Howard NLW (2019) Trends in malaria prevalence and health related socioeconomic inequality in rural western Kenya: results from repeated household malaria cross-sectional surveys from 2006 to 2013. BMJ Open 9(9):e033883. https://doi.org/10.1136/bmjopen-2019-033883

WHO (2013) World malaria report 2013. World Health Organization, Geneva

Winskill P, Rowland M, Mtove G, Malima RC, Kirby MJ (2011) Malaria risk factors in north-east Tanzania. Malar J 10(1):98. https://doi.org/10.1186/1475-2875-10-98

Worrall E, Basu S, Hanson K (2005) Is malaria a disease of poverty? A review of the literature. Tropical Med Int Health 10(10):1047–1059. https://doi.org/10.1111/j.1365-3156.2005.01476.x

Yang Y, Liu Y, Xie Z, Wu S, Yang L, Li W, Quan X (2018) Epidemiology of malaria in Yulin, South China 1999–2016: imported malaria threatens zero local case status. Vector-Borne and Zoonotic Diseases 18(10):533–538. https://doi.org/10.1089/vbz.2017.2236