Rethinking Malaria in the Context to COVID-19

"Rethinking Malaria Control and Elimination in Africa: Reflections on Ways to Accelerate Progress and Sustain Gains," by Fredros Okumu, Margaret Gyapong, Núria Casamitjana, Marcia Castro, Maurice Itoe, Friday Okonofua, and Marcel Tanner

Note: This preprint is part of the "Rethinking Malaria in the Context of COVID-19" series. All of the manuscripts produced in this effort will be submitted for peer-review and published as a compendium. This preprint is being made available to enable a broader discussion around key challenges and solutions.

The "Rethinking Malaria in the Context of COVID–19" global engagement was constituted as a consultative process to 'take stock' and push beyond conventional thinking to question fundamental assumptions and approaches, with a focus on bold new ideas to achieve real-world progress. The process managed by three governance bodies comprising a Steering Committee, Working Group Co-Chairs and contributing authors, and an External Advisory Committee. For a listing of the "Rethinking Malaria" Working Group Co-Chairs and contributing authors and External Advisory Committee members, see Text A1.

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Supporting Information:
Text A1: "Rethinking Malaria in the Context of COVID-19" website.

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Abstract

After a longstanding global presence, malaria is largely non-existent or suppressed in most parts of the world. Today, cases and deaths are primarily concentrated in sub-Saharan Africa. According to many contemporary malaria experts, this persistence on the African continent reflects factors such as resistance to insecticides and drugs as well as insufficient access to essential commodities such as insecticide-treated nets and effective drugs. Crucially, however, this narrative ignores many central weaknesses in the fight against malaria and instead reinforces a narrow, commodity-driven vision of disease control. This paper synthesizes evidence on significant challenges hindering malaria programs in Africa, and highlights key opportunities to reflect and rethink current strategies for sustainable control and elimination. The epidemiology of malaria in Africa presents far greater challenges than elsewhere and requires context-specific initiatives tailored to national and subnational targets. To sustain progress, Africa must systematically address key weaknesses in health systems, improve quality and use of data for surveillance-responses, improve technical and leadership competencies for malaria control, gradually reduce overreliance on commodities while expanding multisectoral initiatives such as improved housing and environmental sanitation, increase funding malaria control, and support pivotal research & development. Effective vaccines, or other potentially transformative technologies such as gene drives used to suppress or replace populations of key malaria vectors, could further accelerate the control efforts and complement current tools. However, our underlying strategies remain insufficient and must be expanded to include more holistic and context-specific approaches critical to achieve and sustain zero malaria cases and deaths.

Background

Since its etiology was first described more than 100 years ago, malaria has become one of the world's best known infectious diseases. Yet there were still more than 400,000 deaths and ~230 million cases worldwide in 2019, nearly all in sub-Saharan Africa [1]. A key question is why malaria control and elimination have proven so difficult in sub-Saharan Africa, while the disease has been either eliminated or greatly diminished elsewhere [2, 3].

Expert risk–benefit analyses suggest that malaria elimination would be both ethically and economically rewarding. Return-on-investment ratios are estimated at 40:1 globally, and up to 60:1 in sub-Saharan Africa [4], yet there appears to be no consensus on whether eventual eradication is possible or whether it should even be pursued by the current generation [5]. A report by the Lancet Commission for Malaria Eradication argued that eradication by 2050, though ambitious, is achievable and necessary [6]. On the other hand, the World Health Organization (WHO) Strategic Advisory Group on Malaria Eradication (SAGME), while calling for greater investments for malaria control and R&D, avoided setting any specific target date for eradication—the group argued that even under the most optimistic scenarios, there would still be 11 million cases by 2050 [7]. Still, some individual countries and the African Union have set specified target dates for malaria elimination [8].

Relative to recorded history since 1900, unprecedented progress was made against malaria between 2000 and 2015 [9]. Development of simple but effective technologies, notably insecticide-treated nets (ITNs), in the 1990s helped renew international interest in malaria. These advances heralded major initiatives such as the 1998 formation of Roll Back Malaria and the 2000 seminal meeting by African heads of states and governments in Abuja, Nigeria [10], both of which laid groundwork for the post-2000 malaria agenda. Establishment of major international funding agencies such as the Global Fund in 2002 [11], US President's Malaria Initiative in 2005 [12], and the Bill & Melinda Gates Foundation in 2000 further unlocked significant increases in funding for malaria and attracted thousands of players to both R&D and implementation programs. WHO approved the first artemisinin combination therapies (ACTs), malaria

rapid diagnostic tests, and long-lasting ITNs, all in 2000. In subsequent years, these commodities were scaled-up steadily via a series of policy decisions, culminating in the Global Technical Strategy (GTS) [13] and, most recently, the High Burden to High Impact Initiative [14].

Despite all these initiatives, the downward trend of malaria cases has plateaued since 2015, and in some cases even reversed [1], as some predicted [15]. Africa now bears >90% of all malaria cases and deaths [1]. Part of this can be explained by expanding population size, but most malariologists typically blame the rise of resistance to insecticides or drugs [16]. Yet these are only symptoms of broader strategic flaws and largely ignore key factors such as the potential of multisectoral approaches or the importance of effectively engaging communities and other stakeholders. Indeed, without multidisciplinary considerations, current scientific methods cannot adequately assess relevant associations between socio-economic variables and disease [17], a concept long championed to explain health outcomes in Europe in the 19th century [18].

As envisioned in both the GTS [13] and the SAGME report [7], malaria-endemic countries require combinations of interventions that are integrated and tailored to local contexts, as well as strong country ownership and leadership to accelerate progress through multisectoral approaches. Transformative technologies such as vaccines and gene-drive mosquitoes also may one day quicken malaria control efforts and reduce costs by multiple orders of magnitude [19]. However, real progress currently requires more holistic strategies that effectively target the root causes of current and past failures. It requires an approach that does not ignore contextual complexities underpinning the delivery of malaria interventions and that considers the needs of key stakeholders including the communities, especially in rural and peri-urban areas.

This paper describes some of the most critical challenges in malaria control in Africa and highlights key opportunities for stakeholders to reflect and rethink malaria control and elimination. We review evidence from multiple sources and reflect on how countries might overcome these challenges and build sufficient momentum for a more realistic malaria control and elimination agenda in sub-Saharan Africa.

Addressing weaknesses in health systems to maximize effectiveness of malaria interventions

Formal and informal health systems are inherently complex and often require careful management of many non-linear relationships and components at play [20, 21]; nowhere is this more obvious than in the management of infectious diseases in low-income countries. Any health technologies tested under experimental settings must still be delivered and proven effective in real-life settings, a process with multiple quandaries including many that are only partially predictable. The COVID-19 pandemic further highlights the importance of strong systems and the inescapable interconnectedness of domains in ways not previously appreciated [22].

Health system weaknesses in malaria-endemic countries are a function of multiple factors that greatly limit effectiveness of health commodities, thereby compromising both quality and timeliness of care. Countries particularly need good governance to ensure effective resource acquisition and utilization, engage effectively with other relevant sectors, and ensure that all components of the health system function at equilibrium. In one study examining the implications of health system factors such as treatment-seeking, provider compliance, patient adherence to treatment and care, and quality of medication on treatment outcomes in 43 sub-Saharan African countries, the coverage of malaria case management ranged from as low as 8% up to 72% [23]. Indeed, even efficacious medicines such as ACTs, which have >95% cure rates [24, 25], may have as low as 20%–40% effectiveness due to health system weaknesses [26, 27]. Important factors in this cascade may vary but broadly include poor accessibility, poor provider compliance with clinical protocols, and suboptimal patient adherence due to socioeconomic

and cultural factors, weak governance, and often supply chain constraints (Figure 1). These are compounded by inadequate knowledge in some communities for management of fevers, and care-seeking from unqualified providers and drug-stores due to the existence of pluralistic health care systems.

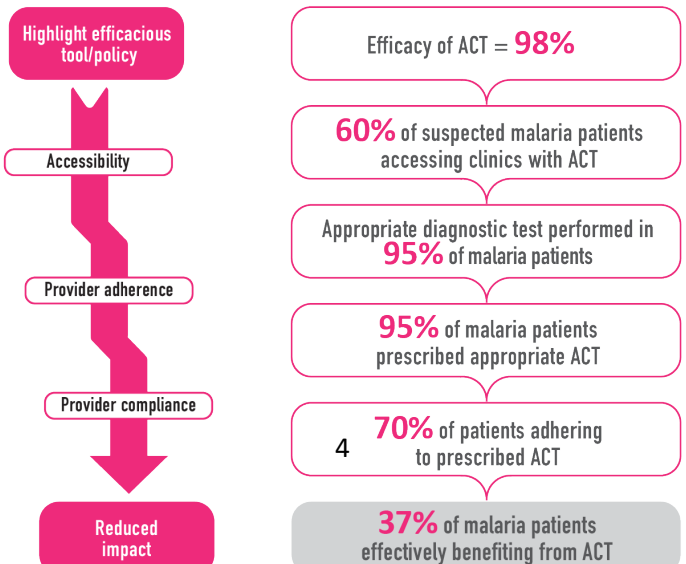
To address these challenges, countries should prioritise implementation research capacity, which uses multidisciplinary approaches to identifying with care providers and program managers the challenges and bottlenecks related to the roll-out of health interventions, developing and testing effective strategies designed to overcome them, determining the best way to introduce innovations into the health system, and promoting their large-scale use and sustainability. Implementation research is characterized by the complex, iterative, systematic, multidisciplinary and contextual processes that take place at multiple levels in order to identify and address implementation problems [28]. More often than not, this will include community participatory research in target areas [29].

Similarly, improved diagnostics are necessary to address challenges such as the rise of *HRP2/3* gene deletions [30] or poor validity of existing diagnostics in low-transmission settings [31]. Ultra-sensitive malaria rapid diagnostic tests have been proposed to improve detection under low transmission intensities or low parasite densities but risk biasing clinical management away from other febrile illnesses [32]. From a health systems perspective, introduction of new diagnostic tools must therefore be part of a broader strategy for case finding and management, instead of purely focusing on the tools. One WHO technical consultation in 2018 noted the importance of assessing broader public health and clinical benefits for patients and communities but declined to recommend the highly sensitive point-of-care diagnostics for use in clinical settings [33].

These health system concerns also extend to vector control interventions as distributed and used in local households. For example, ITNs are most effective when accessible, appropriately used, and maintained or replaced regularly. While access is generally the key determinant of ITN use [34, 35], achieving high coverage and equitable access has been challenging without either expensive mass distribution campaigns [36] or a mix of deployment strategies [37]. Moreover, ITN use even among people with access requires consistent behavior change communication to maximize use [38].

While the emphasis on specific tools for malaria control and elimination (i.e., drugs, vaccines, insecticides, diagnostics) remains vital, endemic countries and their partners must ensure commensurate investments in their health system structures, most urgently for case management, to ensure as few deaths as possible.

Figure 1: Illustration of how the effectiveness of key malaria control tools, in this case, artemisinin combination treatments (ACTs), can decay due to multiple health system weaknesses in malaria-endemic countries (adapted from WHO/TDR Implementation Research Toolkit [29]).



Improving data quality and data use to support malaria responses at national and subnational levels

The annual WHO malaria reports provide the most comprehensive overview of malaria trends globally. The reports are derived from voluntarily submitted records from more than 80 countries, through systems of subnational cascading and summaries. Unfortunately, due to lack of regularly collected high-quality data in many endemic countries, the WHO reports still rely mostly on mathematical models, with large uncertainties around the actual estimates. When WHO recently made changes to the modeling methods, this required retrospective adjustments of early malaria estimates, evoking concerns over the apparent statistical inconsistencies [39]. Though the global agency regularly reports the actual methods of analysis and the statistical uncertainties around its estimates, these are rarely considered in day-to-day conversations or policy decisions, partly because of the detailed technical understanding required and the opacity of the methods to most stakeholders. A deeper analysis of these challenges points to weaknesses of in-country surveillance-responses, notably poor-quality data and lack of capacity to handle the data, failure to establish minimum essential data packages by space and time, and the wider disconnect between public health responses and data.

Many African countries currently use the DHIS2 software platform [40] to collect routine health care delivery data and manage their health information systems [41, 42]. However, there are concerns regarding quality of the data collected and the inability of local program managers to analyze, inteprete or use the data. Other concerns include poor integration of non-clinical data, particularly entomological data for malaria, which are not channeled via health facilities. Often, data from private facilities are also left out.

In addition to the first pillar (ensuring universal access to core interventions) and second pillar (accelerating efforts towards elimination), the third pillar of the GTS (2016–2030) suggested that malaria surveillance be transformed into a core intervention, alongside scale-up of effective vector control and case management [13]. Yet most endemic countries remain too poorly resourced to establish effective surveillance-responses with minimum essential data packages to detect changes and adjust public health responses [43, 44]. One consequence is that control strategies tend to remain mostly unchanged and unlinked to local epidemiological transitions. One study reviewed national malaria strategic plans of 22 sub-Saharan African countries and examined targets for six core malaria indicators in relation to reported population coverage [45]. It also analyzed implementation challenges and solutions proposed during in-country strategy discussions and whether the subsequent strategies integrated the lessons. Of the 135 verified targets, only four were achieved, and none of the countries had reached more than one-sixth of targets [45]. Only four of 22 countries lowered relevant targets in their subsequent strategies. In fact, most countries, contrary to their own evidence, either maintained or raised the targets and did not incorporate lessons from their own assessments.

The WHO's High Burden High Impact response [14] requires that endemic countries have effective surveillance-response capabilities at both national and district levels. Yet evidence suggests that countries

targeted by the initiative have far less capacity than countries approaching elimination [43]. This paradox probably arose from previous strategies, which emphasized "shrinking the malaria map" from the periphery [46] and thus channeled significantly more resources per capita to low-burden countries in the periphery than to high-burden countries. Going forward, endemic countries must strengthen their surveillance-response practices and build relevant human resource capacity for these functions [47]. To strengthen the sub-national stratification efforts, countries should also collect data on the quality of care and implementation and include these in subsequent decisions.

Any minimum essential data packages also should consider genomic data where relevant and address the associated challenges with computing infrastructure, genetic sequencing capabilities, and data sharing guidelines. The need for malaria molecular surveillance is increasingly evident in varying epidemiological settings to address multiple use cases [48], including enabling National Malaria Programs and partners to proactively plan or deploy interventions. Mathematical modelling may address some of these gaps by helping define the minimal essential data needs in space and time and focus areas, designing surveillance-response systems and making vital projections and resource allocation [49]. However, such strategies face even greater limitations in requisite skillsets in endemic countries. Evidence from polio eradication programs suggests that high-quality data, including high-quality maps, combined with modeling are essential for targeting resources to the last hotspots and may offer lessons for malaria elimination, particularly with regard to health system needs, data requirements, essential technologies and partnerships, but more importantly for design of integrated surveillance-responses [50, 51]. However, quantitative datasets from surveys, experiments, and genomic analyses often only inform what is happening, not why it is happening. For a more complete picture, it is therefore important to also incorporate qualitative datasets such as anthropological or human behavioral data to explain underlying drivers of key empirical observations and unravel some of the religious and cultural nuances that influence perceptions about disease causation and health care seeking behavior. It is equally vital to learn from other successful pathogen elimination campaigns, such as polio, guinea worm and onchocerciasis, which have parallels in data quality and data use.

Countries must invest in building capacity for policy makers, program managers, frontline care providers, and their core district teams to interrogate, analyze, and use their data for planning and implementation of malaria control activities.

Adopting more holistic and multisectoral approaches, instead of overreliance on imperfect commodities applied imperfectly

Early control strategies relied heavily on the basic biological understanding of malaria and how the natural environment influences human exposure to *Anopheles* mosquitoes. Despite limited economic opportunities, rudimentary technologies, and lower levels of funding compared to today, countries that considered environmental management and improved housing as core interventions alongside other measures such as quininization made significant gains, and in some cases remain malaria-free [3, 52].

However, once the highly effective insecticide DDT became the cornerstone of malaria control in the 1950s, further innovation for malaria control slowed. In recent years, widespread availability of ITNs and ACTs may have also inadvertently reduced the appeal of more permanent but more demanding measures such as environmental management and improved housing. This is compounded by the difficulty of using standard epidemiological study designs (e.g., cluster randomized control trials) to effectively measure the long-term impact of socioeconomic developments on disease [17]. For example, larval source management and improved housing clearly suppress vector densities and reduce biting risk, yet their epidemiological impact at scale is evident in only selected sites [53-55], and in some cases indemonstrable [56]. Similarly, housing is steadily improving in Africa [57], paid for mostly by individual household

incomes, yet dominant epidemiological analyses of malaria trends only marginally examine the contributions of these trends.

Malaria control is now mostly dependent on commodities, namely drugs, diagnostics, medicines, and insecticides, all of which are imperfect and are often deployed and used imperfectly. The commodities also must be replenished regularly, even as resistance spreads, manufacturing costs rise and at-risk populations increase. This "commoditization of malaria control" also has caused major declines in practical malaria expertise in endemic countries, and instead incentivized many fringe and disconnected players focusing on distribution and performance of the commodities. Major players regularly report short-term outputs, such as number of treatment doses delivered, ITNs distributed, or houses sprayed, with only weak connection to epidemiological impact or effective delivery and use of these comodities. Indeed, there have been more than two billion ITNs [58] and one billion doses of child ACT formulations delivered, yet key malaria trends are stagnating. This raises multiple questions, including whether the products meet essential quality thresholds or if there are certain imperfections. For example, despite manufacturer claims that ITNs last more than three years and 20 washes, recent studies have shown that these nets actually last far shorter periods [59]. Moreover, while ITNs and indoor residual spraying (IRS) effectively tackle indoor-biting and indoor-resting mosquitoes, their effectiveness is limited in areas where significant biting happens outside homes or sleeping hours [60]. Another question is whether delivery of the commodities sufficiently covers all at-risk demographic groups, as well as commonly disenfranchised groups such as migrant and nomadic populations. Lastly, it demonstrates the importance of concurrent investments to build resilience in health systems and the environment and to build requisite human resource capacity to sustain gains catalyzed by current commodities and minimize the decay of effectiveness [26].

Going forward, countries must realize that while ITNs, IRS, drugs, and diagnostics do indeed offer significant benefits against malaria in the short and medium term [61], sustaining these gains requires a much more holistic approach. Greater focus on multisectoral initiatives, stakeholder including community engagement, one-health approaches (including considerations for key agricultural practices), stronger health systems linked to ecosystem approaches, and greater behavior-change communication (involving community members and frontline health workers) will be essential to achieve real progress. These challenges are not unique to malaria, and must be addressed in the wider context of public health needs of individual countries. Decision-makers must accept that there may be certain functions best performed by sectors other than the health sector and that malaria programs should not be siloed. In many sub-Saharan African countries, the public health importance of malaria or the desired to achieve elimination have led creation of vertical control programs, in some cases disconnected from other disease programs or sectors. It is however important to maintain a reasonable level of integration in the wider context of sustainable development goals [62], particularly for improving peoples' health and well-being.

Increasing both domestic and international funding for malaria control, research, and development

The estimated annual global budget for malaria control initiatives is ~$6.6 billion, yet only $3.1 billion was attained in 2019 [1]. A significant proportion of the overall financing for malaria control in Africa is currently from external sources, even in high-burden countries. Contributions and direct investments by endemic countries rose steadily between 2001 and 2010 but have since stagnated at just under $1 billion annually. Only $13 billion of the ~$39 billion invested in malaria control over that ten year period was from domestic sources, the remaining $26 billion having been from external sources, mostly the USA and the UK [1]. Given the economics of most malaria-endemic countries, it is not expected that domestic funding will match international financing soon, but there may be additional opportunities to attract internal financing for control and elimination efforts.

It can be difficult to track malaria-related expenditures, especially since domestic funds may be tied to multiple recurrent costs or salaries, and because there may be many indirect payments by the multiple agencies involved. Besides, where the private sector plays a major role in health care, such data may not be readily reported in standard government portals. One study analyzed domestic malaria spending by source in 106 countries from 2000 to 2016 [63], considering data for out-of-pocket payments, private insurance prepayments, costs for treatment, patient care and direct drug purchases. The study also estimated malaria-related government spending within and beyond National Malaria Programs. The results estimated that since 2000, out-of-pocket spending increased by 3.8% annually, to 13% of total domestic financing for malaria by 2016, and that endemic country governments had spent $1.2 billion the same year [63]. It is expected that the countries will indeed increase their investments in the future, with some countries already taking the lead. In Ghana, where malaria elimination is estimated to eventually cost $1 billion by 2029, government expenditure on malaria control is expanding, though this is still below 25% of total funding [64].

Limited local investment may reduce in-country responsibility over malaria control and the premium put on this subject in terms of progress monitoring. This particularly affects low-income households by constraining their incomes and challenging other competing priorities. The economic burden of health care is well-documented and can be massive [65], or even catastrophic for low-income households [66]. Without removing financial barriers for these households, basic health-seeking behaviors and treatment will likely be deprioritized in favor of alternative medicines or other household needs such as food. In one Tanzanian study, researchers asked household heads whether they were aware that unscreened windows and eave gaps in their houses were a risk factor for malaria [67]. They found that community members were aware of these risks and desired to make improvements, but they were constrained by competing priorities [67]. In many communities, health care-seeking behaviors and investments for health are influenced significantly by household-level decision-making processes, which have economic, cultural, and social determinants and differ across settings [47]. It thus may be beneficial to have household-centered approaches and to consider these factors when designing universal health coverage packages.

These difficulties in funding, coupled with the desire by international donors to track specific malaria program indicators, have further entrenched the vertical structures of malaria control, which are sometimes siloed from other functions of the health sector. The vertical approach to malaria control misses significant multisectoral opportunities to catalyze or sustain gains [68] and unlock additional resources [47]. For example, there are certain aspects of vector control, such as larval source management and improved housing, that are best managed by government ministries beyond health. Moreover, collaborating with sectors such as tourism and finance could unlock additional financing necessary for malaria control. Where feasible, appropriate legislation could further improve compliance, protect vulnerable people, and guarantee long-term domestic financing for malaria.

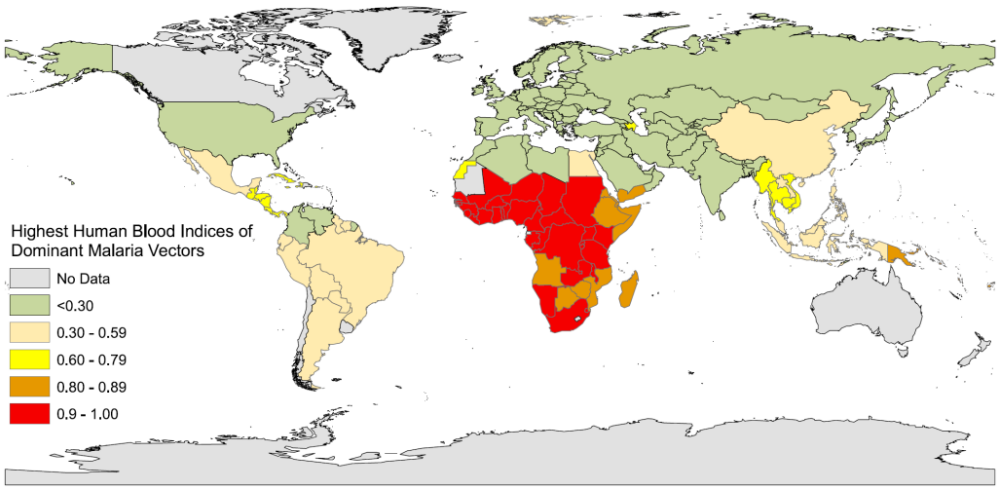
Similarly, the private sector market, despite its growth, remains neglected yet could support local supply and distribution of essential commodities such as ITNs or medicines [69, 70]. Estimates from Ghana suggest that the private sector market could free nearly 40% of investments currently incurred by ITN distribution systems that do not consider individual household preferences and willingness to pay [71]. Greater involvement of the private sector also may generate additional positive externalities, such as local manufacturing of essential tools such as ITNs [72]. Unfortunately today, even the most-affected African countries—such as Nigeria, Democratic Republic of Congo, Mozambique, Uganda, Niger, Burkina Faso, Ghana, and Cameroon, which together constitute nearly 70% of the global malaria burden—still regularly import bed nets, insecticides, and medicines to protect their citizens. Local initiatives such as mosquito net manufacturing and greater involvement of the private sector could increase ownership, reduce overall costs and expand access to interventions.

Beyond direct investments for malaria control, there is a need to accelerate investments for R&D, especially on potentially transformative tools such as vaccines and gene drive mosquitoes. Besides the many technical challenges of developing transformative technologies, particularly vaccines [73], the actual innovation pathway for malaria remains poorly funded and takes far longer than for other diseases. It is worth noting that malaria etiology was first described in 1880, yet no viable vaccine has achieved full approval [74]. In rethinking malaria, African Governments in particular must stop the rhetoric and increase investments in control and R&D for a disease that remains a leading killer on the continent. Yet given large existing funding gaps, any growth of indigenous funding should not be interpreted as a reason to reduce international funding.

Recognizing that the epidemiology of malaria in Africa is more challenging than in other continents and is compounded by resistance to insecticides and drugs

Compared to sub-Saharan Africa, malaria control has advanced much faster in other geographies. One reason is that the epidemiology of malaria in sub-Saharan Africa is particularly challenging due to multiple factors. For instance, the dominant Afro-tropical malaria vectors, *Anopheles gambiae*, *Anopheles funestus,* and *Anopheles colluzzi,* have among the highest propensities to bite humans over other hosts [75] and are among the most competent malaria vectors. One study examined the stability of malaria in relation to multiple factors and derived an index for the epidemiological contribution of dominant malaria vectors in different regions of the world [76]. Key factors included in this analysis were: i) the human blood index (i.e., proportion of blood meals taken from humans instead of other vertebrates), ii) the daily survival probabilities of individual mosquitoes, iii) the duration of the year when malaria transmission is possible, and iv) the incubation period of malaria parasites in mosquitoes. The study concluded that the superior potential of many tropical *Anopheles* means that control efforts in sub-Saharan Africa are far more difficult than in other formerly endemic countries [76]. A recent simplification of these stability maps, showing just human blood index values, also depicts the region as being most amenable to malaria transmission given the extremely high degree to which local *Anopheles* vectors prefer humans [77].

Figure 2: Global map of the highest human blood index among nationally important vectors (adopted from Killeen et al 2014 [77]).



The spread of insecticide resistance in vector populations has further complicated the situation, meaning that formerly impactful interventions such as ITNs and IRS are now limited. Similarly, formerly effective medicines such as chloroquine [78] and sulfadoxine pyremethamine are no longer suitable, and there are signs of artemisinin resistance now arising *de novo* in Africa [79]. Additionally, although people's

knowledge about malaria may have improved across endemic countries over the years, the changing epidemiology means that this knowledge is due for gradual update. For example, farming communities should be made aware of the risks associated with their farming practices and how wanton application of pesticides may contribute to insecticide resistance and consequently, poor performance of ITNs and IRS [80].

Additional factors contributing to greater malaria transmissibility in Africa include human behaviors and occupational exposures. Despite the success of core interventions such as ITNs, residual malaria transmission is in many areas perpetuated by human behaviors or activities that overlap with malaria vector biting exposures beyond actual bed-times [81]. Outdoor biting risk is often discussed as a byproduct of mosquitoes changing their behaviors in response to ITNs and IRS, but it also is a function of human behaviors and practices [82]. In some communities, migrant workers, forest workers, fishing communities, or nighttime staff such as security play an important role in residual malaria transmission. Poor knowledge and exposures associated with these practices may perpetuate malaria risk. The mostly rural African population also has lower access to behavior-modifying factors such as electricity, or mosquito-proof housing and thus spends longer periods outdoors.

Going forward, malaria control initiatives in Africa must be both comprehensive and context-specific to address the region's unique epidemiological challenges. With recent progress starting in 2000, there also is an increasing degree of within-country variation [83], necessitating subnational stratification to better set priorities and effectively allocate resources to be more impactful in decentralized health systems [84].

Improving technical capacity and leadership for public health practice and research in malaria-endemic countries

Effective malaria control and elimination requires well-trained and experienced practitioners and leaders at all levels [47]. It is the human resource that brings together the various aspects necessary to address malaria quandaries such as those addressed above. Beyond financing and implementation policies, technical expertise is needed to adapt best practices to suit local contexts and to manage effective surveillance-response programs. In addition, countries also require implementation research capacity to readily identify and address arising challenges. Tackling these issues requires that capacity building is addressed not as a short-term endeavor but as a long-term program focusing on people's careers, institutional ecosystems, and long-term mentorship. It also requires a comprehensive view that considers not just the scientific components of malaria control but also the public health administration and related services.

After decades of inaction, the 2000 Abuja Declaration by African Heads of State and Government, following other events such as founding of the Roll Back Malaria partnership, catalyzed renewed interest that heralded malaria declines in the post-2000 era. This was a rare show of political leadership and commitment that has not been evident more recently. Instead, global efforts for malaria control are today mostly led by international experts and international agencies, which direct the in-country experts.

Limitations in capacity are widespread, although certain disciplines such as social sciences, genomics, data sciences, and research to policy translation appear to be much more affected [47]. Though Africa is the most affected by malaria, influencial research about the disease is still overwhelmingly led by by non-African researchers and institutions. While these gaps are gradually closing, thanks to improved global health collaborations, African researchers are still far less represented in leadership and agenda-setting. One 2019 study investigated how international collaborations affect representation of local authors in health research conducted in Africa [85]. Nearly 70% of the publications had evidence of international collaborations, most of these with North American and European scientists. However, more importantly,

only 41% of all authors and only 23% of first-name authors were from the respective target countries, and 14% of all papers had no local authors at all [85]. Addressing these gaps will enable greater responsiveness to Africa's needs and better opportunities to effectively address the identified challenges.

The importance of capacity building for malaria control also is core to the greater health system initiatives and multisectoral initiatives. The malaria elimination agenda will require skilled personnel with broad understanding across disciplines as well as people with strong focus on particular fields to advance the testing and implementation of new interventions being developed. The need for trained staff at both national and district levels as well as last-mile operatives will be essential at all levels of transmission, even though current evidence suggests that countries approaching elimination are better staffed than high-burden countries [43].

As sub-Saharan Africa rethinks the malaria control agenda, countries must expand high-quality training as from basic to tertiary levels. Such training will impart skills relevant for addressing the challenges identified here, but also for effective deployment of interventions across epidemiological settings and for development and evaluation of new interventions. Given the socio-economic basis of infectious diseases, countries should expand this research capacity to include methods for assessing the associations between socio-economic variables and malaria and to also demonstrate health impact of these types of intervention.

Where possible, the training should be expanded to different people involved in the supply chain for medical supplies, including distributers, vendors and regulators. A detailed mechanism for building relevant capacity can be found in the paper by Mwenesi and Mbogo [47].

Other challenges to address

The issues raised above are only key examples of the many quandaries of malaria control and elimination programs in Africa. Other challenges include: i) political instability, conflicts, and displacements in some countries, which may compromise efforts to strengthen health systems, conduct relevant research or develop effective tools; ii) disconnected health care systems through ill-defined pluralism and too many partners often working without unified strategies; iii) varied cultural beliefs and unproven traditional practices about malaria and its management, which may reduce appropriate health-seeking and compromise effectiveness of case management; iv) other disease epidemics such as COVID-19 and Ebola, which may disrupt implementation of malaria control activities and reduce political commitments on malaria [86]; v) the looming threat of climate change, which could further expand the geographic range of transmission, increase population vulnerabilities, and reverse previous gains [87]; vi) replacement vectors or invasive vector species such as *Anopheles stephensi*, now established in the horn of Africa, and their potential to spread [88]; and vii) inadequate communication leading to insufficient community knowledge and participation, viii) some human behaviours and practices which reduce compliance to interventions and ix) the steadily increasing populations in endemic countries leading to greater demand for malaria control efforts.

While these additional challenges were not discussed in detail in this paper, they too must be monitored carefully to enable effective implementation of malaria control and elimination programs that are appropriately adapted to local conditions.

Conclusion

Rethinking malaria control and elimination strategies is imperative. Holistic and systemic approaches that include communities and households to effectively stop transmission and deaths are needed. The

exceptionally challenging epidemiology of malaria in Africa requires context-specific initiatives tailored to national and subnational targets. In addition, endemic countries should address the weaknesses in their health systems, improve the quality and use of data for surveillance-responses, improve technical and leadership competencies for malaria control and reduce overreliance on commodities while expanding multisectoral initiatives. The countries should also invest more for malaria control as well as on key research & development agenda, including on potentially transformative technologies such as vaccines and gene drives. To complement these efforts, countries should also build requisite resilience and capacity to support infectious disease control.

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"Rethinking Human Resources and Capacity Building Needs for Malaria Control and Elimination in Africa," by Halima Mwenesi, Charles Mbogo, Núria Casamitjana, Marcia Castro, Maurice Itoe, Friday Okonofua, and Marcel Tanner

Note: This preprint is part of the "Rethinking Malaria in the Context of COVID-19" series. All of the manuscripts produced in this effort will be submitted for peer-review and published as a compendium. This preprint is being made available to enable a broader discussion around key challenges and solutions.

The "Rethinking Malaria in the Context of COVID–19" global engagement was constituted as a consultative process to 'take stock' and push beyond conventional thinking to question fundamental assumptions and approaches, with a focus on bold new ideas to achieve real-world progress. The process managed by three governance bodies comprising a Steering Committee, Working Group Co-Chairs and contributing authors, and an External Advisory Committee. For a listing of the "Rethinking Malaria" Working Group Co-Chairs and contributing authors and External Advisory Committee members, see Text A1.

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Supporting Information:
Text A1: "Rethinking Malaria in the Context of COVID-19" website.

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Abstract

Despite considerable success in controlling malaria worldwide, progress toward achieving malaria elimination has largely stalled. In particular, strategies to overcome roadblocks in malaria control and elimination in Africa are critical to achieving worldwide malaria elimination goals—this continent carries 94% of the global malaria case burden. To identify key areas for targeted efforts, we combined a comprehensive review of current literature with direct feedback gathered from frontline malaria workers,

leaders, and scholars from Africa. Our analysis identified deficiencies in human resources, training, and capacity building at all levels, from research and development to community involvement. Addressing these needs will require active and coordinated engagement of stakeholders as well as implementation of effective strategies, with malaria-endemic countries owning the relevant processes. This paper reports those valuable identified needs and their concomitant opportunities to accelerate progress toward the goals of the World Health Organization's Global Technical Strategy for Malaria. Ultimately, we underscore the critical need to re-think current approaches and expand concerted efforts toward increasing relevant human resources for health and capacity building at all levels if we are to develop the relevant competencies necessary to maintain current gains while accelerating momentum toward malaria control and elimination.

Background

Current malaria statistics indicate that progress toward achieving malaria elimination by 2030 has largely stalled. From 2015 to 2019, cases of malaria declined only by 3% and deaths by 18% worldwide [1]. The 2020 World Malaria Report [2] concludes that the World Health Organization (WHO) Global Technical Strategy (GTS) for Malaria [3] milestones of 40% reduction in malaria morbidity and mortality by 2020 will not be achieved. Countries continue to face the challenge of suboptimal uptake and scaling up of high-impact interventions to achieve high coverage and interrupt malaria transmission and infection. These interventions include testing, treating, and tracking; chemoprevention including intermittent preventive treatment in pregnancy (IPTp), intermittent preventive treatment in infants (IPTi), and seasonal malaria chemoprevention; and use of long-lasting insecticide nets, indoor residual spraying, and environmental actions such as larviciding where feasible. In addition, proper coverage in hard-to-reach areas and populations remains a challenge.

Efforts continue to try to understand the root causes of the stall and to seek solutions to roadblocks for malaria control and elimination. Recent examples include a report of the WHO Strategic Advisory Group on Malaria Eradication [4], Lancet Commission on Malaria Eradication [5], Malaria Eradication Research Agenda (malERA) Refresh series [6, 7], and WHO guidance to countries on responding to malaria in the context of the COVID-19 pandemic [8-10]. These examples illustrate an urgency to rethink efforts to control and eliminate malaria toward attaining GTS goals and milestones.

Ten of the 11 countries with the highest malaria burden are in Africa, and in 2019 the continent had an estimated 215 million cases, approximately 94% of all cases worldwide. One critical domain in the fight against malaria is Human Resources for Health (HRH) and the capacity to implement the GTS elimination agenda. Empirical evidence [2, 6, 11, 12] suggests that malaria persistence in Africa may be attributed largely to a chronic shortage and maldistribution of the existing malaria workforce, as well as a general lack of required skills and competencies for personnel engaged in decision-making, education, research, and implementation of malaria interventions. This problem calls for not only increasing the current number of workers, but also equipping the workforce with relevant knowledge and training that will help maintain current gains while accelerating momentum toward malaria elimination.

Capacity strengthening is required in all relevant areas of malaria research and development, clinical and public health provision, leadership and program management, analytical and problem-solving skills, and community engagement [2, 11, 13]—but especially in deliberate "mainstreaming" of data sciences and literacy in the training and practice of health workers at all levels to enable them to identify, evaluate, and use reliable data for decision-making. This will necessitate not only a change in training approaches at all levels but also a mindset change among all stakeholders, especially policymakers, planners, National Malaria Programs (NMPs), donors, and development partners. Considerations for the workforce must examine the "education, recruitment, employment, performance optimization, and retention" policies in

each country [14]. Addressing HRH for malaria must be prioritized, despite other pressing constraints of already severely challenged health systems in many countries in Africa. Anchoring the effort on the need to achieve United Nations Sustainable Development Goals and a strong primary health care platform for accelerating progress toward universal health coverage (UHC) will expedite the process.

This paper discusses the status of the malaria workforce in terms of adequacy and skills/competencies, as well as its ability to meet GTS goals for malaria control and elimination in Africa by 2030. We conducted an extensive literature review and supplemented this with information from informal feedback with frontline malaria workers, leaders, and scholars from Africa as part of the "Rethinking Malaria in the Context of COVID-19" global engagement. Together, these data and insights highlight three main issues: 1) gaps in training needs (access, quality, and quantity) at national, subnational, and community levels; 2) inadequacy of existing technical and non-technical competencies and skills; and 3) state of available infrastructure, financial resources, and equipment. Recommendations on logistics and approaches to mitigate training/skills/competency gaps and numbers of malaria health workers, as well as making a case for creating an enabling environment with adequate resources to enable more effective implementation of impactful interventions are made.

Challenges for human resources for health: Workforce and capacity building

A strong HRH platform in terms of the workforce and their skills/competencies in a health system is the backbone of not only better health outcomes for all but also achievement of the global Sustainable Development Goals, UHC goals, and, by extension, GTS targets. The 2010 WHO Global Policy on Recommendations on *Increasing Access to Health Workers in Remote Rural Areas through Improved Retention* (WHO, 2010) and the 2016 WHO Human Resources for Health Action Framework [15, 16] include elements designed to address key HRH challenges including workforce shortages, misdistribution of personnel, gaps in skills and competencies, low retention, and poor motivation.

The COVID-19 pandemic not only emphasized the critical role of HRH in health systems but also amplified the serious need for skilled manpower at all levels and particularly in nursing and midwifery. Similarly, the pandemic further revealed the need for countries to recommit to and invest adequate resources in all areas of HRH [17]. The importance of this topic prompted WHO to declare 2021 the year of health and care workers globally [18].

Stalling of GTS targets over the last five years amplifies the need to rethink HRH and capacity building for malaria. According to the GTS, at least 10 countries were expected to be malaria-free by 2020, 25 countries by 2025, and 35 countries by 2030 [3]. While some progress is evident at the global level, there has been a generally poor response at regional and national levels for various reasons, including limited availability of new vector control tools; critical financial, human, and infrastructural resource deficiencies; as well as a focus mainly on biomedical skills training, might require rethinking. As in general health, effective and sustainable malaria elimination can be achievable only with enough and adequately trained human resources, an enabling infrastructure, and a functional health system. The WHO Human Resources for Health Action Framework and the recently developed WHO-sponsored Checklist for Implementing Rural Pathways to Train, Develop and Support Health Workers in Low and Middle-Income Countries are good resources to assist countries and stakeholders not only address malaria-specific HRH issues and a focus on rural, hard-to-reach areas, but also inform the needed integrated approaches to address broader areas of health in the context of limited resources [19].

Training for the malaria workforce: A brief description

Historically, African countries have trained their health workforce and strengthened research capacity through their tertiary education and research institutions and in partnership with the WHO [20, 21] and northern development partners and training institutions. These efforts focus on training individuals in different disciplines relevant to malaria through various formats, including traditional classroom/pedagogical methods for postgraduate and undergraduate degrees and more recent eHealth/mHealth learning at tertiary and middle-level medical training colleges for pre-service and in-service diploma/certificate programs. In these contexts, training takes at least three and upwards of 12 years, depending on the discipline and degree/diploma/certification being pursued.

Continuing education and on-the-job training remain mandatory for some disciplines. Such training may include short courses (certified or non-certified) relevant to an individual's role. Other capacity strengthening approaches include: i) internships and continuous on-the-job coaching and mentoring; ii) use of short-term consultants or long-term technical advisors, attached to NMPs for time-limited periods, to transfer specific skills through targeted malaria technical assistance on areas of need at national and/or subnational levels; iii) cross-country benchmarking exchange visits for malaria experts to learn from each other; and iv) virtual or in-person conferences to strengthen global knowledge exchange. Community of practice face-to-face or virtual platforms also have been used to strengthen capacity. Some of these approaches further allow for hands-on learning [22]. Generally, training has tended to occur away from workstations; however, creating substantial "absenteeism", disrupting service delivery, and increasing cost of training [23].

Training for community-based health workers [24] who help bridge the gap in adequate numbers of professional healthcare workers and cater to remote underserved populations includes classroom and in some instances training in the "open air" under trees. This form of training cascades from the highest to the lowest levels of a health system. While the specifics of cascaded training may differ with the setting, the training generally starts with central training-of-trainers workshops, followed by subnational training of public health professionals and frontline providers at the health facility level who then train community health workers/volunteers (CHWs) at the community level. Training for the different levels takes several days depending on the subject and abilities of instructors and learners.

The training that CHWs receive is recognized by formal health services, yet their certification or accreditation, if it occurs, is not part of the higher education certification process—which is key to recognition and professional career development and promotion at all levels. Also, continuous education, resources, and self-development opportunities vary for this cadre of frontline workers. Thus, CHWs, although perceived as an essential cadre, yet have not been fully utilized in Africa, often due to lack of resources and adequate planning [24].

These methods and approaches have worked relatively well for several decades, enabling countries to respond to global, regional, and national agendas and malaria control and elimination targets. However, the increase in malaria burden, population growth, biological threats (e.g., insecticide and drug resistance), the need for equity, and mounting pressures on health systems from other communicable and non-communicable diseases are challenges related to capacity building and increasing workforce size that must be addressed to achieve 2030 targets and beyond.

Specific malaria capacity expert base and workforce bottlenecks

Most bottlenecks outlined below are policy-related but actionable. They are informed by challenges identified across several malaria technical and service delivery areas as well as by stagnation of various elements in the fight against malaria.

Training, recruitment, and retention inadequacies

Malaria is a complex infection and disease. Its epidemiology is affected by many factors inherent in the disease and its transmission, as well as by social determinants. Therefore, the malaria response requires continuous research and development as well as a review of tools and approaches, which necessitates training and retraining of the requisite workforce. Such efforts must occur in parallel with continued implementation of ongoing interventions, especially in countries progressing from control to elimination. The high cost and time lags in advanced training of scientists and researchers who form the malaria expert base not only affect the pipeline of available experts but also negatively impact timely translation of research evidence into practice [25, 26]. This is compounded by the fact that new knowledge often has to be synthesized at the global level for standard normative guidance, trickling down to the countries where it must be adopted and adapted to different socioeconomic and environmental contexts and health system levels. Unfortunately, dissemination of new global knowledge and updates from national to subnational levels and service delivery points where interventions are implemented is not always optimal.

This review noted a concerning imbalance in the focus of training (Table 1) that has favored basic and biomedical sciences while neglecting knowledge generation and the critical need for a workforce with skills in operational/translational/implementation sciences [2, 27]. For example, articles and consultative meeting reports typically indicate that there are insufficient numbers of entomologists, genomic experts, and data scientists critical for surveillance, monitoring and evaluation, modelling, and logistics for supply chain management [2-4, 6, 11, 28, 29]. However, the dismal number of translational/implementation scientists across the board, especially in social sciences (including sociologists, anthropologists, behavioral scientists, specialists in advocacy and health diplomacy, health promotion and communication experts, policy analysts, health economists, resource mobilizers, gender and human rights specialists, program/project managers, team leaders, and community-based health systems specialists), also is acknowledged as a critical bottleneck but does not receive the same impetus as biomedical sciences to reverse the situation.

Also lacking is global agreement on a malaria training strategy and curricula aligned to current global strategies (WHO) and specific country malaria control/elimination needs. The need to address this gap resulted in the proliferation of many well-meaning organizations and institutions all working individually, without coordination around an overall set of training aims that are monitored over time. Thus, training approaches are fragmented and often even disconnected from national and subnational strategies. This raises important questions not only about the quality of courses and training but also whether they have sufficiently clear goals and objectives to address real-world gaps. Further, at all levels of training, adequate supportive supervision and post-training follow-up to reinforce learning and update the knowledge base, especially for frontline and community-based health workers, is vital yet lacking. In addition, when supervisory activities or visits take place, identified issues are not always addressed [personal observation, HM]. Lack of resources and/or adequate opportunities to apply knowledge and skills learned after training also is a key issue.

Nevertheless, there is a sizable well-trained base of health experts in Africa capable and committed to integrated malaria control and elimination that has contributed to the progress achieved to date. While these experts were trained locally and globally, there is a general lack of follow-up and measurement of the impact of advanced/specialized training on the malaria response, and especially on the capacity of home institutions to provide the right environment and support for globally trained experts to further

develop their capacities once back in their home countries/institutions. As reported by Woyessa et al. [12] and Juma et al. [30] and echoed in the feedback of frontline malaria workers for this review, other post-training constraints abound for individuals trained in malaria-relevant skills and competencies at all levels, from scientists to CHWs. There is a lack of career pathways and personal/professional growth, which is further compounded by poor remuneration and lack of incentives. This leads to high staff turnover and brain-drain, necessitating costly refresher and continuous trainings. Lack of proper planning and management of transfers and retirements also negatively impacts the health workforce [14]. In addition, maldistribution or inequitable distribution of the health workforce as well as political appointments of NMP personnel undermine proper workforce deployment and negatively impact the effectiveness of malaria control/elimination programs. "Siloed" training without integrated approaches that have the potential to not only expand and optimize the malaria expert base but also that for other vector-borne and infectious diseases represents another missed opportunity.

Our review also revealed a lack of information (database or registry) on HRH specifically for malaria in Africa. While this also has been reported for tuberculosis [31], lack of clarity on the current size and competencies/skill sets of a health workforce can prevent appropriate short- and long-term planning, including adequate investment in pre-service training at all levels and strategic recruitment, replacement, and deployment. This type of information also is critical for forecasting future competencies and skills needs as well as other important matters such as financial planning [14, 32].

Weak multisectoral coordination and collaboration

Although frameworks to address malaria through a socioeconomic development lens via multisectoral, intersectoral, and across inter- and intra-national boundaries approaches have long existed [33, 34], their implementation and results are not apparent. The frameworks have addressed various aspects of multisectoral actions between the health sector and non-health partners in finance, public services, agriculture, education, water, sanitation/hygiene, defense/security, transportation, public works/housing/urban planning, and the private sector. However, collaboration across these sectors generally remains weak, especially in terms of education and training at all levels, programming, and workforce management.

This lack of collaboration undermines maximization of potentially available human and financial resources that could be leveraged and rallied around malaria responses where most needed. Further, cross-training, especially for NMP managers with personnel from the other sectors, might open non-traditional platforms to facilitate better workforce management as well as deeper penetration and access to health for remote hard-to-reach populations and geographies. Realization of the importance of this aspect of the malaria response has stimulated re-thinking of non-health sectors that must be included in the fight against malaria, including extractive industries, humanitarian emergency response, primary education, and tourism, as well as better elucidation of what multisectoral action on malaria should look like [35]. However, training and joint programming are not included in the four broad categories proposed for cooperation on malaria control.

Universal health coverage, community engagement, and gender mainstreaming issues

The UHC initiative, which should be anchored on a strong primary health care platform to enable realization of Africa Union's targets for 2030 and beyond [36], has experienced slow adoption to date. A recent report on the *Status of Universal Health Coverage in Africa: Report of the Africa Health Agenda International Conference Commission* [37] indicates that African countries are still struggling to create proper roadmaps to reach UHC targets, exhibiting low achievement in almost all key indicators including

the priority of an increased, skilled, and competent health workforce, especially in public health skills. This also may partly account for the observed stalling in meeting 2030 GTS targets.

With regard to community engagement, home-grown solutions grounded in local knowledge and local actors generally are more sustainable compared to externally driven solutions. However, although there have been commendable efforts to engage communities and to institutionalize and mainstream CHWs into formal health systems, success in different countries is variable. This appears to be mainly due to a somewhat narrow focus on a three-decade-old definition of who a CHW is—"community health workers should be members of the communities where they work, should be selected by the communities, should be answerable to the communities for their activities, should be supported by the health system but not necessarily as part of its organization, and have shorter training than professional workers."[38]. This definition may need to be adjusted to accommodate a more inclusive people and household-centered approach, which would facilitate exploration of other possible models described in the next section and also reconsider "accountability" arrangements.

Further, evidence indicates that 70% of the global health workforce is female, especially at the frontline and community levels [39]. These workers generally have low levels of education, receive minimal training, and are under-resourced, overworked, and underpaid or unpaid. Also, there are few women in sciences in general, few in malaria leadership, and even fewer in global health leadership. The gross under-representation of males at the frontlines should be addressed, as these constraints and lack of gender-sensitive programming for malaria also may be linked to chronically low uptake of core malaria interventions.

Opportunities for improvement and recommendations

These identified areas of training and capacity building or strengthening indicate opportunities to improve and move further toward achieving GTS milestones and goals. Some of the opportunities are already in place and just need to be reinforced; others must be assessed; and yet others are innovative and will require bold global, national, and political commitment because they have cost implications. For example, it will be necessary for countries to include ring-fenced training and capacity building in NMP budgets. The proposed recommendations also may necessitate long-term periodic policy changes, guideline updates, and dissemination due to emerging new evidence until malaria is eradicated. Our review of the literature complemented by informal feedback from frontline malaria workers has informed the following opportunities and innovative approaches for capacity building and workforce enhancement that could be scaled and/or retooled for this purpose.

Strengthening capacity for malaria control and elimination

Malaria endemic countries' ministries of health and education as well as academic and research institutions and other relevant sectors, working with WHO and partners, should assess the impact of training time lags on the malaria response, similar to assessments of the impact of time lags in getting research evidence into practice [26]. The merits of refocusing efforts on training mid-level and frontline health workers also should be assessed [40]. This presents an opportunity for countries to address critical elements of capacity strengthening in partnership, coordination, and collaboration with other health and non-health sectors in an integrated manner.

Investment in integrated malaria capacity-building has the potential for spillover effects on other health interventions and programs, as well as on the entire health system and society at large. Countries must spearhead and own this dialogue as they engage with partners including the Africa CDC, WHO and WHO Academy, donors, and other development partners. This would entail agreeing on a training strategy and

curriculum or series of curricula for training at different levels and for different cadres of malaria workers. This would then be adapted and tailored to specific country needs, ensuring the countries own the entire process—from planning to implementation and post-training follow-up, which is critical in capacity-building/strengthening. It is likely that having a standard, agreed-upon approach would enable its coordinated delivery through multiple agencies/funders. Such standardization would also address issues with quality of courses and training as well as measurement and evaluation of the training over time. Ownership of the process by national governments could help them better plan and focus their domestic resources on training. It also would act as an accountability measure for all stakeholders to assure sustainability.

We suggest some pathways to curriculum/certification standardization to consider. There already exists in the malaria space, the diagnosis through microscopy certification process that could be a pathfinder for other skill sets in malaria. Also, the malaria community could borrow a leaf from the Global Health Network, a platform that runs a professional competence scheme for clinical trials in partnership with the UNDP/UNICEF/WHO Special Program for Research and Training in Tropical Diseases (TDR) which utilizes the power of high-quality resources, virtual learning and a standardized WHO approved curriculum. The training allows an individual progress through various levels - from the most basic to the expert [41]. We envision a similar scheme for malaria control and elimination, which would be coupled with some form of agreed upon of certification, or through standard accreditation processes spanning all aspects of malaria control and elimination regardless of the individual's basic training (i.e., biomedical, public health or social sciences). It would be important that these utilize existing regional and/or in-country academic and board certifying professional organizations, and governmental resources and personnel. Africa currently has centers of excellence in malaria research in Ghana, Kenya, Malawi, Mali, Tanzania to name but a few. This critical mass of experts, together with other malaria global centers and experts could quickly get this urgent process going. Completion of the next steps of the "Informal Consultation on the Development of a Capacity Building Strategy for Malaria Control and Elimination," convened by the WHO's Global Malaria Programme in March 2018, where these proposals could be further interrogated, with an expanded stakeholder base (e.g., relevant non-health partners) to make it inclusive, transparent, and participatory should be expedited.

To help tailor solutions, local universities, and biomedical/public health institutions—on their own or with south–south and/or north–south partnerships—should take the lead in rethinking how to deliver targeted training, which will serve capacity building/strengthening needs at the individual, institutional, and health systems levels. South–south institutional collaborations must be prioritized and emphasized, while northern training institutions should only jointly offer malaria training together with disease-impacted southern counterpart. Additionally, NMPs will need to form new partnerships with humanities, social sciences, and data sciences departments at universities and training institutions to enlist experts in disciplines that inform operational, translational, and implementation aspects of malaria control, including social and behavior change communication and mobilization, policy analysis and development, gender and human rights, and project management. These soft sciences have the potential to improve uptake of existing tools and interventions and ensure they are fully optimized through compliance by providers and users. Thus, existing partnerships with biomedical departments should be strategically reoriented to areas of most need, such as a mechanism to facilitate faster and systematic dissemination of new global knowledge and updates at the country level, and to ensure these seamlessly cascade from national to subnational and community-level service delivery points. Funding agencies also should rethink their agendas and focus their attention on what countries need by promoting demand rather than offer-driven solutions for identified needs via research and training calls/grants.

At the NMP level, improvements that could better serve the malaria response include deliberate periodic analytical assessments of gaps in skills/capacities in each endemic country to strategically tailor short- and

long-term training and/or technical assistance to quickly respond to needs. These regular technical or service delivery assessments also could include reviewing of interventions, approaches, and tools as part of ongoing training. Methods and approaches of "in-service" training that do not take malaria workers from their day-to-day jobs should be prioritized at all levels [23, 41]. This ensures that core work of the workforce is not affected by frequent/long absences from their jobs. Further, implementing partners/agencies (local and international non-governmental organizations) have capacity strengthening models that are currently project-based that should be evaluated to assess their cost-effectiveness and scalability. This includes the Long-Term Technical Assistance program [22] and coaching, mentoring, and cross-country/state/county study tours. Regular, appropriate, supportive post-training supervision is vital and must be strengthened at the NMP level to reinforce newly acquired knowledge and skills for the malaria workforce. For example, this could address a critical and perennial problem of health providers not following protocol on parasitological testing of fever cases before treatment.

Further, countries must institute strategic multisectoral, intersectoral, and cross-border collaboration in relation to training to maximize available human and financial resources that could be leveraged and rallied around the malaria response at country and regional levels. Frameworks and guidelines on how to implement multisectoral approaches exist, but they are silent on how training could be carried out within their ambit. Cross-training with personnel from neighboring countries and other relevant disease programs as well as non-health partners might open non-traditional platforms to optimize health workforce teams that can work across diseases, leveraging synergies and optimizing the available health workforce, especially those working in remote geographies. It is imperative that all stakeholders in health, including ministries of health, health professional regulatory boards, professional associations, training institutes, employers, and workers' representatives, work together to implement successful changes in training and capacity strengthening for malaria [42]. Innovative strategies for broader gender diversity, inclusivity, mainstreaming at all levels, and meaningful engagement of the private sector in this process are highly desirable. An urgent action would be for the malaria community to also explore how large-scale conglomerate industry handles cross-sector training.

Effective and/or innovative community engagement models

Recent evidence indicates that countries that eliminate malaria have relied on cadres of CHWs, paid workers or volunteers who detect, diagnose, and sometimes treat malaria [43]. The recent WHO deep dive into what it will take to engage communities—successfully culminating in development of the Community Engagement Framework for Quality, People-centered, and Resilient Health Services [44]—is an opportunity that could leverage the full potential of the CHW movement, which is already established in most malaria-endemic countries. We posit that it will be necessary to broaden the definition of a CHW to encompass other categories of individuals who could provide frontline health service delivery periodically in the short-term and permanently in the longer term. Another resource that could be useful in further articulating meaningful and effective community engagement is the second edition of the Clinical and Translational Science Awards Consortium Community Engagement Key Function Committee Task Force on the Principles of Community Engagement [45]. Community engagement must emphasize involving communities meaningfully in co-creation of solutions to jointly identified problems from conception to implementation through shared responsibility and with well-defined roles and responsibilities of all partners.

WHO estimates that 18 million more health workers are required to achieve UHC by 2030 in low- and lower-middle-income countries [46]. We propose that new community service delivery models that have potential to also serve hard-to-reach areas [19] can help address the chronic shortage of HRH in general, in order to increase and optimize the health workforce for malaria in particular. The WHO High Burden to

High Impact and E-2025 initiatives [47, 48] present early opportunities to pilot and/or strengthen the models below.

- An estimated 64 million youth are unemployed globally, the majority of whom are in Africa [49]. Careful selection, recruitment, training, and deployment of large numbers of unemployed youth and young adults who have requisite levels of education for specific tasks in malaria control/elimination could exponentially increase frontline health workers. The youth could be trained to perform tasks including community surveillance, case investigation, social and behavior communication/information and education communication to improve treatment-seeking behaviors, uptake and reach of seasonal malaria chemoprevention, compliant and consistent use of long lasting insecticidal nets (LLNs), community intermittent presumptive treatment of pregnant women (IPTp) and intermittent presumptive treatment of infants (IPTi), diagnosis with rapid diagnostic tests and treatment, and referrals. Their jobs could be treated as short-term seasonal work during malaria surges or epidemics, a concept that is acceptable in other areas such as agriculture. A framework already exists that could be used to assess feasibility and scalability of this proposal [50]. Some countries also have youth employment strategies that could be encouraged to incorporate malaria control activities into their plans. For example, Rwanda has an active Youth Against Malaria Organization; Kenya is using a youth employment strategy to improve urban slums, which could be tapped for malaria control/elimination; and there are likely other examples from other countries. The recent Africa Health Agenda International Conference Commission [37] report emphasizes the critical need to harness and empower African youth and women with knowledge and skills to enable them to play a more significant role in UHC delivery. Gender diversity, inclusivity, and mainstreaming must be at the core of women and youth empowerment.

- Training a cadre of health workers who would be deployed in their local areas through collaboration between NMPs and technical/vocational education and training institutions is another possible route to enhance the malaria and broader health workforce. These institutions can and in some countries do train paraprofessional health cadres that could be further trained to supervise CHWs during “seasonal malaria surge-support” periods, increasing support and accountability at this level while increasing the health workforce [22]. El Salvador used a cadre of “epidemiology assistants” and “entomological assistants” who worked side-by-side with volunteer community or “Col Vol” health workers—but also acted as the first tier of supervision for the “Col Vol” workers with impressive results in decline of malaria in the country [51]. These “Col Vol” workers also were trained and strategically deployed according to macro- and micro-stratification needs, especially during high-malaria season periods. In February 2021, El Salvador was declared malaria free.

- Training of high school CHWs to serve underserved communities in their localities could provide a health career pipeline as well as mentoring for underserved students and could promote health education and health literacy in schools and communities. This strategy has the potential to keep youth in school and to produce health workers for tomorrow [52]. The model has been successful in the US, and frameworks that could be adapted globally have been developed. Several countries including India, Indonesia, Tanzania, and Zambia also have implemented this strategy with success.

- Leveraging the large numbers of undergraduate university students and government pre-service Youth Training Programs available in most malaria-endemic countries by creating

rotational/internship programs to coincide with high-burden malaria seasons could be explored during which the students/trainees could deliver community malaria services under supervision. This could be linked to academic credits toward students'/trainees' degrees/diplomas/certificates, creating a win–win situation for both students/trainees and communities. Also, many countries have unemployed graduates from all disciplines who also could be targeted for training in appropriate skill sets for short-term surge-support for malaria control and elimination.

- While faith-based organizations and civil society organizations exist in all malaria-endemic countries, they have not been fully exploited in the fight against malaria. Further, where these organizations are active, they might not be inclusive of all stakeholders. Together with engagement of traditional leaders, partnering with such organizations where appropriate could expand the workforce base beyond clinical services and especially enhance social mobilization, behavior communication, and advocacy on malaria. This point is further elaborated under key theme #3 in paper 2 in this series ("Rethinking Integrated Service Delivery for Malaria").

- Due to changing demographics, Africa has a large reservoir of retired university professors and medics who also could be utilized to provide training and/or advice to NMPs as required.

The above suggestions could be operationalized through one of the key areas of collaboration agreed upon in a memorandum of understanding signed between the Africa Union Commission and WHO [29], aimed at assisting the African region through the Africa Centers for Disease Control and Prevention (Africa CDC) by supporting efforts to strengthen the health workforce in Africa Union member countries. This could be considered part of the proposed establishment of the African Volunteer Health Corps and rational allocation and use of existing resources, including HRH to ensure realization of UHC goals.

Strengthening of HRH information systems

Africa, which carries 17% of the world's population, accounts for the highest global burden of disease at 23% [37] but has only 3% of the global health workforce [53]—making addressing HRH issues an emergency. As a matter of urgency, countries and partners should systematically assess and collect HRH information for malaria and other disease control programs for synergy and integration purposes, to enable a rapid response to resolving workforce issues such as hiring, retention, and redeployment. Countries should be encouraged to create national HRH databases/registries that include all cadres of health workers from doctors to CHWs, and NMPs should include HRH budgeted development plans in national malaria strategic plans, which would be the best platform to address workforce and training needs for malaria. The plans should critically look at issues of attrition through brain drain, retirement, career mobility, and growth as well as retention at all levels. Robust expansion of malaria interventions over the past decade has been accompanied by significant requirements for an increased workforce and expert base at national, district, and community levels. Therefore, deployment of health workers to cater to expanded interventions must be strategic and should consider new roles and structures as countries progress from control to elimination. For more on the issues of data in malaria control and elimination, please see paper 2 in this series ("Rethinking Integrated Service Delivery for Malaria").

Strategic deployment and optimization of roles of the malaria workforce

In a short period, epidemiological/entomological stratification of malaria in countries has enabled definition of malaria risk, and resultant targeted interventions have paid dividends. Countries are better

prioritizing intervention mixes and resources in strata with the highest burdens. Strategic deployment of malaria teams with skills aligned to the needs of each stratum would translate into high coverage, compliance, and impact of interventions. It is recognized that not all countries know what their needs are or have all the right skills mixes, therefore, this also acts as a call for countries to conduct needs assessments to identify their gaps. Nevertheless, deliberate and rational planning and distribution of the malaria workforce could go a long way in progressing countries along the elimination continuum. This has been demonstrated in El Salvador, where malaria risk and corresponding needs were purposely used to determine the numbers and skill sets of "Col Vol" workers selected/distributed to serve specific epidemiological strata, with great success despite the country experiencing a war situation [51].

Incentivization of the malaria workforce

Aside from lack of skills and relevant competencies to support elimination goals, the current malaria workforce is unmotivated due to low remuneration. This phenomenon leads to health workers shifting to better-paying jobs in non-governmental organizations, the private sector, and international organizations (internally and externally) or changing careers entirely, leaving an inadequate pool of personnel to sustainably stem the attrition and thus achieve GTS elimination goals. Motivation and retention packages for malaria workers that could stymie brain-drain from NMPs while motivating personnel and increasing ownership of malaria programs may include financial (better salaries, school debt forgiveness, scholarships), educational, personal, and/or professional growth support at all levels [12]. Further, it has to be emphasized again that women and youth have a right to meaningful participation in health in general, and malaria matters in particular, yet remain significantly underrepresented, especially in leadership levels. This is not only a gender equity issue, but also an important incentive area which should be tackled through career advancement opportunities to leadership positions for women and youth.

Political commitment and funding

The Africa Union, regional health organizations in Africa, and Africa CDC are well-placed to be flag bearers and champions for supporting calls for governments and donors to commit adequate domestic and external resources for workforce enhancement and training at all levels, as well as to push for regional and cross-border efforts to ensure GTS goals are achieved and that no one is left behind. Further, civil society organizations should be encouraged to hold governments accountable for their pronouncements of commitment to ensure these become reality, especially in relation to HRH, primary health care, UHC, expenditure for healthcare, research funding, and general strengthening of health systems. The COVID-19 pandemic illustrated the ability of African governments to act quickly and decisively. African governments can likewise spearhead reinvigoration of the malaria response on the heels of the pandemic. There needs to be intentional capacity building for decision-makers through various forums convened by instruments such as the Africa Union, African Leaders Malaria Alliance, and regional health organizations. International development partners also must reconsider their relationship with malaria-endemic countries and their contribution to the current high dependency of countries on donor funding. Change will have to come from both sides.

Further, due to similar needs across vector-borne diseases, other infectious diseases, and in reproductive, maternal, neonatal, and child health, a shift and focus on integrated training is imperative. We must collectively make deliberate decisions to do things differently by urgently addressing the identified issues, reinforcing what is working and discarding what is not working.

Conclusion

This report highlights the variation in malaria workforce availability and the gaps and need for a health workforce and its required competencies/skills for malaria control and elimination in Africa. This evidence calls for re-examining current approaches as well increasing continuous and concerted efforts toward capacity building for biomedical and social scientists, public health specialists, mid- and lower-level health cadres, and decision-makers to equip them with relevant competencies and skills that will enable them to maintain current gains while accelerating momentum toward malaria elimination. We propose stakeholders who should spearhead the rethinking/retooling of capacity building and workforce enhancement as well concrete approaches that could be quickly explored and implemented. We emphasize the need for all stakeholders to collaborate and coordinate their activities while placing the ownership of relevant processes to malaria endemic countries. This implies that any efforts to enhance the workforce and setting of standardized and tailored training and capacity building should primarily be demand-driven, as opposed to often offer-driven earlier efforts. Consequently, enhanced long-term investments to massively increase the size and skill sets of professional and frontline cadres in malaria and other vector-borne disease-endemic countries as well as for peripheral healthcare and promotion should be an absolute requirement for any strategic and operational decision embraced by international, regional, and national stakeholders in malaria control and elimination as well as the entire global health agenda.

Nevertheless, even as we advocate for a competent and skilled malaria workforce, we also caution against compartmentalized training and encourage a holistic view of the problem that calls for an integration of different control programs to maximize effect and optimize resources. The COVID-19 pandemic has revealed and amplified key issues and left in its wake significant lessons in this regard.

The literature is awash with numerous global and regional commitments to HRH, primary health care, UHC, and community engagement in the form of pronouncements, frameworks, memorandums of understanding, and strategies that if implemented could address the identified issues in a short period of time. However, if they remain aspirational and rhetorical, and without an accountability mechanism with attached sanctions to ensure all stakeholders involved in malaria control and elimination efforts play their part, the desired change will continue to be a mirage—2030 will be another missed opportunity.

Table 1. Capacity Strengthening and Training for Malaria: Current Status

Current Status	Core Courses	Specialized Courses	Gaps/Weaknesses	Opportunities	Threats
Biomedical Sciences	Epidemiology	Surveillance and stratification	Micro-stratification Medical entomology Lack of good data sciences	A plethora of existing materials from WHO, PMI/CDC, Global Health Network, EDCTP, Harvard-ISG-Swiss TPH consortium, and Networks in Asia and ACTMalaria Existence of a substantial mass of African centers of excellence for malaria research and teaching in Central, East, Southern and West Africa that can address the identified weaknesses	Lack of coordination and common training strategy Lack of real estimates of need, and therefore failure of implementing effective strategies Territorialism Lack of funding and lack of interest in working in an area that might become obsolete when malaria is eradicated Lack of political commitment and country ownership Over-reliance of countries on external funding Perceived dominance of the malaria response by the North Data illiteracy at all levels of the health workforce and in all
	Entomology and vector control	Vector resistance and surveillance			
	Diagnostics and case management	Microscopy, Therapeutic Efficacy Studies, drug resistance Chemoprevention			
	Pharmaceutical Sciences	Drug discovery, Dispensing, pharmacovigilance, etc.	Limited number of pharma scientists		
Implementation and Operational Sciences	Planning and management of malaria programs	Leadership training, advocacy and social mobilization	Health information sciences Logistics and supply chain management Policy dialogue, analysis, and development	Public health schools could collaborate with departments of humanities to provide degree, certificate, and short-term	

		Resource mobilization	Operational research Community engagement Training in ethics Human rights and gender Health economics Multi/trans/intra disciplinary approaches Analytical problem-solving skills Partner coordination	courses to address identified gaps Focus on training mid-level career health workers Training of CHWs could include training of informal drug dispensers on whom many communities depend for first treatment of perceived malaria symptoms	sciences (biomedical and social) Huge challenge to regulate and reach the large number of this cadre especially in urban areas.

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