

COMBATING MALARIA: THE POTENTIAL OF MHEALTH

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INTRODUCTION

Humanity has fought malaria for millennia. Despite significant advances in medicine and technology, malaria continues to claim lives – about 1300 children daily.¹ We understand the transmission of malaria and have reliable anti-malarial treatments and evidence-backed methods of prevention. As a collaborative global community, we have successfully decreased the mortality of malaria over the past decades. Yet malaria rages on.

In order to combat malaria effectively, we must utilize a broad range of proven preventative and therapeutic treatments. Mobile health – commonly abbreviated as mHealth – hosts the potential to more effectively connect preventative and therapeutic resources to hard-to-reach communities. By using mobile technologies, like mobile phones, health systems could engage a larger population, increase access to high quality care, and reduce intervention costs. Greater efforts to collect evidence on the cost-effectiveness of anti-malarial mHealth interventions must be exerted, but early studies suggest that mHealth can catalyze anti-malarial interventions.

The ties between poverty and malaria run deep. Malaria generally thrives in the most disadvantaged communities.² These communities are generally found in tropical and subtropical zones with the highest rates in sub-Saharan Africa (SSA). In fact, about 80% of malaria-related deaths occur in this region of Africa, mostly among children under the age of five.³ In order to reduce poverty and increase the range of opportunities accessible to the disadvantaged populations in malaria endemic regions, we must remove, or at least reduce, the burden of malaria.

¹ World Health Organization. *World malaria report 2013*. World Health Organization, 2013: v.

² Sachs, Jeffrey, and Pia Malaney. "The economic and social burden of malaria." *Nature* 415, no. 6872 (2002): 680.

³ World Health Organization: 61.

ON MALARIA

Following the Millennium Summit of the United Nations (UN), world leaders established eight bold millennium development goals that would drive over a decade of innovative aid projects. Target 6C seeks the impedance and reversal of global malaria incidence by 2015.⁴ While that target might not be realized in every nation by 2015, the global progress has been encouraging. Between 2000 and 2012, the incidence of malaria-related deaths decreased by 29%.⁵ Similarly, the mortality rates for malaria have decreased by 45% globally during the same period.⁶ The progress suggests that malaria can be controlled, but only with a strong, globally unified approach.

Target 6 mentions malaria along with HIV/AIDS, TB, and “other major diseases,” which seems to diminish the importance of malaria.⁷ So, does malaria deserve special consideration? John Gallup and Jeffery Sachs argue that the economic burden of malaria warrants particular scrutiny, especially among those concerned with the ties between poverty and health.⁸ The global distribution of per-capita gross domestic product (GDP) and malaria risk are inversely related (Figures 1 & 2). As previously mentioned, malaria seems to be concentrated in tropical and subtropical regions (Figure 2). Figure 2 also shows that non-tropical malaria endemic countries have been able to reduce their status as high risk of malaria between 1946 and 1994. This evidence suggests a strong correlation between malaria and poverty, but it does not address the issue of causality.

Gallup and Sachs explored the relationship between malaria and macroeconomic income levels using cross-country regression analyses. Many SSA countries are landlocked or have ports that are far from international trade hubs. This limits their ability to participate in global trade and reduces their income potential.

⁴ "United Nations Millennium Development Goals." *UN News Center*. UN, n.d. Web. 13 Mar. 2014.

⁵ World Health Organization: v.

⁶ Ibid.

⁷ "United Nations Millennium Development Goals."

⁸ Gallup, John Luke, and Jeffrey D. Sachs. "The economic burden of malaria." (2001): 85.

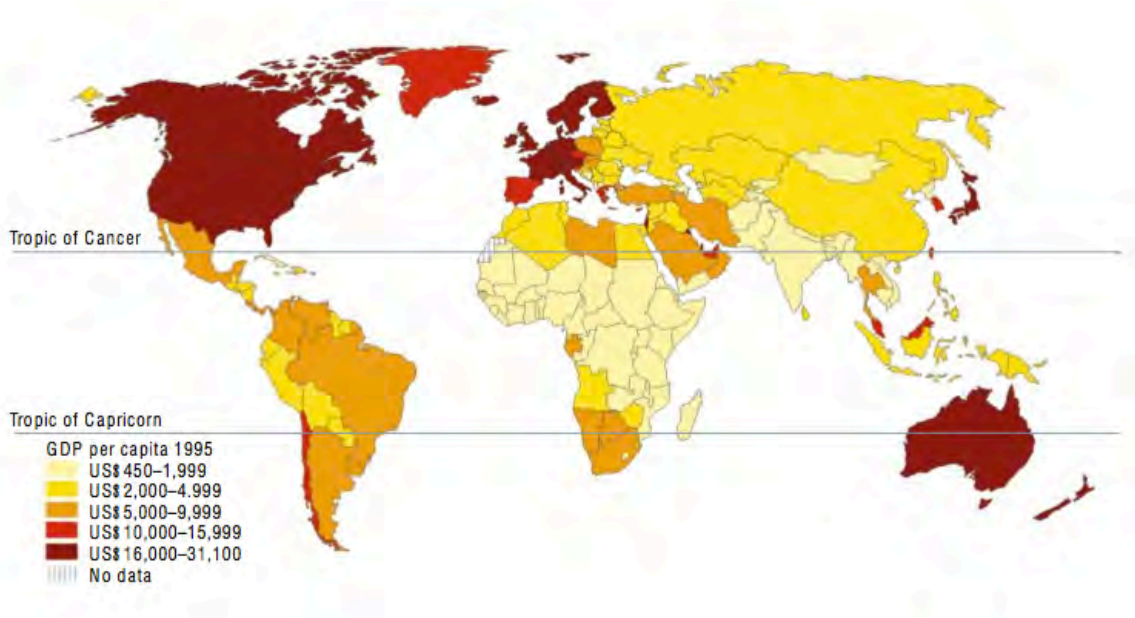


Figure 1 - Global Distribution of per-capita GDP⁹

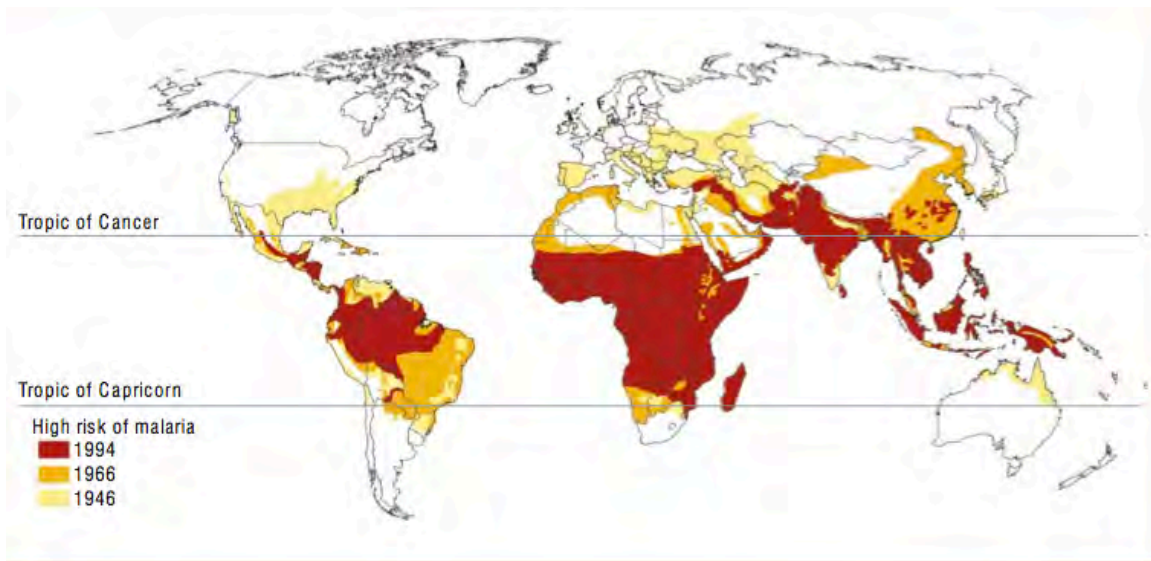


Figure 2 - Global Distribution of Malaria¹⁰

⁹ Sachs and Malaney: 682.

¹⁰ Sachs and Malaney: 681.

In order to participate in international trade, it is also important to have access to natural resources. Gallup and Sachs used access to hydrocarbons resources as a proxy for natural resource deposits. They observed a “penalty” for tropical land mass in their initial regression.^{11,12} The penalty for tropical land mass loses significance after malaria is included in Regressions 2 and 3 (Figure 3), but reappears in Regression 4 indicating that it might have a malaria-independent impact. After controlling for all those factors, malaria proved to have a significant effect on income levels. The second and third regression seen in Figure 3 show that malaria endemic countries had 31% of per-capita GDP of non-malaria endemic countries in 1950 and that by 1995 the negative effect of malaria grew so that malaria endemic countries had less than 30% of the per-capita GDP of non-malaria endemic countries.¹³

| Variable | Regression model | | | | | |
|---------------------------------------|---------------------------------|-------------------|--------------------|-------------------|-------------------|-------------------|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| | Log GDP per capita [†] | | | | | |
| | 1995 | 1950 | 1995 | 1995 | 1995 | 1995 (non-Africa) |
| Population within 100 km of coast (%) | 1.26 (6.31)** | 0.80 (5.19)** | 0.57 (2.74)** | 0.65 (3.40)** | 0.33 (2.23)* | 0.40 (2.76)** |
| Log distance to major markets | -0.35 (3.79)** | -0.12 (1.37) | -0.33 (4.03)** | | | |
| Log hydrocarbons per person | 0.01 (2.28)* | 0.01 (2.56)* | 0.01 (1.86) | 0.01 (2.13)* | 0.00 (1.36) | 0.00 (1.27) |
| Tropical land area (%) | -0.68 (3.97)** | -0.14 (0.89) | -0.23 (1.01) | -0.59 (3.04)** | -0.09 (0.59) | -0.10 (0.83) |
| Falciparum malaria index | | -1.17 (6.28)** | -1.22 (5.67)** | -1.16 (4.73)** | -1.16 (6.41)** | -1.10 (4.34)** |
| Socialist | | | | -0.80 (5.20)** | -0.10 (0.66) | -0.05 (0.30) |
| Colony | | | | -0.14 (2.18)* | -0.05 (0.89) | -0.12 (2.24)* |
| Trade openness (0–1) | | | | | 0.50 (2.99)** | 0.43 (2.98)** |
| Quality of public institutions (0–10) | | | | | 0.22 (6.85)** | 0.23 (7.82)** |
| Constant | 10.50 (14.10)** | 8.54 (13.54)** | 10.91 (17.36)** | 8.75 (46.40)** | 7.15 (29.27)** | 7.15 (32.30)** |
| Observations | 149 | 127 | 127 | 149 | 97 | 66 |
| R ² | 0.47 | 0.59 | 0.62 | 0.62 | 0.88 | 0.88 |

† Robust *t*-statistics are in parentheses.
* Significant at 5% level.
** Significant at 1% level.

Figure 3 - Gallup and Sachs Level of per-capita GDP Analysis¹⁴

¹¹ Gallup and Sachs: 87.

¹² This penalty might partially be a proxy for malaria since tropical regions host the most effective malaria vectors.

¹³ The table seen in Figure 2 shows the log per-capita GDP. I used $e^{(-1.17)}$ and $e^{(-1.22)}$ in order to calculate the per-capita GDP of malaria endemic countries for 1950 and 1995,

¹⁴ Gallup and Sachs: 87.

In order to demonstrate the robust nature of the economic burden of malaria, Gallup and Sachs considered political policies and historical factors. They controlled for countries that were socialist in the post-World War II era, former colonies, and had two variables that weighed economic policies that encouraged trade and the quality of public institutions. After controlling for these factors, the general magnitude and significance of the effect of malaria did not change.¹⁵ They ran their model on non-African nations and the economic burden of malaria was slightly smaller but still significant (these nations had 33% of the income of non-malaria endemic nations in 1995). High rates of malaria had a larger impact on per-capita GDP than any other factor in regressions that controlled for malaria.¹⁶ Other factors contribute to the lower levels of economic productivity, but effect of malaria on the population health cannot be easily ignored.

| Variable | Regression model ¹⁷ | | | | | |
|--|--------------------------------|------------------|------------------------|--------------------------------|------------------|------------------|
| | 1 1965-1990 | 2 1965-1990 | 3 1965-1990 (IV) | 4 1965-1990 (non-Africa) | 5 1965-1990 | 6 1980-1995 |
| Log initial GDP per capita | -2.6 (8.07)** | -2.6 (7.90)** | -2.4 (7.54)** | -2.5 (6.36)** | -2.3 (8.04)** | -3.6 (7.95)** |
| Log initial secondary schooling | 0.1 (1.04) | 0.1 (0.90) | 0.1 (0.60) | 0.1 (0.62) | 0.1 (0.77) | -0.2 (0.62) |
| Log initial life expectancy | 4.4 (4.46)** | 3.1 (3.41)** | 3.0 (3.51)** | 3.8 (2.34)** | 4.6 (4.19)** | 9.6 (3.44)** |
| Trade openness (0-1) | 1.8 (4.91)** | 1.7 (4.91)** | 1.6 (4.51)** | 1.7 (4.14)** | 1.7 (4.55)** | 3.0 (5.10)** |
| Quality of public institutions (0-10) | 0.4 (3.29)** | 0.4 (3.79)** | 0.3 (3.32)** | 0.4 (2.95)** | 0.3 (2.78)** | 0.6 (4.03)** |
| Tropical land area (%) | -0.6 (1.30) | -0.6 (1.31) | -1.0 (2.55)** | -0.6 (1.28) | -1.0 (2.50)** | -0.6 (1.22) |
| Population within 100 km of coast (%) | 0.9 (2.85)** | 0.7 (2.64)** | 0.7 (2.41)** | 0.6 (1.66) | 0.8 (2.36)** | 0.9 (1.80) |
| Initial falciparum malaria index | -1.3 (2.24)** | -2.1 (3.77)** | -1.8 (3.12)** | -1.8 (1.77) | -1.3 (1.98)** | |
| Change of falciparum malaria index | | -2.6 (4.07)** | -2.5 (3.48)** | -2.2 (2.24)** | | |
| Tropical disease, first principle component | | | | | 0.1 (1.51) | |
| Initial World Health Organization advisory malaria index | | | | | | -1.6 (2.8)** |
| Constant | 1.3 (0.36) | 6.1 (1.68) | 5.7 (1.58) | 3.7 (0.63) | -0.9 (0.21) | -14.8 (1.42) |
| Observations | 75 | 75 | 73 | 60 | 73 | 78 |
| R ² | 0.77 | 0.80 | 0.80 | 0.76 | 0.77 | 0.71 |

* Robust t-statistics are in parentheses.
 * Significant at 5% level.
 ** Significant at 1% level.

Figure 4 – Gallup and Sachs GDP Growth Analysis¹⁷

¹⁵ Gallup and Sachs: 87-88.

¹⁶ Ibid.

¹⁷ Gallup and Sachs: 92.

The analysis of income levels failed to account for initial levels of income and health, so Gallup and Sachs also analyzed the growth of per-capita GDP between 1965 and 1990 (Figure 4). Here, Gallup and Sachs show that after controlling for factors that address the initial levels of economic strength, education, and health, as well as those factors previously considered, the effect of malaria remained robust.¹⁸ On average, a malaria endemic country saw their per-capita GDP grow by 1.3% less than non-malaria endemic countries each year between 1965 and 1990.¹⁹ Gallup and Sachs also considered the effects of twenty other tropical diseases, including dengue fever and sleeping sickness, but controlling for their incidence did not change the economic burden of malaria.²⁰ No other communicable disease analyzed significantly affected per-capita GDP.²¹ Therefore, malaria does warrant special consideration. Its effects on macroeconomic income levels and growth are robust and sizable. This also suggests that causality runs from malaria to poverty.

In order to understand the causal relationship between malaria and poverty, Jeffery Sachs and Pia Malaney explored potential mechanisms. They believe that two categories of mechanisms should be addressed in regards to malaria and poverty: (1) “changes in household behavior in response” to malaria and (2) “macroeconomic costs that arise specifically in response to the pandemic nature” of malaria.²² Malaria is deadliest among children below the age of five. In malaria endemic countries, a quarter of all deaths among children below the age five can be attributed to malaria.²³ Sachs and Malaney note that high rates of infant mortality historically are linked with high fertility rates.²⁴ Households with limited resources are less capable of making adequate investments in healthcare and education as they grow in size. This behavior tends to have a greater effect on girls.

¹⁸ Gallup and Sachs: 91.

¹⁹ Gallup and Sachs: 92.

²⁰ Gallup and Sachs: 93-94.

²¹ Gallup and Sachs note that the burden of HIV/AIDS was still quite small by 1990. It is possible that post-1990 data would see a significant economic burden from HIV/AIDS not seen in the data analyzed by Gallup and Sachs.

²² Sachs and Malaney: 682.

²³ Ibid.

²⁴ Ibid.

If women in a malaria endemic region are more likely to have more children, then they will spend a greater portion of their adult life childbearing in comparison to women in a non-malaria endemic region. The investment of education for girls might be seen as unnecessary in these contexts.

Even if families do choose to invest in education, malaria contributes to high rates of school absenteeism.²⁵ For the children that do go to school, malaria could affect their cognitive abilities and reduce their educational achievement.²⁶ In addition to these behaviors, malaria reduces the amount of disposable income available to households, due to the medical costs associated with malaria, and also precipitate lost productivity.²⁷ These economic costs are felt by at the household level, but their repercussions can be measured by macroeconomic measures. In addition to these household costs, Sachs and Malaney discuss the macroeconomic costs of migration, decreased trade, and reduced tourism due to malaria.²⁸ The manifestation of these factors could be the lower growth of per-capita GDP in malaria endemic regions observed by Gallup and Sachs.²⁹

While the evidence presents malaria as a robust cause of poverty, Sachs and Malaney suggest that causality can also run the other way; poverty can contribute to increased levels of malaria transmission.³⁰ They note that malaria incidence can be prevented, or at least reduced, by purchasing ITNs or other proven preventative resources. Disadvantaged populations in malaria endemic regions lack access to preventative and therapeutic resources. These malaria endemic regions need a globally unified response to address this barrier and eliminate malaria. A 10% reduction in the malaria index correlates with a 0.3% increase in GDP growth,³¹ so even the more modest goal of reducing malaria incidence can have notable poverty reduction effects.

²⁵ Sachs and Malaney: 683.

²⁶ Ibid.

²⁷ Sachs and Malaney: 683-684.

²⁸ Sachs and Malaney: 684.

²⁹ Gallup and Sachs: 92.

³⁰ Sachs and Malaney: 681.

³¹ Gallup and Sachs: 91.

ON MHEALTH

In 2013, the UN recognized two interventions that exhibited great promise in combating malaria: (1) the wide distribution of insecticide-treated nets (ITNs) in countries as seen in the Democratic Republic of Congo and (2) a mHealth campaign that used smart phones to collect data and monitor treatment of drug-resistant malarias in Thailand.³² The expansive literature on ITNs strongly encourages their use. These studies have shown that ITNs are cost-effective, even with free distribution.³³ The World Health Organization (WHO) treats ITNs as the most important resource for malaria prevention and recommends their free distribution to all persons at risk for malaria.³⁴ On the other hand, interventions in mHealth are novel and worthy of further analysis.

mHealth involves the use of mobile technologies in a broad range of healthcare applications. Developing nations have seen the sales and distribution of mobile devices proliferate over the past decade. In SSA alone, mobile device sales grew by 80% between 2009 and 2012.³⁵ There are now more people in the world that have access to a commercial mobile signal than have access to an electrical grid.³⁶ Of the 6 billion people that have access to commercial mobile signals, 5 billion are wireless subscribers.^{37,38} No longer is it uncommon for individuals in rural, impoverished communities to have access to cell phones, yet it remains uncommon for those individuals to have access to goods and services that impact health such as potable water, electricity, and healthcare.

Governments, donors, and healthcare practitioners have developed great enthusiasm for the potential of mHealth to increase efficiency and decrease inequality in access to healthcare in a cost-

³² "United Nations Millennium Development Goals."

³³ Cohen, Jessica, and Pascaline Dupas. *Free distribution or cost-sharing? evidence from a malaria prevention experiment*. No. w14406. National Bureau of Economic Research, 2008.

³⁴ World Health Organization: x.

³⁵ "Sub-Saharan Africa Mobile Observatory 2012 | Spectrum." *Spectrum*. N.p., n.d. Web. 05 Mar. 2014.

³⁶ Kay, Misha, Jonathan Santos, and Marina Takane. "mHealth: New horizons for health through mobile technologies." *World Health Organization* (2011): 1-5.

³⁷ Misha, Santos, and Takane: 1.

³⁸ This claim assumes unique subscriber data (original data source not analyzed).

effective manner.³⁹ Rural communities in developing countries are notoriously difficult to reach with healthcare interventions. Many innovative healthcare projects begin in urban centers with the hope of expanding their services into rural communities, but budgetary constraints restrict the expansion of these services. When these services do reach rural communities, they might be of inferior quality to their better-resourced urban counterparts. mHealth can lower the cost of rural expansion by decreasing the startup cost of these endeavors. Simple mobile phones are now copious and affordable. The expansion of a healthcare service no longer requires a brick-and-mortar building; simply a vehicle loaded with mobile-phone-equipped health workers.



Figure 5 – The 12 Common Applications of mHealth⁴⁰

The enthusiasm surrounding mHealth has spurred the creation of countless pilot programs. In a short period of time, mHealth programs have grown from unfamiliar to sought-after interventions. In response to this rapid development, Labrique et al. provide a classification system for mHealth interventions based on the current scope of the mHealth literature (Figure 5). Not all of these mHealth applications are feasible in developing countries, so not all of these applications

³⁹ Labrique, Alain B., Lavanya Vasudevan, Erica Kochi, Robert Fabricant, and Garrett Mehl. "mHealth innovations as health system strengthening tools: 12 common applications and a visual framework." *Global Health: Science and Practice* 1, no. 2 (2013): 160.

⁴⁰ Labrique et al.: 163.

would be reasonable avenues to combat malaria in malaria endemic countries. The majority of mobile phone subscribers use simple mobile phones (as opposed to “smart phones”). These phones primarily utilize talk and short message service (SMS or, colloquially, text messages) features. Smart phones, more common in developed countries, are able to use a wider range of features including General Packet Radio Service (GPRS), 3G/4G Internet services, Global Positioning System (GPS), and Bluetooth.

Of the twelve common applications, client education and behavior change (Application 1), data collection and reporting (Application 4), provider training and education (Application 9), supply chain management (Application 11), and financial transactions and incentives (Application 12) have foreseeable anti-malarial implementations.

Client education and behavior change “deliver[s] content intended to improve people’s knowledge, modify their attitudes, and change their behavior.”⁴¹ These interventions would be aimed at individuals at-risk of malaria. Talk, Interactive Voice Recordings (IVRs), or SMS featured could be utilized to disseminate the content of these interventions.⁴² Possible content could include reminders to properly use anti-malarial medication and conversations aimed to increase the utilization of ITNs. Tangible results are important for this class of interventions since the primary recipient is the patient or someone close to the patient.

Data collection and reporting allow healthcare workers to move from paper-based reports to electronic reports that can be more widely accessed and utilized.⁴³ This application could use the same features as Application 1 (talk, IVR, SMS). Prior to the proliferation of mobile technologies, the collection and distribution of patient data among medical personal and researchers proved to be

⁴¹ Labrique et al.: 161.

⁴² Interactive voice recordings (IVRs) are pre-recorded messages that attempt to engage the client in a conversation. The IVR commonly alternates between providing information and asking questions. After asking a question, the IVR will pause anticipating a respond. The IVR will either record the response for later interpretation by a human or interpret the response and respond accordingly.

⁴³ Labrique et al.: 165.

cumbersome. With this mHealth application, rural healthcare workers can easily collect patient data and instantaneously submit that data via SMS. The data could be collected at a central database, like the Ministry of Health, and be analyzed for geographic or temporal trends. This application has the greatest potential for epidemiologists interested in infectious disease outbreaks, but it can also be used to study the incidence and control of malaria.

Provider training and education can help address the issue of “brain drain” in developing countries. Individuals that receive high levels of training might choose to migrate to a developed country. The deficiency of highly trained individuals in developing nations imposes a significant strain on therapeutic resources. mHealth interventions utilizing this application could increase the quantity of highly-trained healthcare workers and, thus, reduce the effects of brain drain. This application would also utilize the same features as Application 1 (talk, IVR, SMS) in resource-scarce environments.

Supply chain management “track[s] and manage[s] stocks and supplies of essential commodities.”⁴⁴ A common issue in resource-scarce areas are stock-outs. If a rural health clinic near Rubavu, Rwanda had a stock-out of anti-malarial medication, a healthcare worker might be able to travel to the Rubavu district hospital to replenish its stock. Since rural health clinics have few workers, a healthcare worker leaving for even a few hours would dramatically reduce the capacity of that clinic.⁴⁵ It is more than likely, however, that the worker would have to travel to Kigali to replenish the stock of medicine, which would mean a full day of travel. mHealth would allow central health ministries to monitor the stock of essential commodities, like anti-malarial medication, for all clinics country-wide. This allows for the anticipation of stock-outs and quicker restocks. This application would also utilize the same features as Application 1 (talk, IVR, SMS).

⁴⁴ Labrique et al.: 167.

⁴⁵ Not to mention that the remaining workers would still be unable to assist individuals with malaria while the stock-out persists.

Financial transactions and incentives might be of greatest interest to researchers, but they have potential applications for health system utilization. Mobile finance (mFinance) allows for the transfer of funds between mobile phone users. This ability comes standard with many pay-as-you-go phones, which is the most common mobile carrier payment scheme in developing countries.⁴⁶ Healthcare researchers can utilize mFinance to design either supply- or demand-side incentive structures.⁴⁷ For example, clients could be incentivized to attend educational sessions about malaria or rewarded for utilizing preventative resources. This application could be used in tandem with other mHealth applications or novel malaria treatment and preventative strategies.

Of the five applications highlighted, four primarily utilize the talk, IVR, and SMS features of simple mobile phones. Otieno et al. performed cross-sectional surveys at four health centers in Western Kenya to determine the feasibility of using mHealth to combat uncomplicated malaria, primarily applications that utilized SMS.⁴⁸ Otieno et al. chose to focus on text-messages because they are the cheapest form of mobile communication.⁴⁹ Under some payment schemes, the receipt of a text message does not need to pay or pays a small amount in comparison to the initiator of the text message. The four health centers included one small urban hospital, one rural district hospital, one rural sub-district hospital, and one rural health clinic. These clinics were in a malaria endemic region with a high rate of infant and child mortality. They performed outpatient exit surveys aimed at the caregivers of children with malaria. Inclusion required that the caregiver had a child under the age of

⁴⁶ In a pay-as-you-go scheme, the subscriber puts funds onto a mobile phone account. Payments are automatically deducted as the subscriber uses mobile services, e.g. makes phone calls or sends text messages. This scheme is more common in developing countries because mobile phone usage might be less common or more sporadic in nature and a monthly fee would be impractical to the average subscriber. There are also differences in pricing based on if you are the initiator or recipient. For example, under some networks, it might be free or extremely cheap to receive a message.

⁴⁷ Labrique et al.: 167.

⁴⁸ Otieno, Gabriel, Sophie Githinji, Caroline Jones, Robert W. Snow, Ambrose Talisuna, and Dejan Zurovac. "The feasibility, patterns of use and acceptability of using mobile phone text-messaging to improve treatment adherence and post-treatment review of children with uncomplicated malaria in western Kenya." *Malaria journal* 13, no. 1 (2014): 44.

⁴⁹ Otieno et al.: 45.

five, that the child was treated as an outpatient⁵⁰, and that the recommended treatment for the child was a three-day regimen of anti-malarial medication. Nurses trained to perform the interviews and familiar with mHealth assessments executed the surveys. The results of their study can be seen in Figure 6.

| | Bondo DH | Got Agulu SDH | Ndori HC | Madiany DH | All sites |
|---|-------------------|-------------------|-------------------|-------------------|--------------------|
| Network coverage, phone access and ownership | N = 100 | N = 100 | N = 100 | N = 100 | N = 400 |
| Mobile network at home | 100 (100%) | 99 (99.0%) | 100 (100%) | 100 (100%) | 399 (99.8%) |
| Has access to mobile phone | 98 (98%) | 90 (90%) | 95 (95%) | 89 (89%) | 372 (93.0%) |
| Has personal mobile phone | 78 (78%) | 66 (66%) | 73 (73%) | 78 (78%) | 295 (73.8%) |
| Use of mobile phones | N = 98 | N = 90 | N = 95 | N = 89 | N = 372 |
| Voice | 98 (100%) | 90 (100%) | 95 (100%) | 89 (100%) | 372 (100%) |
| Receive SMS | 97 (99.0%) | 86 (95.6%) | 89 (93.7%) | 76 (85.4%) | 348 (93.6%) |
| Send SMS | 91 (92.9%) | 81 (90.0%) | 83 (87.4%) | 74 (83.2%) | 329 (88.4%) |
| Money transfer | 92 (93.9%) | 79 (87.8%) | 74 (77.9%) | 81 (91.0%) | 326 (87.6%) |
| Browsing | 9 (9.2%) | 13 (14.4%) | 4 (4.2%) | 19 (21.4%) | 45 (12.1%) |
| E-mail | 5 (5.1%) | 12 (13.3%) | 2 (2.1%) | 17 (19.1%) | 36 (9.7%) |
| Brought phone to the facility | 63 (64.3%) | 44 (48.9%) | 49 (51.6%) | 56 (62.9%) | 212 (57.0%) |
| Able to charge phone at home | 29 (29.6%) | 22 (24.4%) | 17 (17.9%) | 8 (9.0%) | 76 (20.4%) |
| Patterns of SMS receiving | N = 97 | N = 86 | N = 89 | N = 76 | N = 348 |
| No of SMS/week (median[IQR]) ^a | 5 [3-10] | 7 [5-10] | 5 [3-10] | 21 [14-35] | 9 [4-20] |
| Able to open and read SMS | 96 (99.0%) | 86 (100%) | 89 (100%) | 76 (100%) | 347 (99.7%) |
| Reading of SMS (day time) ^a | | | | | |
| Immediately | 88 (90.7%) | 75 (88.2%) | 68 (76.4%) | 72 (94.7%) | 303 (87.3%) |
| Within 1 hour | 9 (9.3%) | 6 (7.1%) | 20 (22.5%) | 3 (4.0%) | 38 (11.0%) |
| After 1 hour | 0 | 4 (4.7%) | 1 (1.1%) | 1 (1.3%) | 6 (1.7%) |
| Reading of SMS (night time) | | | | | |
| Immediately | 23 (23.7%) | 33 (38.8%) | 75 (84.3%) | 29 (38.2%) | 160 (46.1%) |
| In the morning | 74 (76.3%) | 52 (61.2%) | 14 (15.7%) | 47 (61.8%) | 187 (53.9%) |

^aDenominators for these variables at Got Agulu SDH and at all sites do not include one observation with missing value.

Figure 6 – Mobile network access and ownership information for Otieno et al.⁵¹

The data show that mHealth interventions directed at the caregivers of children with malaria could be feasible. Of the 93% of caregivers that had access to mobile phones, 93.6% had the ability to receive text messages. Of those that could receive text messages, the vast majority opened those messages immediately or within the first hour of receiving them. This suggests that time-sensitive

⁵⁰ Since the child was treated as an outpatient, the malaria symptoms were not considered life threatening. The aim of their study to assess the feasibility of an mHealth intervention designed to improve medication adherence, thus falling under Application 1 of the common mHealth application. mHealth acts as a catalyst, so its ability to help a child with life-threatening malaria will be limited to the its potential to catalyze the ability of a health system to administer care.

⁵¹ Otieno et al.: 48.

information could be successfully transmitted without the need of a phone call.⁵² The surveys also suggest that the majority of those surveyed had basic mobile phones given the limited access to browsing and email, which are key features of smart phones.

Based on these data, anti-malarial mHealth interventions can utilize talk, IVR, and SMS. Of these three features, SMS hosts the greatest potential due to the cheap costs of receiving text messages. mFinance can be utilized to subsidize the costs associated with any of these features. Most importantly, this level of access to mobile phones was observed in a malaria endemic region at four health facilities of various sizes. The lowest level of mobile phone access was not at the rural health clinic in Ndori, but surprisingly at the Madiany District Hospital. The nature of the study does not allow for greater insight into why this trend was seen.

Utilization of mHealth to treat malaria does not necessarily require further infrastructure, nor is literacy a significant barrier to SMS-centric mHealth interventions.⁵³ The lack of access to electricity at home does pose a barrier, but caretakers employ a variety of methods to keep their phones charged.⁵⁴ In the qualitative survey data, caretakers of children with malaria demonstrated a “high willingness” to receive text message reminders concerning therapeutic treatment adherence and post-treatment review.⁵⁵ This strongly supports the implementation of an Application 1 mHealth intervention, but it also demonstrates favorable conditions for other mHealth applications. These rural, malaria endemic communities are perhaps the most important but hardest to reach. The favorable conditions for mHealth provide a mechanism for the future of anti-malarial interventions in these regions.

⁵² While all those with access to mobile phones had the ability to call, the costs associated with calling might prevent patients from responding to those calls – especially if those calls were made regularly.

⁵³ Otieno et al.: 47.

⁵⁴ Otieno et al.: 47,49.

⁵⁵ Otieno et al.: 49.

ON ANTI-MALARIA MHEALTH INTERVENTIONS

The UN recognized malaria as a disease of importance because, among communicable disease, it ranks near the top in total deaths per year. While malaria might be a significant source of mortality, modern medicine can both prevent and treat malaria. Malaria persists due to its intimate ties with poverty. Since malaria can be treated and, better yet, prevented, governments, non-governmental organizations, and communities should cooperatively combat malaria. If mHealth can assist antimalarial campaigns in a cost-effective manner that increases equality of access and/or the efficacy of treatment, then we should invest in the innovation, development, and promotion of such technologies

A recent cluster-randomized study in Kenya utilized text messages to improve health worker adherence to malaria treatment guidelines.⁵⁶ The Kenyan government recommends artemether-lumefantrine treatment (a specific artemisinin-based combination therapy or ACT) for acute uncomplicated malaria. This protocol, commonly seen under the trade name Coartem, meets the WHO pre-qualifications criteria for safety, effectiveness, and quality.⁵⁷ The full treatment protocol is designed to maximize patient adherence to the treatment protocol, which increases the likelihood of recovery and decreases the potential for building treatment resistance for the patient (see Figure 7). Correct management, i.e. following all ten components of the protocol, seldom occurs in rural health centers.⁵⁸

⁵⁶ Zurovac, Dejan, Raymond K. Sudoi, Willis S. Akhwale, Moses Ndiritu, Davidson H. Hamer, Alexander K. Rowe, and Robert W. Snow. "The effect of mobile phone text-message reminders on Kenyan health workers' adherence to malaria treatment guidelines: a cluster randomised trial." *The Lancet* 378, no. 9793 (2011): 795.

⁵⁷ Barnes, Karen I., Pascalina Chanda, and Gebre Ab Barnabas. "Impact of the large-scale deployment of artemether/lumefantrine on the malaria disease burden in Africa: case studies of South Africa, Zambia and Ethiopia." *Malaria journal* 8, no. Suppl 1 (2009): S8.

⁵⁸ I have not analyzed the effectiveness of the Kenyan government's protocol - that is to say that I do not present evidence to defend the claim that adherence to these subscribed protocols decreases the proliferation of resistance strains of malaria. The protocol recommended by the Kenyan government is based on international standards, and those standards are based on best-principle guidelines for preventing the spread of resistant malaria strains.

Zurovac et al. studied 107 rural health centers in two malaria endemic areas in Kenya: Greater Kwale and Greater Kisii and Gucha. Health workers in these regions received three rounds of malaria case-management training and were given national guideline documents and drug management wall charts by the Kenyan government in the years prior to the text-message intervention. Despite this formal training, only 11-21% of the rural health centers studied employed the full treatment protocol.⁵⁹ Participants in the study's intervention group received two text-messages daily excluding weekends and national holidays for six months.⁶⁰ These messages featured malaria treatment tip related to the Kenyan guidelines and an encouraging quotation unrelated to malaria treatment. The quotation was included to grab the participant's attention; participants were told of the inclusion of these quotations prior to the intervention to minimize confusion.^{61,62} Health center surveys, conducted by trained nurses, were collected at three points: prior the invention to establish a baseline, immediately after the intervention (six months after the intervention began), and one year after the intervention began to study long-term effects.⁶³

The data, seen in Figure 7, shows that the text-message intervention increased completion of the full protocol by 23.7% immediately after the intervention in comparison to the baseline (difference of difference effect size).⁶⁴ Interesting, these effects were seen to be long lasting; completion of the full protocol increased to 24.5% (in comparison to the baseline) six months after the intervention stopped.⁶⁵ Not only did health workers continue to follow the complete protocol after they stopped receiving messages, they increased their adherence to the protocol.

⁵⁹ Zurovac et al., 800.

⁶⁰ Zurovac et al., 796.

⁶¹ Zurovac et al., 797.

⁶² Special efforts were taken to ensure that the messages were understandable and that the encouraging quotations were not distracting. Given the limit of 160 characters per text message, Zurovac et al. chose to test all the messages prior to this study. The treatment tip was limited to 120 characters and the encouraging quotation was limited to 40 characters.

⁶³ Zurovac et al., 800.

⁶⁴ Ibid.

⁶⁵ Ibid.

| | Baseline | | Follow-up one | | Follow-up two | | Effect size (difference of differences) | | | |
|---|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|---|---------|------------------------------------|---------|
| | Control | Intervention | Control | Intervention | Control | Intervention | Immediately after end of intervention | | 6 months after end of intervention | |
| | | | | | | | % change (95% CI) | p value | % change (95% CI) | p value |
| Composite performance | | | | | | | | | | |
| Correctly managed | 422/47 (11.1%) | 439/90 (20.5%) | 358/59 (16.5%) | 391/194 (49.6%) | 332/58 (17.5%) | 327/168 (51.4%) | 23.7% (7.6 to 40.0) | 0.0040 | 24.5% (8.1 to 41.0) | 0.0034 |
| Individual components | | | | | | | | | | |
| 1. Antimalarial treatment prescribed | 422/347 (82.2%) | 439/358 (81.6%) | 358/302 (84.4%) | 391/336 (85.9%) | 332/271 (81.6%) | 327/273 (83.5%) | 2.1% (-8.3 to 12.8) | 0.6759 | 2.5% (-9.1 to 14.1) | 0.6676 |
| 2. AL treatment prescribed | 347/303 (87.3) | 358/312 (87.2) | 302/239 (79.1) | 336/320 (95.2) | 271/234 (86.4) | 273/255 (93.4) | 16.2% (1.1 to 31.5) | 0.0361 | 7.1% (-4.8 to 19.2) | 0.2382 |
| 3. AL prescribed in recommended dose | 303/291 (96.0) | 312/297 (95.2) | 239/225 (94.1) | 320/307 (95.9) | 234/218 (93.2) | 255/247 (96.9) | 2.6% (-2.2 to 7.4) | 0.2799 | 4.5% (-1.2 to 10.3) | 0.1196 |
| 4. AL dispensed to take home | 303/302 (99.7%) | 312/309 (99.0%) | 239/239 (100%) | 320/319 (99.7%) | 234/234 (100%) | 255/255 (100%) | 0.4% ND | ND | 0.7% ND | ND |
| 5. First AL dose given at health facility | 302/45 (14.9%) | 309/79 (25.6%) | 239/42 (17.6%) | 319/191 (59.9%) | 234/49 (20.9%) | 255/142 (55.7%) | 31.6% (7.4 to 55.9) | 0.0105 | 24.1% (1.5 to 46.6) | 0.0364 |
| 6. Explained how to take AL dose | 302/287 (95.0%) | 309/282 (91.3%) | 239/233 (97.5%) | 319/316 (99.1%) | 234/219 (93.6%) | 255/250 (98.0%) | 5.3% (-1.9 to 12.6) | 0.1469 | 8.1% (0.1 to 16.4) | 0.0478 |
| 7. Advised to take second dose after 8 h | 302/114 (37.8%) | 309/131 (42.4%) | 239/96 (40.2%) | 319/245 (76.8%) | 234/92 (39.3%) | 255/182 (71.4%) | 32.0% (9.4 to 54.6) | 0.0056 | 27.5% (4.4 to 50.5) | 0.0198 |
| 8. Advised to take AL after meal | 302/103 (34.1%) | 309/107 (34.6%) | 239/109 (45.6%) | 319/164 (51.4%) | 234/108 (46.2%) | 255/168 (65.9%) | 5.3% (-11.3 to 21.8) | 0.5318 | 19.2% (2.1 to 36.3) | 0.0277 |
| 9. Advised what to do if vomiting occurs | 302/22 (7.3%) | 309/17 (5.5%) | 239/20 (8.4%) | 319/85 (26.7%) | 234/12 (5.1%) | 255/71 (27.8%) | 20.1% (7.5 to 32.6) | 0.0017 | 24.5% (12.6 to 36.4) | <0.0001 |
| 10. Advised to complete all doses | 183/302 (60.6%) | 309/213 (68.9%) | 239/148 (61.9%) | 319/249 (78.1%) | 234/163 (69.7%) | 255/220 (86.3%) | 7.9% (-9.4 to 25.0) | 0.3740 | 8.3% (-7.6 to 24.1) | 0.3067 |

Data are N/n (%) unless otherwise stated. AL=artemether-lumefantrine; ND=not done (the model did not converge because outcome levels were very close to 100%).

Figure 7 – Correctness of ACT management from Zurovac et al.⁶⁶

The results of this study are encouraging, but Zurovac et al. encourage co-interventions when considering large-scale implementation of their protocol. While a significant increase in adherence was seen, only 51.4% of the health workers in the intervention cluster followed the full protocol one year after the intervention began; only 17.5% of the health workers in the control cluster adhered to the full protocol. This intervention relied on the successful completion of treatment-specific training by the Kenyan government. The text-message intervention sent out information already available to the participants; they were taught the information in training sessions and were provided the information in writing through the government literature. This mHealth invention cannot be a substitute proper training; it can only be a complement.⁶⁷ Treatment adherence might increase by making the protocol more accessible during and after training, but it is clear that the quality of these training sessions must be improved.

⁶⁶ Zurovac et al., 800.

⁶⁷ Zurovac et al., 801.

It is notable, however, that this mHealth intervention is among the most promising interventions for improving health worker adherence in the literature – the median improvement in health worker performance, based on a systematic review of 172 studies, is 9%.⁶⁸ The mHealth intervention also might be among the cost-effective. Although a thorough cost-effectiveness analysis needs to be done, the distribution of text-messages to all rural health workers in Kenya would cost \$39,000.⁶⁹ A full cost-effectiveness analysis would need to include costs, like the cost of a distribution system, as well as assess the cost-benefit of the 24.5% increase in treatment adherence. This would require a known relationship between health worker adherence and patient adherence. The data would also have to draw upon the relationship between patient adherence to the treatment protocol and the reduction of malaria incidence.

Zurovac et al. also encourage further analysis of the qualitative burden of this intervention – i.e. how burdensome was it to receive two message daily for six months?⁷⁰ This qualitative data could optimize the protocol and reduce the cost of text-message distribution (if fewer text messages can be sent with negligible loss in treatment adherence). Other considerations for the intervention include the availability of cell-phones and the content of the messages. Only one of the 120 health workers in the region did not have a personal cell phone, but this might not be the case in all rural regions. For those with cell-phones, coverage might not be available in all areas (which could delay or prevent the reception of text-messages) or health workers might change phone numbers and fail to update their information.⁷¹ The content of the text messages were independently tested for understanding prior to the intervention, but they might be further optimized and new text messages can be drafted. The effect of the additional encouraging quotation is also unknown. If this

⁶⁸ Ibid.

⁶⁹ Zurovac et al., 802.

⁷⁰ Ibid.

⁷¹ In a pay-per-service structure, consumers have greater fluidity in controlling their carrier and frequency of mobile technology purchasing. If a consumer runs out of minutes, they have the choice of buying new minutes from the same carrier, buying minutes for a new carrier, or not buying minutes. Whenever these choices result in a new SIM card purchase, a new number can be assigned.

intervention can be scaled to other areas, then it might also be possible for this intervention to work with other treatment protocols (antimalarial or otherwise). Cluster-randomized studies that utilize text-messages for HIV treatment adherence in Kenya have seen similar effects.^{72,73}

Health worker adherence to a treatment protocol is, admittedly, a distant mode of decreasing the incidence of malaria. Therapeutic resources are a more direct way to decrease malaria mortality and morbidity. As previously mentioned, stock-outs prevent timely treatment of malaria. Ensuring a sufficient supply of rapid diagnostic tests (RDTs) and anti-malaria drugs are critical to timely malaria management. Kamanga et al. studied the use of mobile phones to perform active case detection. Active case detection utilizes timely data detailing the emergence of new cases to “deploy supplies, plan interventions, or focus attention on specific locations.”⁷⁴ Kamanga et al. recruited twelve rural health centers in the Choma and Namwala districts of Zambia to send weekly information by text message. The data was sent to the Malaria Institute at Macha where it was processed and distributed. Based on the data, the Malaria Institute at Macha was able to keep track of the stock of RDTs and anti-malaria drugs and limit the number of stock-outs.⁷⁵ They were also able to study the emergence of new cases more rapidly.

Again, this study failed to perform a full cost-effectiveness analysis. The Malaria Institute at Macha reimbursed the rural health workers for their text message submissions by using mFinance resources. These costs would be minimal given that each health center would only need to submit one report weekly. The cost-benefit analysis would need to assess the effect of a stock-out and would require knowledge of the previous frequency of stock-outs. The study did measure the

⁷² Lester, Richard T., Paul Ritvo, Edward J. Mills, Antony Kariri, Sarah Karanja, Michael H. Chung, William Jack et al. "Effects of a mobile phone short message service on antiretroviral treatment adherence in Kenya (WelTel Kenya1): a randomised trial." *The Lancet* 376, no. 9755 (2010): 1838.

⁷³ Kelly, John D., and Thomas P. Giordano. "Mobile phone technologies improve adherence to antiretroviral treatment in a resource-limited setting: a randomized controlled trial of text message reminders." *AIDS* 25, no. 8 (2011): 1137.

⁷⁴ Kamanga, Aniset, Petros Moono, Gillian Stresman, Sungano Mharakurwa, and Clive Shiff. "Rural health centres, communities and malaria case detection in Zambia using mobile telephones: a means to detect potential reservoirs of infection in unstable transmission conditions." *Malaria journal* 9, no. 1 (2010): 96.

⁷⁵ Kamanga et al.: 97.

qualitative willingness to participate and found that health workers were willing to send weekly text messages.

These studies show both the potential of mHealth interventions and the current weakness in large-scale implementation. The lack of evidence supporting the cost-effectiveness of mHealth interventions at the pilot-level raises questions of its sustainability. Interventions that utilize text-messages are cheap in the context of national spending. The cost of sending text messages to every health-worker in Kenya for six months was \$39,000, while the cost of receiving text messages for malaria active case detection in Zambia would be on the order of a couple thousand for an entire year.^{76,77} We know, however, that countries with high risk for malaria are resource constrained. These governments cannot be wasteful in their spending, so mHealth interventions must prove their cost-effectiveness. Additionally, it must be emphasized that mHealth interventions are health system catalysts. mHealth interventions are useless without effective preventative methods and therapeutic treatments. Therefore, investment in mHealth must be restricted in a cost-effective manner so that adequate investment can be made in the improvement of preventative methods and therapeutic treatments. It is not possible for individual nations burdened with malaria to make sufficient investments, so the elimination of malaria requires global collaboration.

In *Just Health*, Norman Daniels presents the case that health is of special moral importance and that distribution should apply general principles of justice (e.g. Rawls' Justice as Fairness).⁷⁸ Daniels focuses on the obligations of individual nations to address their own obligation to national health, but opens the door for a framework regarding global health justice. Gorik Ooms and Rachel Hammonds use Daniels' theory of justice for health and international human rights law to build an

⁷⁶ Zurovac et al., 802.

⁷⁷ The actual cost was not stated by Kamanga et al., so this estimate is based on available data on the number of health clinics in Zambia.

⁷⁸ Daniels, Norman. *Just Health*. Cambridge University Press, 2008.

argument for global health justice.⁷⁹ The utilization of both justice for health and international human rights law goes against Daniels' recommendation; however, the Ooms and Hammonds feel that international human rights law presents a reasonable moral compass and that Daniels' objection fails to consider the role of international aid.⁸⁰ Ooms and Hammonds begin by building on Daniels' foundation and arguing that obligations of global health justice exist. Daniels believes that a "health inequality is an inequity if it is the result of an unjust distribution of the socially controllable factors affecting population health and its distribution."⁸¹ The global free market's effect on growing inter-country wealth inequalities supports Gunnar Myrdal's concept of "circular and cumulative causation," which predicts growing inequalities in the global market in a free-market scheme.⁸² Ooms and Hammonds do not call for the removal or restriction of the global free market – instead they argue that our obligation to global health justice requires the establishment of an institution that can distribute health goods that could offset the effects of inequality.

At its core, health justice is a national issue; however, given the context of global inequalities in health, the global community has an obligation to promote global health justice. Ooms and Hammonds point to the Global Fund to fight AIDS, Tuberculosis, and Malaria as a model institution for the achievement of our moral obligations to global health justice.⁸³ Based on the framework of Ooms and Hammonds, the elimination of malaria should be a global commitment. The distribution of anti-malarial preventative and therapeutic resources meet a moral obligation to improve health, and the alleviation of the economic burden of malaria could reduce inter-country inequalities.

⁷⁹ Ooms, Gorik and Rachel Hammonds. "Taking up Daniels' Challenge: The case for Global Health Justice." *Health & Human Rights: An International Journal* 23, no. 1 (2010).

⁸⁰ Ooms and Hammonds: 34.

⁸¹ Daniels: 101.

⁸² Ooms and Hammonds: 31-34.

⁸³ Ibid.

CONCLUSION

The ties between poverty and malaria run deep with a robust economic burden of malaria. The evidence strongly supports the view that malaria causes poverty; however, causal mechanisms also suggest that poverty can also contribute to the transmission of malaria. The reduction of malaria will not only improve individual economic outcomes, but reduction in malaria has shown growth at the macroeconomic level.

Since the establishment of the millennium development goals, the collaborative global effort to combat malaria has dramatically reduced the mortality and morbidity of malaria. In order to sustain our gains against malaria, the global community must remain committed beyond the 2015 deadline. This commitment can come from both the recognition of a moral obligation to address issues of global health justice, and a desire to reduce the injustice of poverty.

The potential of mHealth is significant. mHealth can reach disadvantaged communities in rural, malaria endemic regions without additional infrastructure and with very low intervention costs. Of the twelve common applications of mHealth, five present clear pathways toward malaria reduction in resource-scarce environments. Through those applications, mHealth could play an important role in the distribution and optimization of anti-malarial preventative and therapeutic resources. In order to justify the use of mHealth, however, the research community must provide strong evidence of mHealth cost-effectiveness. It is also important to recognize that mHealth is, at best, a health system catalyst. While the benefits of a catalyst could be significant, investments must still be made to improve preventative and therapeutic interventions – especially investments in a malaria vaccine.

Humanity has fought malaria for millennia – but let this century could be the last.

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