The uncertain burden of *Plasmodium falciparum* epidemics in Africa

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Although the control of malaria epidemics has been a priority for the World Health Organization and other agencies for many years, surprisingly little is known about the public health burden of these epidemics. Here, we evaluate the available evidence of the morbidity and mortality impacts of individual epidemics in Africa and examine the problems associated with using these data to estimate the average annual burden of epidemics at national and continental scales. We argue that conventional approaches that are used to assess the burden of epidemics are inadequate, and outline the future steps that are required to produce estimates that are more accurate.

The burden of malaria epidemics in Africa

There have been renewed efforts in recent years to understand the determinants, epidemiology and public health impact of *Plasmodium falciparum* malaria epidemics in Africa. Commitment to tackling this major public health problem has been reaffirmed by the Roll Back Malaria (RBM: http://www.rbm.who.int) partnership. This partnership has adopted epidemic detection and response as one of the four principal pathways through which to achieve its mandate of reducing by half the global burden of malaria risk, morbidity and mortality by 2010 [1]. Reducing the impact of epidemics remains a prominent goal in the revised strategy of RBM for 2005–2015 [2].

Malaria control in epidemic-prone areas represents a different challenge from that in endemic settings [3]. In Africa, populations that are exposed to the risks of epidemics reside in areas of unstable malaria transmission. These areas are commonly along the fringes of stable, endemic malaria transmission. These populations have little or no acquired functional clinical immunity, and the consequences of rapid expansion of parasite transmission can have potentially devastating public health impacts. The challenges of detecting sudden upsurges in transmission, mobilizing resources and rapidly deploying interventions to mitigate the public health impact of epidemics cannot be met by routinely applying prevention and control tools from endemic settings. In particular, an effective response to epidemics can be achieved only through precise and accurate targeting of interventions (typically, indoor residual spraying or mass drug administration) in space and time—a fact that places special emphasis on disease surveillance systems.

There have been two systematic attempts to describe the disease burden due to malaria epidemics in Africa. Snow et al. [4] reviewed the available literature, estimated the average clinical attack and mortality rates associated with individual epidemics and went on to derive average annualized estimates of morbidity and fatal outcomes. This was done using combinations of assumptions regarding epidemic duration, periodicity and populations potentially at risk of unstable transmission derived from climate-based models of malaria risk. Worrall et al. [5] undertook

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**Glossary**

- **All-cause mortality rate**: the number of deaths per population per unit time from any cause. In emergencies, this is usually per 10 000 persons per day and can be age stratified.
- **Annualized estimate (burden) of morbidity and mortality**: the mean burden of malaria epidemics per year, expressed as total episodes and/or deaths or in terms of attack rate or cumulative mortality rate per PAR.
- **Case fatality rate**: the proportion of episodes resulting in death.
- **Clinical attack rate**: the cumulative proportion of the population that experiences an episode of malaria over a defined time period. The term 'clinical' indicates that the episode was symptomatic and that the diagnosis was established presumptively, without parasitological confirmation.
- **Duration of epidemic events**: the time elapsed between the onset and the end of the epidemic.
- **Epidemic burden**: the sum of the public health consequences of the epidemic within the population affected by it over its entire duration. This includes a minimum morbidity and mortality in excess of that expected, in addition to indirect consequences such as long-term sequelae of infection, increased rates of anaemia and malnutrition, economic losses and decreased educational achievement.
- **Epidemic periodicity**: the average frequency with which epidemics occur in a given region or population.
- **Epidemic stratum**: the subregion or subpopulation within the entire population that is characterized by specific aetiology, demography and pattern of disease transmission.
- **Malaria-specific mortality rate**: the mortality rate attributed to malaria.
- **Passive case detection**: the detection of malaria cases based on the spontaneous presentation of ill patients to fixed health services.
a similar analysis using different approaches to estimate populations at risk (PAR) and different parameter estimates of the average clinical attack rate, case fatalities and epidemic periodicity (see Glossary). Neither approach has been validated and the sensitivities of the implicit assumptions have not been tested.

**Burden of individual epidemics**

Attempts to estimate the disease burden associated with individual epidemics have been hampered in two ways. First, the term 'epidemic' has been used to refer to a wide range of scenarios, from 'classic' large epidemics in non-immune populations [6] – a situation that is further complicated by the many and various ecological and anthropogenic determinants of epidemics [7,8]. The lack of clarity in definitions of epidemics makes comparisons between epidemic events difficult and, therefore, reduces the extent to which ‘aggregated’ sets of epidemic data are representative. Second, and more fundamentally, little reliable data exists regarding the risk of morbidity and mortality in epidemic situations. In Africa, for example, the most exhaustive review of data on malaria burden to date was carried out by Snow et al. [4], who found only 15 reports on morbidity and mortality risks during epidemics for the period 1929–1988 (of which half referred to events that occurred before 1960). To our knowledge, the only reliable estimates of epidemic-related mortality since that time have come from retrospective surveys carried out by the World Health Organization (WHO: http://www.who.int) [9] and Epicentre at Médecins Sans Frontières (http://www.epicentre.msf.org) [10,11].

Combining Snow et al.’s dataset with these more recent data for Africa provides a total of 12 records of all-cause mortality rates during malaria epidemics and ten records of malaria-specific mortality (although the reliability and appropriateness of this distinction are moot). Summary statistics from these records indicate median mortality rates of 2.3 and 1.6 deaths per 10 000 population per day for all-cause and malaria-specific estimates, respectively. Where all-cause or malaria-specific mortality rates among children are reported, they tend to be higher than corresponding rates in the general population. Data on clinical attack rates from 11 reports indicate an overall median morbidity rate of 32.2 per 10 000 population per day (Table 1). Eight reports contained estimates of the case fatality rate (data not shown in table) either among inpatients who attended fixed or mobile clinics or based on comparisons of community estimates of morbidity cases and deaths (range = 3–21%, median = 6%). These relatively high rates are thought to reflect a high occurrence of acute, life-threatening disease (and cerebral malaria in particular) and the relatively wide range of ages affected during epidemics. However, they could result, in equal measure, from poor access to health services, inadequate case management, overwhelmed health services, poor immunological competence because of malnutrition, a general disruption to livelihoods because of often-associated flooding, or a combination of these factors.

The daily disease rates shown in Table 1 are higher than one would expect among populations exposed to stable *Plasmodium falciparum* transmission [12]. In Africa, the most notable epidemic event occurred in Ethiopia in 1958 and was responsible for an estimated 150 000 deaths among a largely nonimmune population with little access to curative services.

### Table 1. Key indicators of burden for individual malaria epidemic events

<table>
<thead>
<tr>
<th>Locality</th>
<th>Dates</th>
<th>Malaria morbidity rate (cases/10 000/day)</th>
<th>All-cause mortality rate (deaths/10 000/day)</th>
<th>Malaria-specific mortality rate (deaths/10 000/day)</th>
<th>Refs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>All ages</td>
<td>All ages Under five years</td>
<td>All ages Under five years</td>
<td></td>
</tr>
<tr>
<td>Kitale, Kenya</td>
<td>1929</td>
<td>4.1</td>
<td>–</td>
<td>–</td>
<td>[40]</td>
</tr>
<tr>
<td>Mupumulo, South Africa</td>
<td>1931–1932</td>
<td>5.2</td>
<td>2.4</td>
<td>–</td>
<td>[41]</td>
</tr>
<tr>
<td>Eshowe, South Africa</td>
<td>1931–1932</td>
<td>3.4</td>
<td>–</td>
<td>–</td>
<td>[41]</td>
</tr>
<tr>
<td>Munzini, South Africa</td>
<td>1931–1932</td>
<td>2.0</td>
<td>–</td>
<td>–</td>
<td>[41]</td>
</tr>
<tr>
<td>Nkandah, South Africa</td>
<td>1931–1932</td>
<td>2.5</td>
<td>–</td>
<td>–</td>
<td>[41]</td>
</tr>
<tr>
<td>Kericho, Kenya</td>
<td>1942–1947</td>
<td>8.9</td>
<td>–</td>
<td>–</td>
<td>[42]</td>
</tr>
<tr>
<td>Lake Tana area (site 1),</td>
<td>1958</td>
<td>61.6</td>
<td>–</td>
<td>10.3</td>
<td>[13]</td>
</tr>
<tr>
<td>Ethiopia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lake Tana area (site 2),</td>
<td>1958</td>
<td>26.8</td>
<td>–</td>
<td>1.6</td>
<td>[13]</td>
</tr>
<tr>
<td>Ethiopia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lake Tana area (site 3),</td>
<td>1958</td>
<td>62.8</td>
<td>–</td>
<td>4.0</td>
<td>[13]</td>
</tr>
<tr>
<td>Ethiopia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lake Haik, Ethiopia</td>
<td>1958</td>
<td>28.2</td>
<td>–</td>
<td>6.0</td>
<td>[13]</td>
</tr>
<tr>
<td>Gane District, Ethiopia</td>
<td>1958</td>
<td>–</td>
<td>–</td>
<td>8.9</td>
<td>[13]</td>
</tr>
<tr>
<td>Manarintsoa, Madagascar</td>
<td>1988</td>
<td>32.2</td>
<td>3.9</td>
<td>–</td>
<td>[14]</td>
</tr>
<tr>
<td>Balcad, Somalia</td>
<td>1988</td>
<td>3.8</td>
<td>–</td>
<td>–</td>
<td>[43]</td>
</tr>
<tr>
<td>Ziway, Ethiopia</td>
<td>1992</td>
<td>–</td>
<td>2.7</td>
<td>4.3</td>
<td>[9]</td>
</tr>
<tr>
<td>Nshamba, Tanzania</td>
<td>1998</td>
<td>–</td>
<td>–</td>
<td>1.4</td>
<td>[10]</td>
</tr>
<tr>
<td>Karuzi, Burundi</td>
<td>2000</td>
<td>–</td>
<td>0.9</td>
<td>3.1</td>
<td>[11]</td>
</tr>
<tr>
<td>Kayanza, Burundi</td>
<td>2000–2001</td>
<td>35.3</td>
<td>1.0</td>
<td>3.6</td>
<td>[11]</td>
</tr>
<tr>
<td>Karuzi, Burundi</td>
<td>2001</td>
<td>107.3</td>
<td>1.1</td>
<td>3.0</td>
<td>[11]</td>
</tr>
<tr>
<td>Ngozi, Burundi</td>
<td>2000–2001</td>
<td>32.9</td>
<td>1.8</td>
<td>5.9</td>
<td>[11]</td>
</tr>
<tr>
<td>Median</td>
<td></td>
<td>32.2</td>
<td>2.3</td>
<td>3.6</td>
<td>1.6</td>
</tr>
<tr>
<td>Interquartile range</td>
<td></td>
<td>17.8–48.4</td>
<td>1.6–3.5</td>
<td>3.2–4.7</td>
<td>1.1–5.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.3–2.8</td>
</tr>
</tbody>
</table>
The data in Table 1 illustrate the high levels of malaria mortality experienced at four sites during this epidemic, in contrast to the lower levels of mortality recorded in highland malaria epidemics in Madagascar [14], Burundi [11] and Ethiopia [9,11] from the late 1980s onwards. The lower rates of mortality that were experienced during these more recent episodes are unlikely to be the result of lower intensities of malaria transmission because the rates of morbidity associated with these events were significant, even by historical standards (Table 1). It is more probable that they reflect both an improvement in access to emergency care, including antimalarial drugs, and comparatively high levels of pre-existing clinical immunity resulting from previous parasite exposure. Since the 1980s, there have been numerous reports of increased malaria transmission in areas of the African highlands that were previously considered to be free of infection or subject to low or sporadic levels of transmission [15–20]. Although the drivers behind the changing epidemiology of malaria transmission in these areas have been the subject of much debate [18,21,22], less disputed is the fact that areas that were once subject to infrequent ‘classic’ epidemics now experience more-frequent transmission and acutely seasonal clinical surges of disease incidence. This has manifested a change in the age-specific patterns of disease, which indicates age-acquired clinical immunity following repeated annual parasite exposures [23]. Data from several recent epidemics show relatively high rates of malaria-specific mortality among children – not the predominantly flat age profile that would be expected in populations that lack immunity [9,11,24].

Although mortality rates experienced during recent malaria epidemics have been markedly lower than those reported in Ethiopia in 1958, associated disease burdens might still be substantial, not least because of the large PAR at risk in densely inhabited highland areas. An epidemic in Burundi in 2000–2001, for example, affected nine of the 16 provinces in the country and resulted in ~3.5 million malaria cases [24]. Results from retrospective mortality surveys carried out in the area indicated that, during the epidemic, >12 000 malaria-attributable deaths occurred in a population of ~1.1 million. This represents a cumulative mortality rate of 91 deaths per 10 000 population over the survey periods (average of 120 days) [11]. A similar survey that was carried out during an epidemic in Damot Gale district (Ethiopian highlands) in 2003–2004 indicated ~5000 excess deaths in a population of 290 000, at a cumulative rate of 173 deaths per 10 000 over 125 days [11]. In highland areas, the high burden of recent epidemics seems to be the product of relatively long-lived events (lasting 30 weeks or longer [24]) that affect large populations, rather than particularly high mortality rates per se. This is in contrast to an epidemic that occurred in the lowland desert fringe district of Wajir, Kenya, in 1998. Here, mortality rates were extremely high (Table 1) but the overall effect of the epidemic was limited by the relatively small size of the affected population and by the comparatively short duration of the epidemic [24].

Therefore, the key characteristics of epidemics – their causality, presentation, evolution and impact – vary markedly between epidemic-prone sites [8] and over time at individual localities. Although this brings into question the sense of previous attempts to derive average rates for morbidity and mortality across all types of epidemic event, there might be scope for developing a ‘typology’ of epidemic types based on, for example, the principal determining factors involved, the ecology of the area affected, the timing of the epidemic and the characteristics of affected populations [8]. Given the paucity of the existing data record, attributing meaningful epidemiological characteristics to such a typology will not be a straightforward exercise; nevertheless, it is doubtful whether current estimates of epidemic burden can be improved without this change.

### Annualized estimates of epidemic burden

Scaling up locality-based estimates of epidemic burden to the national, regional or continental scale requires knowledge of the distribution of PAR from epidemics. To articulate epidemic risk in terms of an average annualized burden, basic assumptions need to be made with regard to the frequency and length of epidemic events, the shape of the epidemic curve and the distribution of incidence between age groups.

### Defining PAR

The first estimates of epidemic PAR for Africa were produced by the WHO in 1996 and were subsequently used by Worrall et al. [5]. These estimates were derived for 26 countries and were based on local expert opinion regarding the percentage of the national population that was deemed to be at risk of epidemics. An alternative approach, adopted by Snow et al. [4], used models of climate suitability for malaria transmission [25] to define geographical risk zones for epidemics. These zones were then overlaid with data on human population distribution within a geographical information system to derive PAR. Given the different methodologies involved, PAR estimates derived from these two approaches differ substantially at both continental and national scales (Table 2, Figure 1). The quantitative climate model used by Snow et al. uses climate suitability limits to define epidemic-prone regions that are not validated against empirical or expert opinion information. The methodology used by WHO, which relied upon expert national opinion, historical incidence data and knowledge of risk factors [26], is, by its nature, subjective and not

### Table 2. Available estimates of populations at risk of malaria epidemics in Africa in 2005

<table>
<thead>
<tr>
<th>Source of estimate</th>
<th>Number of countries included in estimate</th>
<th>Year of original estimate</th>
<th>PAR in 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHO [5]</td>
<td>26</td>
<td>2001</td>
<td>131 905 028*</td>
</tr>
<tr>
<td>Snow et al. [4]</td>
<td>29</td>
<td>1995</td>
<td>76 143 097*</td>
</tr>
</tbody>
</table>

*The PAR estimates by the WHO were originally calculated on the basis of 2001 population data. This figure was projected to 2005 using published information in the United Nations (UN) Population Prospects database (http://esa.un.org/unpp).

*Estimated by repeating original analysis using Gridded Population of the World (v2.0) [46] data to generate population distribution maps for Africa for the year 2000. Per-country urban–rural growth rates from the UN Population Prospects database were then used to extrapolate PARs to 2005.
reproducible. Clearly, both approaches suffer from the lack of a standardized definition of what constitutes epidemic risk and neither takes into account variations in the aetiologies of epidemics. Future work that is aimed at defining PAR of epidemics should use combinations of quantitative and qualitative risk definitions that are subjected to rigorous validation and include an appropriate sensitivity analysis.

Defining ‘typical’ epidemic characteristics

Even if it were possible to derive reliable estimates of epidemic PAR, several other parameters would require quantification before the average annualized burden of epidemics could be calculated. At the most basic level, information is needed on epidemic periodicity and the average duration of epidemic events – the immunological and environmental drivers of which are still only rudimentarily understood [27]. In terms of periodicity, it is usually accepted that recurring climate-driven epidemics occur every two to seven years [8] but the evidence for this seems to be limited and there has not been a concerted effort to refine or validate this estimate for the purposes of estimating epidemic burden. Regarding the length of an epidemic, Snow et al. [4] assumed a typical epidemic duration of 12 weeks but, in reality, this period is likely to be highly variable and epidemic periods of 15–36 months have been reported [24]. Within this epidemic period, the exact shape of the epidemic curve will also have a direct impact on the associated public health burden and could show substantial spatial and temporal variation.

The sensitivity of estimated burden to variations in these assumptions becomes apparent when following the approach used to calculate current WHO burden estimates. Here, an epidemic periodicity of five years is assumed, together with an average attack rate (during epidemic years) of 0.5 [5]. On the basis of these assumptions, the annual number of epidemic malaria cases for Africa in 2005 could have been as low as 7.6 million or as high as 13.2 million depending on which estimate of PAR is used in the calculations (Table 3).

Estimates of total burden are particularly sensitive to the attack rate parameter. Based on reports included in Table 1, the overall ‘documented’ unweighted median attack rate is 0.29 (assuming, in the absence of data on epidemic duration from many of these reports, a typical epidemic duration of 12 weeks). If, for the purpose of illustration, this lower rate were applied to the WHO calculations, projected caseloads would be substantially reduced (Table 3). However, it should be recognized that these attack rate estimates include data derived from health-centre-based surveillance and probably suffer from underdetection bias because of poor access to formal health care in many of the remote, impoverished communities in which epidemics have taken place. Antimalarial treatment coverage is mostly poor wherever it is measured [28]. For example, only 7% of childhood fevers were treated promptly in Kenya [29] and coverages of 33% and 47% were estimated in Tanzania and The Gambia, respectively [30,31]. More-favourable results (>60% access to treatment) were found in the Ugandan highlands – to our knowledge, the only estimate of treatment access from an epidemic setting [32]. Estimation of attack rate is further complicated by the low specificity of diagnosis, especially when, as in all of the cited studies, cases are treated presumptively (which would lead to a probable overestimation of attack rate). More-reliable estimates are needed of true attack rates during epidemics based on community surveillance and parasitological diagnosis.

The uncertainty in burden estimates will increase with the number of steps (and, thus, assumptions) involved in their derivation. Worrall et al. [5], for example, extended their basic morbidity calculations to generate estimates of the average annual number of cases of severe malaria and malaria-related deaths. They used the assumption that 5% of malaria cases develop acute symptoms and that, of these symptomatic cases, between 25 and 50% die. In this scenario, the average number of deaths could be anywhere between ~24 000 and 330 000, depending on which estimates of PAR and attack rates are used as inputs (Table 2). These estimates are also sensitive to changes made to the assumptions. For example, if a more ‘optimistic’ scenario
were generated by reducing by 10% both the frequency of epidemics and the clinical attack rate associated with them (while keeping constant assumptions concerning rates of severe disease and mortality), the average annual number of deaths associated with epidemics would decline to as few as 16 000 or 110 000, again depending on which PAR and attack rates were used (Table 3). Conversely, in a 10% more ‘pessimistic’ scenario, annual deaths calculated on the basis of PAR from the WHO could be almost as high as 0.5 million, which would represent a substantial proportion of existing estimates of total annual malaria deaths in Africa across all endemicities [33].

Uncertainty in burden estimates

The findings presented here demonstrate that there is still a huge amount of uncertainty surrounding current methods and estimates of malaria epidemic burden at regional level. This reflects a basic lack of high-quality epidemiological data for past epidemics and for epidemic-prone localities, in addition to the technical difficulties of producing meaningful summary indicators of burden for a wide range of epidemiological scenarios (which all, nevertheless, come under the heading of ‘epidemic’ or ‘unstable’). For example, although Table 1 represents a useful summary of some key indicators of burden in several epidemics (and a timely reminder of the potentially devastating effects of individual outbreaks), it is an unsound basis for producing scaled-up estimates of burden for epidemic-prone regions because it is unlikely that the records included are fully representative of the ‘epidemic-prone’ epidemiological stratum. Indeed, it could be argued that any attempt to come up with definitive figures on epidemic burden is flawed in that a single epidemic stratum is largely illusory – the characteristics of epidemic-prone localities and the aetiologies of epidemics themselves being too diverse and dynamic to enable simple aggregation. Derivative estimates of the average annualized burden of epidemics should, perhaps, be viewed with even greater caution because the burden parameters used in their calculation (e.g. clinical attack rate, rates of severe disease and mortality) are unlikely to apply equally to all the epidemiological scenarios that correspond to the diverse types of area where PAR are predicted (by expert opinion or through a more objective means) to live.

Implications of uncertainty in burden estimates

Clearly, current estimates of epidemic burden are a suboptimal basis for generating general policy in the area of epidemic prevention and control. For Africa, this is evident at the continental level but it is especially apparent at national level (Figure 1), where the design of more-specific policy measures is required. The current lack of credible burden data is particularly unfortunate given recent initiatives in some countries to strengthen disease surveillance or early warning systems for epidemics [34,35] and/or to reintroduce malaria prevention strategies in epidemic-prone areas [36]. In the absence of accurate data on burden, evidence-based planning of malaria control and rational targeting of epidemic prevention and control measures are difficult to achieve and the basis for evaluating the cost effectiveness of such measures is limited.

Concluding remarks

The problem of generating more-accurate estimates of epidemic burden is not intractable but several basic conditions must be met before progress in this area can be made. First, and most fundamentally, better epidemiological data
(for morbidity and mortality risks) over a range of epidemic settings are needed. This article is not an exhaustive review and it is probable that relevant epidemic data exist that have not been included in Table 1; however, it seems unlikely that a large number of such records exists and, arguably, it would be more productive to focus efforts on ensuring that reliable information from future epidemics is captured routinely at country level. Methods to estimate all-cause mortality rates through retrospective surveys or through prospective surveillance are already well established but require timely intervention by experienced teams of epidemiologists with considerable resources [37]. Alternative, indirect approaches for estimating mortality (e.g. through simple prospective community surveillance systems) might be less costly overall but are also associated with substantial human resource costs. Therefore, obtaining high-quality representative data hinges as much on the willingness of policy makers and the research community to invest in better evidence gathering as on developing appropriate protocols for data collection during and after epidemic events.

Second, a better empirical basis for estimating typology-specific parameters for epidemic periodicity, length, shape and age distribution of incidence is also required. The levels of evidence needed here are probably less demanding than those required to obtain community-level estimates of morbidity and mortality risks, and substantial advances could be made by reviewing passive case detection data, supplemented with a full systematic review of published and unpublished records.

Third, better PAR estimates require both high-fidelity population estimates – often a particular problem in rain-fall-limited epidemic-prone areas that are characterized by nomadic and transient populations [38] – and an objective evidence-based stratification of malaria endemicity that includes epidemic risk [39]. The Malaria Atlas Project (MAP: http://www.map.ox.ac.uk) is committed to mapping the distribution of malaria endemicity globally [39]. A huge logistical investment is underway to develop a global database of contemporary data on malaria prevalence and ancillary environmental data with which to make extensive malaria endemicity maps. This effort has been extended to recording the global distribution of the dominant malaria-vector mosquito species to inform this endemicity mapping process. In addition, population distribution information is being searched, archived and forwarded to collaborators to help make higher-fidelity population maps. The exact project scope and the protocol by which MAP will develop these new global malaria endemicity maps and then revise PAR estimates globally are detailed in Ref. [39]. Thus, better defining the PAR of epidemic malaria is integral to the wider effort to refine the estimate of the total global malaria burden. Finally, these uncertainties must all be compounded to provide realistic confidence intervals around PAR and related burden estimates provided to international agencies, donors and national governments.

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References
Free journals for developing countries

The WHO and six medical journal publishers have launched the Health InterNetwork Access to Research Initiative, which enables nearly 70 of the world’s poorest countries to gain free access to biomedical literature through the internet.

The science publishers, Blackwell, Elsevier, Harcourt Worldwide STM group, Wolters Kluwer International Health and Science, Springer-Verlag and John Wiley, were approached by the WHO and the British Medical Journal in 2001. Initially, more than 1500 journals were made available for free or at significantly reduced prices to universities, medical schools, and research and public institutions in developing countries. In 2002, 22 additional publishers joined, and more than 2000 journals are now available. Currently more than 70 publishers are participating in the program.

Gro Harlem Brundtland, the former director-general of the WHO, said that this initiative was “perhaps the biggest step ever taken towards reducing the health information gap between rich and poor countries”.

For more information, visit www.who.int/hinari