The Development of Health System Resiliency: How Kenya's Experience with Malaria Impacted Its Reaction to the COVID-19 Pandemic

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Abstract

Public health scholars have recently focused on health system resiliency to explain how previous experiences dealing with public health crises impact the healthcare sector, public behavior, and policy response to novel crises. However, it is unclear how resiliency develops. This study contributes by testing whether a health system's experience with a health emergency and significant interventions impacts the response to a novel crisis. This research asks, "How has Kenya's experience with malaria impacted its response to COVID-19?" Using the United States Agency for International Development (USAID) Malaria Indicator Survey (MIS), I develop a malaria adherence score to measure county-level compliance with standard malaria prevention protocols. I use publicly available data from the Kenyan Ministry of Health's (MOH) situation reports and the Bureau of Statistics to create cumulative COVID-19 prevalence and vaccination rates for each county. I test the hypothesis that higher malaria adherence scores are associated with higher COVID-19 vaccination uptake in a given community. Controlling for a host of other factors that could explain COVID-19 outcomes, I find mixed evidence in support of the hypothesis. Counties with higher rates of malaria protocol adherence are associated with higher COVID-19 vaccination rates. However, rates of malaria protocol adherence were also associated with higher COVID-19 rates, which challenges the expectation that previous compliance with interventions leads to more resilient health systems. Issues of reverse causality, ecological inference, and incomplete data limit the scope of the findings and are addressed in the discussion.

Introduction

As of March 4, 2023, there have been over 758,390,564 confirmed cases and 6,859,093 confirmed deaths related to COVID-19, with normalcy in society slowly returning after the distribution of a vaccine. Despite its global impact, the COVID-19 pandemic was not the first worldwide or major health emergency in the past fifty years or even in the past five years. Indeed, infectious disease outbreaks have plagued society for millennia and continue to challenge the health of populations despite significant advances in health systems, increasing sophistication of medical interventions, and new scientific discoveries. Whether a society overcomes, or succumbs, to a disease outbreak is an important test of its *health system resiliency*—that is "the degree of change a system can undergo while maintaining its functionality" (Biddle et al. 2020).

The purpose of this thesis is to examine the process by which health system resiliency is developed and how such resiliency impacts societal responses to novel public health emergencies. In particular, it is possible that experience with previous public health interventions is the start of a virtuous cycle wherein public health officials establish effective pathways for communicating public health information and the public learns that adherence to their recommendations benefits community health and safety. In one of his last published articles, D.A. Henderson, a global health leader for over fifty years, and the individual credited with leading the smallpox eradication campaign, explains:

> Experience has shown that communities faced with epidemics or other adverse events respond best and with the least anxiety when the normal social functioning of the community is least disrupted. Strong political and public health leadership to provide reassurance and to ensure that needed medical care services are provided are critical elements. If either is seen to be less than optimal, a manageable epidemic could move toward catastrophe (Inglesby, Nuzzo, O'Toole, & Henderson, 2006).

Published nearly twenty years ago, Henderson and his co-authors emphasized that infectious disease threats posed by a globalized society, particularly viral infections like

influenza and coronaviruses. Unfortunately, this threat became a reality at the start of 2020, when a novel coronavirus, SARS-Cov-2 or COVID-19, spread to every continent. Henderson's message reflects the conventional wisdom health scholars have emphasized for decades— previous experience with health crises impacts how a country or other administrative entities respond to future health crises. Resiliency and the capacity to respond to health crises is a learning process, but how this learning process occurs is under-examined in existing research. The goal of this thesis is to fill this gap by attempting to answer the question: "How does previous adherence with low-level public health interventions predict early adherence with public health interventions at a time of uncertainty?"

Building on the emerging literature on health system resiliency, this thesis examines the evolution of the term, summarizes key findings from the existing literature, and seeks to uncover potential casual pathways to resiliency through the analysis of a single case-study (i.e., Kenya). Using insights gained from field experience and a county-level statistical analysis of sub-national variation in Kenya using data collected by USAID's Demographic Health Survey (DHS) and WHO situation reports, this thesis examines how adherence to interventions to limit the spread of malaria was related to the public's subsequent response to interventions to mitigate the spread of COVID-19. I find that counties with higher rates of protocol adherence are associated with higher COVID-19 vaccination rates. However, rates of malaria protocol adherence were also associated with higher COVID-19 rates, which challenges the expectation that previous compliance with interventions leads to more resilient health systems. These findings suggest that more research is needed on how a country's experience and response to previous health challenges informs and impacts future responses, especially those with novel health challenges.

Kenya is an important and valuable case study for this topic. The country is a critical location in understanding malaria spread and prevention, but also because of the varied burden of COVID-19 within the Kenyan population. Sub-Saharan Africa is seen as one of the key regions for global health work. Significant strides have been made on

the improvements and growth of sub-Saharan African and low income and middle-income country's health systems and public health preparedness in recent years. The United States and many high-income western nations experienced significant COVID-19 burden for the duration of the pandemic with repeated spikes in cases and emerging new variants. Kenya, on the other hand, had little COVID-19 overall burden in comparison to other countries and its other health challenges. This is in line with most other sub-Saharan African countries. There is a potential to learn something from how Kenya enacted COVID-19 regulations and used aspects of their health system to respond to a novel health emergency. Investigating how Kenya's early response to COVID-19 interacts with the country's experience with malaria control can help inform research and policy about the resiliency of the state's health system and the impact of widescale infectious disease control programs.

Various policy and intervention strategies have attempted to reduce the prevalence of malaria in Kenya, but it has remained a significant health challenge for decades (Snow et al., 2015). This thesis seeks to add to the literature on preparedness and health system resiliency in terms of community adherence to health interventions. By analyzing and interpreting adherence to previous low-level public health interventions on malaria prevention, how can this predict adherence to early public health interventions at a time of uncertainty near the beginning of the COVID-19 pandemic? States and their health systems have built upon their experiences to improve policies and overall responses to each health crisis that emerges.

Literature Review

The idea of health system resiliency has recently gained traction in the literature as a way of explaining variation in COVID-19 responses, although the term can be found in global health policy throughout the 21st century and in documents related to varied health emergencies over the last two decades. Indeed, when Fridell et al (2020) conducted a scoping review to map characteristics, keywords, and definitions of health system resiliency in research, international organizations, and global health experts he

found an exponential increase in the number of publications focused on this topic. Due to the rapid expansion of research on this topic, scholars have yet to reach a shared agreement on the exact definition of health system resilience, however, the term is mainly described through its relation to adaption, maintenance, absorption, learning, transformation, withstanding, and responding to shocks.

Despite the continuing work on establishing a shared conceptual definition, scholars agree that resiliency is a learned process and can be measured and analyzed in different ways. Durski et al. (2020) explain how disease outbreaks and health emergencies can push health systems to a breaking point. According to this article, a resilient health system is one that can absorb the initial shock of a health emergency and continue providing fixed health services. Durski explains that important steps in building resiliency is the integration of skilled experts from all disciplines and industries and the investment of resources in health system strengthening.

Kruk at al. (2015) examine the 2014 West Africa Ebola epidemic to gain insights on characteristics of resilient health systems. They find resilient health systems are characterized by an awareness of present needs and vulnerabilities, as well as self-regulating, that is able to contain and isolate novel health threats while still delivering regular health services. A resilient health system has a diverse capacity of issues it can address and integrated to formulate solutions and initiate action. Thus, this thesis bridges knowledge on how to build health system resiliency and is an example the connections between previous health crises and novel crises.

Many comparisons have been made between the severe acute respiratory syndrome (SARS) and middle east respiratory syndrome (MERS) outbreaks in the 21st century and COVID-19. The SARS 2003 pandemic emerged in a similar fashion as COVID-19 through zoonotic spillover in a wet market in China and then spreading to 4 countries in total. MERS also emerged as a zoonosis from domesticated camels originally in Saudi Arabia, and clustered outbreaks have been reported in 24 countries since 2012. All three diseases, SARS, MERS, and COVID-19 are in the coronavirus family of viruses

that have significantly shaped domestic and international health and emergency preparedness policies. Huang et al. (2020) found statistically significant negative correlation between exposure to SARS and/or MERs and the incidence of COVID-19 cases per 100,000 population within the first 30 days after the report of the first confirmed case, meaning countries with experience were more likely to have lower initial COVID-19 incidence.

Relevant research to the scope of this study has been done on widescale public health campaigns as well as their influence on outbreak preparedness and response. Kouadio et al. identified how polio infrastructure strengthened disease outbreak preparedness and response in the WHO African Region. Specifically, the Polio Eradication Initiative (PEI) infrastructure and resources were used to supplement other public health activities in Ethiopia, including outbreak control for Marburg Hemorrhagic fever, Dengue fever, Ebola Virus Disease, Measles, Anthrax and Shigella, immunization programs, and strengthening of national surveillance (2016). In Angola, resources from PEI, like vehicles, personnel, and tools, also supported preparedness and response to other vaccine-preventable diseases. Kouadio et al. also found the WHO polio efforts aided in fighting the 2014 Ebolavirus epidemic throughout West Africa (2016).

Njenge et al. outline an example of how Kenya and Tanzania made efforts to build health system capacities in responding to outbreaks after the 2014 West Africa Ebola virus outbreak (2021). The authors noted, "If countries understand their baseline health capacities, they can be operationally ready to respond confidently when a health emergency occurs, such as the current COVID-19 pandemic." In a similar vein, Afolabi et al. address commonalities between Ebola virus disease (EVD) and COVID-19 and list recommendations for strengthening sub-Saharan Africa's COVID-19 response (2021).

A significant amount of literature confirms that previous knowledge and experience in responding to outbreaks and health emergencies informs future responses and greater health system resiliency. (Anyanwu, 2021; Hussein et al., 2020) found a significant correlation between the national malaria burden and COVID-19 mortality suggesting a

connection between a lack of malaria immunity and an increase COVID-19 deaths. Both papers used an international level of analysis looking at 195 countries. However, this paper is one of the first studies to look specifically at how populations with experience responding to malaria health interventions than in turn respond to COVID-19 protocols as a novel health crisis.

Case Backgrounds

In this section, I provide an overview on Kenya, malaria, and COVID-19 and how the topics relate to my research and the examined theories. Kenya is a key middle state in terms of health system strengthen and COVID-19 burden compared to sub-Saharan Africa. The country also has varied malaria burden between counties because of geographical differences. Malaria prevention has been at the forefront of much global health work because of its significant burden worldwide, including Kenya. Little research has been conducted on malaria prevention efforts' impact on health system strengthening, so there is a gap in understanding. COVID-19 is inarguably an impactful world crisis. Along with this, there is a need to study and evaluate its impacts and how policies, behaviors, and experiences varied its burden globally.

Kenya

Kenya is a pivotal state to expand knowledge pertaining to malaria and health system resiliency. The Global Health Security Index ranks Kenya 84th out of 195 counties, relatively in the middle of all states (GHS, 2021). Within the score, Kenya's preparedness and health system strength varies. For example, the country is ranked 191st in rapid response to and mitigation of the spread of an epidemic. Still, it is ranked 27th in the state's early detection and report for an outbreak of international concern. The COVID-19 pandemic heavily impacted Kenya in relation to other sub-Saharan countries, but most of its impact was economic, mainly because of the prominent tourism industry in Kenya.

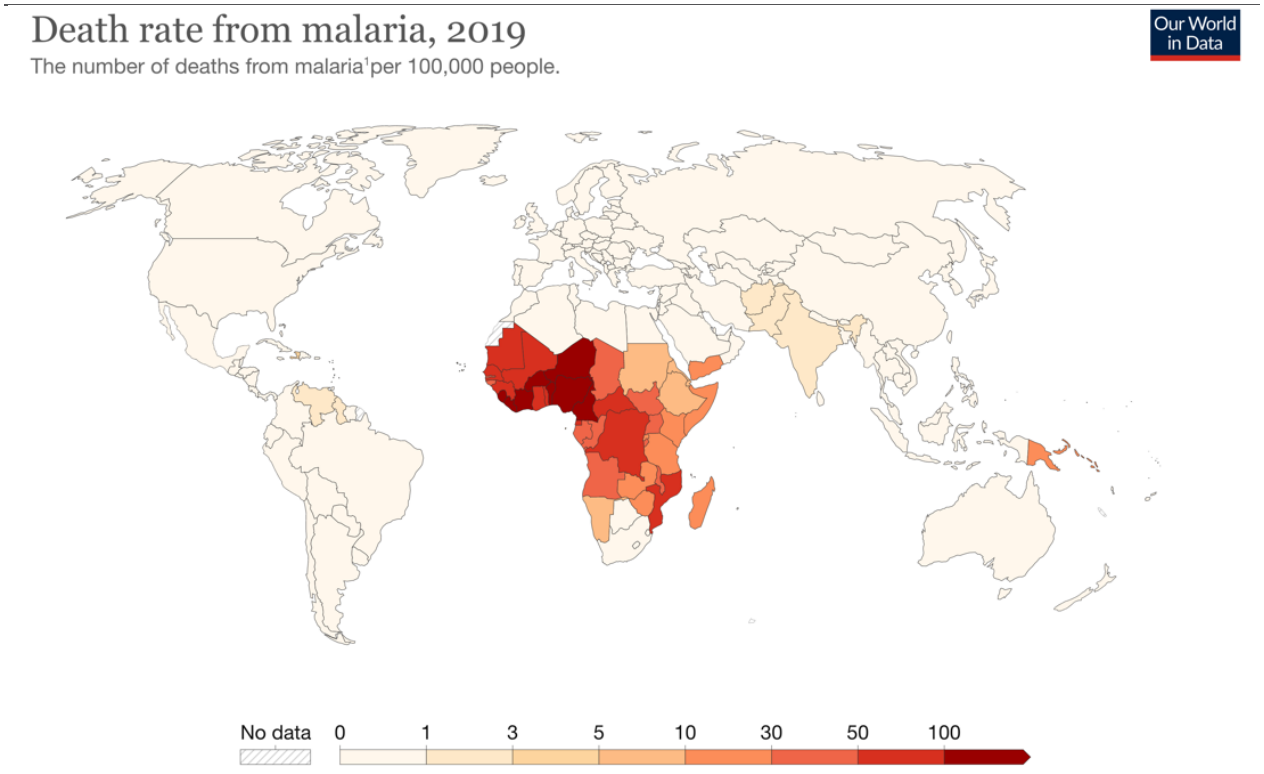
While Kenya does not have the highest prevalence and burden of malaria in malaria-endemic countries, it has the key analysis that some, not all, of its counties are malaria endemic. This allows for a county-level analysis comparing Kenyan counties with and without a high malaria caseload. Furthermore, sub-Saharan Africa is a region of the world severely hit by infectious disease outbreaks and health challenges. As mentioned earlier, much literature exists on predicting how the 2014 Ebola outbreak impacted the state's COVID-19 response. Large health challenges tend to change existing policies and are turning points for health systems (Funk et al., 2009).

Malaria

Malaria is endemic in many regions of the world, particularly the tropics in sub-Saharan Africa. In 2017 alone, the WHO reported over 219 million cases and 435 million deaths related to malaria. (Were et al., 2019). Figure (1) below shows worldwide malaria prevalence. Malaria is the major cause of morbidity and mortality in western Kenya, one of the most malaria-endemic regions of the world, with more than 70% of the population in western Kenya being at risk of malarial illness (Were et al., 2019). Were et al. established socioeconomic inequalities that affect the prevalence of malaria parasites and infection with higher prevalence within the poorest populations across all age groups (2019).

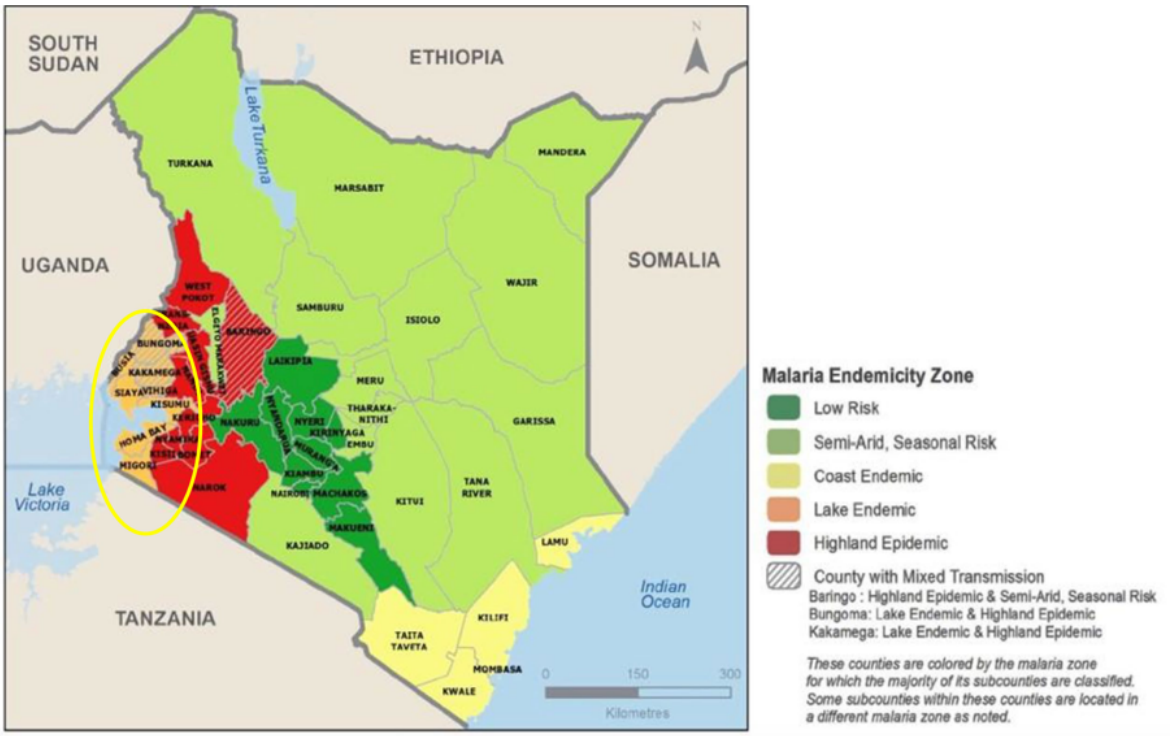
Along with these findings, Welch et al. (2012) used Demographic Health Survey (DHS) data, the same data used in this study, in Cambodia to establish barriers to access to insecticide-treated bed nets. This study also found that the poorest populations and those in rural areas have less access to malaria prevention interventions and are less likely to seek healthcare. In the same communities with the largest prevalence and risk of malaria, COVID-19 social distancing and quarantining protocols were most difficult, if not impossible, to follow. This relationship could be visualized in statistically significant analyses.

Figure 1: Malaria Prevalence World Map (2019)



Source: Institute for Health Metrics and Evaluation (2019)

Figure 2: Malaria Endemicity Zones in Kenya with County Borders



Source: U.S. President's Malaria Initiative, Malaria Operational Plan FY 2020

COVID-19

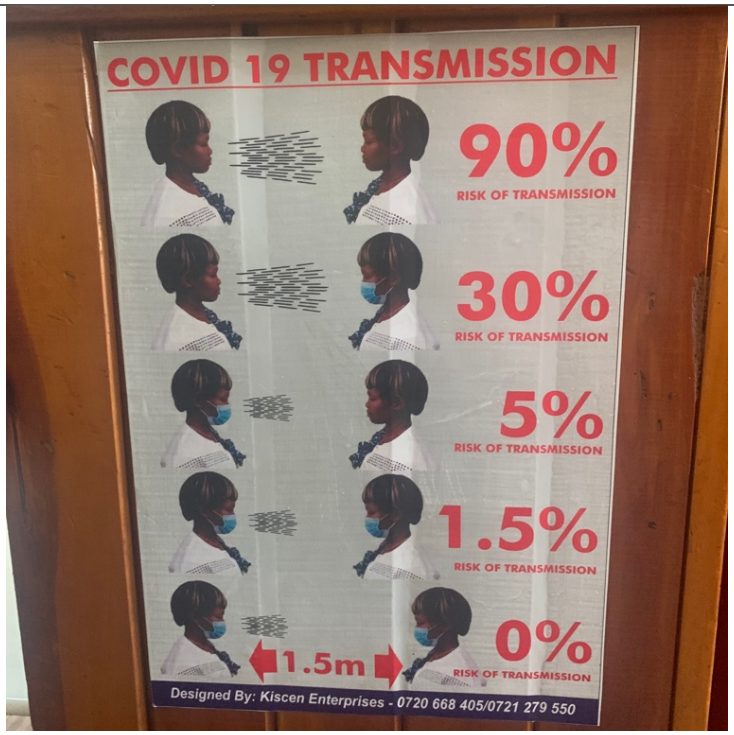
Emerging in late 2019 in Wuhan, China, the COVID-19 virus rapidly spread to all continents. As of 3rd of March 2023, there have been over 758,000,000 confirmed cases and 6,800,000 deaths related to the disease (WHO, 2023). Many of the impacts of the COVID-19 pandemic in Kenya and throughout most of sub-Saharan Africa are not only disease spread and burden but also indirect effects of control measures on social and economic indicators. Other studies have also found that epidemiological outcomes of containment and closure policies work better in higher-income countries than in lower-income countries (Pincombe et al., 2021). Nonadaptable outbreak response policies are likely adding to the limited capacity of governments to respond to health emergencies and to the public to abide to health regulations. Figure (3) shows not only examples of the living conditions of many low-income Kenyans in urban areas and the visible difficulty in following social distancing and quarantining measures but also the challenge to limit malaria exposure in housing arrangements.

Health scholars examining the pandemic have identified a phenomenon. Although sub-Saharan Africa was predicted to be severely impacted by the pandemic, it has experienced little case burden and a significantly lower case fatality rate. A total of 8.9 million cases have been reported in Africa, representing approximately 1.2 percent of all cases globally (WHO, 2023). For comparison, the United States averaged 30,800 cases per 100,000 in its population, while Kenya averaged 637 cases per 100,000 people. At a regional level, the WHO Europe region reported approximately 36,664.8 cases per 100,000 persons compared to the WHO Africa region with an average of 781.3 cases per 100,000 persons throughout the duration of the pandemic. This outcome is particularly surprising because of the area's limited health system infrastructure and a sizeable immunocompromised population from existing health challenges like HIV/AIDS and malnutrition, which would typically create a storm for a highly infectious pathogen like COVID-19. In addition, its large growing population, and urban density affords little opportunity for social distancing and increases the potential for disease spreading points. Despite these conditions, the region has not been devastated by the emergence of COVID-19. Why?

Figure 3: Urban Settlement in Mathare (Nairobi, Kenya)

Source: Laura Kraft (October 2010)

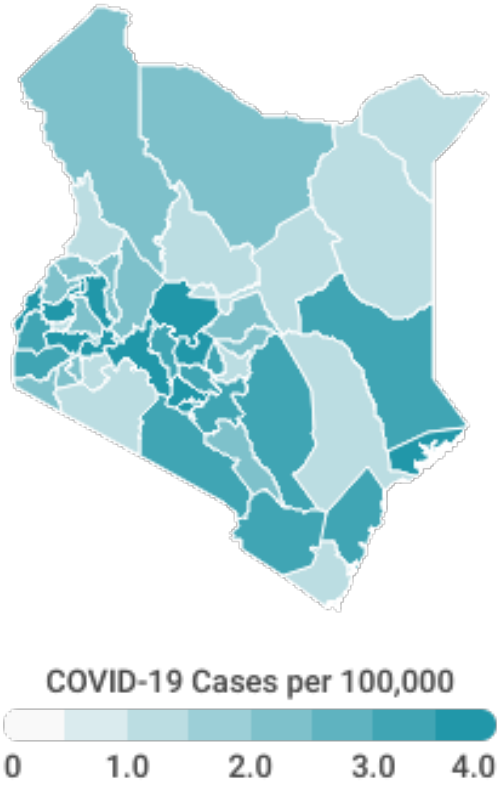
Figure 4: COVID-19 Transmission Poster in Restaurant in Kisumu, Kenya



Source: Ward Fieldwork Photo (June 2022)

Some scholars have suggested the limited cases were from a lack of testing. However, the limited cases were not from a lack of testing as later investigated. The Kenya Medical Research Institute has premium testing capacities available throughout the country (Ojal et al., 2022). Chitungo and Dzobo (2020) also confirm the intricacies of the low caseload in Africa going far beyond a lack of testing capacity.[1] Why has Africa not experienced COVID-19 burden to the same or worse extent than high-income countries, and how has the sub-Saharan African population approached the pandemic in relation to previous health crisis experiences?

Figure 5: Map of COVID-19 Cases per 100,000 November 6, 2021



Source: Infogram geographic visualization of COVID-19 case prevalence data using Kenyan MOH data

[1] When trying to understand the overall lack of impact COVID-19 seemed to have in Kenya, I was reminded of a quote from a boat tour guide helping us navigate Lake Victoria. He said, "Covid is mzungu' [white person] and Asian disease. It doesn't affect Africans. Africans have traditional methods to treat sickness and colds." This was a surprisingly common belief I heard throughout Kenya. Yet this experience contributes to an overall phenomenon and begs more questions.

This thesis poses another answer to this question: a state's experience with malaria and existing resources informed and prepared it for the COVID-19 pandemic. Many other health scholars focus on preparedness literature and states' experiences with health crises on how to transform future responses (Munnoli et al., 2020; Priyadarsini et al., 2020; Sharma et al., 2021). This thesis specifically provides an opportunity to bring together how Kenya's extensive experience with malaria could potentially prepare the population and health system to respond to novel disease outbreaks like COVID-19 and make adherence to health interventions more of a norm for most Kenyans, especially in the regions where malaria is endemic.

Data and Methods

This study hypothesizes that previous adherence to health interventions predicts adherence during a novel health emergency. Specifically, county-level malaria bed net usage can predict COVID-19 vaccination rates. In order to test this hypothesis, I conduct a large N statistical analysis using cross-sectional data within a single country. This thesis analyses COVID-19 at a point in time instead of as a time series analysis. Studying the pandemic response at this point will provide a clearer picture of how malaria interventions and adherence could have helped prepare policymakers and the public for COVID-19. The cumulative COVID-19 case counts account for cases recorded from March 2020 to November 2021. This stage in the pandemic focuses the study solely on the initial vaccination role out and when there was still significant uncertainty on COVID-19 protocols. I use counties to study Kenya as a whole, formulating predicted malaria adherence scores by county and correlating this with observed COVID-19 cases and vaccination uptake. Adherence can be quantified into a score with controls for socioeconomic and demographic indicators and focus on the adherence to malaria interventions listed in the Demographic Health Survey's Malaria Indicator Survey for Kenya through the USAID.

The demographic health survey is ideal to use in this study for the malaria section of the analysis as it is the gold standard for global health surveys (Murray & Evans, 2003)

The survey collected significant sociodemographic and economic data from participants, including literacy, education level, age, income, housing, health information access, family planning, distance to health services, county, household size, religion, and rural or urban environment. These can be used to improve conceptualization of adherence to health interventions aimed at preventing malaria spread, and outside of the direct scope of this thesis, access, and utilization of health interventions like bed nets and insecticide-treated bed nets.

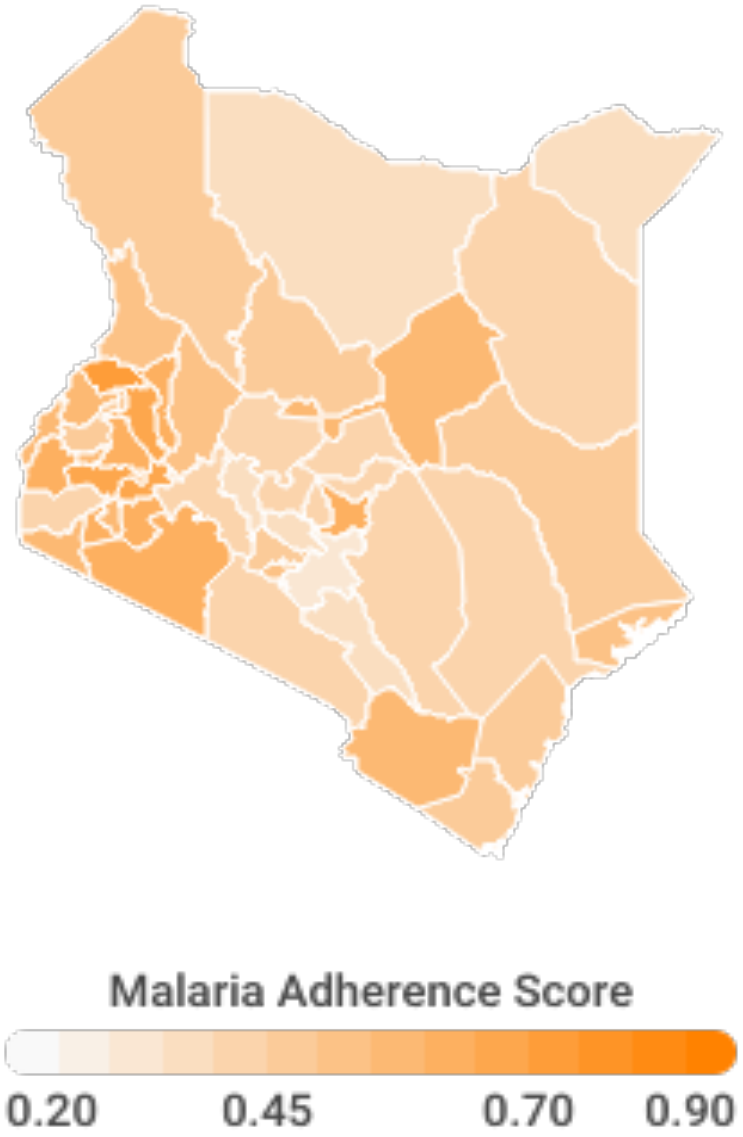
Known indicators that are correlated with adherence to other health threats include income, education level, literacy rates, and public health announcements about the given health threat. Adherence to one health initiative or program can predict adherence to future health measures, and this thesis aims to use this to test how/if malaria adherence predicts COVID-19 adherence in Kenyan counties. At the community level, the thesis seeks to explains how a given community demonstrates adherence to preventative health measures for malaria with simple interventions like bed nets.

Malaria Adherence Score

Using the 2020 Malaria Indicator Survey (MIS) from DHS, I developed a malaria adherence score by county, which predicted the likelihood that individuals in a given county adhere to malaria health protocols. The malaria health intervention in consideration is bed net usage, which is the recommended prevention method for malaria at this time. Whether bed nets were treated with insecticide or not was not considered, but instead strictly if a bed net was used correctly by the survey respondent. Correctly refers to if the individual used the bed net to sleep under and not for nontraditional and unintentional uses like cooking and cleaning. Along with the bed net variable I selected sociodemographic and economic controls from the individual-level MIS dataset, which included the region of the respondent, religion, literacy rate, total educational attainment, yes or no if malaria messages were seen in the past six months, yes or no if respondent lives in endemicity zone for malaria, recorded lives

births respondent had in last three years, wealth index, and the difference between rural-urban index that accounts for extreme differences between urban and rural wealth disparities. DHS provides details on variable definitions and calculations and the recode manual is included in this study's citations.

Figure 6: Map of Malaria Adherence Score



Source: Infogram geographic visualization of Malaria adherence scores from MIS survey analysis

A logistic odds ratio (logit) model was used to correlate the likelihood an individual used a bed net, the dependent variable, given sociodemographic and economic conditions. Using "predict" in Stata I could then predict the logit outcomes for bed net

usage and collapse these by county so that the data is at the county level instead of the individual level. The given data are the malaria adherence scores by county. Adherence is a score between 0 to 1 with a higher number indicating more adherence or more bed net usage in the given county.

COVID-19 Analysis

These malaria adherence scores by county can be used to predict COVID-19 outcomes in Kenya based on the theory that previous experience and adherence predict future adherence to health interventions. It was a significant challenge finding public data for all Kenya counties at an exact point in time early into the pandemic instead of just cumulative cases presently. Time-series analysis was out of consideration because of the inconsistency of daily reports. However, an available daily situation report from the MOH 18 months into the COVID-19 pandemic in Kenya contained details on cumulative COVID-19 cases and initial vaccination records by county. This data was used to form a binary variable of yes or no if the given county was above or below the national average for prevalence of COVID-19 cases and national vaccination average. Two models were also conducted omitting Nairobi County for the set of all 47 Kenyan counties because of its outlier characteristics.

The analysis used a logit to assess the probability of the tested relationship. The analysis used two dependent variables with one independent variable included with eight socioeconomic and relevant controls. Our dependent variables used in separate analyses were binary COVID-19 cases above the national county average. Each county had a count of 0 or 1 whether or not the cases as of November 6, 2021 were above the national COVID-19 case average of 359.93 COVID-19 cases per 100,000 people in the given county. The second dependent variable was also binary variable cataloging counties that were above the national average for COVID-19 vaccination rate at the same given point in time. The vaccination dependent variable is notably important because it has the chance to predict willingness to adhere to new health interventions based on previous adherence (i.e., malaria bed net usage).

All of the control measures used in the COVID-19 analysis originated from the Kenyan Bureau of Statistics and Public Knoema Data Hub, the MOH COVID-19 data analysis portal, or aggregated from the DHS survey. The control "Proportion of sample population that cannot read" was a variable derived from the DHS survey. I started with the same literacy variable used in developing the malaria adherence score but then collapsed the data by county for those with the lowest literacy level overall respondents to get the proportion of respondents in each county with the lowest literacy category. Inpatient beds per 10,000 and health workforce per 10,000 were both health metrics collected in the MOH's COVID-19 data analysis portal as useful measures of health system strength and preparedness to respond to a large level of emergency healthcare need in the given county population. The remaining controls, population density, average household size, female-to-male ratio, GDP per capita in US dollars, and population increase from 2009-2010, were all sourced from the Kenyan Bureau of Statistics and Public Knoema Data Hub primarily using data collected in the 2019 Kenya census.

Results

Out of the controls used to generate the malaria adherence scores, multiple were statistically significant with bed net usage. Wealth index score, number of births in the last three years, malaria endemicity score, and yes/no malaria messages were seen were all significant at the 99th percentile. Education attainment score, the religion of the survey respondent, and the wealth index urban/rural were all significant at the 90th percentile. Region and literacy were not significant at all.

Table (1) demonstrates the results from estimating Equation 2, and robust standard errors are shown in parentheses below the estimated coefficients. Columns (1) through (4) demonstrate results for four different logit models. Column (1) is the binary logit model of COVID-19 case prevalence. A county has a score of 0 if it was below the national average or 1 if it was at or above the national average for COVID-19 cases per 100,000 in the population. Column (2) is the logit model results from vaccination uptake

above the national average. Counties had a score of 1 if the vaccination rate was at or above the national average for COVID-19 vaccinations per 100,000. Columns (3) and (4) are the same logit models as (1) and (2) except that they omit Nairobi County from the number of observations, so these two models have 46 instead of 47 observations. All four models found a positive relationship between COVID-19 outcomes and malaria adherence scores. Whether including all 47 counties or omitting Nairobi County because of its dense urban character, COVID-19 case prevalence was more likely to be above the national average if the malaria adherence score was higher, showing a positive logistic relationship. This relationship is significant at the 5 percent level.

The logistic model correlating vaccination uptake and malaria adherence was significant at the 10 percent level and also showed a positive relationship with counties being above the national average for COVID-19 vaccination rates more likely to have higher malaria adherence scores. Some controls in the models were statistically significant. Population density and average household had statistically significant negative relationships with vaccination uptake. The number of health workers and inpatient beds per 10,000 people in the given county was positively correlated with COVID-19 case prevalence, inferring that there was a larger health workforce in counites with larger COVID-19 caseloads. Omitting Nairobi County proved to not significantly change the strength of the relationship at all for either dependent variable.

Table 1: Regression Models with COVID-19 case prevalence and initial vaccination rates for all 47 counties.

	[1] Binary COVID-19 case prevalence above national average, logit model	[2] Binary vaccination uptake above national average, logit model	[3] Binary COVID-19 case prevalence above national average, logit model, omitted Nairobi	[4] Binary vaccination uptake above national average, logit model, omitted Nairobi
A. Malaria Adherence Score	10.632**	10.447*	10.632**	10.774*
	(5.316)	(5.963)	(5.316)	(6.102)
B. Population Density	0.00004	-0.0006**	0.0003	-0.0008*
	(0.00006)	(0.0003)	(0.0006)	(0.0004)
C. Average Household Size	-2.001	-7.317***	-2.001	-7.435***
	(1.627)	(2.242)	(1.627)	(2.291)
E. GDP per Capita, USD	0.0006*	0.00001	0.0006*	-0.00001
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
F. Inpatient beds per 10,000	-0.332*	0.229	-0.332*	0.237
	(0.199)	(0.296)	(0.199)	(0.294)
G. Health Workforce per 10,000	0.285**	-0.104	0.284**	-0.111
	(0.132)	(0.146)	(0.132)	(0.149)
H. Female to Male Ratio	16.638	-13.901	16.647	-14.445
	(22.495)	(21.442)	(22.482)	(21.589)
I. Population Increase from 2009-2010	0.135*	-0.023	0.1345*	-0.026
	(0.082)	(0.032)	(0.082)	(0.043)
J. Proportion of sample population that cannot read	0.805	-7.652*	0.799	-7.818*
	(4.382)	(5.411)	(4.386)	(5.455)
Observations:47				

*** p≤0.01 **p≤0.05 *p≤0.1 and standard errors included in parenthesis

Discussion of Results

While these findings are insightful, there is a gap in understanding adherence and outcomes in this particular question that we cannot answer with the given data. There is recorded adherence to malaria-related health interventions (i.e. bed net usage), and we can test the relationship between this and COVID-19 vaccination uptake. This relationship is statistically significant and has real-world validity. At the county level,

counties with higher malaria adherence scores also had above national average rates for COVID-19 vaccinations shortly after COVID-19 vaccinations became accessible in Kenya. This is in line with my hypothesis. However, in order to fully understand how policy interventions influence COVID-19 case burden, information on the effectiveness of other COVID-19 protocols beyond vaccinations is needed. Incomplete data, especially in reference to county-level controls, limits the scope of this analysis and its implications. Not enough county-level controls were available, especially ones relevant to this analysis. Furthermore, this thesis had conflicting findings.

A positive relationship, like the one noted in the regression results, between COVID-19 case rates and previous health intervention adherence does not follow logically. In this thesis, I observe how a given community follows a malaria protocol but whether the same community follows a COVID-19 protocol and whether that protocol is effective are both not observed. What is then in turn observed in this given data are the COVID-19 case rates and vaccinations in the community. There are too many contributing factors for the COVID-19 case relationship with malaria adherence score to have external validity despite the statistically significant p-value. Reverse causality is a likely explanation of this relationship. A cross-sectional analysis does not do it justice.

This study had limitations in access to data and had to slightly change directions during the process. The Kenyan MOH did not have published situation reports or daily case information for all days in the early stages of the pandemic. Panel data could show variation over time and counties would have likely shown the story more effectively, but this was not available. Another potential change in methods is to use individual level data instead county level data, but again, this data was not available.

Empirically, more research is needed to understand the full relationship in question. Can we study the relationship between other COVID-19 protocols and malaria health interventions, and does this relationship exist in other levels of analysis, such as at the individual or neighborhood level? Furthermore, it adds to the conceptualization of how communities and defined populations build upon understanding and experiences.

Conclusions and Future Research

Health entities in Kenya reported experiencing significant disruptions in malaria programs during COVID-19. A likely next direction of this research is reversing the relationship to study how COVID-19 impacted malaria burden and control measures in Kenya. Many scholars noted the changes in malaria case rates in endemic areas during COVID-19 lockdowns (Aborode et al., 2021; Rogerson et al., 2020). Lockdowns where people are required to stay home in theory could lower malaria infections, especially in outdoor classrooms and work environments, but that does not include the risk of malaria transmission in the home. There are also noted coinfections of malaria and COVID-19 and the challenges with identifying cases and allocating resources when there are simultaneous health emergencies (Hussein et al., 2020). The impact of coinfections is multiple research articles entirely. While this is not the first time an outbreak has disrupted malaria control, COVID-19 posed unprecedented challenges globally and created unique challenges for African economies and health supply chains (Pincombe et al., 2021).

The COVID-19 pandemic continues to evolve even today. It has been three years since the outbreak first emerged. With multiple major variants, repeated spikes in cases, and political challenges, many believe COVID-19 has shaped society for lifetimes to come. There have been 6 confirmed waves of COVID-19 in Kenya since February 2020, and this study takes into account the first four before the large Delta variant wave that devasted many regions of the world. The last half of the pandemic in Kenya in not represented in this study but still needs to be assessed. This study helps open our understanding of how the pandemic in Kenya was influenced by previous health emergencies. Capacity building occurs in multiple ways as noted by previous scholars. In this instance, resiliency is built through existing understanding and normalcy of health interventions. Health system resiliency is a continuous process, and as a country responds to health emergencies, they can use these instances to learn and adapt their responses to lower the burden and impact of disease on their population.

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