2022

A comparative policy analysis of the early public health response to mitigate the spread of COVID-19 in Nigeria, Rwanda, and Zambia

BOSTON UNIVERSITY

SCHOOL OF PUBLIC HEALTH

Dissertation

A COMPARATIVE POLICY ANALYSIS OF THE EARLY PUBLIC HEALTH RESPONSE TO MITIGATE THE SPREAD OF COVID-19 IN NIGERIA, RWANDA, AND ZAMBIA

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Submitted in partial fulfillment of the

requirements for the degree of

Doctor of Public Health

2022

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DEDICATION

I would like to dedicate this work to my parents, Azeb Tefera and Solomon Woldemariam, whose sacrifices, love, and support have allowed me to reach this point.

ACKNOWLEDGMENTS

First and foremost, I would like to thank God for giving me the opportunity and guidance to achieving my goal and to be successful in this endeavor.

This dissertation would not have been possible without the support of many people. My heartfelt thanks to my incredible doctoral dissertation committee, Professors Hamer, Thea, Sabin, Galea, and Lucey, who have supported me through this journey. I cannot thank you all enough for your direction, honest feedback, and the time you have invested. To my Chair, David, thank you for being a mentor and advisor through this journey at BU. I am so thankful for the opportunities you have created for me and the mentorship you have provided me. To Lora, the best academic advisor, thank you for helping me navigate through my DrPH—from the application cycle to the comprehensive exam to this point—I am forever thankful to you and your kindness. I would also like to thank the Martin Luther King Jr. Fellowship which has allowed me to fund my education and continue to grow in my public health career.

Moreover, I want to thank my personal support network of friends and family. My deep appreciation for you all could be its own dissertation. Thank for your support, prayers, and encouragement. This wasn't an easy journey, but you have given me so much grace and love these last 3.5 years.

I would also like to thank the participants in Nigeria, Rwanda, Zambia, Congo, and Kenya who graciously gave their time and allowed me to gain a deeper perspective. Lastly, I would like to acknowledge the millions of lives lost and affected by the COVID-19 pandemic.

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ABSTRACT

Background: In the early parts of the COVID-19 pandemic, non-pharmaceutical interventions (NPIs) were implemented worldwide including sub-Saharan Africa to prevent and control transmission of SARS-CoV-2. This mixed methods study aims to examine adherence to and enforcement of NPIs implemented to curb COVID-19 in Nigeria, Rwanda, and Zambia, leading up to the 10,000th case of COVID-19 in each country. Additionally, we aim to broadly evaluate the relationship between levels and changes of NPIs over time and changes in COVID-19 cases and deaths.

Methods: This mixed methods analysis utilized semi-structured interviews and a quantitative dataset constructed using multiple open data sources, including the Oxford COVID-19 Government Response Tracker. Quantitative data were analyzed using four case windows (0 cases, 1-100 cases, 101-1,000 cases, and 1,001-10,000 cases). To understand potential barriers and facilitators in implementing and enforcing NPIs and how other epidemics within the countries may have affected compliance with NPIs, qualitative data were collected from those involved in the COVID-19 response and analyzed using

NVivo. Quantitative results were analyzed using descriptive statistics, plots, ANOVA, post hoc Tukey, and correlation analyses.

Results: Individual indicator scores varied with the COVID-19 response in all three countries. Nigeria had sustained levels of strict measures for containment and closure NPIs, while in Rwanda there was a lot of variation in NPI score as it transitioned through the different case windows for the same measures. Zambia saw moderate stringency throughout the pandemic with gathering restrictions and business/school closure measures but maintained low levels of strictness for other containment and closure measures. Rwanda by far had the most consistent and stringent measures compared to Nigeria and Zambia. Their success in implementation was partly due to strong enforcement and having a population that generally obeys their government.

Conclusion: Various forces either facilitated or hindered adherence and compliance to these measures. There were several lessons learned which highlight the need to engage communities early and create buy-in, as well as the need for preparation to ensure that response efforts are proactive rather than reactive when faced with an emergency.

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LIST OF ABBREVIATIONS

95% CI	95% Confidence Interval
Africa CDC	Africa Centers for Disease Control and Prevention
ANOVA	Analysis of Variance
ARISE	Africa Research, Implementation Science, and Education
ARR	Adjusted Risk Ratio
CFR	Case Fatality Rate
CPDS	Coordinated Procurement and Distribution System
EVD	Ebola Virus Disease
FCT	Federal Capital Territory of Abuja
GDP	Gross Domestic Product
GIS	Geographic Information System
HCW	Health care worker
IPC	Infection Prevention and Control
KII	Key Informant Interview
LGAs	Local Government Areas
MA	Moving Averages
MERS-CoV	Middle Eastern Respiratory Syndrome
NCDC	Nigeria Centers for Disease Control
NPIs	Non-pharmaceutical Interventions
NRL	National Reference Laboratory
OxCGRT	University of Oxford COVID-19 Government Response Tracker
PHEOC	Public Health Emergency Operation Center

PPE	Personal Protective Equipment
RCCE	Risk Communication and Community Engagement
SARS-CoV	Severe Acute Respiratory Syndrome Coronavirus
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
SI	Statutory Instrument
WHO	World Health Organization
WHO AFRO	WHO African Region
ZNPHI	Zambia National Public Health Institute

CHAPTER ONE

Introduction

In a pandemic, non-pharmaceutical interventions (NPIs) are crucial in curbing disease spread, especially in the absence of vaccines and other pharmaceutical interventions.[1] The impact of NPIs has been largely studied in controlling influenza outbreaks, including the 1918/1919 influenzas pandemics.[1,2] Numerous studies focus on the role of NPIs in controlling influenza outbreaks.[1,2] NPIs include actions that can be taken by individuals and the larger community. These include frequent hand washing, covering coughs and sneezes, isolating sick persons, quarantining exposed persons, and physical/social distancing measures for the general population.[1,3,4] The latter includes containment strategies such as the closing of schools and workplaces, restricting public gatherings, curfews, quarantine, and maximizing telework (when applicable).[4–7] During pandemics, apart from effective vaccine strategies, NPIs are one of the most important tools that individuals and communities can take to limit the spread of disease and reduce deaths. In addition, the timing of NPI implementation is crucial. Delayed implementation of NPIs will lead to unchecked proliferation of disease in the community and overwhelm health systems.[3,7,8] However, in addition to timing, the success of NPIs depends largely on the fidelity of implementation and the willingness of individuals to comply with the NPIs.[9–12] Careful consideration to tailored NPI measures for the specific community context may lead to less resistance and improved compliance.

The rapid increase in cases of COVID-19 in Africa as most countries experience their second and third waves is concerning as the continent's health resources are already

overburdened due to lack of focus and funding, and high rates of infectious disease including HIV/AIDS, malaria, pneumonia, diarrhea, and other endemic diseases such as cholera.[13] Additionally, the recent rise of non-communicable diseases on the continent further burdens already weak health systems that cannot effectively respond to a surge and efficiently address COVID-19 cases. It is widely accepted in public health that early interventions are crucial to halting the progression of a new communicable disease threat.[14].

Epidemiology of COVID-19

COVID-19, officially named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is the most recently identified of seven coronaviruses that cause human disease.[15,16] Coronaviruses are one of the largest known groups of RNA viruses and the family of viruses includes the severe acute respiratory coronavirus (SARS-CoV) and the Middle Eastern respiratory syndrome coronavirus (MERS-CoV). SARS-CoV, MERS-CoV, and SARS-CoV-2 can cause severe to deadly pneumonia in humans.[17]

In late December 2019, COVID-19 was first reported and linked to a single wet market where seafood and live animals were sold, in Wuhan City, Hubei Province, China.[18] It was hypothesized that, like MERS-CoV and SARS-CoV, COVID-19 originated from bats; however, there is still more evidence needed to confirm the origin of the new virus and its transmission to humans from an intermediate animal host.[18,19]

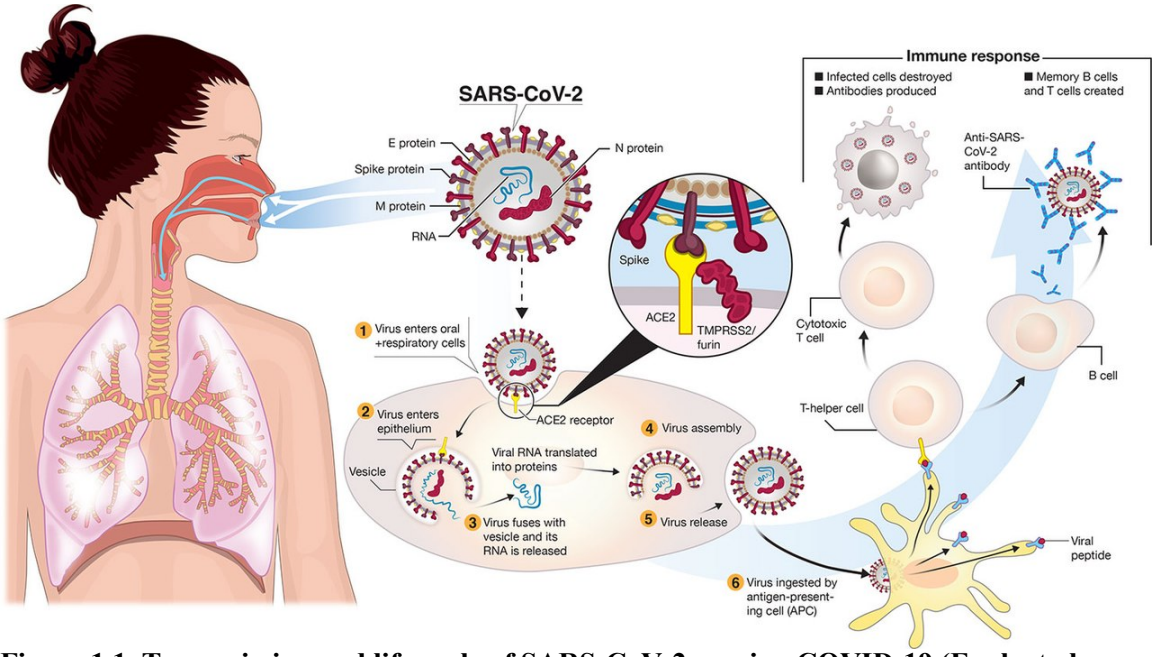


Figure 1.1. Transmission and life cycle of SARS-CoV-2 causing COVID-19 (Funk et al., 2020)

Recently, there has been increased speculation that the virus that causes COVID-19 emerged from a laboratory.[20] However, this too has not been confirmed.

COVID-19 has proved to be more contagious and spreads more rapidly than SARS-CoV and MERS-CoV.[17,21] The virus can easily spread from person to person mainly through physical proximity (within 6 feet) by way of respiratory droplets of someone who is infected with COVID-19 (Figure 1).[18,22] COVID-19 can also be spread by airborne transmission especially in enclosed spaces that have inadequate ventilation.[18,23] The mean incubation period for COVID-19 is 4-5 days from exposure to symptom onset.[24] The signs and symptoms of the disease vary and may differ with the severity of the disease. Some individuals may remain asymptomatic even though they are infectious and able to spread disease.[25,26] Common signs and symptoms are fever or chills, cough, new loss of taste or smell, sore throat, shortness of breath or difficulty breathing, headache, fatigue, muscle or

body aches, congestion or runny nose, and diarrhea.[24] The estimated basic reproduction number (R_0) has varied depending on geography and public health interventions, as well as which variant of concern is predominate.[27,28] A review comparing SARS-CoV-2 with SARs-CoV and influenza pandemics estimated the R_0 of COVID-19 to be 2.5 (range=1.8-3.6), compared to 2.0-3.0 for SARS-CoV and 1918 influenza pandemic, 0.9 for MERS-CoV, and 1.5 for the 2009 influenza pandemic; this also exceeds the WHO estimate of 1.4-2.5.[17,27,29] The R_0 is much higher with variants of concern, particularly the Delta variant.[27] In mid-2021, the U.S. Centers for Disease Control and Prevention (CDC) estimated that the R0 of the Delta variant was around 5-6, and as transmissible as the chickenpox.[30]

Global Burden of COVID-19

By December 2020, COVID-19 had spread to every corner of the globe, including Antarctica. As of March 23rd, 2022, there have been 487,816,657 confirmed cases and 6,099,380 deaths, globally. When broken down by WHO region, Europe exceeds other regions with COVID-19 morbidity and mortality. On March 23rd, 2022 the European region had a cumulative 195.4 million COVID-19 cases and 2.6 million deaths attributed to COVID-19.[31] The United States, India, and Brazil account for the majority of the global burden of COVID-19 cases. As of March 23rd, 2022, the 3 countries alone accounted for one-third of the global burden of COVID-19 cases and had almost 2000% of the cases in the entire WHO Africa Region.[31]

Burden of COVID-19 in the African Region

As of March 23rd, 2022, the WHO African Region had the least number of cumulative COVID-19 cases and deaths with 8.5 million cases and ~171,000 deaths.[31]

However, case and death counts are likely severe underestimations of the true burden of COVID-19 across the African region due to the lack of capacity of the health systems for testing, surveillance, and contact tracing.[32] When WHO declared COVID-19 a pandemic on March 11, 2020, only nine countries in the WHO African Region (Algeria, South Africa, Senegal, Nigeria, Cameroon, Burkina Faso, Cote d'Ivoire, the Democratic Republic of the Congo, and Togo) had recorded cases of COVID-19.[33] By May 13th, 2020, all 47 WHO African Region Member States were reporting cases of COVID-19.[34] The majority of cases were attributed to community transmission and cross-border transmission; the latter as a result of long-distance truck drivers and illicit transboundary movements.[35] Throughout the pandemic, South Africa reported the greatest burden of cases and deaths in the Region. As of March 23rd, 2022, South Africa accounted for 3.7 million cases of the 8.5 million cases in the WHO African Region.[31] Health workers were particularly at risk for infection due to the lack of health system infrastructure, inadequate access to personal protective equipment (PPE), and weak infection prevention and control measures.[36] As of March 13th, 2022, there were 158,851 cases among health workers reported in the previous seven-days in the WHO African Region, with 71,113 among health workers in South Africa (~45%).[37] As of the third week of March 2022, COVID-19 cases were declining in the African region.

Global Implementation of NPIs during COVID-19

In the absence of treatment beyond supportive care and vaccination for the early parts of the COVID-19 pandemic, NPIs were implemented across the world to prevent and control SARS-COV-2. Until recently, the effectiveness of NPIs has not been systematically tested and early measures of efficacy were explored through the use of mathematical

models, and limited published studies have reviewed the limited historical evidence of NPIs during past pandemics.[1,2,38] During the 2003 SARS epidemic and 2015 MERS-CoV epidemic, several NPIs were also implemented. In many countries, quarantine was required by law and monitored closely for enforcement.[39–43] Additionally, mask mandates were in place in several countries.[1,44,45] A study in Beijing found that wearing masks outside the home may have increased protection from contracting SARS.[45] The closing of international borders was also another NPI that was implemented in several countries during 2003 SARS epidemic.[40,45,46] Similarly, mask mandates and public health measures were undertaken during the MERS-CoV epidemic.[41,43]

A few studies have explored the impact of public health interventions and NPIs during the 1918-1919 influenza pandemic where NPIs played a critical role in delaying the temporal effects of the pandemic, in addition to reducing the overall and peak attack rate and the number of cumulative deaths.[2,38] A study by Markel et al. that examined the implementation of NPIs in 43 cities in the continental United States during the 1918-1919 influenza pandemic grouped NPIs into three categories: school closures, cancellation of public gatherings, and isolation and quarantine.[2] The authors found that cities that implemented NPIs earlier in the pandemic had greater delays in reaching peak mortality, lower peak mortality rates, and lower total mortality.[2] They also found that there was a statistically significant association between increased duration of NPIs and reduced total mortality in the 43 cities studied.[2] Notably, the striking contrast of mortality outcomes between Philadelphia, Pennsylvania and St. Louis, Missouri appeared to be correlated with the quality and timing of NPI implementation. In Philadelphia, after the identification of

the index case, authorities downplayed the significance of the disease and allowed public gatherings to continue, while St. Louis moved to rapidly introduce a series of social distancing measures two days after the identification of its first case.[2] The difference in response time between the two cities was around 14 days from the first reported cases of influenza, however, the mortality outcomes were profound.[2] Philadelphia experienced a peak weekly excess pneumonia and influenza death rate of 257/100,000 and a cumulative excess pneumonia and influenza death rate of 719/100,000 while St. Louis experienced a peak pneumonia and influenza death rate of 31/100,000 and a cumulative excess pneumonia and influenza death rate of 347/100,000.[2] Another study by Hatchett et al. explored the timing of 19 types of NPIs in 17 U.S. cities during the 1918-1919 pandemic and found that cities that implemented multiple NPIs in the early phase of the pandemic had lower cumulative excess mortality and less-steep epidemic curves. Early implementation of NPIs, such as closures of schools, churches, and theaters was associated with lower peak death rates.[38] They also found no single intervention showed an association with improved outcomes and disease spread increased upon relaxation of NPIs.[38]

Similar to the measures that were undertaken during the 1918-1919 influenza pandemic, many countries implemented social distancing NPIs such as school and workplace closures, restrictions on mass gatherings, maintaining physical distancing, isolation, and quarantine during COVID-19.[10,11,47] Other NPIs have included contact tracing, mask mandates, travel restrictions, public awareness campaigns, and increased surveillance efforts.[47–49] The degree of implementation has varied widely across the globe.

Compliance has also widely varied depending on enforcement, political governments, and receptiveness by the public.

On January 23, 2020, Hubei Province in China imposed a mass quarantine of 57 million people to restrict the movement of people who may have been exposed to COVID-19. Across the globe in New Rochelle, NY in the United States, a containment zone was established from March 12th-25th, 2020 restricting the movement of people living within a cluster of cases which at the time were linked to 108 of New York state's 173 COVID-19 cases.[50,51] In Europe, Italy enforced a national quarantine by imposing criminal penalties on those who were found to violate its quarantine rules.[52] Norway announced in early March partial quarantine measures for the country and threatened to enforce the measures by imposing fines (up to $2,000) or jail time (15-day sentences) for those in violation.[53]

Mask mandates were also largely implemented globally, especially in indoor spaces. After the first couple of months of the pandemic, masks were identified by public health experts as one of the most effective interventions to mitigate the spread of COVID-19 in terms of feasibility and scalability. In China, masks were recommended as early as the end of January 2020, although it was not required until late March 2020.[54] However, enforcement measures also varied widely. In the early phase of the pandemic, there was no federal mask mandate in the U.S.[55] Mask mandates in the U.S. were at times divided among political lines and lacked uniformity and consistency throughout the pandemic.[56] In the United Kingdom, the government imposed a countrywide mask mandate for shops and supermarkets in mid-July 2020.[55] France also followed suit and expanded its mandate to apply to all enclosed public spaces. However, enforcement was challenging, especially in

western countries with some people refusing to wear masks and reports of business owners facing physical attacks when trying to enforce mandates. In certain countries like Lebanon and the United Arab Emirates, fines were imposed for those not wearing a mask.[55,57] Others like Madagascar imposed punishment;[55,58] while Qatar and Cuba threatened multiple years of jail time.[55] Mask mandates were relaxed in certain countries as cases began to stabilize but were strengthened again with the introduction of various variants.[59]

Implementation of NPIs during COVID-19 in Africa

By early March 2020, several countries (affected and unaffected by COVID-19) began mobilizing in response to the pandemic. The African Union established a task force for coronavirus responses and resources from other diseases (e.g., Ebola) were re-allocated toward COVID-19. The Africa Centers for Disease Control and Prevention (Africa CDC) began mobilizing Member States to strengthen capacity for preparedness and response to COVID-19 by activating its Emergency Operations Center for COVID-19 before the end of January—much earlier than many Western countries.[60–62] This included prompt case identification, information campaigns to sensitize citizens, and building laboratory capacity.[63,64] Some countries relied on innovative strategies such as using locally produced cloth masks, soaps, and hand sanitizers, developing cheap diagnostic tests, testing pooled COVID-19 samples, and using drones to transport test kits and samples from hard-to-reach areas.[60–62]

Nonetheless, the underlying weak health infrastructure of many countries across the region was once again brought to light. The region severely lacked standard critical facilities, modern laboratories, resilient healthcare facilities with beds, ventilators, and

human resources. In April 2020, there were fewer than 2,000 working ventilators across 41 African countries, 10 African countries had none.[65] There were also fewer than 5,000 intensive care beds in 43 countries, which amounted to about 5 beds per million people.[65] Additionally, COVID-19 testing and surveillance capacity varied across the region, leading to substantial underestimates of the total COVID-19 burden.

By the end of March 2020, many countries in the region had imposed travel bans on flights arriving from certain Asian and European countries. In the following two months, almost two-thirds of the countries in the region closed their borders to all international travelers, except for cargo, freight, and expatriation of foreign nationals.[60,61] Fifteen countries implemented border closures before any COVID-19 cases were confirmed.[66] Other NPIs, such as restrictions of movement and public gathering, and closure of schools and workplaces were also implemented across the region.

In the early stages of the pandemic, many countries in the region replicated NPIs, such as travel restrictions and shelter-in-place orders, as some Western countries in Europe and the United States. However, approaches that worked in countries outside of Africa were not necessarily appropriate for the African region. Given the heterogeneity in populations, health systems, and governments in the region, blanket NPI measures such as the restriction of the movement were met with difficulty. Almost three-fourths (71%) of Africans work in the informal sector and were met with severe economic hardship with the enforcements of lockdowns and border closures.[50,62,67] With the implementation of certain measures, some countries were met with food shortages, social unrest, and economic instability.[61,62] Additionally, in countries where governmental authority was weak or

contested, or misinformation was high, enforcement of NPIs was met with resistance and incompliance.[68–71] The Africa Research, Implementation Science, and Education (ARISE) Network conducted a telephone survey in Burkina Faso, Ethiopia, and Nigeria between July and November 2020 to understand COVID-19 knowledge, attitudes, practices and their impacts on health, nutrition, and education.[72,73] The education sector was profoundly affected by school closures. Food shortages and insecurity were rampant across the three sites in the study. There was decreased consumption of a range of staple foods in all three countries as well as an increase in prices of staples, legumes, vegetables, fruit, and animal-source foods.[72,74] Additionally, with increased unemployment and decreased crop production, respondents described reductions in general food intake and dietary diversity.[72,74]

Additionally, physical, or social distancing measures were also difficult to enforce and implement. Aside from the high population density in many communities in Africa, social interaction is a key aspect of life. In urban areas in Africa, public transportation systems are often overcrowded, dense shanty towns and informal settlements are part of the physical infrastructure, and many do not have the luxury to self-isolate even if they are positive, as many homes face overcrowding. For example, Alexandra in Johannesburg, South Africa has 700,000 people who live in less than 1.9 square miles, Makoko in Lagos, Nigeria has 300,000 people whose homes are built on stilts in a lagoon.[69] In rural areas, many households share sanitation facilities and have only access to water from a communal tap. Ekumah et al. (2020) used Demographic and Health Survey data from 25 countries in sub-Saharan Africa to explore how vulnerability to COVID-19 was affected by access to

basic necessities (sanitation, water, and food) within a household.[75] They found that 46% of sampled households (except South Africa) did not have access to any of the three basic necessities, and only 8% had access to all three.[75] Thus, physical distancing measures, including shelter-in-place measures, were unrealistic in overcrowded areas with inadequate sanitation.

With already weak and overburdened health systems, COVID-19 has also further exacerbated health service utilization and increased health disparities among populations. Healthcare providers in Burkina Faso, Ethiopia, and Nigeria who were interviewed as part of the ARISE network study, reported that 56% of essential health services have been affected since the beginning of the pandemic.[76] They reported that about one-third (33%) of child health services and HIV/surgical/other services faced service interruption compared to maternal health services (31%).[76] Healthcare providers working at private facilities (Adjusted Risk Ratio=0.71; 95% Confidence Interval=0.59-0.84) had a lower risk of reporting high service interruption compared to those who worked at governmental facilities.[76] Stay-at-home/shelter-in-place measures have worsened disparities in access to health care especially in countries like Nigeria and Ethiopia where there is already a marked difference in accessing essential primary healthcare and skilled healthcare professionals before the start of the pandemic.[76]

In addition to several long-term effects of implementing NPIs, timing plays a crucial role in the implementation of NPIs. However, it is challenging to determine what is an optimal time to implement different interventions. If governments wait too long, this may lead to the proliferation of disease at a rapid rate and overwhelm health systems

quickly. Consequently, the roll-out of NPIs that are too premature or uniform across an entire country may also increase the risk of a "second wave" of infections once the initial measures are halted.[8,77] The implementation of NPIs, especially for a long time, can have significant detrimental consequences in terms of social and economic costs. While NPIs are generally effective in reducing the burden of disease and alleviating pressure on health infrastructures, studies have found that a longer duration of NPI implementation may have consequences such as increased unemployment, economic hardship, and social disruption.[78] Resource-poor settings and developing countries are at an especially increased risk, with some data showing income reduction as great as 70% and reduction in consumption expenditure by 30%.[78–80] Furthermore, NPIs are dependent on enforcement and citizens' willingness to comply with the measure. Compliance generally wanes the longer measures are in effect.[81] Poverty and economic dislocation also reduce compliance especially with NPIs focused on containment (i.e., shelter-in-place).[82]

Public Health Significance

Understanding the effect of the actions taken by different African countries in implementing or not implementing NPIs during this unprecedented pandemic will be a significant public health contribution. Additionally, monitoring, and documenting policy strategies governments have undertaken during the COVID-19 pandemic is important to understand the progression of the pandemic. The intended contributions of this dissertation include adding to this body of knowledge in terms of infectious disease mitigation as well as informing public health decision-making and policies and programs at the country level. This dissertation aims to identify effective and ineffective NPIs implemented in Nigeria,

Rwanda, and Zambia during four case windows: no cases, case 1–100, case 101–1,000, and case 1,001–10,000; and how specific actions either slowed or enhanced the spread of disease. The three countries were selected to ensure variety in population size, region, and World Bank income classification (Table 1)

Table 1.1. Characteristics of Selected Countries

Country	Region	Population Size (2019)[14]	World Bank Classification[15]
Rwanda	East	12,626,938	Low-Income
Nigeria	West	200,963,603	Lower-Middle-Income
Zambia	South	17,861,034	Lower-Middle-Income

Research Objectives

The dissertation will focus on the following research objectives:

1. To characterize new and total COVID-19 cases and deaths over time in Nigeria, Rwanda, and Zambia.
2. To characterize changes in the implementation of NPIs over time in Nigeria, Rwanda, and Zambia.
3. To broadly evaluate the relationship among the levels/changes in NPIs and changes in COVID-19 cases and deaths in Nigeria, Rwanda, and Zambia. This objective has three core goals:
    a. To examine the longitudinal changes in COVID-19 cases and deaths relative to the first implementation of NPIs.
    b. To examine the degree of implementation of NPIs relative to four case windows (0 cases, 1-100 cases, 101-1,000 cases, and 1,001-10,000 cases).

   c. To examine the relationship between prior levels and changes in the implementation of NPIs relative to rising COVID-19 cases and deaths.

4. To understand the facilitators and barriers in implementing NPIs during the COVID-19 pandemic in Nigeria, Rwanda, and Zambia.

CHAPTER TWO

Literature Review

The purpose of the literature review was to identify the burden of COVID-19 in each country and assess the level of response, including the implementation of non-pharmaceutical interventions. The key objectives of the review were to understand the heterogeneity of the political systems, population sizes, and healthcare infrastructure of each country, and understand the progression and spread of cases from the first case to the 10,000th case.

Methods

Electronic databases and websites were searched to identify relevant articles published before June 2021. Disease burden estimates as of June 1, 2021, are used for the purpose of this literature review. A research librarian was also consulted to assist with search term strategy for search in peer-reviewed and non-peer-reviewed literature. Google Advanced Search was utilized for non-peer-reviewed literature using keywords and country-specific domains. The below table was utilized to assist in the search of the literature.

Table 2.1. Search terms utilized in literature review

	Non-Pharmaceutical Interventions	AND	COVID-19 Pandemic	AND	Zambia, Nigeria, Rwanda
MeSH	Respiratory Protective Devices Travel/Legislature & Jurisprudence Quarantine Physical Distancing Social Isolation Health Policy Communicable Disease Control		COVID-19 Coronavirus Infections Pandemics/Control		Zambia Nigeria Rwanda
OR					
Keywords	NPI Face mask Cloth mask Disposable mask Isolation Social distance Border Control		SARS-COV-2 Severe acute respiratory syndrome Coronavirus 2 Novel coronavirus		Zambia Northern Rhodesia Nigeria Rwanda Kigali Abuja Lusaka

Nigeria

Background

Nigeria, a Federal Presidential Republic, is the most populous country in Africa, with over 200 million people residing in the country.[83] Nigeria is comprised of three levels of government: Federal, State, and Local, with 36 states, 774 local government areas (LGAs), and 6 geo-political zones.[84] In 2019, Nigeria's gross domestic product (GDP) per capita was $2,229.86, higher than the average GDP per capita in sub-Saharan Africa of $1,599.02.[7]

Nigeria's health service delivery system is divided into three levels: primary, secondary, and tertiary care.[85] Primary care serves as the entry point for care, comprised of

primary health centers, and is under the purview of the local government.[85] Secondary care includes general hospitals that are run by the state government.[85] Tertiary hospitals that provide highly specialized care are managed by the federal government.[85] Additionally, there has been a growing use of traditional and spiritual healers as a result of the inadequate primary health system in Nigeria.[86] The Nigerian health care system utilizes a mix of sources, including out-of-pocket payments, donor funding, tax revenue, and health insurance.[85] While the government oversees the quality of health services citizens access, out-of-pocket spending is still the major source of health financing in Nigeria.[85]

Rural areas in Nigeria face a wide range of issues in the health delivery system, ranging from lack of a health workforce to inadequate financing of health services.[85] The primary health care system is highly dilapidated with only about 20% of the 3,000 primary care facilities working in the country.[87] This has had a direct effect on health outcomes in Nigeria. Infectious diseases are widespread, only a quarter of children under 1 year of age are fully vaccinated, only 36% of women deliver in a health facility, and under-5 mortality is 128 per 1000 live births.[86] Additionally, 3.1% of Nigeria's population of over 200 million are elderly (aged >65 years) who are at an increased risk for non-communicable diseases such as diabetes, hypertension, other cardiovascular diseases, and cancers.[64]

COVID-19 Burden in Nigeria

While the definitions of a suspect case and probable case have changed throughout the early days of the pandemic, the case definition of a confirmed case has remained consistent in Nigeria.[88–91] A confirmed case of COVID-19 is defined as a laboratory confirmation of SARS-CoV-2 infection with or without signs and symptoms.

[88–91] The first case of COVID-19 was reported on February 27, 2020, in Nigeria.[92] As of June 1st, 2021, Nigeria had recorded 166,315 cases (3,175 health worker infections) and 2,099 deaths attributed to COVID-19.[93,94] Nigeria reached its 100th case about a month after its first recorded cases on March 29, 2020, where it recorded 111 cases (+22 cases from the previous day). No deaths attributed to COVID-19 were recorded among the first 100 cases. However, just three months after its first case, Nigeria recorded its 10,000th case of COVID-19 on May 31, 2020, when the country's cumulative number of cases was recorded at 10,162 cases (+307 cases from the previous day) and a total of 14 deaths were attributed to COVID-19 (case fatality rate (CFR)=0.14%).[93] When Nigeria reached its 10,000th case, the total cases per million persons was 49.30 cases; the total deaths per million persons was 1.39 deaths.[93] During the first 10,000 cases of COVID-19 no variants of concern were prominent in Nigeria. The presence of the Delta variant in Nigeria was confirmed by the WHO during epidemiological week May 24-30, 2021.[95]

Community transmission has been a driving force in the spread of COVID-19 in Nigeria. In the first 100 days of COVID-19 spread in Nigeria, 35 out of the 36 states in Nigeria had all recorded COVID-19 infections. Three states, Lagos, Kano, and the Federal Capital Territory of Abuja (FCT) had the highest prevalence, 46.2%, 8%, and 7.6%.[96] According to the Nigeria Centers for Disease Control (NCDC), 80% of the COVID-19 cases seen in the first 100 days of COVID-19 spread in the country were characterized by mild symptoms and deaths were among those who suffered from pre-existing conditions, such as non-communicable diseases.[96]

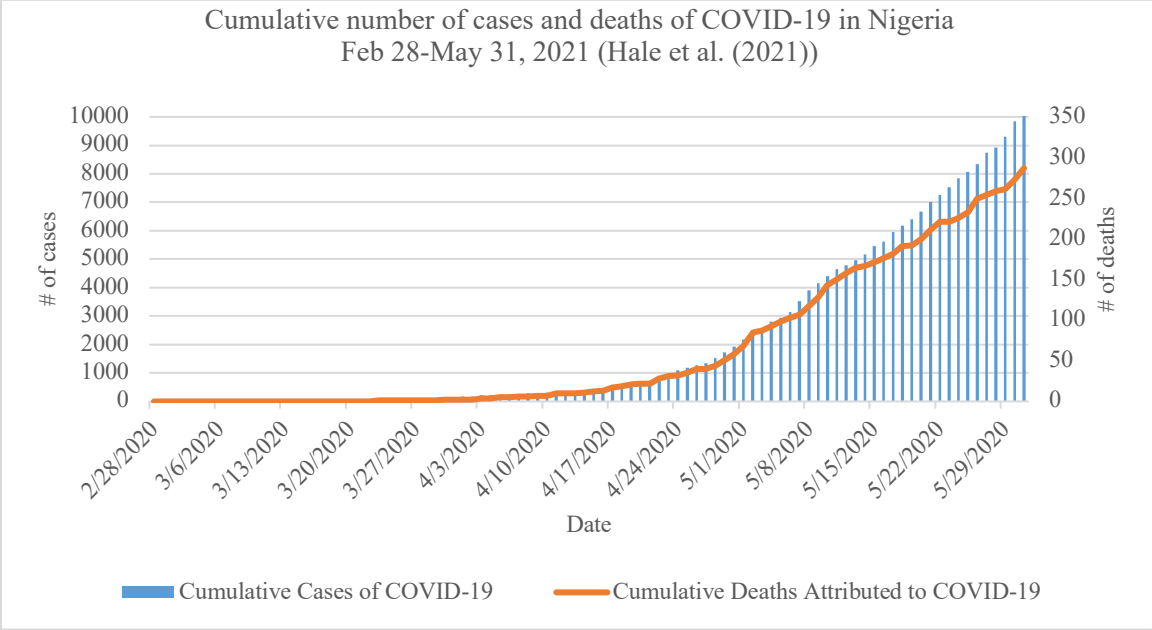


Figure 2.1. Cumulative number of cases and deaths of COVID-19 in Nigeria, Feb. 28-May 31, 2021.[97]

COVID-19 Response in Nigeria

Before the onset of COVID-19 in Nigeria, the Africa Centers for Disease Control and Prevention (Africa CDC) put together a task force to be able to detect COVID-19 cases in Nigeria promptly. A Presidential Task Force was convened following the detection of the index case of COVID-19. The WHO African Region COVID-19 Readiness Status categorized Nigeria's readiness as moderate but rated its readiness status to be limited in the following areas: rapid response teams, case management, surveillance, and infection prevention and control.[98] The country faced challenges such as inadequate medical equipment, lack of funds, and limited human resources. Before the COVID-19 pandemic, the country was equipped with 350 ventilators and 350 ICU beds for the entire population.[99] After the start of the pandemic, Nigeria was able to receive 100 more ventilators, but this still proved to be limiting in terms of the population at hand.

Nigeria's biggest response to the COVID-19 pandemic occurred between March and May 2020 and included the implementation of key non-pharmaceutical interventions (NPIs) (Figure 3). The Nigerian government issued several measures to implement physical distancing, including a lockdown and a ban on nonessential gatherings.[99,100] In March 2020, with the formation of the Presidential Taskforce for COVID-19, Nigeria moved to implement NPIs swiftly. This included the enforcement of an international travel ban, a federal mandate to close schools, a limit on religious gatherings of no more than 50 persons, and a lockdown in three states (FCT, Lagos, and Ogun).[99] In April 2020, Nigeria banned domestic flights, and many states began implementing their lockdowns.[99] In early May, face masks became mandatory in public places.[99] Businesses were instructed to implement a 'no mask, no entry' or 'no mask no service' policy.[101] As with other NPIs implemented during this time, persons not following public health measures faced either summary conviction by fine or six months imprisonment in accordance with section 5 of the Quarantine Act.[102] Unfortunately, there were instances of misuse and abuse of face masks. An article in the American Journal of Tropical Medicine and Hygiene detailed several media outlets showing the general public, healthcare workers, and government officials not wearing their face masks appropriately.[103] Additionally, before the wide use of cloth masks, surgical masks and respirators meant for healthcare workers were being worn by the general public and government officials even though supplies were insufficient in healthcare settings.[103]

Lockdowns were initially implemented in two ways: intra-city and inter-city enforcement. Intra-city measures were aimed at restricting people to their streets and

people could travel no more than a few kilometers from their homes. Inter-city measures restricted people from traveling to other cities or states. The initial phase of the lockdown was announced by the President to go into effect from May 4-17,2020.[104,105] After an extension, the government moved toward implementing a nationwide overnight curfew from 8 pm–6 am.[99,104]

In the first six months of the pandemic, Nigeria was able to expand testing by decentralizing its testing facilities and implementing community-wide testing and contact tracing. However, the level of testing was not sufficient for the population of Nigeria. Around the time Nigeria reached its 10,000th case, at the end of May 2020, the country could only test 2,500 samples per day. However, it only administered about half that amount (1,250 tests) due to the shortage of human resources.[99,100] In comparison, South Africa with a fraction of Nigeria's population, had already administered 1.6 million COVID-19 tests.[99] Contact tracing also faced challenges due to limited national testing capacity, community resistance due to political and healthcare mistrust, non-adherence to self-isolation and quarantine recommendations, and inadequate human and financial resources as cases began to rise.[106]

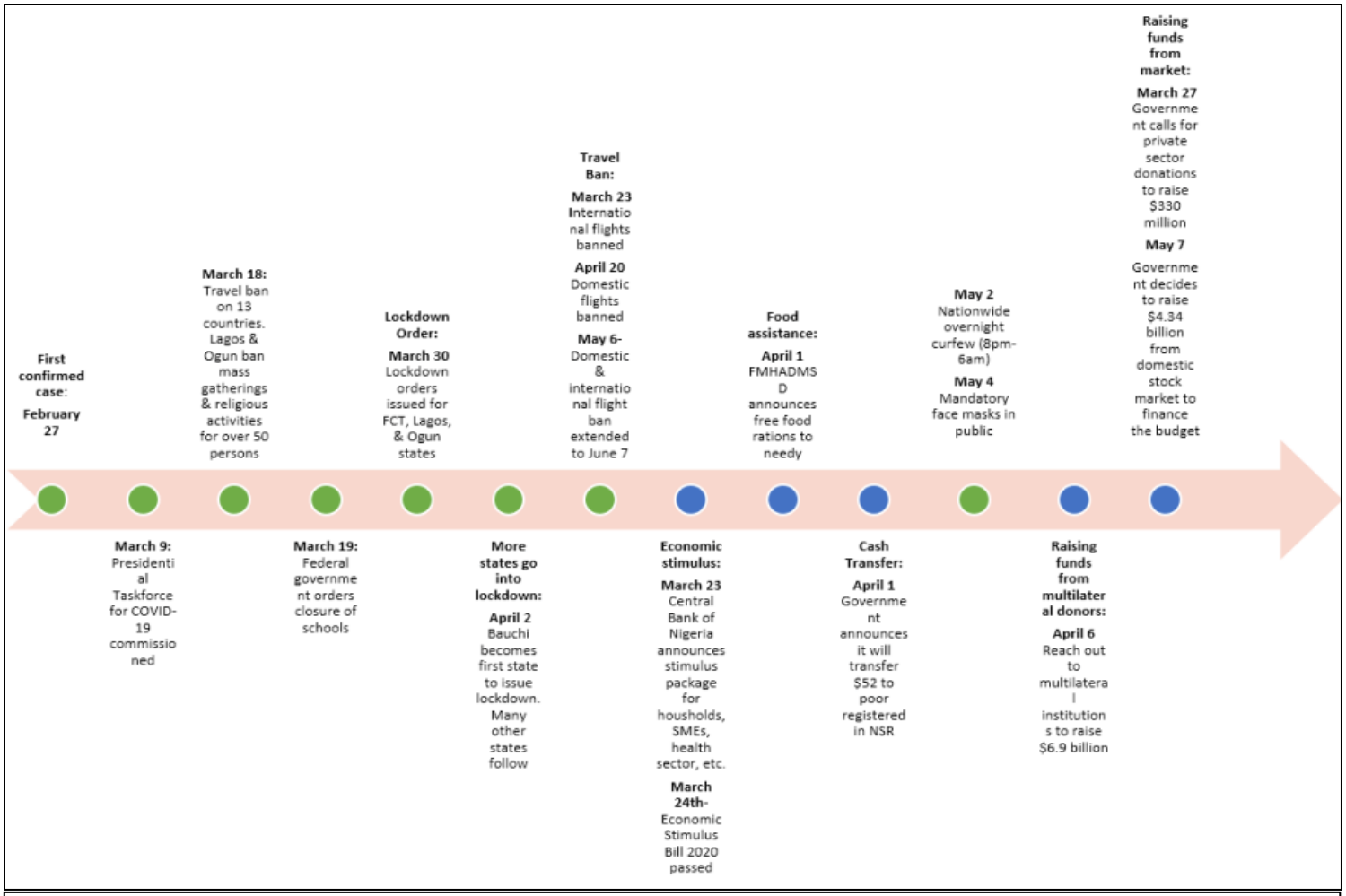


Figure 2.2. Timeline of important steps taken by government of Nigeria.[99]

Information campaigns were also widely utilized in Nigeria to aid with the dissemination of public health messaging. Upon identifying its index case, the Nigerian government used social media platforms such as Twitter, Facebook, and WhatsApp to spread crucial information about the virus. There were collaborations with non-profit and faith-based organizations throughout the country to promote social distancing, proper handwashing, and good personal hygiene. The Nigerian Centre For Disease Control (NCDC) translated resources into local languages to ensure that all populations were being reached and began a "Take Responsibility Campaign" (Figure 2.3).[107] NCDC also began sharing daily data to the larger global community on the status of COVID-19 in the country across various social media platforms, including launching a COVID-19 blog to share the stories of Nigerians dealing with COVID-19.[108] The NCDC also launched public information campaigns on YouTube, Instagram, and set-up a tollfree number for citizens to call.

Despite a robust public information campaign, many residents did not initially adhere to the recommendations aimed at reducing the spread of COVID-19. This caused high tension between the civilians and armed forces who became violent when trying to enforce certain protocols. To enforce lockdown and curfew measures, policy, paramilitary, and military personnel were deployed to various areas in the country. Among the challenges in this implementation were persistent corruption and political distrust.[104,109] There were also multiple reports of unlawful use of force and misconduct of the Nigerian police, including assaulting and abusing women, during the enforcement of COVID-19 measures.[110,111] Implementation and enforcement were marred with a lack of compliance

Figure 1.3. Take Responsibility Campaign Poster on Physical Distancing in Nigeria

from the public and limited the outcomes of the government response to COVID-19. According to a study by Ezeibe et al. (2021), an online survey found that 86% of survey respondents indicated that distrust of government initiatives to mitigate the spread of COVID-19 in Nigeria was either "high" or "very high."[109] An article in The Guardian covered Nigerians defying the stay-at-home orders which some attributed to distrust in the government and rising reports of hunger.[68] There were also reports of security operatives being susceptible to bribes from those choosing to defy lockdown measures.[104] This weakened the impact of travel restrictions and lockdown measures on the slowing down of COVID-19 in the country. The lockdowns implemented across Nigeria also placed a strain on the economic health of the country. According to the World Bank, 40% of Nigerians live below the international poverty line of $1.90/day. Thus, lockdown and restrictions on movement exacerbated unemployment and hunger throughout the country which were not adequately addressed with the economic response to COVID-19.[68,100,112]

In terms of economic measures, Nigeria passed a stimulus package and began putting measures in place to support its citizens during the pandemic. The economic stimulus package provided a 50% tax rebate for registered businesses; however, given that

90% of the workforce in Nigeria were in the informal sector, this bill had limited effect. To assist poor and vulnerable households registered in the National Social Register, the Nigerian government announced in April 2020 that it would transfer 20,000 Naira (~$52 United States dollars) in the form of a cash transfer to these vulnerable households.[99] There were significant shortcomings to the implementation of the cash transfers as most of the poor were not registered in the National Social Register. Additionally, due to Nigeria's weak national information system, most who were registered were not able to get their cash transfers because of issues with electronic payment transfers.[99,100] Moreover, only 40% of Nigerians have bank accounts which also deters citizens from receiving direct aid from the government.[99] Food assistance was also announced by the government as many were facing hunger due to extended lockdowns in many states. Due to widespread corruption in the distribution system, many were not able to receive the food rations promised to vulnerable households in states who imposed lockdowns.[99]

Rwanda

Background

Rwanda is a presidential republic located in East Africa with a population of 12,952,209 in 2020.[93] Rwanda is comprised of administrative units overseen by the Executive, Legislative, and Judicial Branches of government. Rwanda has five provinces: Northern Province, Western Province, Southern Province, Eastern Province, and Kigali Province. The five provinces are further divided into thirty districts, known as akarere. In 2019, Rwanda's GDP per capita was $820.15.

Rwanda's health services are delivered through the public sector, government-assisted health facilities, private health facilities, and traditional healers. The public sector is divided into two-three levels: central, intermediate, and peripheral. The central level operates out of Kigali and is responsible for the overall strategic and technical framework in which health services are delivered.[113–115] It is also responsible for managing the national referral facilities. The intermediate level is constructed of 11 provincial health offices and the Public Health Department of Kigali City.[113–115] Lastly, the peripheral level consists of district health offices, which are made of administrative offices, district hospitals, and primary health care facilities. Government-assisted health facilities—called agréé facilities— are run by religious groups and non-profit organizations.[113–115] These facilities are integrated into the public sector regardless of their resources. In Rwanda, 85% of the population receives health services at the public, primary health center level (Figure 2.4).[113–115] While funding for health service delivery is decentralized at the district level, there can be long delays for local, primary health centers to receive reimbursement for all services rendered during patient visits.[113–115] However, the quality of care is emphasized strongly by the government and primary health facilities work hard to ensure they are delivering quality care with the funds they have available.[113–115] Rwanda's health care system and its road to achieving universal health coverage are widely documented.[113,116–118] In the past 20 years, premature mortality rates have dramatically decreased, life expectancy has doubled since the mid-1990s, and the country has a strong community-based health insurance scheme.[113,116]

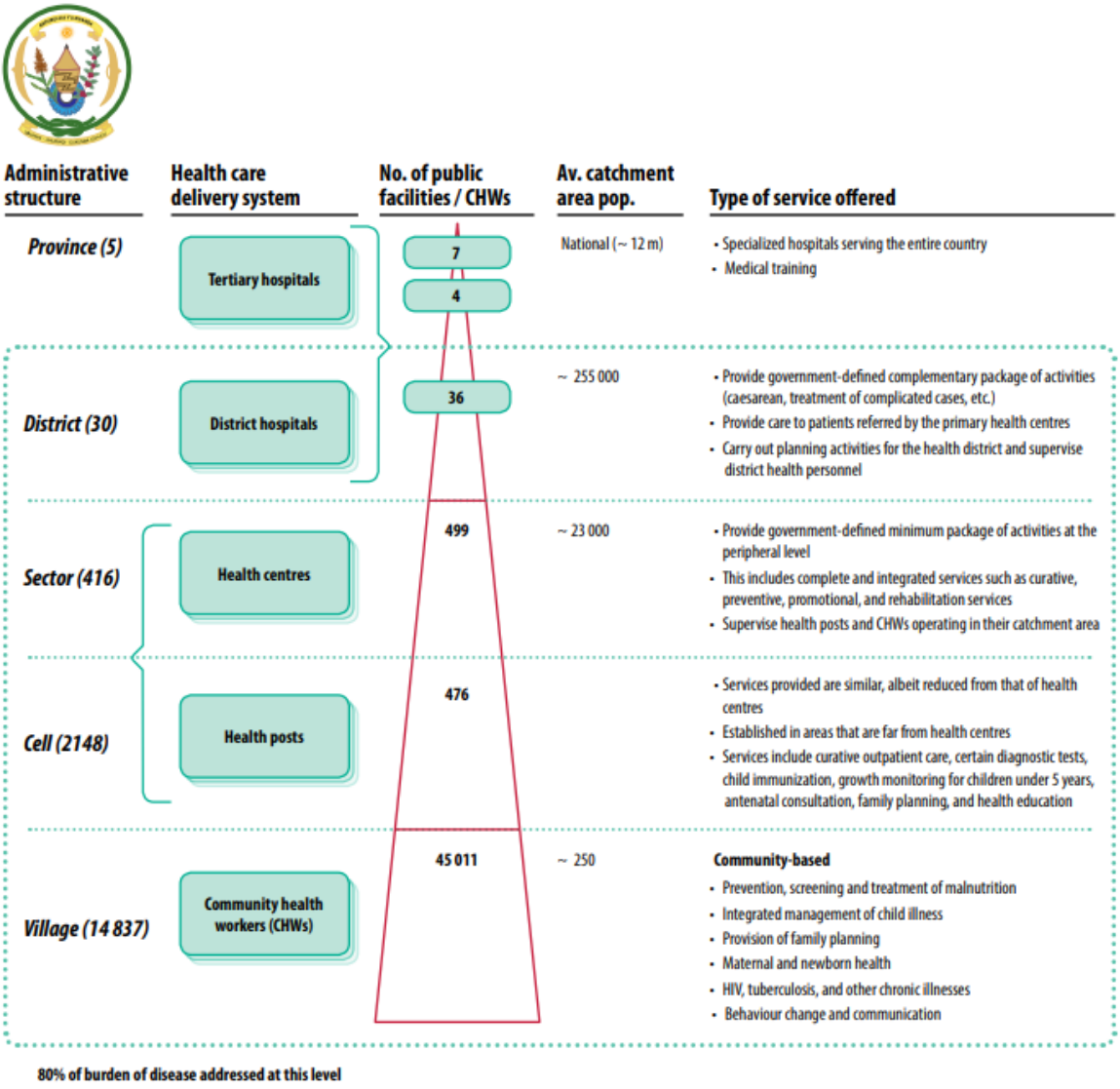


Figure 2.4. Representation of the health care system of Rwanda.

COVID-19 Burden in Rwanda

A confirmed COVID-19 case in Rwanda was defined as a person with laboratory confirmation of COVID-19, irrespective of clinical signs and symptoms.[119] The first case of COVID-19 was reported on March 14, 2020. As of June 1, 2021, Rwanda has recorded 27,023 cases of COVID-19 (682 healthcare worker infections) and 357 deaths attributed to COVID-19.[93,94] Rwanda reached its 100th case on April 4, 2020, less than a month after its

first reported case of COVID-19. On June 29, 2020, Rwanda recorded its 1,000th case of COVID-19 and its 10,000th case on January 13, 2021, marking a much slower spread than many other countries in the region.[93,120–122] Despite its slow spread, given its smaller population size, cases per million were much higher than in other larger countries. When Rwanda reached its 10,000th case, the total cases per million persons was 781.5 cases; the total deaths per million persons was recorded at 13.2 deaths. During the first 10,000 cases of COVID-19 no variants of concern were prominent in Rwanda. The Delta variant was identified in Rwanda during epidemiological week July 12-18, 2021 by the WHO.[123]

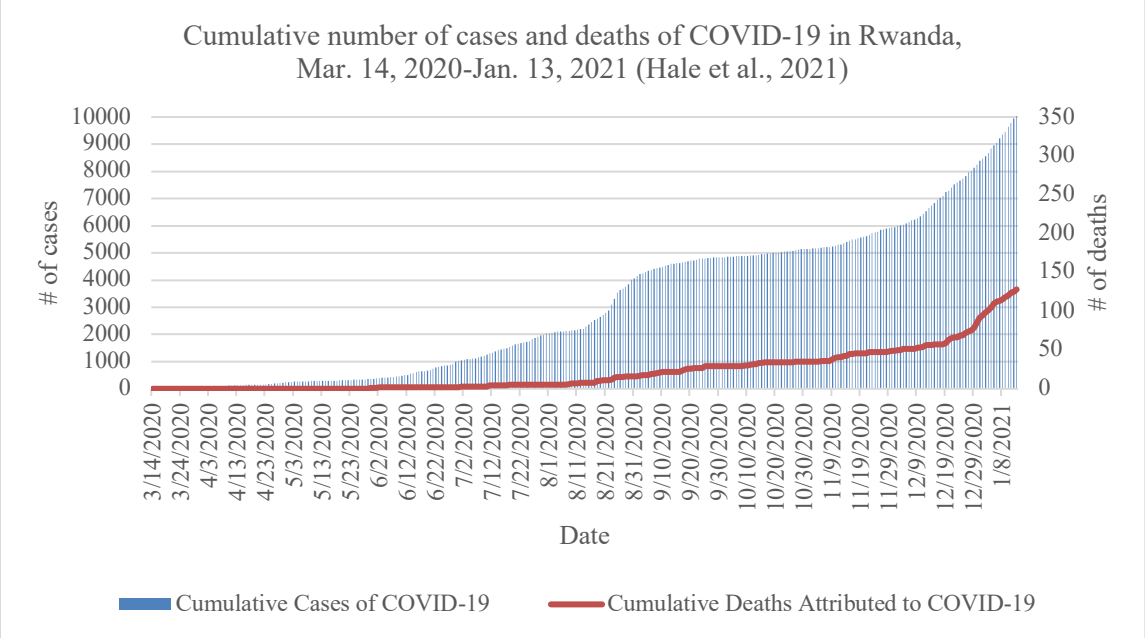


Figure 2.5. Cumulative number of cases and deaths of COVID-19 in Rwanda, Mar. 14, 2020-Jan. 13, 2021[97]

COVID-19 Response in Rwanda

Before the first case of COVID-19, the Rwandan government implemented temperature checks and handwashing protocols at all border entry points.[124] After the first case of COVID-19 was identified on March 14, 2020, the government laid down several

strategies to curb the spread of the disease. In just a few days, international flights were suspended, a two-week lockdown, including the closing of land borders, was implemented, and all workplaces were closed.[124] In October 2020, when other countries had far surpassed 10,000 cases, Rwanda had less than 5,000 confirmed cases and only 34 deaths. Rwanda's aggressive and stringent public health measures played a significant role in its ability to flatten the COVID-19 case curve during the first wave of the pandemic.

Given the novelty of the COVID-19 virus, Rwanda had to adjust to various systemic and operational activities within its healthcare system to help curb the spread of disease. The country also moved quickly to employ various public health measures including lockdowns, curfews, and travel restrictions. Rwanda was the first country in Africa to completely close its borders to international travel and issue a total lockdown in the country from March 21st to May 4th, 2020. The lockdown required everyone to stay confined to their homes except health workers who were provided with a pass that they presented to authorities when they left their homes to go to work.[125,126] Once it opened its borders again, all incoming travelers, including Rwandan nationals, were subjected to testing and quarantine at a pre-specified hotel for 14 days. These rapid and extensive measures contributed to slowing down the spread of COVID-19, which was evidenced by the low case counts during waves 1 and 2 of the pandemic in comparison to neighboring nations like Kenya and Uganda. However, these measures also contributed to substantial economic and social consequences, including food insecurity and increased poverty. These consequences necessitated the rapid reversal of various containment measures when cases stabilized. However, the country raised its stringency levels on measures whenever cases

began rising again creating a state of instability in terms of economic and social consequences.[127]

Before the COVID-19 pandemic, Rwanda was working to improve its economy and provide job security to its citizens. With the onset of COVID-19, many households that were once above the poverty line began falling into poverty and households struggled to stay afloat.[126,128] Small scale retailers are a vital part of the economy in Rwanda, but due to increased fares for public transportation and motorbikes, many were unable to sell the goods that they once sold for income. To combat food insecurity, the government set a fixed price for food and worked with farmers and factories to prevent the scarcity of food commodities. Additionally, price monitoring played a major role in ensuring that individuals in refugee camps were still able to afford goods for their families during this time of need.[129] Price monitoring and fixed prices for food were crucial in minimizing exploitation of consumers and producers during this time.[130]

Before the identification of the index case, the National Reference Laboratory in Kigali had tested 900 samples— all negative.[131] However, within 20 days of the index case being identified, community transmission was already evident.[131] Within the first 10 days of COVID-19 in Rwanda, the caseload had grown to 36 confirmed cases; by the end of March 2020, there were 75 confirmed cases.[124] With clear community transmission, the Rwandan government acknowledged the need to expand testing, contact tracing, and containment capacity. By July of 2020, Rwanda adopted a national strategy and began testing COVID-19 samples using a pooled method, which allowed for a more efficient method of using expensive laboratory equipment.[120,132] While using this method, the

country repurposed automated HIV testing machines for COVID-19 testing in the country.[120] This allowed the country to capitalize on existing infrastructure and human resources while building up capacity for COVID-19 testing.

Rwanda also used various tactics drawn from the country's experience in its fight against the Ebola virus. The country's experience with Ebola virus detection, which included the use of thermo-guns to check temperatures, made Rwanda unique in response to the invasion of COVID-19 compared to other East African countries.[121,133] The measures employed by the Rwandan government to fight the spread of COVID-19 in Rwanda also included the use of university and college students to help with contact tracing efforts. This made it possible to contact trace—to find those who might have interacted with a COVID-19 positive person and urge them to get tested and quarantined to curb the further spread.[133] The government also used frontline workers in the enforcement of public health measures required to contain the spread of the disease, including police, medical practitioners, and community health workers, which was pivotal in terms of policy and financial rollouts towards disease containment. Financial rollouts included supporting workers and vulnerable persons through food relief efforts to the hardest-hit households living in Kigali and other urban centers, zero charges on mobile money transfers, and removing the maximum transaction limit on mobile payments; as well as supporting businesses by working on a fund to support access to capital for small and medium enterprises, and extending the deadline for businesses to file and pay income taxes.[134] A multi-agency team led by Rwanda's COVID-19 National Command Post worked to also ensure that local community leaders were involved in contact tracing efforts and linking those identified

with testing.[135] The Rwandese government's formation of the multi-sectoral agency helped in the mobilization of required resources towards the fight against the spread of the disease.[106,130]

The role of inter-governmental cooperation between Rwanda and other countries was crucial in allowing the country to utilize innovative strategies to contain the spread of COVID-19. Rwanda partnered with various nations and international bodies to secure financial resources and other key commodities such as testing reagents and face masks. [27] Commonwealth countries also came together to pool funds that Rwanda was able to benefit from. Rwanda became a beneficiary of grants and loans from developed countries like the United States and other Western countries, as well as, from organizations such as the World Health Organization, International Monetary Fund, and the World Bank.[136] Additionally, private investors such as Jack Ma and the Alibaba Foundation contributed to providing Rwanda with testing reagents, face masks, and other commodities — a contribution that significantly improved the efficiency in identifying, testing, and containing the further spread of the disease in the country.[137] The government utilized new and innovative technologies such as robots in the treatment of COVID-19 patients. The robots were donated by the United

Figure 2.6. Robots at a COVID-19 treatment center in Rwanda

Nations Development Program and the Rwanda Ministry of Information, Communication, and Technology and Innovation. Health clinics and hospitals used robots to take temperatures, deliver food and medications, and screen people for COVID-19 (Figure 2.6).[120]

The government also relied on mobile technology such as mobile money transfers to buy and sell goods, to minimize the physical handling of cash. Additionally, it also used GPS-enabled phone applications to track and contact trace persons that may have had contact with a positive case.[106] Drones were further utilized to disseminate public health messages, such as social distancing, across the country (Figure 2.7).[121,138,139] Megaphones mounted on drones reminded pedestrians in city streets and villages to socially distance, while health workers wearing personal protective equipment took samples from drivers at traffic intersections.[121,140]

Compliance with public health measures, including mask-wearing, was governed strictly by police and an anti-corona task force. Anecdotal reports detailed police pulling over cars with unmasked drivers and/or passengers, hand-washing stations and sanitizer dispensers were monitored for use before entering businesses, and arrests were made of those violating the country-wide 10 p.m. curfew.[140] Communities were placed on lockdown when a COVID-19 case was identified to minimize spread to other communities. Rwanda's COVID-19 intra-action plan lauded its strong coordination structures ranging from the village to the national level with strong political backing in effectively responding to the COVID-19 pandemic.[141] It also recognized risk communication and community engagement, data management, surveillance and points of entry screenings, overall

coordination, and laboratory capacity-building as best practices for the COVID-19 response in Rwanda (Table 2.2).[141]

Figure 2.7. Drones in Rwanda displaying public health messaging

Table 2.2. Highlights of best practices for Rwanda's COVID-19 Response[141]

Cross-Cutting • Leveraging on capacity built during Ebola virus disease (EVD) preparedness • Digital innovations and use of virtual platforms
Coordination • Setting up village COVID-19 committees with daily reporting systems and structure from village to the national level • Virtual coordination: In Western Province, coordination between provincial and district levels were enhanced through online meetings with the district command posts
Data Management • Digitalization of COVID-19 data systems for all response components with geographic information systems (GIS) based systems for real-time data collection and spatial analysis • System for virtual care of patients at home enabled interaction with patient and health professionals
Risk Communication and Community Engagement (RCCE) • Video conferencing to enhance RCCE coordination at central and decentralized levels • Engagement of Village and Isibo leaders as well as opinion leaders
Surveillance and Points of Entry • Utilization of different technologies and innovative approaches in case investigations and contact tracing, such as the use of bracelets • Exit and entry requirements were put in place, which included systematic screening, testing, and isolation of all incoming and outgoing travelers, and infection prevention and control (IPC) facilities at points of entry
Laboratory • Developed an action plan to scale up testing which provided opportunities for increasing the laboratory testing capacity and resource mobilization • Design and implementation of pooled testing approach which was cost-effective • Infection prevention and control • Innovative capacity building: developed and implemented a comprehensive cascade training plan in collaboration with Rwanda College of Physicians • Monitoring and enforcement of IPC measures
Case Management • Involvement of all clinical sectors and medical associations in implementing case management interventions • Use of robots in treatment centers
Logistics and Operations Support • Mechanisms for emergency procurement were put in place • A centralized management system for ambulances, fleet, drivers, vehicle maintenance services, and fuel allowed for better transport facilitation
Continuity of Essential Health Services • Reorganization of services and transport system to allow access to essential services and specialized care • Conducted survey reviews to assess and monitor access to essential health services

The report also highlighted some key challenges including communication across sectors, levels, and stakeholders, inadequate human resources, equipment, supplies, and infrastructure, limited interoperability between data management systems, difficulty in coordinating the use of approved messages with non-governmental organizations, and insufficient linkages between national reference laboratory (NRL) and decentralized laboratories. The report also provided recommendations for the highlighted challenges (Table 2.3).[141]

Table 2.3. Highlights of challenges and recommendation for Rwanda COVID-19 Response, Rwanda COVID-19 Intra-Action Review Report[141]

Challenges	Recommendations
Cross Cutting	
Communication across sectors, levels, and stakeholders	• Develop a communication plan clearly defining information-sharing mechanisms between different actors and reporting pathways • Video conferencing between command posts, within pillars and inter-pillar
Inadequate human resources, equipment, supplies, and infrastructure	Determine needs based on different scenarios and conduct needs assessment for human resources, supplies, and infrastructure
Lack of funds for COVID-19 research	Create a mechanism for providing regular updates, cascade training, and virtual training
Coordination	
Provincial-level command posts activated but with limited capacity	• Public health emergency operation center (PHEOC) charter to be developed and ensure PHEOCs meet the minimum requirements • Enhance capacities of the provincial level command posts, human resources, and equipment
COVID-19 resource tracking done separately for government and partners resources do not include the status of implementation	Develop a tool to jointly track investments including updates on the implementation status

Data Management	
Multiple systems for data management with limited interoperability	Improving the existing data system by creating a platform with a different backend system
Limited knowledge and capacity at a decentralized level compared to the central level	Build capacity of the district teams on data management
Risk Communication and Community Engagement	
Difficulty in coordinating proper use of approved messages by non-governmental organizations in the communities	• Remind partners of the existence of compass Rwanda which shows the approval mechanisms • Develop a brand manual
Spreading of rumors and misconceptions about COVID-19 via social media	Conduct regular mass and social media monitoring at all levels to allow for timely addressing rumors and misconceptions
Surveillance and Points of Entry	
Deficiency of a clear plan for integrated multi-surveillance approaches	Develop a comprehensive COVID-19 surveillance strategy incorporating all the surveillance strategies
Centralized surveillance data analysis	Decentralize surveillance data to the districts to allow for use for data for decision-making at the district level
Laboratory	
Insufficient linkages between NRL and decentralized laboratories and unclear sample networking system	• Establish a platform for coordination within the pillar • Develop a sample networking guide
Challenges in the maintenance of equipment and lack of backup of some equipment in decentralized laboratories	Allocate budget for equipment maintenance and procure additional equipment
Infection Prevention and Control	
Insufficient alignment between IPC guidelines and supply chain of related commodities	Alignment between guidelines and supply chains to have a common understanding of supply needs
Reporting format not harmonized	Establish the harmonized reporting formats
Case Management	
Lack of diagnostic tools including laboratory and imaging services in the COVID-19 treatment centers	Avail diagnostic services in COVID-19 treatment centers
Insufficient follow-up of recovered patients post-discharge in terms of systematic follow-up of recovered patients	Institute a robust follow-up mechanism for discharged patients

Logistics and operations support	
Procurement procedures regulations not set up for health emergencies	Put in place a legal framework for emergencies
Requisition, validation, and distribution of supplies done manually	Integrate the COVID-19 logistics planning activities into the Coordinated Procurement and Distribution System (CPDS) mechanisms
Continuity of essential health services	
The initial COVID-19 structure did not include continuity of essential health services	Update the coordination structure to include continuity of essential services
Challenge in follow-up and tracking of patients with chronic diseases	Engage community health volunteers in conducting follow-up

Zambia

Background

Zambia, in southern sub-Saharan Africa, covers a surface area of 752,612 square kilometers.[23] Administratively, Zambia is divided into 10 provinces and 105 districts. Of the approximately 18 million people living in Zambia, about 60% reside in rural areas, while the remaining 40% reside in urban areas.[142] The country is landlocked and shares borders with eight countries: Mozambique, Zimbabwe, Democratic Republic of Congo, Tanzania, Malawi, Botswana, Namibia, and Angola.[143,144] In 2019, the GDP per capita in Zambia was $1,305.[145]

The country's political system is comprised of a three-branch multi-party democracy with a distinct separation of power between each branch. The three branches that make up the Zambian political system are the legislative, executive, and judiciary branches.[146,147] The Legislative branch is compromised of the President, Vice President, and members of parliament. The executive branch is made up of the cabinet which is comprised of select members of the National Assembly appointed by the President as

Ministers of respective government ministries. The judiciary branch is compromised of the Courts of Law which encompasses 2 of the highest courts—Supreme Court and Constitutional Court—and smaller courts including the Court of Appeals, Small Claims Courts, and Industrial Relations Court.[148]

The Minister of Health sits under the legislative branch and is a Member of Parliament.[146] The Minister oversees all aspects of the Ministry of Health. According to the 2017–2021 National Health Strategic Plan, the Ministry of Health has begun its decentralization process to the district and hospital levels, which now receive funds directly from the Ministry of Finance.[149] The Ministry of Health is responsible for policy formulation and guidance, monitoring and evaluation, and donor coordination. The 10 Provincial Health Offices maintain responsibility for coordinating health service delivery in their respective provinces including providing direction to provincial hospitals and serving as the main link between the central level (Ministry of Health) and district level. All District Health Offices are responsible for health service delivery at district hospitals, health centers, health posts, and at the community level.[149] Additionally, the District Health Offices are responsible for providing administrative supervision of health facilities and data compilation. Before the decentralization process, Zambia faced significant issues as all service delivery coordination and supervision came from the central government.

Zambia has both private and public health systems. These systems provide a range of healthcare services including diagnostic care and curative care. As in most other developing countries, bilateral and multilateral organizations and global health initiatives are involved in the policy processes in Zambia.[150] Most bilateral and multilateral

organizations and global health initiatives give funding for their various projects directly to the government which has experienced major issues related to the accountability of funds. While organizations have tried to put in place systems and processes to ensure aid reaches the intended beneficiaries and achieves the expected results, there have been recent issues within the Zambian political system that point to mismanagement of donor funds and corruption.[151]

As of 2017, Zambia has more than 2,900 health facilities, the vast majority of which are government-administered health facilities.[142] Health care services are provided at first-level hospitals (district level), second-level hospitals (province-level), and third-level hospitals (central level). At sub-district levels, health services are provided at urban and rural health centers, health posts, and at the community level. A package of basic health services is provided at no cost or cost-sharing at the facilities. The basic health care package includes maternal and child health services, antiretroviral therapy, and malaria testing and treatment services. A referral is conducted linearly through the various health care levels from the lowest health facility (health post) to the highest.

There is a high burden of infectious diseases in Zambia. Communicable, maternal, neonatal, and nutritional diseases continue to be the leading causes of death in the country.[152] In 2019, the under-5 mortality rate was 51.1 per 1000 live births.[152] Human resources for health are a major bottleneck for the delivery of health services in Zambia. Zambia continues to only have about 50% of the health workforce it needs and many openings for different cadres of health workers, such as nurses, doctors, and clinical officers remain vacant and unfilled.[153]

COVID-19 Burden in Zambia

A confirmed COVID-19 case in Rwanda was defined as a person with laboratory confirmation of COVID-19, irrespective of clinical signs and symptoms The first case of COVID-19 in Zambia was reported on March 18, 2020. As of June 1st, 2021, Zambia had recorded 95,821 cases of COVID-19 (1,121 health worker infections) and 1,282 deaths attributed to COVID-19.[93,94] Zambia reached its 100th case at the end of April 2020 when it recorded 106 cases of COVID-19 (+9 cases from the previous day) on April 30th, 2020. Three (3) deaths were attributed to COVID-19 with the first 100 cases. On August 19, 2020, 5 months after its first case, Zambia recorded its 10,000th case of COVID-19, where the cumulative number of COVID-19 was recorded at 10,218 (+237 cases from the previous day), and a total of 269 deaths attributed to COVID-19 (CFR=2.6%).[93] When Zambia reached its 10,000th case, the total cases per million persons was 555.8 cases; the total deaths per million persons was 14.6 deaths.[93] During the first 10,000 cases of COVID-19 no variants of concern were prominent in Zambia. The B.1.351 variant was introduced in Zambia in mid-December 2020.[154] The presence of the Delta variant was reported during epidemiological week May 24–30, 2021 by the WHO.[95]

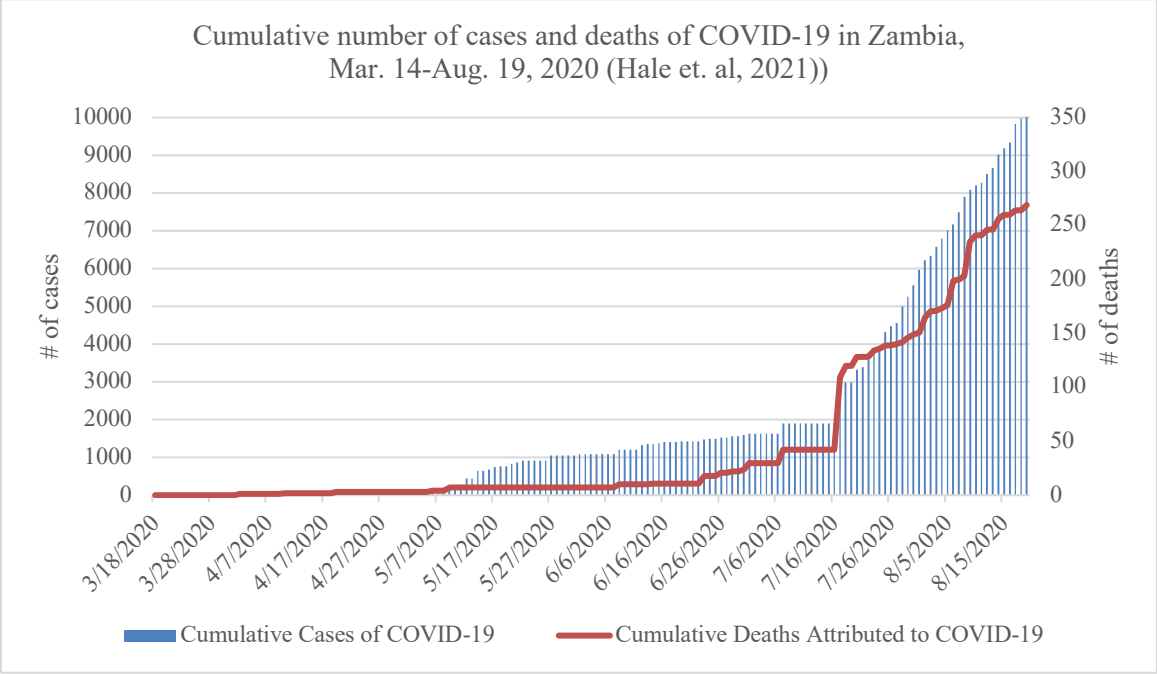


Figure 2.8. Cumulative number of cases and deaths of COVID-19 in Zambia, Mar. 14-Aug. 19, 2020.[97]

COVID-19 Response in Zambia

The Zambia National Public Health Institute (ZNPHI) categorized suspected COVID-19 cases per the World Health Organization's guidance released on March 20th, 2020.[155] A suspected case of COVID-19 was identified as presenting with acute respiratory illness within 14 days of international travel, history of contact with COVID-19 lab-confirmed case, hospitalization due to respiratory illness, or in a household with a confirmed COVID-19 case.[155] Zambia identified cases of COVID-19 through various methods including port-of-entry surveillance, contact tracing, health care worker (HCW) testing, facility-based inpatient screening, community-based screening, and calls from the public into a national hotline.[155] Port-of-entry surveillance including taking temperatures of travelers, assessing symptoms in the last 14 days, and inquiring about any contact with

someone who had been confirmed with COVID-19.[155] If a traveler was suspected of COVID-19, they were tested on-site. In the 28 days after confirmation of Zambia's first COVID-19 case, almost two-thirds (65%) of new cases were identified via point-of-entry surveillance and contact tracing.[155] In April of 2020, the Zambian Ministry of Health began mandating testing for COVID-19 in health care facilities. This applied to an individual who was admitted to hospitals, individuals admitted for surgery, and HCWs who worked where COVID-19 patients were isolated.[155]

Days before its first case was identified, the Minister of Health signed and introduced two statutory instruments (SIs) which designated COVID-19 a public health emergency.[156] The SIs provide a regulatory framework for disease mitigation strategies. Within a week of the index case being identified, the Zambian government put in place restrictions on public gatherings. Schools and universities, restaurants, nightclubs, cinemas, among other public gatherings, were indefinitely closed to assist in containing the further spread of the virus.[130,157] The government also mandated the closure of bars and cinemas and implemented a nationwide curfew.[130,157] Unlike neighboring countries Zimbabwe and Malawi, Zambia did not impose a stay-at-home order. Additionally, apart from the closing of the Zambia-Tanzania border for 5 days, the country never formally closed its international borders, in contrast to others in the region.[158]

Zambia employed various techniques to pass COVID-19 health-related messages to the public. Upon identifying the first case, the Zambian government utilized social media platforms such as Twitter, Facebook, and WhatsApp to spread crucial information about the virus.[159] Subsequently, most of the news agencies updated citizens on reported figures,

safety measures, and the efforts made by the government to contain different effects. Broadcast and print media also played crucial roles in disseminating relevant information. Media houses and print media held necessary debates on the best remedies to tackle the pandemic.[160] In April 2020, Zazu also implemented an SMS-based bot known as 'CoronaBot', that surveyed the Zambian population on its acceptance of health messaging.[161] These results were part of social listening reports curated by those in the risk communication and community engagement sector.[161] Non-governmental and community-based organizations were also actively involved in creative COVID-19 awareness within the communities. Community-based organizations benefited from understanding the local context and were able to tailor health messages appropriately. Social media and internet platforms were heavily utilized. Existing platforms such as U-Report that were initially utilized for HIV/AIDS were repurposed to disseminate knowledge on COVID-19. This was essential to increasing knowledge about disease and prevention on trusted platforms while attempting to decrease misinformation. However, the continuation of restrictions, including mask mandates, and economic consequences, caused an increase in pandemic fatigue and a decrease in the compliance of restrictions.

The economic impact of COVID-19 was felt deeply by citizens. Containment measures heavily contributed to the economic consequences of the pandemic in Zambia. The economy, which is heavily dependent on the export of minerals as its main source of revenue, experienced a 14.8% decline in export earnings, despite a 16.5% increase in copper exports.[158] The supply value chain was impacted negatively, particularly concerning goods channeled through South Africa, which was experiencing the worst wave

of COVID-19 in the region. Additionally, a loss of revenue from reduced tourism also had a large impact on the Zambian economy. International border restrictions imposed in other parts of the world deterred tourists even though Zambia's borders were open. During the first half of 2020, international arrivals into Zambia declined by more than half a million due to widespread suspensions in international travel.[158,162] A World Bank Survey of households in Zambia, found that 71% of respondents who worked in the tourism sector reported experiencing joblessness.[158,163]

To reduce the immense economic effect of containment measures and the overall pandemic, the country made several efforts to support its citizens during the pandemic. The country opted for a social cash transfer scheme to alleviate poverty, especially among low-income families affected by the pandemic.[164] About 700,000 out of 8 million Zambians living in poverty were enrolled as part of the social cash transfer program.[164] Additionally, with the informal sector in Zambia employing 90% of the workforce, the government implemented tax measures targeting informal workers to obtain funds for supplying food and other necessities in urban areas. The government later introduced fiscal measures to fight the adverse impacts of COVID-19. The measures included tax relief, continuity of businesses, easing liquidity, and engaging multilateral organizations.[165] The most critical aspect of fiscal policy was implementing the budget by mobilizing resources that would later assist various sectors in containing COVID-19-related impacts. As a result, the government released about K2.5 billion to ease liquidity in the economy.[165,166] Zambia also implemented tax relief in most sectors which benefited local businesses involved in manufacturing face masks, sanitizers, among other essential goods.[166] Due to the

prevalence of COVID-19 in most parts of the country, the government encouraged digital financial services to reduce face-to-face interaction. In return, the financial institutions were encouraged to issue relief to the private sector.[165–167] The relief was crucial for the long-term issuing of loans that would aid in economic development. Importantly, citizens were encouraged to work locally. This also involved encouraging the production and selling of locally manufactured goods. Despite its best efforts, the pandemic caused the Zambian economy to enter its deepest recession in history with the economy shrinking by 4.2% in 2020. [165–167] Zambia was also the only country to default on their Eurobond national debt.[168] An assessment of the Zambian economy a year into the pandemic reflected that the "recession goes beyond the containment measures (which were moderate) and reflects vulnerabilities to external shocks and unfavorable internal macroeconomic decisions, with potential long-term implications."[158]

Gaps in the Literature

There continues to be a gap in the literature about the impact of NPIs on the progression of the pandemic in Africa. Existing research on the impact of NPIs on COVID-19 focuses on high-income countries in Europe and Asia, who were heavily affected at the beginning of the global pandemic, not on African countries. This literature review had to heavily rely on non-peer-reviewed articles such as situation reports, news articles, blogs, and white papers, as there are not many published articles on the impact of NPIs on the pandemic in Nigeria, Rwanda, and Zambia. This dissertation will add to the body of knowledge on infectious disease mitigation efforts while informing public health decision-making and policies and programs at the country level.

CHAPTER THREE

Research Design and Methods

The dissertation used a mixed methods approach to answer the proposed research questions and provide a thorough policy analysis. Quantitative analysis utilized several data sources including the Johns Hopkins COVID-19 Dashboard and the OxCGRT, in addition to country-level strategic plans and both peer-reviewed and non-peer-reviewed literature.[13,94,169] Qualitative data utilized key informant interviews (KIIs) with decision-makers and other officials involved in the pandemic response, including officials at the WHO African Regional Office, the country-level, and the Africa CDC Secretariat and Regional Collaborating Centers.

Quantitative Data

A quantitative dataset containing variables from different sources was utilized to achieve the proposed research objectives. All sources were open-source, publicly available data. The dataset for the dissertation utilized a time-series dataset beginning on January 1st, 2020, for each of the three countries (Nigeria, Rwanda, and Zambia) and ending on the date when each country surpassed its 10,000th case. Variables in the dataset included total confirmed cases of COVID-19, total new cases for each day, total deaths attributed to COVID-19, new deaths attributed to COVID-19 for each day, real-time estimate of the effective reproduction rate (R) of SARS-CoV-2, estimated population size in 2020 for each country, and population density. A full list of variables in the dataset and their sources can be found in Appendix A. In addition to COVID-19 case and death aggregates, the dataset also included variables from the University of Oxford COVID-19 Government Response

Tracker (OxCGRT), which collects publicly available information on 20 indicators of government response to help decision-makers understand governmental responses.[97] The dissertation focuses on variables in the tracker that measured non-pharmaceutical interventions (NPI) and policies.

The quantitative dataset for this project included three policy indices that were produced and validated by OxCGRT (overall government response index, containment and health index, and stringency index).[97] All three indices aggregate the data of individual policy measures into a single number, between 0 to 100, that reflects the level of a government's response along certain dimensions to measure how many relevant indicators a government has acted upon, and to what degree.

The overall government response index is calculated using all the ordinal indicators in the larger OxCGRT dataset (C1-C8, E1-E2, H1, H2, H3, H6, H7, and H8) (Table 3.1). This index records how the response of governments has become stronger or weaker over the course of the pandemic. The containment and health index is calculated using all ordinal containment and closure policies (C1-C8) and health system polices (H1-H3, H6-H8). Lastly, the stringency index is calculated using indicators C1-C8 and one health system policy indicator (H1), which records public information campaigns. All indicators and indices in the dataset are recorded on ordinal scales. Some indicators in the dataset—C1-C7, H1 and H6 have an additional binary flag variable, coded as 0 or 1, that corresponds to the geographic scale of the policy (0=geographic scope of policy is targeted and 1=geographic scope of policy is general).

Table 3.1. Non-Pharmaceutical Policies Tracked in the OxCGRT

Variable	Description
C1	Record closings of schools and universities
C1 flag	Binary flag for geographic scope
C2	Record closings of workplaces
C2_flag	Binary flag for geographic scope
C3	Record cancelling public events
C3 flag	Binary flag for geographic scope
C4	Record limits on gatherings
C4 flag	Binary flag for geographic scope
C5	Record closing of public transport
C5 flag	Binary flag for geographic scope
C6	Record orders to "shelter-in-place" and otherwise confine to the home
C6 flag	Binary flag for geographic scope
C7	Record restrictions on internal movement between cities/regions
C7 flag	Binary flag for geographic scope
C8	Record restrictions on international travel (this records policy for foreign travelers, not citizens)
H1	Record presence of public info campaigns
H1 flag	Binary flag for geographic scope
H2	Record government policy on who has access to testing Note: this records policies about testing for current infection (PCR tests) not testing for immunity (antibody test)
H3	Record government policy on contact tracing after a positive diagnosis Note: Policies include only those that would identify all people potentially exposed to COVID-19
H4*	Announced short term spending on healthcare system, e.g., hospitals, masks, etc.
H5*	Announced public spending on Covid-19 vaccine development
H6	Record policies on the use of facial coverings outside the home
H6 flag	Binary flag for geographic scope
H7*	Record policies for vaccine delivery for different groups
H8	Record policies for protecting elderly people (as defined locally) in Long Term Care Facilities and/or the community and home setting
H8 flag	Binary flag for geographic scope
E1*	Record if the government is providing direct cash payments to people who lose their jobs or cannot work.
E2*	Record if the government is freezing financial obligations for households (e.g., stopping loan repayments, preventing services like water from stopping, or banning evictions)
E3*	Announced economic stimulus spending
E4*	Announced offers of Covid-19 related aid spending to other countries
*Not included in dissertation dataset asides from calculation of index scores	

All the indices calculated by the OxCGRT are simple averages of the individual component indicators using equation 1 below, where k is the number of component indicators in an index and I_j is the sub-index score for an individual indicator.[97]

$$Equation\ 1..\quad index = \frac{1}{k}\sum_{j=1}^{k} I_j$$

The sub-index score for an individual indicator is calculated using Equation 2. Each sub-index score (I) for any given indicator (j) on any given day (t), is calculated by the function described in equation 2 based on the following parameters:

- the maximum value of the indicator (N_j)
- whether that indicator has a flag (F_j=1 if the indicator has a flag variable, or 0 if the indicator does not have a flag variable)
- the recorded policy value on the ordinal scale ($v_{j,t}$)
- the recorded binary flag for that indicator ($f_{j,t}$)

$$Equation\ 2.\quad I_{j,t} = 100\,\frac{v_{j,t} - 0.5(F_j - f_{j,t}}{N_j}$$

Quantitative Data Analysis

NPIs were grouped into two policy categories: containment and closure policies, and health system policies, as tracked in the OxCGRT. To address the proposed research objectives, the following analysis strategies were undertaken. All analyses were performed using SAS statistical software version 9.4 (SAS Institute Inc., Cary, NC).[170]

Research Objective 1: To characterize new and total COVID-19 cases and deaths over time in Nigeria, Rwanda, and Zambia. Descriptive statistics (means, standard deviations (SD) and minimum/maximum, $25^{th}/50^{th}$[median]/75^{th} percentile values) and plots were used to show changes in new and cumulative COVID-19 cases and deaths over time by country. Data are depicted by four case windows (0 cases, 1-100 cases, 101-1,000 cases, and 1,001-10,000 cases).

Research Objective 2: To characterize changes in the implementation of NPIs over time in Nigeria, Rwanda, and Zambia. Descriptive statistics (means, SD, median values for 0-100 indices) and plots of NPI implementation levels over time (both 0-100 indices and individual health and containment NPIs) were used to describe overall longitudinal changes and across the four case windows (0 cases, 1-100 cases, 101-1,000 cases, and 1001-10,000 cases). Additionally, the dates of first implementation of specific NPIs were obtained. The three indices that were investigated, which are documented above, are overall government response index, containment and health index, and stringency index. Several specific NPIs, falling within two broad area of containment/closures and health policy, were examined:

1. **Containment and closure NPI policies:** School closing, workplace closing, cancelling of public events, limits on gatherings, closing of public transport, shelter-in-place orders, movement restrictions between cities/regions, and restrictions on international travel for foreign travelers.
2. **Health policy NPI policies**: Presence of public information campaigns, testing policy, contact tracing after a positive diagnosis, policies on the use of facial

coverings outside the home, and the protection of elderly people in long term care facilities and/or the community.

Research Objective 3: To broadly evaluate the relationship among the levels/changes in NPIs and changes in COVID-19 cases and deaths in Nigeria, Rwanda, and Zambia. This objective has three specific goals:

a. To examine longitudinal changes in COVID-19 cases and deaths relative to the first implementation of NPIs.
b. To examine the degree of implementation of NPIs relative to four total case windows (0 cases, 1–100 cases, 101–1,000 case, and 1,000–10,000 cases).
c. To examine the relationship between prior changes in the implementation of NPIs relative to rising COVID-19 cases and deaths.

First, descriptive statistics and plots were used to show how COVID-19 cases and death trajectories differed before and after the implementation of specific NPIs. Second, changes in NPIs over time were examined through visual plots and descriptive statistics stratified by the four total case windows. Lastly, descriptive, and correlational analytic approaches were utilized. Seven day moving averages (MA) were computed for all indices (stringency, government response, and containment and health), number of new COVID-19 cases, and number of new COVID-19 deaths. Weekly changes on these average NPIs, cases, and deaths were computed. Then, the lagged relationships between changes on NPIs and subsequent changes in COVID-19 cases and deaths were examined using Spearman correlations (ρ). Two time-lags were examined for the NPIs, 7-day and 14-day. For example, the 7-day time lags evaluated whether changes in the NPIs in the prior week (7

days) correlated with later changes in COVID-19 cases and deaths. Likewise, the 14-day time lags evaluated whether NPI changes 2 weeks earlier (14 days) were associated with later change in COVID-19 cases and deaths.

Qualitative Data

To understand the potential barriers and facilitators in implementing and enforcing NPIs and how other epidemics within the countries may have affected compliance in NPIs, qualitative data was collected from decision-makers and those involved in the COVID-19 response. Respondents included officials of Ministries of Health, Africa CDC Regional Collaborating Centers, and WHO AFRO. Recruitment utilized purposive and convenience sampling, including a snowball sampling approach. All participants provided verbal consent before the start of the interview. Each KII took on average 30 minutes to complete. There was some trouble recruiting participants and the number of interviews that needed to be conducted was reduced from 10–12 interviews to 6–8 interviews after consultation with the doctoral dissertation committee. A total of 10 semi-structured interviews were conducted with participants from all three countries of interest. Given the current climate of restrictive travel, interviews were conducted via BU Zoom. The audio recordings were downloaded from BU Zoom and then immediately uploaded to BU SharePoint account and deleted from the computer. Transcription took place upon completion of the interviews. All transcripts were transcribed independently by author. Thematic analysis using inductive coding and grounded theory were used to analyze the interviews in an iterative matter. Key themes were extracted via theme development during analysis. Both coding and analysis were conducted using NVivo Release 1.6 Mac Edition. The interview guide

can be found in Appendix B. The codebook can be found in Appendix C.

Ethical Clearance

The DrPH Candidate submitted this dissertation proposal to the Boston University Medical Center Institutional Review Board for ethical clearance. IRB exemption was granted on May 5, 2021 (IRB number: H-41329). IRB exemption expires on April 4, 2024.

CHAPTER FOUR

Results

To assess the degree of NPI implementation in Nigeria, Rwanda, and Zambia, a mixed-methods approach was undertaken to answer four specific research objectives. A robust quantitative methodology was utilized to characterize new and total COVID-19 cases and deaths, and changes in the implementation of NPIs over time, and to evaluate the relationship between changes in NPI implementation and changes in cases and deaths. A time-series dataset constructed using case and death aggregates and variables from the OxCGRT was utilized to answer research objectives 1-3, while semi-structured interviews were used to answer research objective 4. In this chapter, each of these objectives will be examined in turn. The differences in the national responses to COVID-19 in the three countries of interest will be examined in turn.

Research Objective One

The first research objective was to characterize new and total COVID-19 cases and deaths in Nigeria, Rwanda, and Zambia. To achieve this objective, descriptive statistics and plots were used to show changes in new and cumulative COVID-19 cases and deaths over time by country.

Nigeria

Table 4.1 depicts the daily new cases and deaths in Nigeria across the four cumulative case windows (no cases (W_0), 1-100 cases (W_1), 101-1,000 cases (W_2), and 1,001-10,000+ cases (W_3)). Upon identification of the index case, it took Nigeria 30 days to reach 100 cases of COVID-19. During this time-period, Nigeria saw on average,

approximately 3 cases per day (standard deviation (SD) = 4.9 cases per day). During W_2, the average new cases per day was 34 (SD = 43.2). While it took Nigeria a little over a month from surpassing 1,000 cases of COVID-19 to surpass 10,000 cases, the average cases per day was drastically higher in W_3 than any of the other case windows. During W_3 Nigeria saw on average 242 cases per day (SD = 97.9), with a minimum of 64 cases per day, and a maximum of 553 cases in a single day. During the first approximately 10,000 cases of COVID-19, Nigeria saw a total of 287 deaths. On average, there were 2 deaths per day (SD = 3.6). The maximum number of deaths in a single day during the first 10,000 cases was 17, which occurred during the last case window.

The progression of COVID-19 spread is shown in Figure 4.1a. The plot depicts new cases of COVID-19 in Nigeria across the four cumulative case groups. The plot shows the rapid spread of COVID-19 in Nigeria after it reached its 1,000th case. The exponential rise in cases is further illustrated in Figure 4.1b.

Table 4.1. Descriptive Statistics of Daily COVID-19 Cases and Deaths, Nigeria

		Daily New Cases				Daily New Deaths			
Window	**# Days**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Pooled	152	66.9	114.3	0	553	1.9	3.6	0	17
W_0	58	0	0	0	0	0	0	0	0
W_1	30	3.0	4.9	0	19	0.03	0.2	0	1
W_2	26	34.3	43.2	0	208	1.2	1.5	0	6
W_3	38	241.6	97.9	64	553	6.7	4.3	0	17
W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases **Min:** minimum value, **SD:** Standard Deviation, **Max:** maximum value									

Figure 4.1a. New Cases of COVID-19, Nigeria

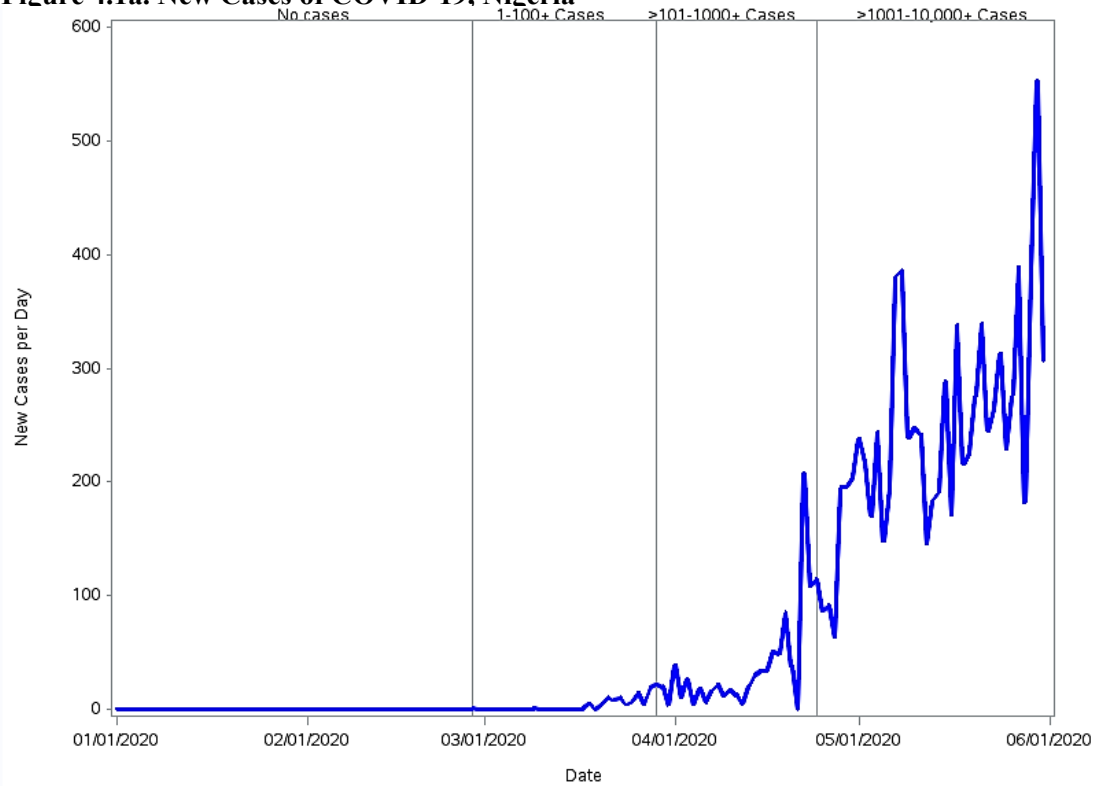


Figure 4.1b. Cumulative Cases of COVID-19, Nigeria

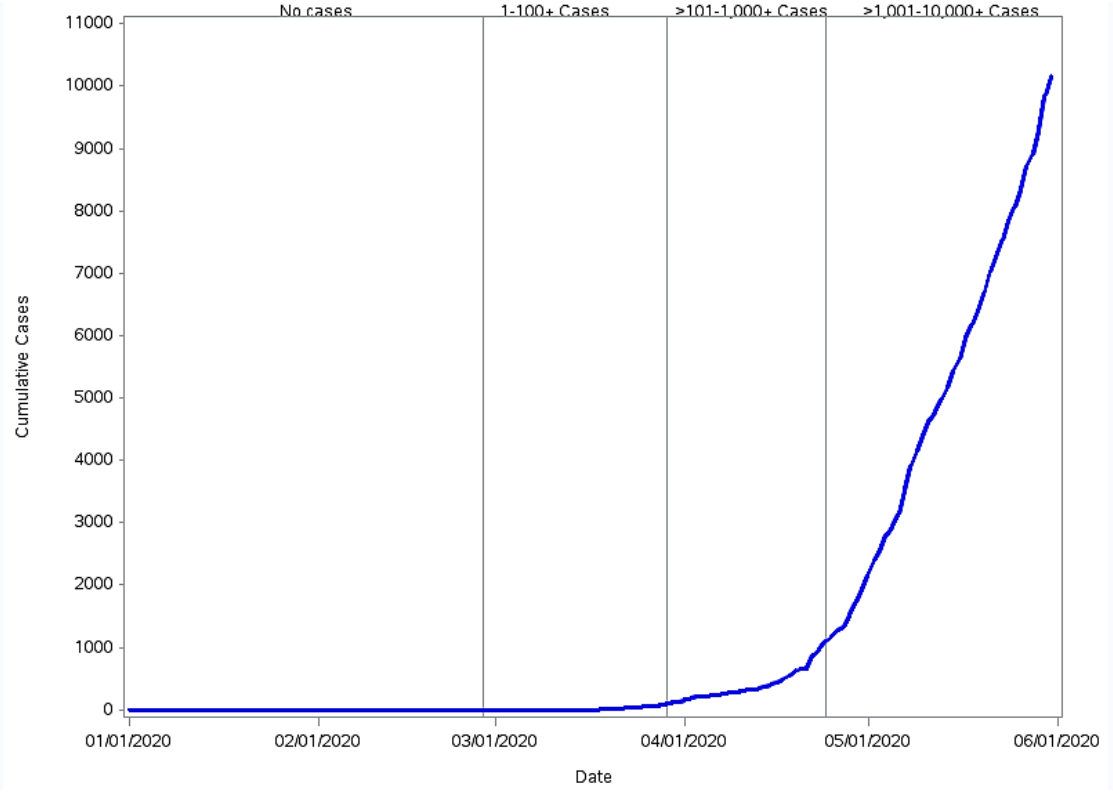


Figure 4.2a. New Daily Deaths of COVID-19, Nigeria

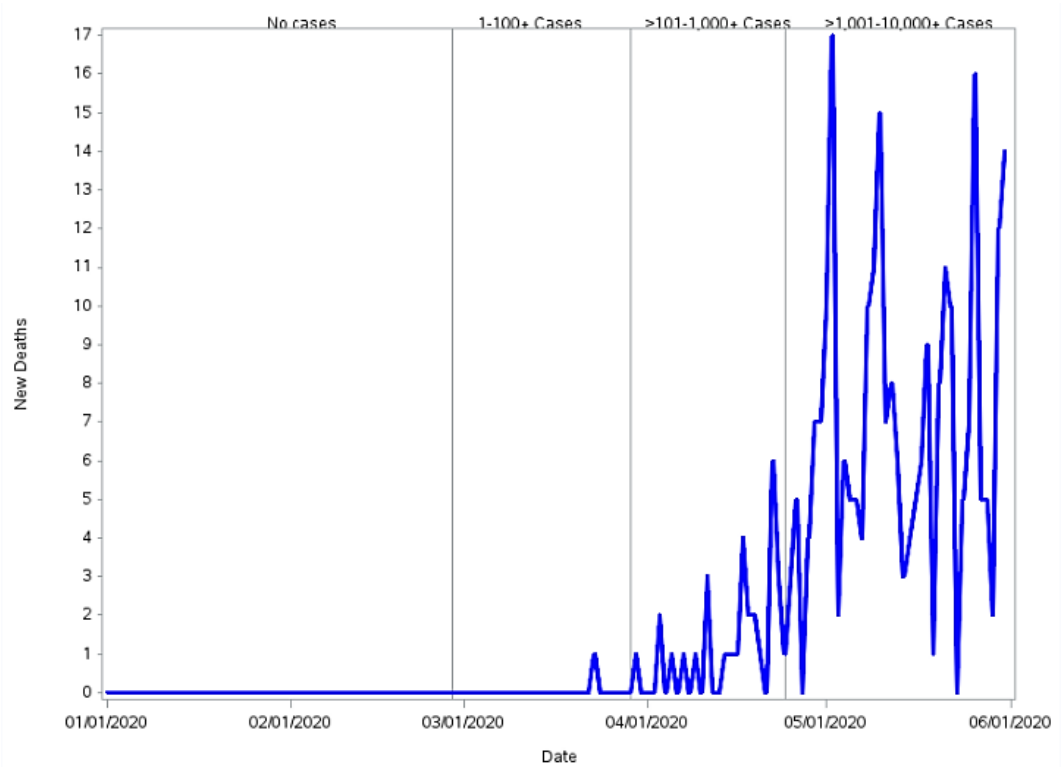
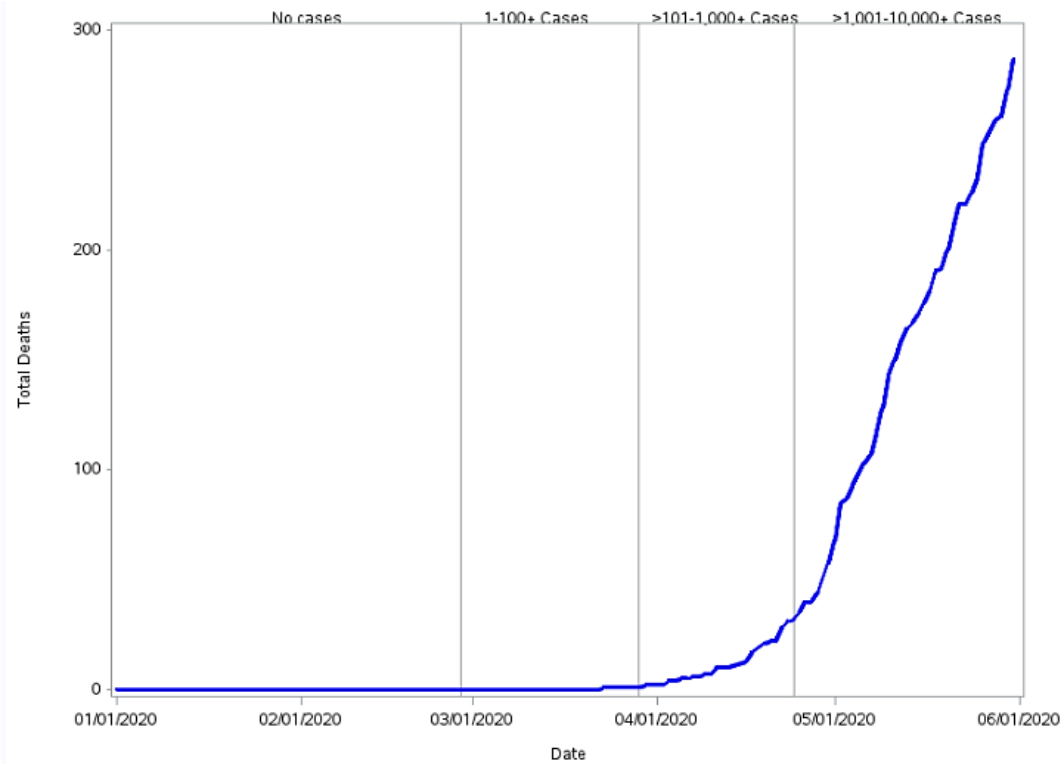


Figure 4.2b. Cumulative Deaths of COVID-19, Nigeria



Rwanda

Table 4.2 shows the daily new cases and deaths across the cumulative case windows for Rwanda. It took Rwanda 21 days from the identification of its index case to reach its 100th case of COVID-19. On average, Rwanda saw 4 cases per day (SD = 4.3) during the 21 days it took to reach the first 100 cases of COVID-19. The progression of disease spread slowed down after the initial 100 cases. During W_1 Rwanda saw on average 9 cases per day (SD = 10.5) over 86 days. During W_3, Rwanda saw on average 46 cases per day (SD = 46.5) over a period of 199 days. During this time, the minimum number of cases per day was 1 and the maximum in a single day was 231 cases. Rwanda experienced a total of 128 deaths during the first 10,000 cases of COVID-19. On average, there was less than one death per day (SD = 0.9). The maximum number of deaths in a single day during the first 10,000 cases was 7 which occurred during the last case window.

Table 4.2. Descriptive Statistics of Daily New COVID-19 Cases and Deaths, Rwanda

		Daily New Cases				Daily New Deaths			
Window	**# Days**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Pooled	379	26.7	39.9	0	231	0.3	0.9	0	7
W_0	73	0	0	0	0	0	0	0	0
W_1	21	4.2	4.3	0	17	0	0	0	0
W_2	86	9.4	10.5	0	59	0.02	0.2	0	1
W_3	199	46.3	46.5	1	231	0.6	1.2	0	7
W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases Min: minimum value, SD: Standard Deviation, Max: maximum value									

The progression of COVID-19 spread is shown in Figures 4.3a and 4.3b. The plot on the left depicts new cases of COVID-19 in Rwanda across the four cumulative case groups while the one on the right highlights the rapid spread of COVID-19 in Rwanda during the last case window. The progression of new deaths during the same time is shown

in Figure 4.4a below. The number of deaths quickly grew during W_3 compared to the first two case windows. The cumulative deaths of COVID-19 in Rwanda are illustrated in 4.4b.

Figure 4.3a. New Cases of COVID-19, Rwanda

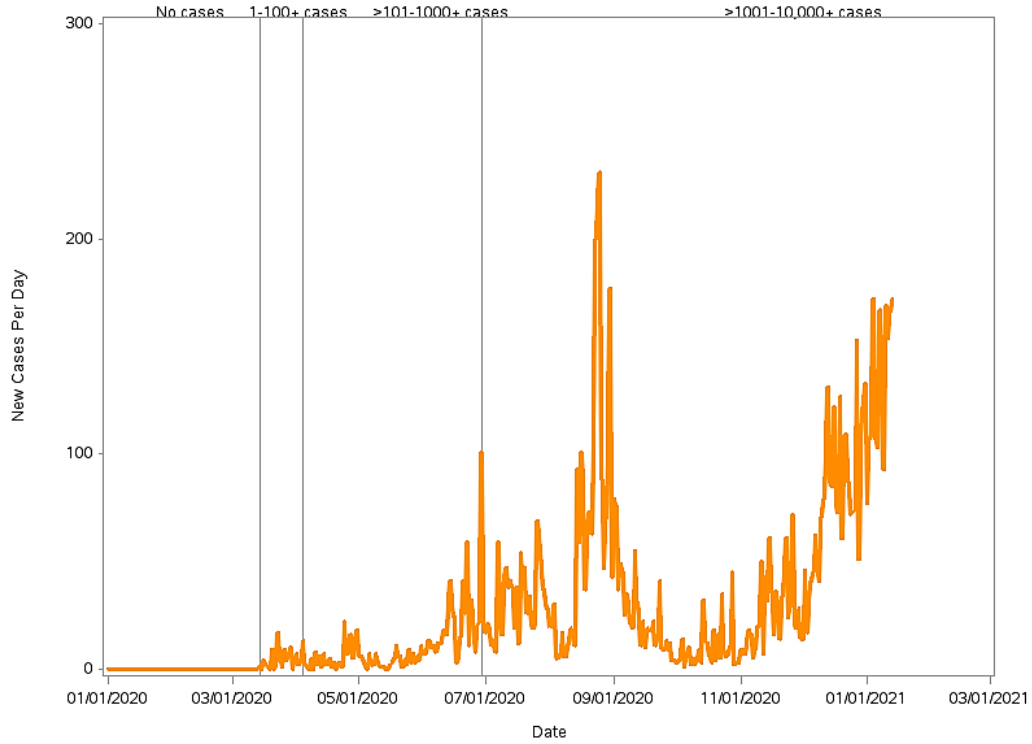


Figure 4.3b. Cumulative Cases of COVID-19, Rwanda

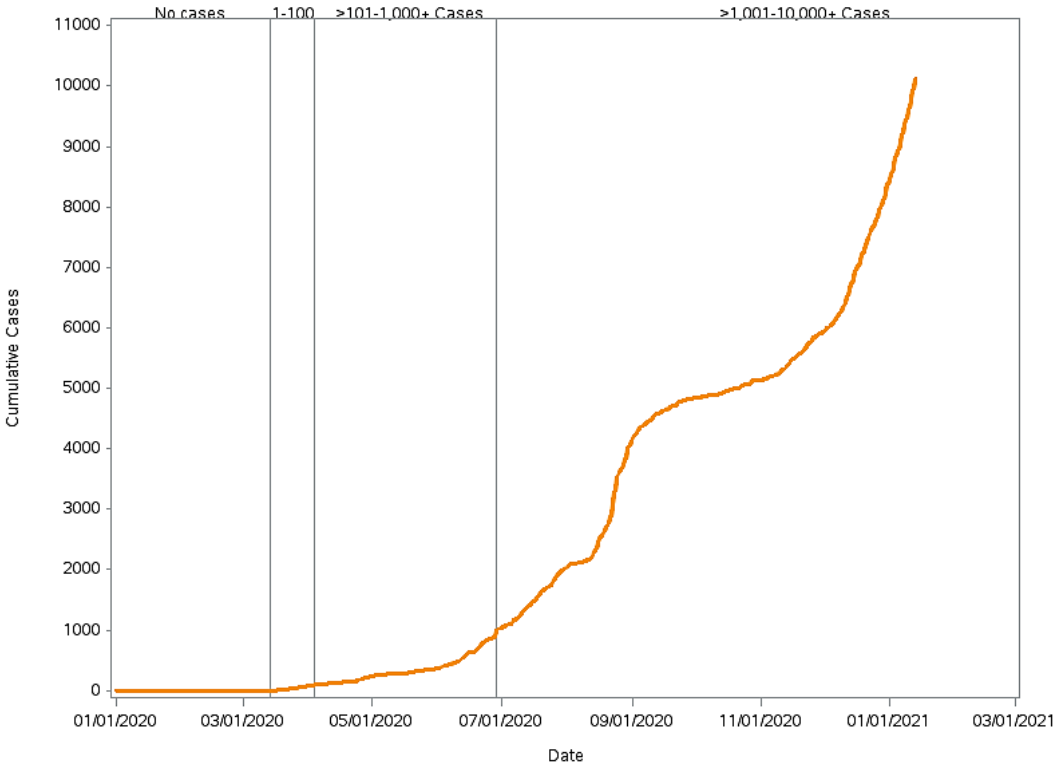


Figure 4.4a. New Deaths of COVID-19, Rwanda

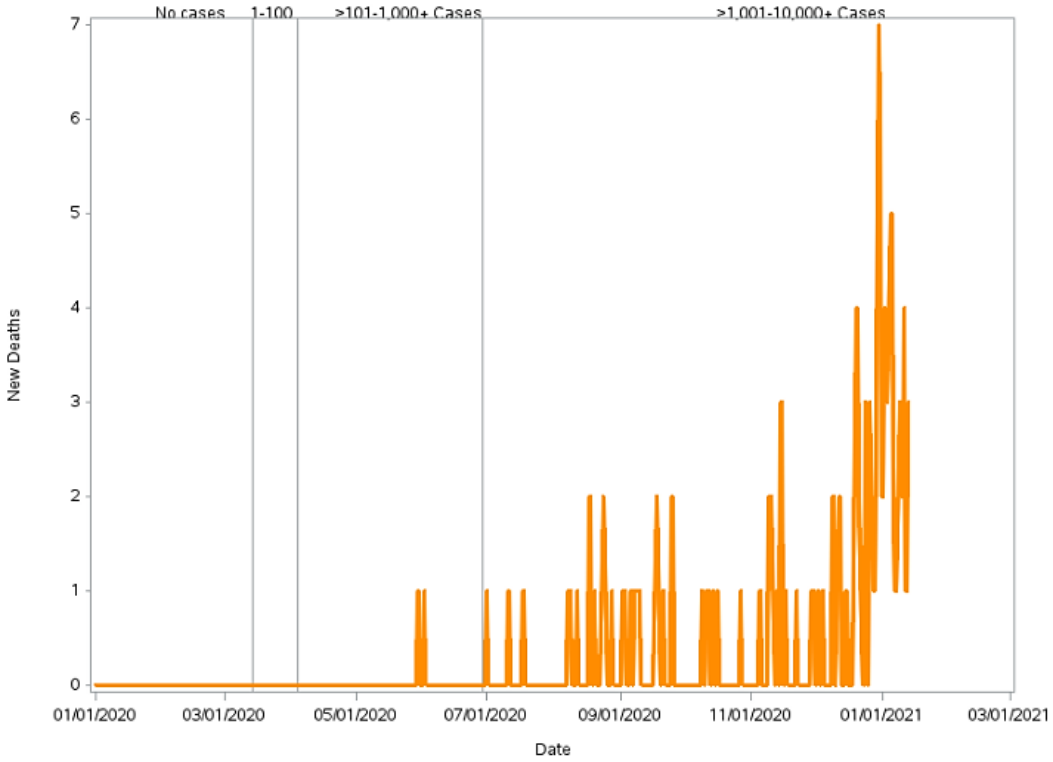
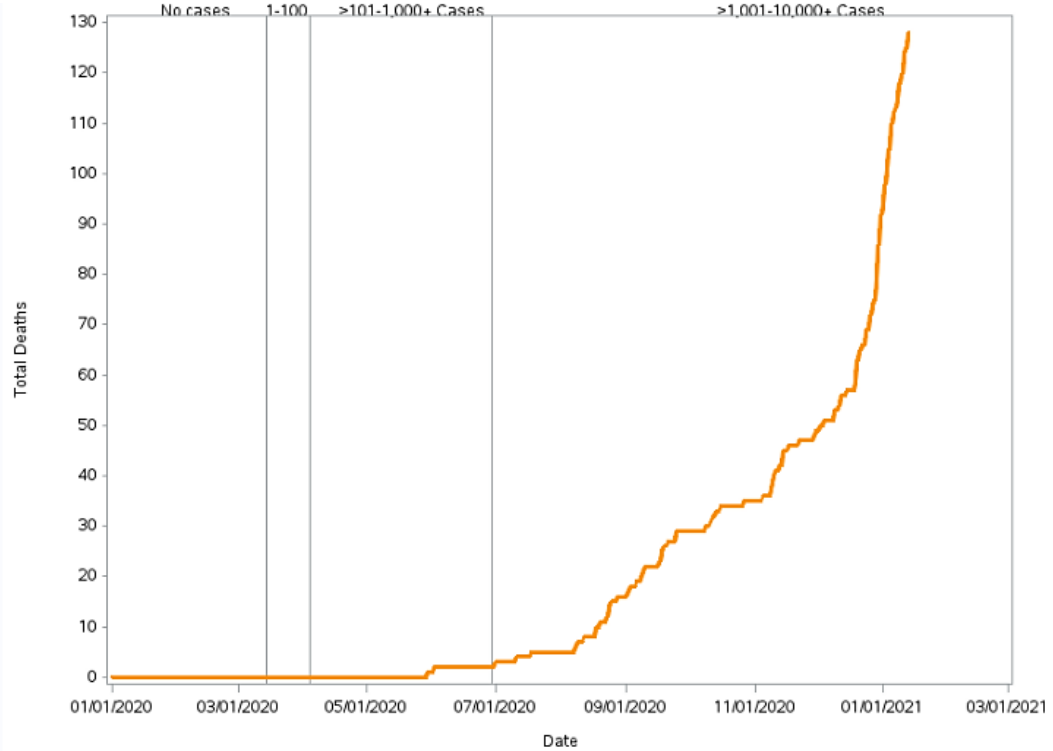


Figure 4.4b. Cumulative Deaths of COVID-19, Rwanda



Zambia

Table 4.3 shows the daily new cases and deaths across the cumulative case groupings for Zambia. There were no cases of COVID-19 for the first 77 days of 2020. Upon the identification of the first case in March 2020, it took Zambia 43 days to surpass 100 cases, with an average of 2 cases per day (SD = 2.6) during this period. It took less than a month (27 days) for Zambia to surpass 1,000 cases after reaching its 100th case. During W_2 there were approximately 30 cases per day (SD = 52.1). During W_3, there were approximately 109 cases per day (SD = 159.1), and it took Zambia 85 days to surpass 10,000 cases of COVID-19. During W_3, there was a maximum of 915 cases in a single day, which was drastically higher than in case windows W_1 and W_2. There was a total of 269 deaths attributed to COVID-19 in Zambia during the first 10,000 cases. The greatest number of deaths per day occurred during W_3, when there were on average 3 deaths per day (SD = 8.6) and a maximum of 67 deaths in a single day. The progression of COVID-19 spread is shown in Figures 4.5a and 4.5b. There was an exponential rise in cases during W_3. The progression of new deaths during the first 10,000 cases of COVID-19 is illustrated in Figure 4.6a and 4.6b. Similarly, there was a rapid rise in deaths during W_3.

Table 4.3. Descriptive Statistics of New COVID-19 Cases and Deaths, Zambia

		Daily New Cases				**Daily New Deaths**			
Window	# Days	Mean	SD	Min	Max	Mean	SD	Min	Max
Pooled	232	44.0	109.9	0	915	1.2	5.4	0	67
W_0	77	0	0	0	0	0	0	0	0
W_1	43	2.3	2.6	0	9	0.07	0.3	0	1
W_2	27	30.5	52.1	0	208	0.2	0.6	0	3
W_3	85	109.4	159.1	0	915	3.2	8.6	0	67
W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases Min: minimum value, SD: Standard Deviation, Max: maximum value									

Figure 4.5a. New Cases of COVID-19, Zambia

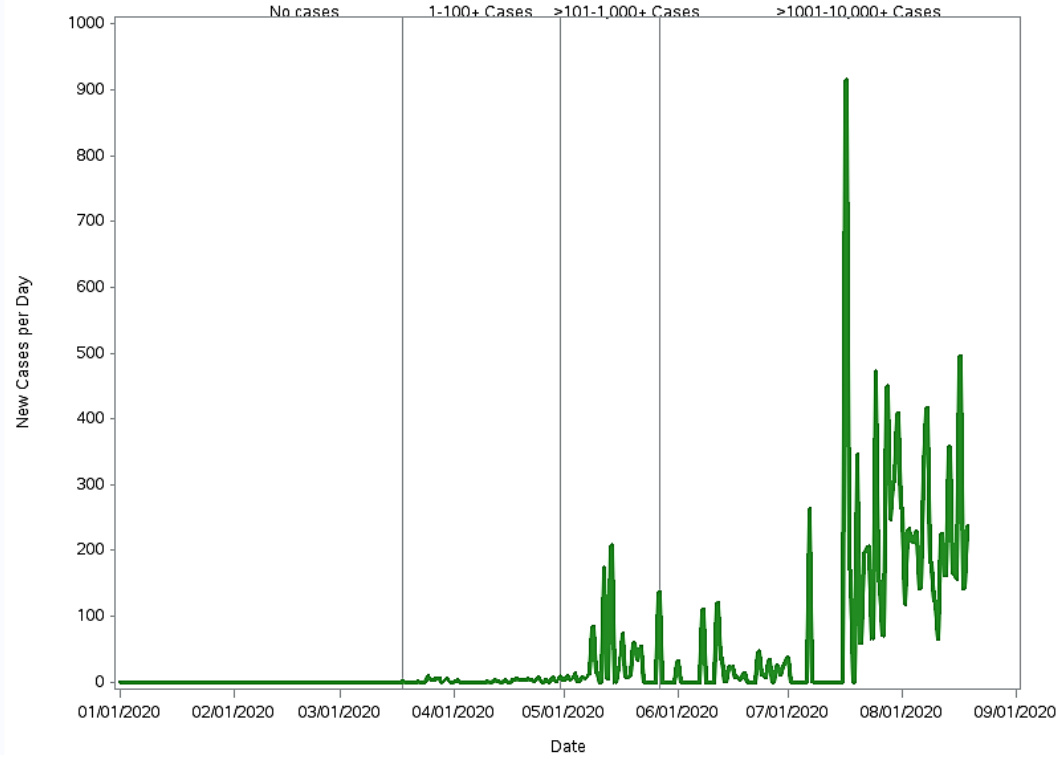


Figure 4.5b. Cumulative Cases of COVID-19, Zambia

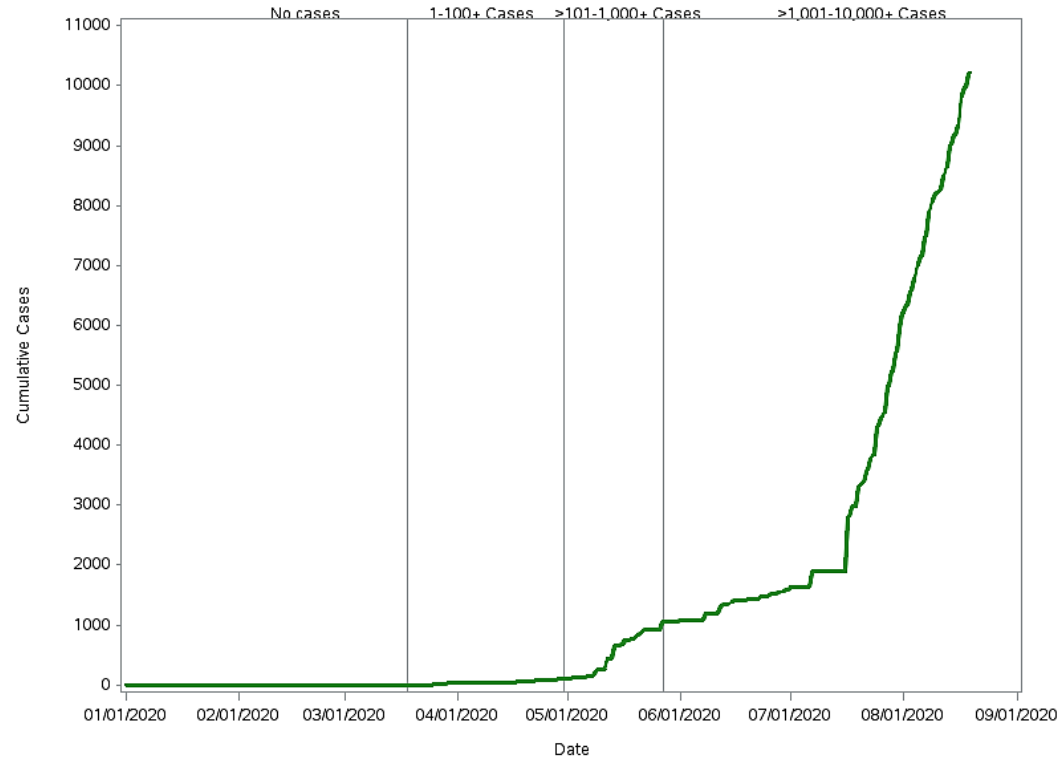


Figure 4.6a. New Deaths of COVID-19 in Zambia

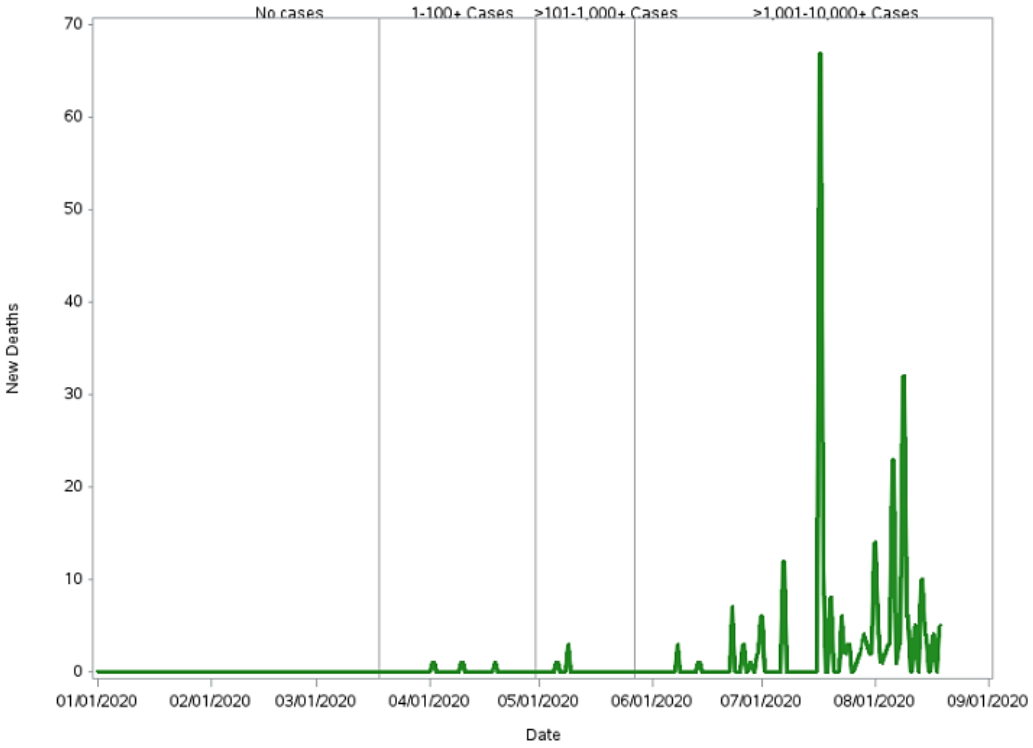
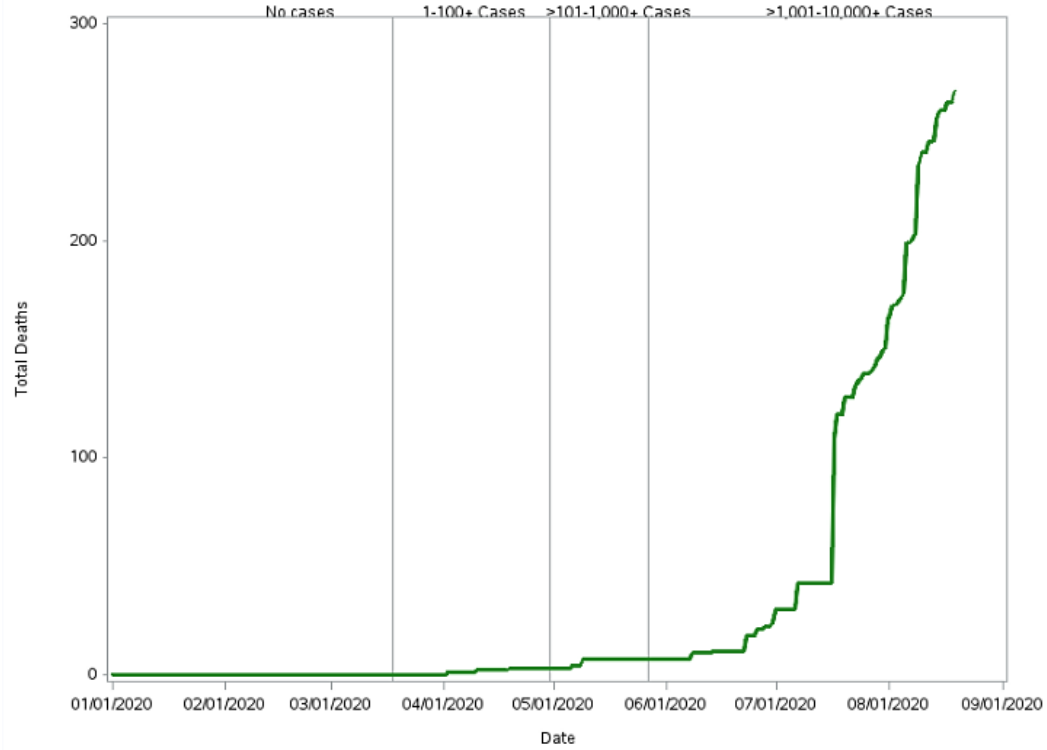


Figure 4.6b. Cumulative Deaths of COVID-19 in Zambia



Summary

Research objective one utilized descriptive statistics and plots to characterize new and total COVID-19 cases in Nigeria, Rwanda, and Zambia across the four case windows. It highlights important trends in each country. For instance, it took Rwanda significantly longer to surpass 10,000 cases (379 days) compared to Nigeria and Zambia (152 and 232 days, respectively). Rwanda required the shortest time to surpass the first 100 cases (21 days) compared to Nigeria (30 days) and Zambia (43 days), indicating either rapid spread of disease or increased surveillance and testing for detecting more cases after the index case was identified. All three countries experienced an exponential rise in cases after surpassing 1,000 cases of COVID-19.

Research Objective Two

The second research objective aimed to characterize changes in the implementation of NPIs in Nigeria, Rwanda, and Zambia. To achieve this objective, descriptive statistics and plot were used to show the timing of first implementation of specific NPIs and how levels of NPI implementation changed over time.

Stringency, Government Response, and Containment and Health Indices

Nigeria

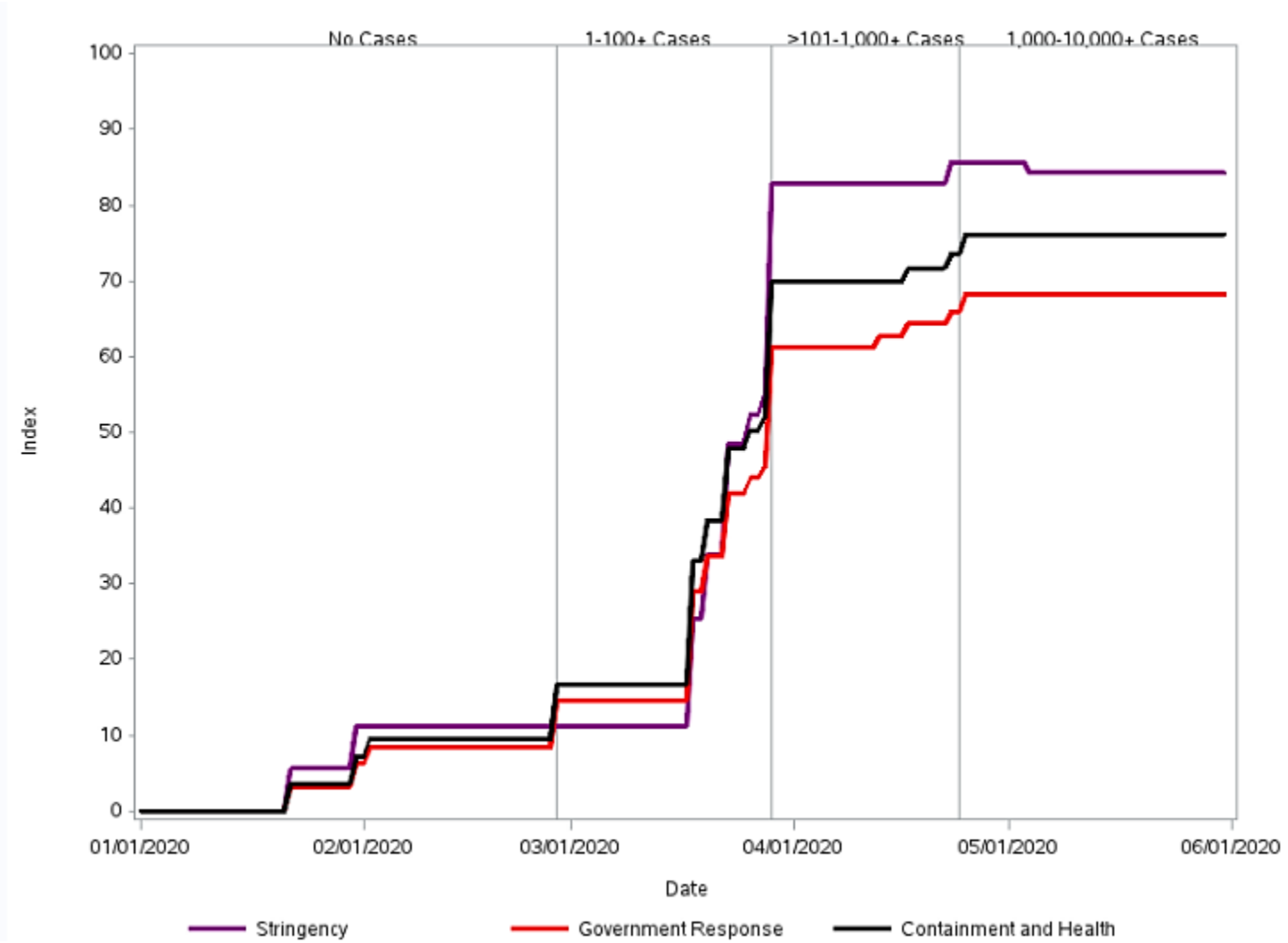
Table 4.4 shows the average scores for the stringency, government response, and containment and health indices. The average score of the stringency index which includes all 8 containment and closure and NPIs and one health system NPI (public information campaigns) indicator from January 1st, 2020, until Nigeria surpassed its 10,000th case was 42.1 out of 100 (SD = 37.1). In Nigeria, the stringency index score increased between the

case windows, indicating a higher response level as cases increased. During W_0 when there were no cases recorded, the stringency index was at 6.23 (SD = 5.1). After identification of the index case, the stringency index increased to 22.30 (SD = 16.3) during W_1. During case windows W_2 and W_3, the stringency score increased to 83.0 (SD = 0.5) and 84.6 (SD = 0.6), respectively, indicating an upgrade to a higher response level. The average score for the government response index, which accounts for all 16 ordinal NPIs in the OxCGRT was 33.97 (SD = 28.7), indicating a relatively low to moderate government response level. During W_0 the government response index was 4.4 (SD = 3.8). In W_1, the score increased to 23.2 (SD = 12.1). During case windows W_2 and W_3, the government response index scores were 62.3 (SD = 1.5) and 68.2 (SD = 0.4), respectively, indicating an increase in government response during the last two case windows. The average score for the containment and health index which measures all 14 ordinal containment and closure, and health system NPIs was 38.3 (SD = 32.2). Like the other two indices, average scores increased as cases increased, indicating implementation of stricter measures as cases increased. The containment and health index score before the identification of the index case was 5.07 (SD = 4.4). The score increased to 26.5 (SD = 13.8) during W_1. After surpassing 100 cases, the score increased to 70.49 (SD = 1.0) and 76.1 (SD = 0.4) during case windows W_2 and W_3, respectively. The variation in the indices is illustrated in Figure 4.7.

Table 4.4. Descriptive statistics for OxCGRT Indices, Nigeria

		Stringency Index		Government Response Index		Containment and Health Index	
Window	# Days	Mean	SD	Mean	SD	Mean	SD
Pooled	152	42.1	37.1	34.0	28.7	38.3	32.2
W_0	58	6.2	5.1	4.4	3.8	5.1	4.4
W_1	30	22.3	16.4	23.2	12.1	26.5	13.8
W_2	26	83.0	0.6	62.3	1.5	70.5	1.0
W_3	38	84.6	0.6	68.2	0.4	76.1	0.4
Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases SD: standard deviation							

Figure 4.7. Variation in OxCGRT Indices, Nigeria

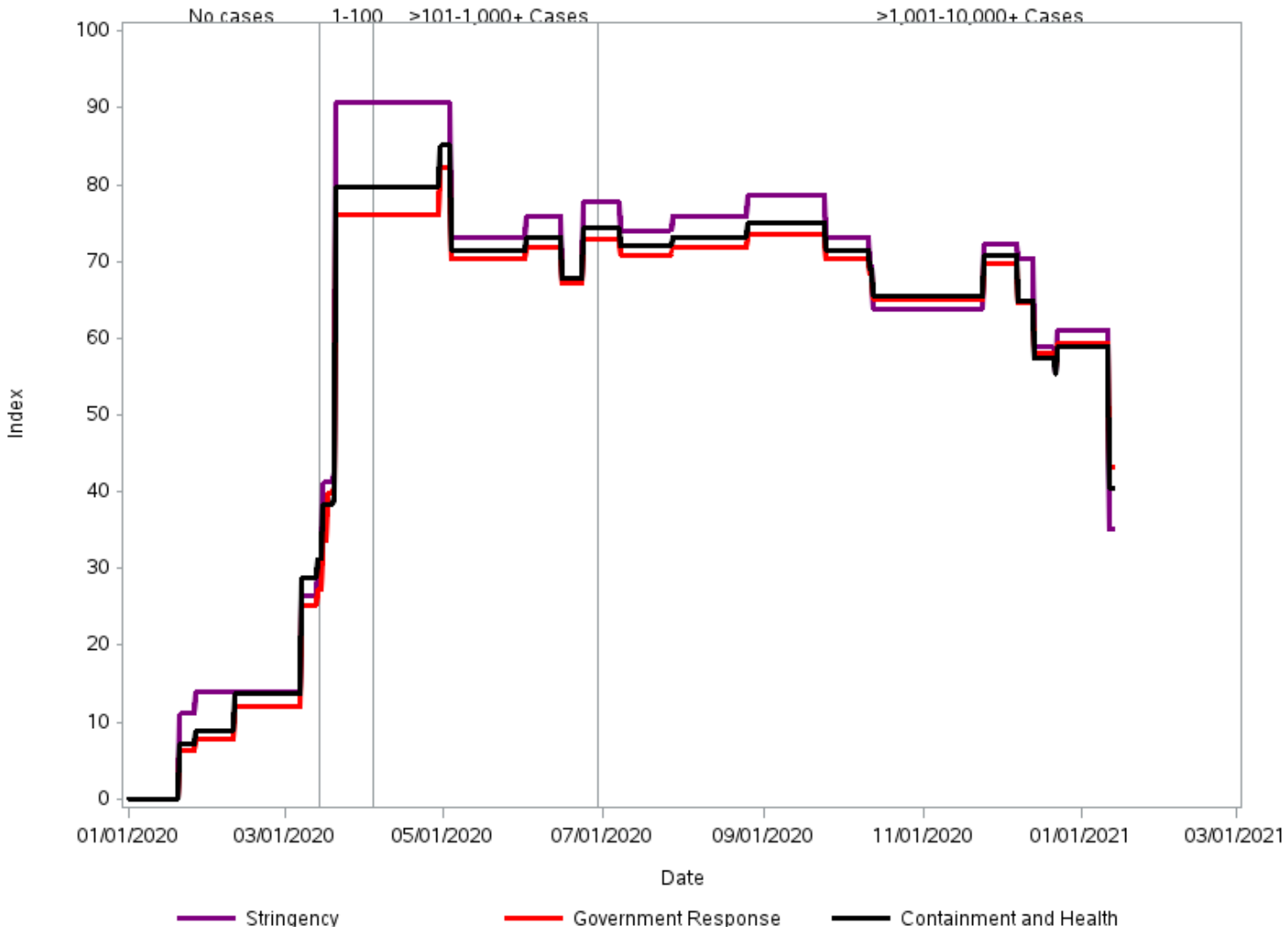


Rwanda

Table 4.5 shows the average scores for the stringency, government response, and containment and health indices for Rwanda. The average score of the stringency index, from January 1st, 2020, until Rwanda surpassed its 10,000th case was 61.1 out of 100 (SD = 26.6), indicating a sustained moderate to high response level throughout this period. In Rwanda, the stringency index score increased between case windows W_0 to W_1 to W_2 (10.9 (SD = 7.6) to 73.2 (SD = 25.6) to 79.5 (SD = 8.6), respectively); however, there was a decrease from W_2 to W_3 (79.5 (SD = 8.6) to 70.3 (SD = 7.5), indicative of the easing of certain measures. The average score for the government response index during the 379 days between January 1, 2020, and when Rwanda surpassed its 10,000th case of COVID-19 was 57.2 (SD = 25.0), indicating a moderate to high government response. During W_0, the government response index was 8.5 (SD = 7.0). The score increased during W_1 to 52.2 (SD = 20.3), which suggests a dramatic increase in the stringency of measures after identification of the first case. Like the stringency index, there was a decline between case windows W_2 and W_3, where the government response index scores were 72.7 (SD = 3.6) and 67.9 (SD = 5.5), respectively. The average score for the containment and health index during the first 10,000 cases was 58.5 (SD = 25.3), again indicating a sustained moderate to high level of response. The average score increased between case windows W_0 to W_1 to W_2 from 9.7 (SD = 8.0) to 65.3 (SD = 21.0), to 74.7 (SD = 4.6), respectively, indicating a strengthening of measures as cases increased. There was a decrease in score 68.7 (SD = 6.2) during W_3 which lasted 199 days with frequent fluctuations (Figure 4.8).

Table 4.5. Descriptive statistics for OxCGRT Indices, Rwanda							
		Stringency Index		**Government Response Index**		**Containment and Health Index**	
Window	# Days	Mean	SD	Mean	SD	Mean	SD
Pooled	379	61.1	26.6	57.2	25.0	58.5	25.3
W_0	73	10.9	7.6	8.5	7.0	9.7	8.0
W_1	21	73.2	25.6	62.2	20.3	65.3	21.0
W_2	86	79.5	8.6	72.7	3.6	74.7	4.6
W_3	199	70.3	7.5	67.9	5.5	68.7	6.2
Note: W_0: 0 cases**, W_1:** 1-100+ cases**, W_2:** >101-1,000+ cases**, W_3:** >1,001-10,000+ cases, **SD:** standard deviation							

Figure 4.8. Variation in OxCGRT Indices, Rwanda

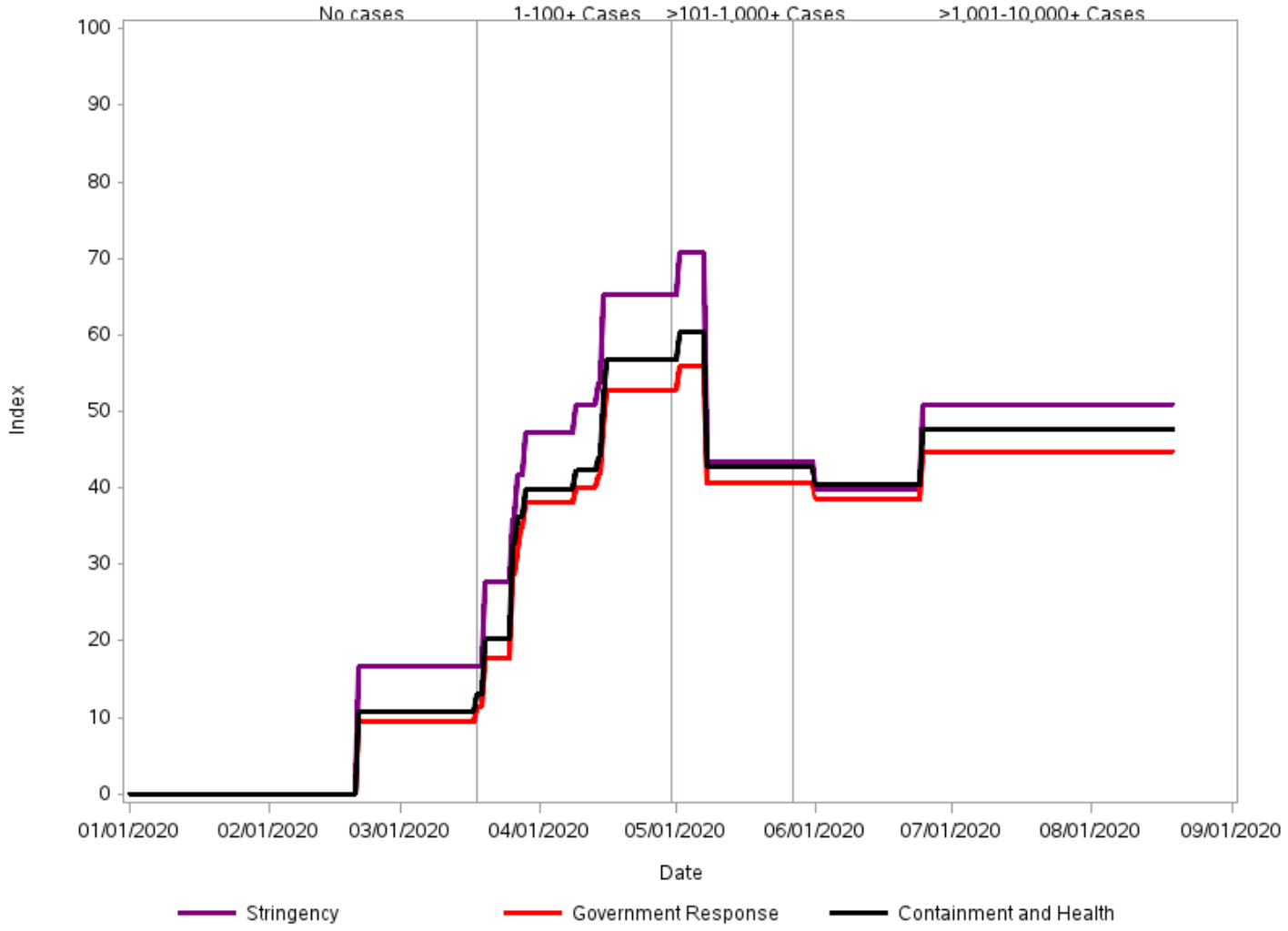


Zambia

Table 4.6 shows the average scores for the stringency, government response, and containment and health indices for Zambia. The average score of the stringency index from January 1st, 2020, until Zambia surpassed its 10,000th case was 34.3 (SD = 22.3) indicating a relatively low-level response. During the 77 days of W_0 when there were no cases reported, the average score for the stringency index was 5.6 (7.9). Between identification of the index case and surpassing the 100th case in W_1, the average score for the stringency index was 49.5 (SD = 14.7). This increased during W_2 to 51.2 (SD = 12.1) but decreased slightly during W_3 to 47.4 (SD = 5.1). The pooled average for the government response was 29.17 (SD = 19.7), which again suggests low stringency in the measures implemented. During W_0 the average government response index score was 3.2 (SD = 4.5), suggesting little to no response prior to the identification of the index case. There was an increase after the index case was identified as measures began to be implemented. Case windows W_1 and W_2 recorded an average score of 38.9 (SD = 13.1) and 44.9 (SD = 6.8), respectively, showing a slight increase in the level of measures implemented between the first case and surpassing 1,000 cases. There was a decrease during W_3 to an average score of 42.8 (SD = 6.8) indicative of some easing of restrictions. The containment and health index saw similar trends as the other two indices. The pooled average score was 31.1 (SD = 20.8). There was an increase from W_0 to W_1 to W_2 with scores of 3.6 (SD = 5.1), 41.7 (SD = 13.7), and 47.8 (SD = 7.8), respectively. There was an observed decrease during W_3 to an average score of 45.3 (SD = 3.3). There was little fluctuation observed during the last case window across indices, suggesting very little variation in response (Figure 4.9).

Table 4.6. Descriptive statistics for OxCGRT Indices, Zambia							
		Stringency Index		**Government Response Index**		**Containment Health Index**	
Window	# Days	Mean	SD	Mean	SD	Mean	SD
Pooled	232	34.3	22.3	29.2	19.7	31.1	20.8
W_0	77	5.6	7.9	3.2	4.5	3.6	5.1
W_1	43	49.5	14.7	38.9	13.1	41.7	13.7
W_2	27	51.2	12.1	44.9	6.8	47.8	7.8
W_3	85	47.4	5.1	42.8	2.9	45.3	3.3
Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases, SD: standard deviation							

Figure 4.9. Variation in OxCGRT Indices Leading up to 10,000th Case of COVID-19 in Zambia



Containment and Closure NPI Policies

The timing of containment and closure of NPI implementation is shown in Table 4.7. The dates show when the policy was implemented in practice, not the day it was announced.[97] Restrictions on international travel for foreign travelers was the first containment and closure NPI implemented in both Rwanda and Zambia. Nigeria began implementing most containment and closure NPIs in mid-March, although its index case was identified at the end of February. In contrast, Rwanda implemented limits on public gatherings, canceled public events, and placed restrictions on international travel for foreign travelers before it identified its first case of COVID-19. Additional measures such as workplace and school closings, as well as shelter-in-place orders were implemented upon identification of its index cases on March 14, 2020. Zambia was the only country of the three to not close public transport or issue shelter-in-place orders.

Table 4.7. Timing of containment and closure NPI onset in Nigeria, Rwanda, and Zambia

Containment and Closure NPIs	Nigeria	Rwanda	Zambia
School closing	3/20/2020	3/16/2020	3/20/2020
Workplace closing	3/18/2020	3/14/2020	5/2/2020
Cancelling of public events	3/18/2020	3/8/2020	4/15/2020
Limits on gatherings	3/18/2020	3/8/2020	3/26/2020
Closing of public transport	3/29/2020	3/21/2020	-
Shelter-in-place orders	3/23/2020	3/21/2020	-
Movement restrictions between cities/regions	3/29/2020	3/21/2020	3/29/2020
Restrictions on international travel for foreign travelers	3/23/2020	1/27/2020	2/21/2020

Figures 4.10, 4.11, and 4.12 depict the variation in the scale of each NPI. NPIs are recorded on an ordinal scale that represents the level of strictness of the policy (e.g., the higher the NPI score, the stricter the policy).

Figure 4.10. Variation in Levels of Containment and Closure NPI Implementation in Nigeria

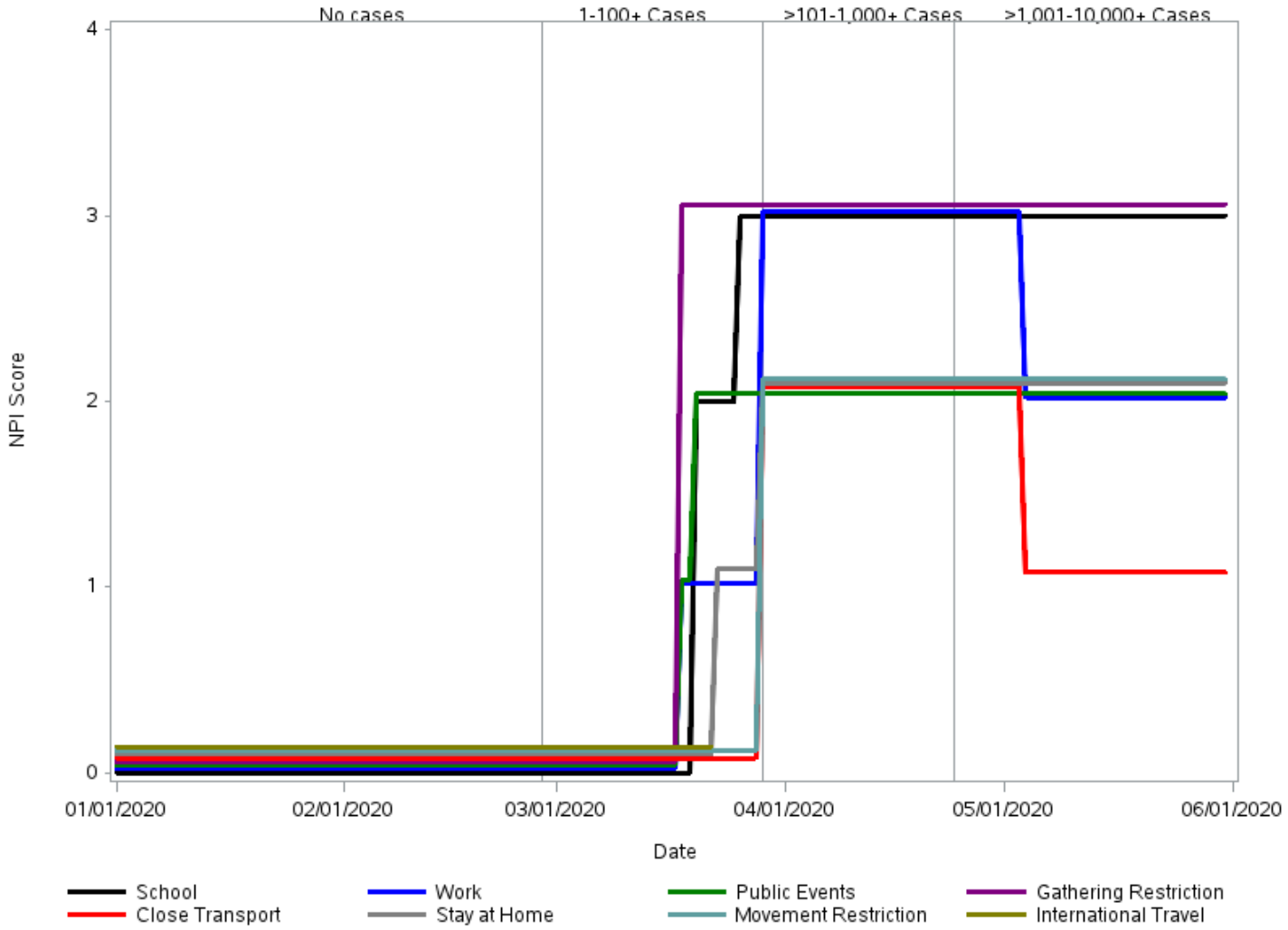


Figure 4.11. Variation in Levels of Containment and Closure NPI Implementation in Rwanda

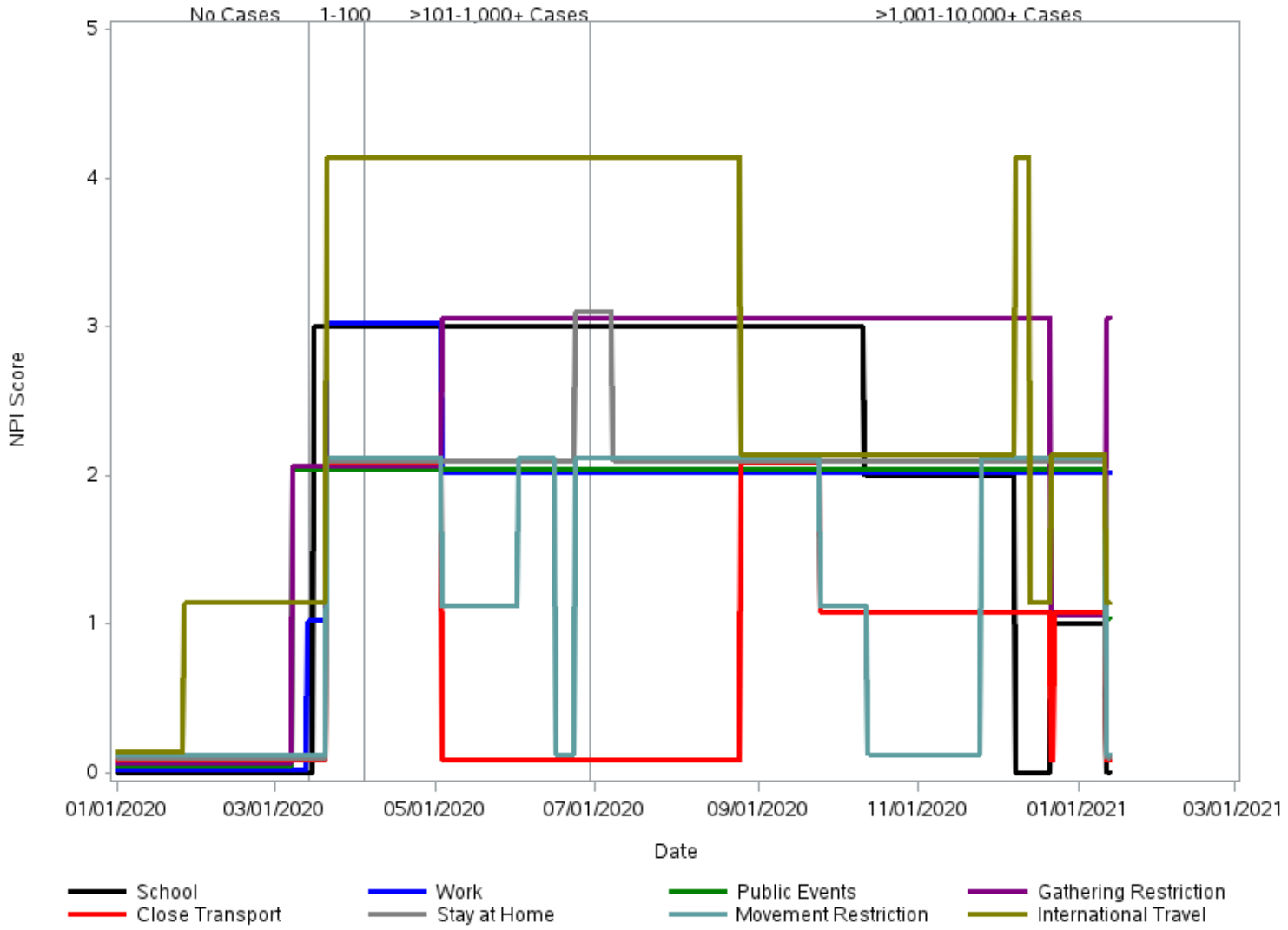
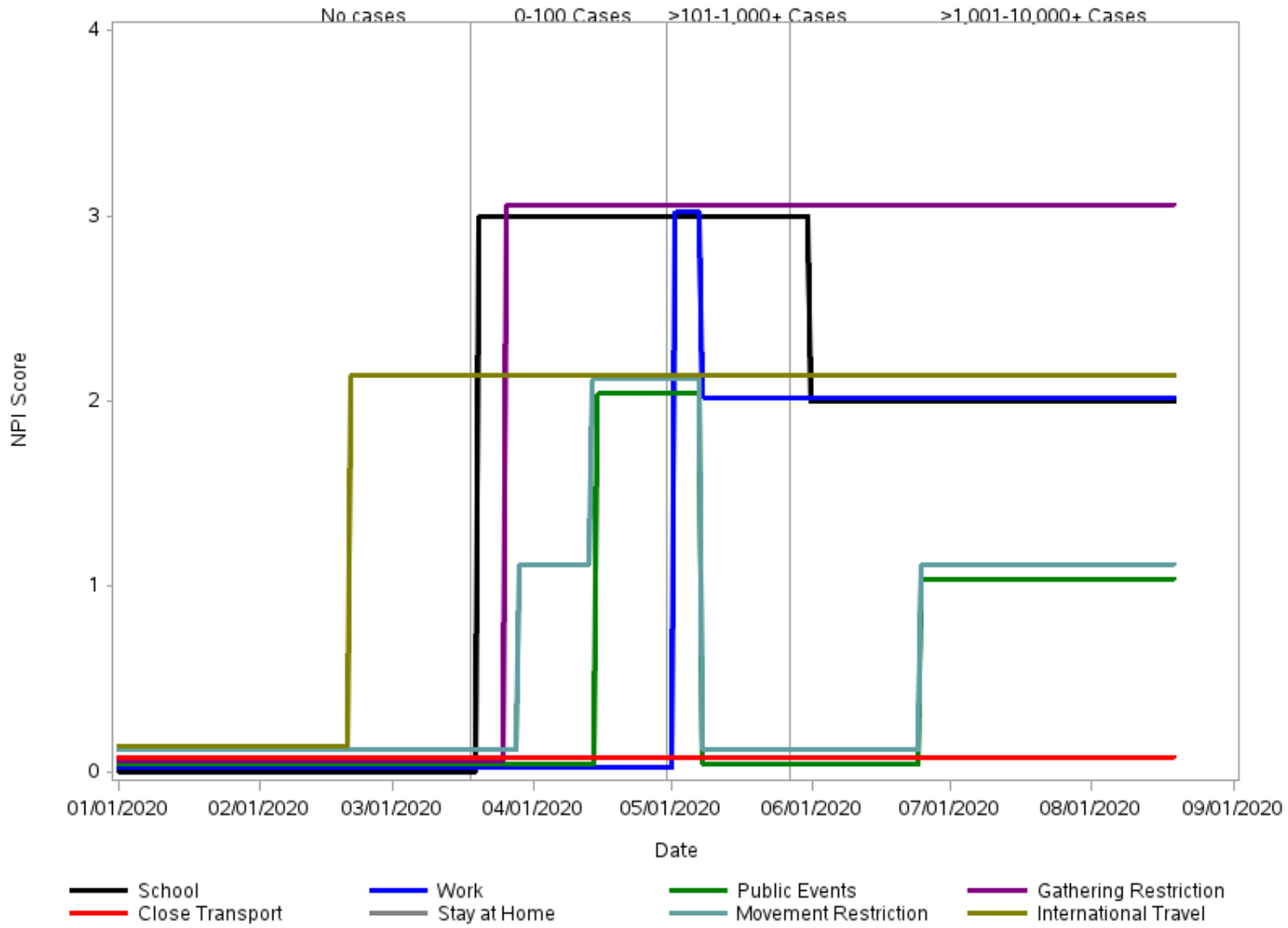


Figure 4.12. Variation in Levels of Containment and Closure NPI Implementation in Zambia



Health System NPI Policies

The timing of health system NPI implementation is shown in Table 4.8. The dates show when the policy was implemented in practice, not the day it was announced.[97] There were public information campaigns about COVID-19 in all three countries before identification of the index case. Nigeria and Rwanda both implemented testing policies and contact tracing measures before identification of the index case whereas Zambia did not implement these health system NPIs until after the identification of the index case. By mid-April 2020 all countries had policies on the use of facial coverings outside the home. Both Nigeria and Rwanda had policies for protecting elderly people (as defined locally) in long term care facilities (LTCF) and/or the community and home setting, while Zambia did not.

Table 4.8. Timing of health system NPI onset across countries

Health System NPIs	Nigeria	Rwanda	Zambia
Presence of public information campaigns	1/22/2020	1/21/2020	2/21/2020
Testing policy	2/2/2020	2/11/2020	3/18/2020
Contact tracing after a positive diagnosis	2/28/2020	3/8/2020	3/26/2020
Policies on the use of facial coverings outside the home	4/17/2020	4/30/2020	4/16/2020
Protection of elderly people	3/18/2020	3/21/2020	-

Figures 4.13, 4.14, and 4.15 depict the variation in the scale of each NPI. NPIs are recorded on an ordinal scale that represents the level of strictness of the policy (e.g., the higher the NPI score, the stricter the policy).

Figure 4.13. Variation in Levels of Health NPI Implementation in Nigeria

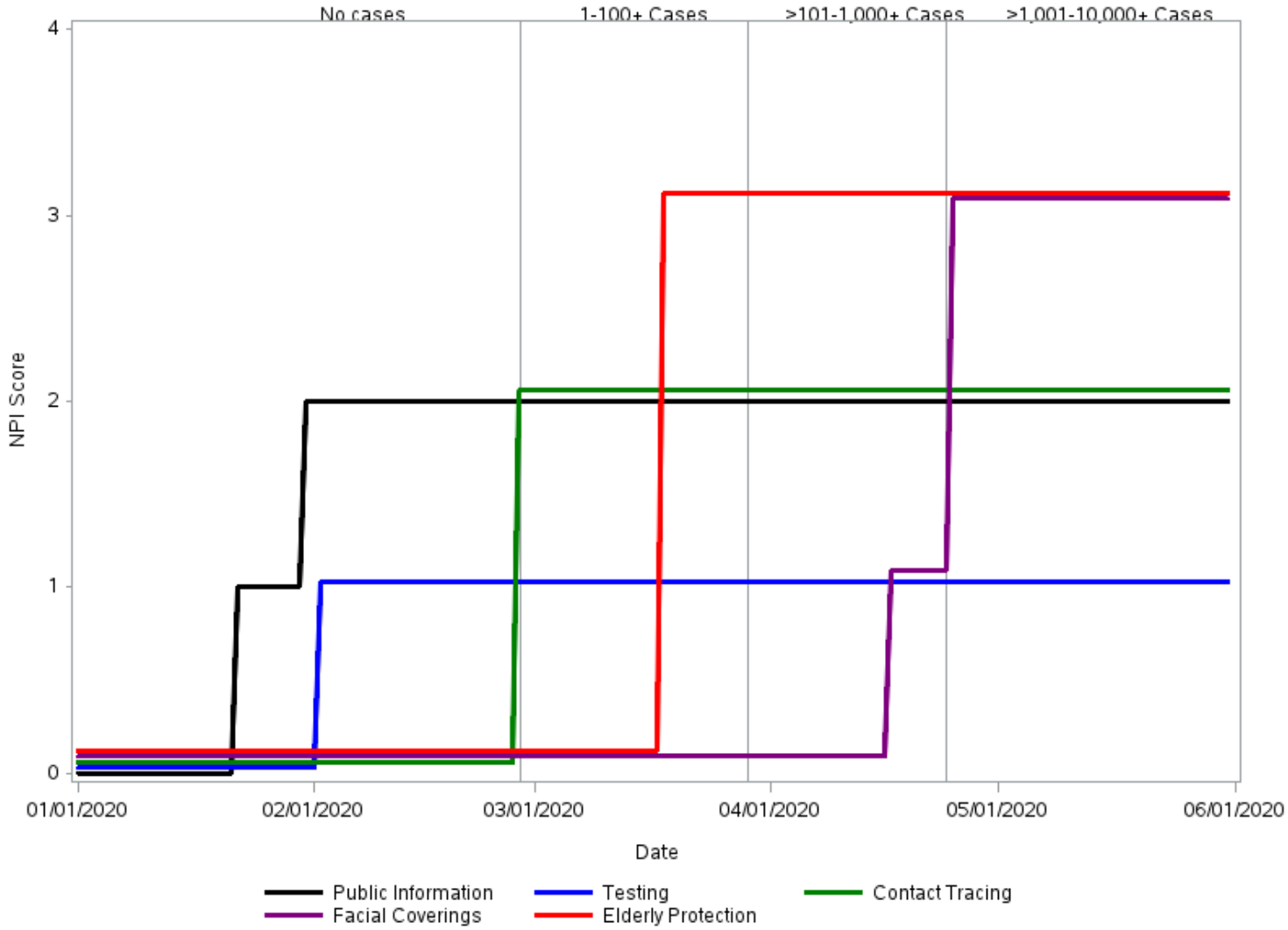


Figure 4.14. Variation in Levels of Health NPI Implementation in Rwanda

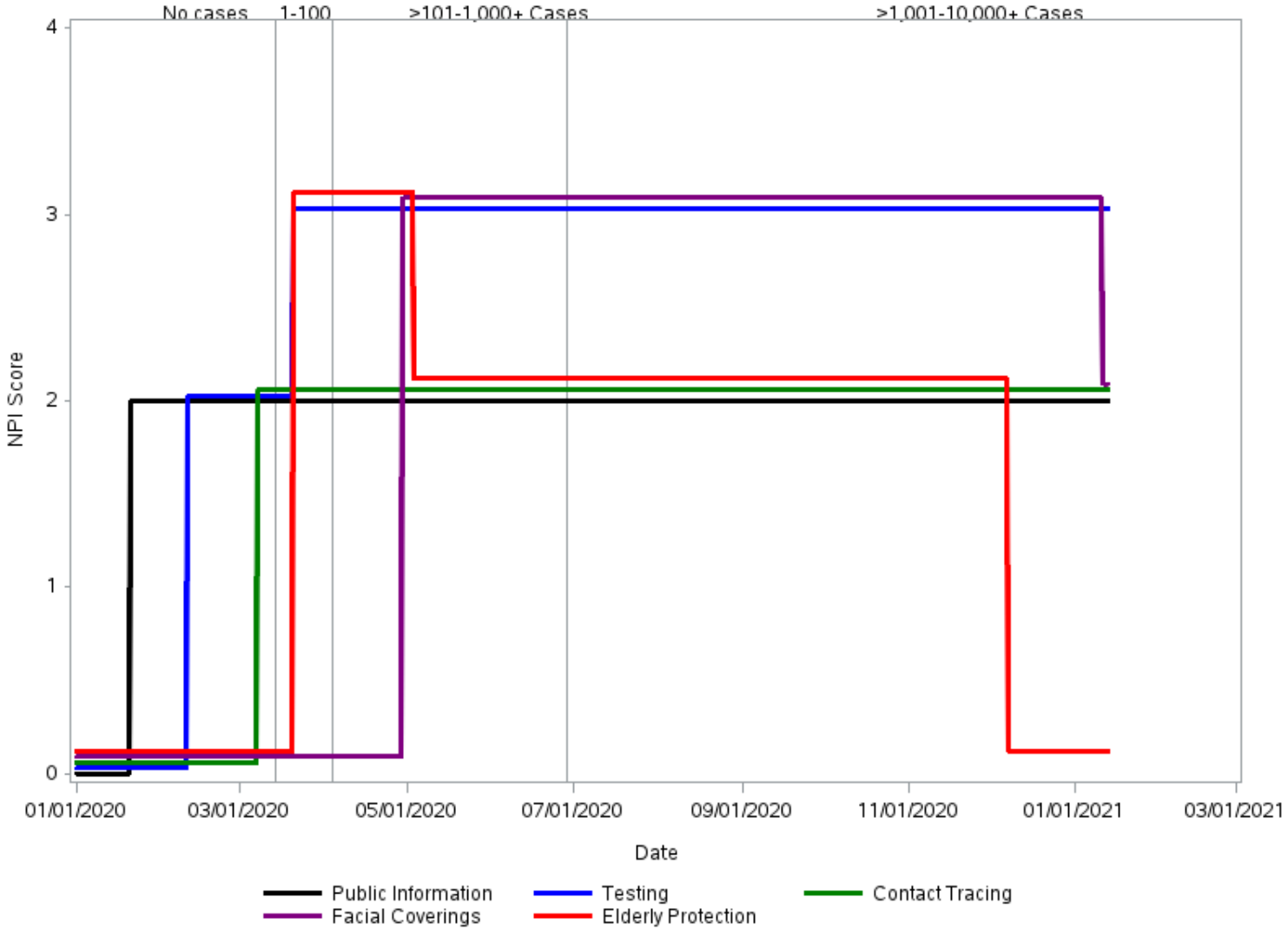
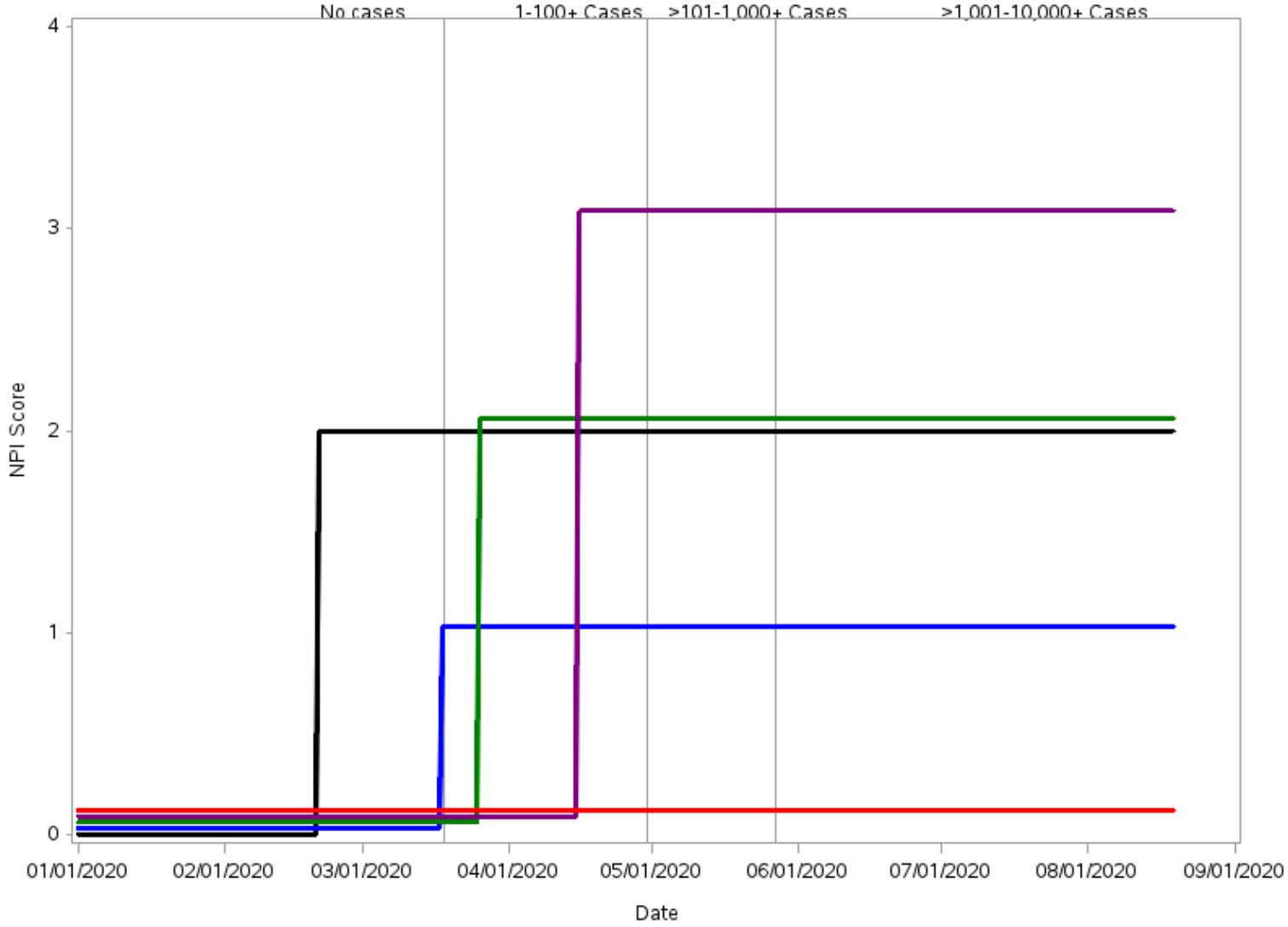


Figure 4.15. Variation in Levels of Health NPI Implementation in Zambia



Summary

Descriptive statistics and plots were used to show the timing of first implementation of specific NPIs and how the levels of NPI implementation changed over time. Three OxCGRT indices were used to examine how stringency, government response, and implementation of containment and health indices changed in each country in the period leading up to 10,000+ cases. Individual indicator scores varied with the response in all three countries. Nigeria experienced sustained levels of strict measures for containment and closure NPIs, while Rwanda experienced a great deal of variation in NPI score as it transitioned through the different case windows for the same measures. Zambia experienced moderate stringency throughout the pandemic with gathering restrictions and business/school closure measures but maintained low levels of strictness for other containment and closure measures. Variation in the levels of health system policies that were implemented also varied between the countries. Nigeria had stricter measures for protecting the elderly from the middle of W_1 until end of W_3; however, it maintained less stringent levels for other health system NPIs compared to Rwanda. Similarly, Zambia only had strict measures related to mask wearing beginning in the middle of W_1, but other measures were not as stringent. The results of this analysis indicate that Rwanda implemented more stringent measures for both containment and closure NPIs and for health system NPIs among the three countries.

Research Objective Three: Core Goal One

The overarching goal of research objective three was to evaluate the relationship among the levels/changes in NPIs and changes in COVID-19 cases and deaths in Nigeria,

Rwanda, and Zambia. Core goal one under this objective was to examine the longitudinal changes in COVID-19 cases and deaths relative to the first implementation of NPIs. To achieve this goal, descriptive statistics were used to show how COVID-19 cases and death trajectories differed before and after the implementation of specific NPIs. NPIs were grouped together if they were implemented within one week of each other. The "# days" shows two timepoints: 1) before each NPs was implemented ("pre"), and 2) after each NPI was implemented ("post"). The mean number of daily new cases and deaths were calculated for each country.

Containment and Closure NPIs

New cases and deaths pre- versus post- implementation of containment and closure NPIs are shown in Tables 4.9, 4.10, and 4.11 for Nigeria, Rwanda, and Zambia, respectively. NPIs were grouped if they were implemented within one week of each other. The number of days pre-implementation show the period of days before the NPIs were implemented. The number of days post-implementation show the number of days after the NPIs were implemented to surpass 10,000 cases. The mean number of daily new cases and deaths were calculated for each country. Average daily cases and deaths were much higher post-NPI onset relative to pre-NPI onset across all countries due to the exponential rise in case and likely due to community transmission.

Table 4.9. COVID-19 cases and deaths pre- vs. post-implementation of containment and closure NPIs, Nigeria

		Daily New Cases		Daily New Deaths	
	# Days	**Mean**	**SD**	**Mean**	**SD**
School closing, workplace closing, cancelling of public events, and limits on gatherings					
Pre	77	0.04	0.19	0	0
Post	75	135.5	131.3	3.8	4.4
Closing public transport, shelter in place orders, movement restrictions, restrictions on international travel for foreign travelers					
Pre	82	0.4	1.6	0	0
Post	70	144.7	131.0	4.1	4.4

Table 4.10. COVID-19 cases and deaths pre- vs. post-implementation of containment and closure NPIs, Rwanda

		Daily New Cases		Daily New Deaths	
	# Days	**Mean**	**SD**	**Mean**	**SD**
School closing, workplace closing					
Pre	73	0	0	0	0
Post	306	33.1	42.0	0.4	1.0
Cancelling public events, limits on gatherings					
Pre	67	0	0	0	0
Post	312	32.4	41.9	0.4	1.0
Closing public transport, shelter in place orders, movement restrictions					
Pre	80	0.2	1.1	0	0
Post	299	33.8	42.2	0.43	1.0
Restrictions on international travel for foreign travelers					
Pre	26	0	0	0	0
Post	353	28.7	40.7	0.4	0.9

Table 4.11 COVID-19 cases and deaths pre- vs. post-implementation of containment and closure NPIs, Zambia

		Daily New Cases		Daily New Deaths	
	# Days	**Mean**	**SD**	**Mean**	**SD**
School closing					
Pre	79	0.03	0.2	0	0
Post	153	66.8	129.7	1.8	6.6
Workplace closing					
Pre	122	0.9	2.0	0.02	0.2
Post	110	91.9	145.5	2.4	7.7
Cancelling public events					
Pre	105	0.4	1.4	0.02	0.1
Post	127	80.1	138.7	2.1	7.2
Limits on gatherings, movement restrictions					
Pre	85	0.1	1.0	0	0
Post	147	69.4	131.6	1.8	6.7
Restrictions on international travel					
Pre	51	0	0	0	0
Post	181	56.5	121.6	1.5	6.1

Health System NPIs

Similarly, the same methods were undertaken to explore new cases and new deaths pre- versus post- implementation of health systems NPIs (tables 4.12, 4.13, and 4.14) for Nigeria, Rwanda, and Zambia, respectively. Average daily cases and deaths were much higher post-NPI onset relative to pre-NPI onset across all countries due to the exponential rise in cases that was likely due to community transmission.

Table 4.12. COVID-19 cases and deaths pre- vs. post-implementation of health system NPIs, Nigeria

		Daily New Cases		Daily New Deaths	
	# Days	**Mean**	**SD**	**Mean**	**SD**
Presence of public information campaigns					
Pre	21	0	0	0	0
Post	131	77.57	119.70	2.19	3.80
Testing policy					
Pre	32	0	0	0	0
Post	120	84.68	122.66	2.39	3.91
Contact tracing					
Pre	58	0	0	0	0
Post	94	108.11	129.20	3.05	4.19
Facial coverings					
Pre	107	4.13	8.55	0.12	0.43
Post	45	216	110.98	6.09	4.31
Protection of elderly					
Pre	77	0.04	0.19	0	0
Post	75	135.45	131.26	3.83	4.36

Table 4.13. COVID-19 cases and deaths pre- vs. post-implementation of health system NPIs, Rwanda

		Daily New Cases		Daily New Deaths	
	# Days	**Mean**	**SD**	**Mean**	**SD**
Presence of public information campaigns					
Pre	20	0	0	0	0
Post	359	28.2	40.5	0.4	0.9
Testing policy					
Pre	41	0	0	0	0
Post	338	30.0	41.1	0.4	0.9
Contact tracing					
Pre	67	0	0	0	0
Post	312	32.4	41.9	0.4	1.0
Facial coverings					
Pre	120	1.9	3.9	0	0
Post	259	38.2	43.7	0.5	1.1
Protection of elderly					
Pre	80	0.2	1.1	0	0
Post	299	33.8	42.2	0.4	1.0

Table 4.14. New cases and deaths of COVID-19 pre- vs. post-implementation of health system NPIs, Zambia

		Daily New Cases		Daily New Deaths	
	# Days	**Mean**	**SD**	**Mean**	**SD**
Presence of public information campaigns					
Pre	51	0	0	0	0
Post	181	56.5	121.6	1.5	6.1
Testing policy					
Pre	77	0	0	0	0
Post	155	65.9	129.1	1.7	6.5
Contact tracing					
Pre	85	0.1	1.0	0	0
Post	147	69.4	131.6	1.8	6.7
Facial coverings					
Pre	106	0.5	1.5	0.02	0.1
Post	126	80.7	139.1	2.1	7.2

Summary

To examine longitudinal changes in COVID-19 cases and deaths, descriptive statistics and plots were used to show how cases and deaths trajectories differed before and after implementing specific NPIs. Average numbers of daily new cases were assessed for pre-implementation and post-implementation of NPIs which were implemented around the same time. In all three countries, cases increased post-NPI implementation indicating community transmission and spread of disease. However, Rwanda had lower number of cases and post implementation of NPIs, while Nigeria and Zambia had higher levels. For example, school and work closures, cancelling of public events, and limits on gatherings saw an average of 33.1 cases post-implementation, whereas Nigeria saw on average 135.5 cases post-implementation. Similarly, Rwanda had an average of 28.8 cases/day post-implementation of restrictions on international travel, while Zambia had an average of 56.5

cases. These differences may indicate that the level and stringency of implementation in each country may have affected disease spread.

Research Objective Three: Core Goal Two

Core goal two under research objective three aimed to examine the degree of implementation of NPIs relative to the four case windows. Indices were compared across case windows using analysis of variance (ANOVA) models with post-hoc comparisons (p-values adjusted using Tukey's method). Specific NPI item levels were compared across total case windows using Fisher's exact tests.

There were significant differences between the three countries in the level of NPIs implemented across the case windows. The specific case window differences varied slightly across countries. Tables 4.15a, 4.15b, and 4.15c show the mean comparisons of the three indices across case windows for Nigeria. There was a difference between the mean stringency scores across case windows as determined by one-way ANOVA ($F(3, 148) = 1058.3$, $p<0.0001$). A Tukey post hoc test shows the mean stringency index scores in case windows W_1, W_2, and W_3 were statistically significantly different than W_0 ($p<0.0001$), indicating a rise in stringency as cases increased. Similarly, the mean stringency index scores in case windows W_2 and W_3 were statistically significantly different when compared to W_0 ($p<0.0001$). However, there was no difference between the mean stringency index scores between W_2 and W_3 ($p=0.85$) indicating stringency scores stayed relatively around the same level. The mean government response index scores were statistically significantly different across case windows ($F(3,148) = 1153.1$, $p<0.0001$). A

Tukey post hoc test shows the mean government response scores were statistically significantly different across all windows indicating a meaningful difference in the level of stringency from one case window to the next. Similarly, there was a statistically significant difference between the containment and health index scores across case windows as determined by a one-way ANOVA ($F(3,148) = 1113.7$, $p<0.0001$). A Tukey post hoc test shows the mean containment and health index scores were statistically significant different across all case windows.

Table 4.15a. One-Way ANOVA of the Stringency Index Score by Case Window, Nigeria

				Tukey's Post-hoc Comparisons			
Case Window	*n*	Mean	*SD*	**W_0**	**W_1**	**W_2**	**W_3**
W_0	58	6.2	5.1		<0.0001	<0.0001	<0.0001
W_1	30	22.3	16.3	<0.0001		<0.0001	<0.0001
W_2	26	83.0	0.6	<0.0001	<0.0001		0.85
W_3	38	84.6	0.6	<0.0001	<0.0001	0.85	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days, *SD:* standard deviation

Table 4.15b. One-Way ANOVA of the Government Response Index Score by Case Window, Nigeria

				Tukey's Post-hoc Comparisons			
Case Window	*n*	Mean	*SD*	**W_0**	**W_1**	**W_2**	**W_3**
W_0	58	4.4	3.8		<0.0001	<0.0001	<0.0001
W_1	30	23.2	12.1	<0.0001		<0.0001	<0.0001
W_2	26	62.3	1.5	<0.0001	<0.0001		0.0008
W_3	38	68.2	0.4	<0.0001	<0.0001	0.0008	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days, *SD:* standard deviation

Table 4.15c. One-Way ANOVA of the Containment and Health Index by Case Window, Nigeria

				Tukey's Post-hoc Comparisons			
Case Window	*n*	Mean	*SD*	**W_0**	**W_1**	**W_2**	**W_3**
W_0	58	5.1	4.4		<0.0001	<0.0001	<0.0001
W_1	30	26.5	13.8	<0.0001		<0.0001	<0.0001
W_2	26	70.5	1.0	<0.0001	<0.0001		0.0065
W_3	38	76.1	0.4	<0.0001	<0.0001	0.0065	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days, *SD:* standard deviation

Tables 4.16a, 4.16b, and 4.16c show the mean comparisons of the three indices across case windows for Rwanda. There was a statistically significant difference between the mean stringency scores across case windows as determined by one-way ANOVA ($F(3, 375) = 838.5$, $p<0.0001$). A Tukey post hoc test shows the mean stringency index scores in case windows W_1, W_2, and W_3 were significantly different than W_0 ($p<0.0001$) indicating a change in stringency index score after identification of index case compared to pre-identification of index case. Similarly, the mean stringency index scores in W_1 and W_3 were statistically significantly different when compared to W_2 ($p<0.05$). However, there was no difference between the mean stringency index scores between W_1 and W_3 ($p=0.53$) suggesting that the stringency levels in which measures were implemented during W_1 and W_3 were similar. The mean government response index scores were statistically significant different across case windows ($F(3,375 = 1455.3$, $p<0.0001$) indicating the government response varied during each case window. A Tukey post hoc test shows the mean government response scores were statistically significant different across all windows. There was a statistically significant difference between the containment and health index scores across case windows as determined by a one-way ANOVA (F (1191.9,

p<0.0001). A Tukey post hoc test shows the mean containment and health index scores in case windows W_1 and W_3 were statistically significantly different compared to W_2 (p<0.001). However, there was no difference between the mean containment and health index scores in W_1 and W_3 indicating that the implementation of measures calculated in the containment and health index were similar during W_1 and W_3.

Table 4.16a. One-Way ANOVA of the Stringency Index by Case Window, Rwanda

				Tukey's HSD Comparisons			
Case Window	*n*	Mean	*SD*	**W_0**	**W_1**	**W_2**	**W_3**
W_0	73	10.9	7.6		<0.0001	<0.0001	<0.0001
W_1	21	73.2	25.6	<0.0001		0.04	0.54
W_2	86	79.5	8.6	<0.0001	0.04		<0.0001
W_3	199	70.3	7.5	<0.0001	0.54	<0.0001	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days, *SD:* standard deviation

Table 4.16b. One-Way ANOVA of the Government Response Index by Case Window, Rwanda

				Tukey's HSD Comparisons			
Case Window	*n*	Mean	*SD*	**W_0**	**W_1**	**W_2**	**W_3**
W_0	73	8.5	7.0		<0.0001	<0.0001	<0.0001
W_1	21	62.2	20.3	<0.0001		<0.0001	0.003
W_2	86	72.7	3.6	<0.0001	<0.0001		<0.0001
W_3	199	67.9	5.5	<0.0001	0.003	<0.0001	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days, *SD:* standard deviation

Table 4.16c. One-Way ANOVA of the Containment and Health Index by Case Window, Rwanda

				Tukey's HSD Comparisons			
Case Window	*n*	Mean	*SD*	**W_0**	**W_1**	**W_2**	**W_3**
W_0	73	9.7	8.0		<0.0001	<0.0001	<0.0001
W_1	21	65.3	21.0	<0.0001		<0.0001	0.24
W_2	86	74.7	4.6	<0.0001	<0.0001		<0.0001
W_3	199	68.7	6.2	<0.0001	0.24	<0.0001	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days, *SD:* standard deviation

Tables 4.17a, 4.17b, and 4.17c show the mean comparisons of the three indices across case windows for Zambia. There was a statistically significant difference between the mean stringency scores across case windows as determined by one-way ANOVA ($F(3,228) = 66.6$, $p<0.0001$). A Tukey post hoc test shows the mean stringency index scores in case windows W_1, W_2, and W_3 were statistically significantly different than W_0 ($p<0.0001$) indicating that Zambia's stringency levels varied post-identification of the index case compared to the pre-identification. However, there was no difference between the mean stringency index scores across case windows W_1, W_2, and W_3, suggesting that the stringency levels in how the measures were implemented did not differ despite increases in cases. There was a statistically significant difference between the mean government response scores across case windows as determined by one-way ANOVA ($F(3,228) = 562.6$, $p<0.0001$). There was a statistically significant difference between the mean government response index score in case windows W_1, W_2, and W_3 compared to W_0 ($p<0.0001$). Similarly, the mean government response index scores in case windows W_2 and W_3 were statistically significant compared to W_1 ($p<0.05$). There was no difference between the mean government response index score in W_2 and W_3 ($p=0.48$) indicating that the government response was similar during the last two case windows compared to the first case window. Like the government response index, the mean containment and health index scores were statistically different across as determined by one-way ANOVA ($F(3,228) = 540.5$, $p<0.0001$). There was a statistically significant difference between the mean containment and health index scores in case windows W_1, W_2, and W_3 were statistically significantly different than W_0 ($p<0.0001$). However, there was no difference

in the mean containment and health index scores between W_2 and W_3 (p=0.43), which again indicates similar implementation of the measures calculated in the containment and health index during W_2, and W_3.

Table 4.17a. One-Way ANOVA of the Stringency Index by Case Window, Zambia

				Tukey's HSD Comparisons			
Case Window	*n*	Mean	*SD*	**W_0**	**W_1**	**W_2**	**W_3**
W_0	77	5.6	7.9		<0.0001	<0.0001	<0.0001
W_1	43	49.5	14.7	<0.0001		0.87	0.63
W_2	27	51.2	12.1	<0.0001	0.87		0.25
W_3	85	47.4	5.1	<0.0001	0.63	0.25	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days, *SD:* standard deviation

Table 4.17b. One-Way ANOVA of the Government Response Index by Case Window, Zambia

				Tukey's HSD Comparisons			
Case Window	*n*	Mean	*SD*	**W_0**	**W_1**	**W_2**	**W_3**
W_0	77	3.2	4.5		<0.0001	<0.0001	<0.0001
W_1	43	38.9	13.1	<0.0001		0.002	0.01
W_2	27	44.9	6.8	<0.0001	0.002		0.48
W_3	85	42.8	2.9	<0.0001	0.01	0.48	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days, *SD:* standard deviation

Table 4.17c. One-Way ANOVA of the Containment and Health Index by Case Window, Zambia

				Tukey's HSD Comparisons			
Case Window	*n*	Mean	*SD*	**W_0**	**W_1**	**W_2**	**W_3**
W_0	77	3.6	5.1		<0.0001	<0.0001	<0.0001
W_1	43	41.7	13.7	<0.0001		0.005	0.05
W_2	27	47.8	7.8	<0.0001	0.005		0.43
W_3	85	45.3	3.3	<0.0001	0.05	0.43	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days, *SD:* standard deviation

Specific NPI item levels were compared across all case windows using Fisher's exact test. Tables 4.18a, 4.18b, and 4.18c show the number of days each containment and closure NPI was implemented and at what level across the case windows in each country. NPIs are ranked on a simple numerical scale by level of stringency (the higher the ordinal value, the stricter the policy). There were significant differences in the level of NPIs between the total case windows. In Nigeria, the level of restrictions significantly increased with case counts for all containment and closure NPIs (Table 4.18a). During W_2 and W_3, Nigeria implemented more stringent policies than in W_0 and W_1. For example, during W_0 no containment and closures restrictions were implemented in Nigeria. While there were still a couple of NPIs that were not implemented during W_1 (closing of public transport and movement restrictions between cities and regions), the government did begin implementing some levels of restrictions during this case window. For example, during the 30 days spent in W_1, nine of those days (30%) were at a level 2 (required cancelling of public event). During W_2, most containment and closure NPIs were implemented at the most stringent level of each policy. However, there were some easing of restrictions during W_3. For example, limits on gatherings were at a level 3 (restrictions between 11-100 people) for 28 days (74%) during W_3, even though it spent all 26 days of W_2 at a level 4 (restriction of 10 people or less). Similar patterns were observed for closing of public transport and workplace closures).

Table 4.18a. Comparison of the level of containment and closure NPIs levels across case windows using Fisher's Exact Test, Nigeria

	W_0 (58 days) % (n)	W_1 (30 days) % (n)	W_2 (26 days) % (n)	W_3 (38 days) % (n)	Fisher's Exact Test
School closing					
0 – no measures	100 (58)	70 (21)	0 (0)	0 (0)	p<.0001
2 – require closing certain schools	0 (0)	20 (6)	0 (0)	0 (0)	
3 – require closing all schools	0 (0)	10 (3)	100 (26)	100 (38)	
Workplace closing					
0 – no measures	100 (58)	63.3 (19)	0 (0)	0 (0)	p<.0001
1 – recommend closing	0 (0)	36.7 (11)	0 (0)	0 (0)	
2 – require closing some sectors	0 (0)	0 (0)	0 (0)	73.7 (28)	
3 – require closing for all but essential workplaces	0 (0)	0 (0)	100 (26)	26.3 (10)	
Cancelling of public events					
0 – no measures	100 (58)	63.3 (19)	0 (0)	0 (0)	p<.0001
1 – recommend cancelling	0 (0)	6.7 (2)	0 (0)	0 (0)	
2 – require cancelling	0 (0)	30 (9)	100 (26)	100 (38)	
Limits on gatherings					
0 – no restrictions	100 (58)	63.3 (19)	0 (0)	0 (0)	p<.0001
3 – restrictions between 11-100 people	0 (0)	33.3 (10)	0 (0)	73.7 (28)	
4 – restrictions of 10 people or less	0 (0)	3.3 (1)	100 (26)	26.3 (10)	
Closing of public transport					
0 – no measures	100 (58)	100 (30)	0 (0)	0 (0)	p<.0001
1 – recommend closing	0 (0)	0 (0)	0 (0)	73.7 (28)	
2 – require closing	0 (0)	0 (0)	100 (26)	26.3 (10)	
Stay at home orders					
0 – no measures	100 (58)	80 (24)	0 (0)	0 (0)	p<.0001
1 – recommend not leaving home	0 (0)	20 (6)	0 (0)	0 (0)	
2 – require not leaving home with certain exceptions	0 (0)	0 (0)	100 (26)	100 (38)	
Movement restrictions between cities/regions					
0 – no measures	100 (58)	100 (30)	0 (0)	0 (0)	p<.0001
2 – internal movement restrictions in place	0 (0)	0 (0)	100 (26)	100 (38)	
Restrictions on international travel for foreign travelers					
0 – no restrictions	100 (58)	80 (24)	0 (0)	0 (0)	
2 – quarantine arrivals from some or all regions	0 (0)	20 (6)	100 (26)	100 (38)	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n*:* number of days

Table 4.18b compares containment and closure NPI levels across case windows in Rwanda. Rwanda gradually increased its stringency across case windows. The country also implemented certain measures before it identified its first case. During the 73 days from January 1, 2020, to the identification of its first case, Rwanda placed restrictions on gatherings of 101-1,000 people for 6 (8%) of those days; and screening of arriving international travelers for 47 (64%) of the 73 days. During W_1 the stringency of NPIs increased. Schools were closed at all levels for 19 days (90%), workplaces were closed for all but essential workplaces for 14 days (67%), recommendations to not leave the home were also in place for 14 days (67%), limits on gatherings were placed at 101-1,000 people for the entire duration of W_1, and restrictions on public events and public transport were at the highest level for the entire 21 days of W_1. There were some easing of restrictions during W_2, where there were no restrictions on public transport for most that period (65%). During the last case window, most of the containment and closure NPIs were at their most stringent levels for most of the 199 days. Schools were closed at all levels for 105 days (53%), public events were cancelled for 197 days (99%), gatherings were limited to 11-100 people for 178 days (89%), requirements to leave the home with exceptions for daily exercise, grocery shopping, and essential trips were in place for 188 days (95%), and internal movement restrictions were in place for 136 days (68%).

Table 4.18b. Comparison of the level of containment and closure NPIs levels across case windows using Fisher's Exact Test, Rwanda

	W_0 (58 days) % (n)	W_1 (30 days) % (n)	W_2 (26 days) % (n)	W_3 (38 days) % (n)	Fisher's Exact Test
School closing					
0 – no measures	100 (73)	9.52(2)	0 (0)	8.0 (16)	p<.0001
1 – recommended closing	0 (0)	0 (0)	0 (0)	10.6 (21)	
2 – require closing certain schools	0 (0)	0 (0)	0 (0)	28.6 (57)	
3 – require closing all schools	0 (0)	90.5 (19)	100 (86)	52.7 (105)	
Workplace closing					
0 – no measures	100 (73)	0 (0)	0 (0)	0 (0)	p<.0001
1 – recommend closing	0 (0)	33.33 (7)	0 (0)	0 (0)	
2 – require closing some sectors	0 (0)	0 (0)	65.1 (56)	100 (199)	
3 – require closing for all but essential workplaces	0 ((0)	66.7 (14)	34.9 (30)	0 (0)	
Cancelling of public events					
0 – no measures	91.8 (67)	0 (0)	0 (0)	0 (0)	p<.0001
1 – recommend cancelling	0 (0)	0 (0)	0 (0)	1 (2)	
2 – require cancelling	8.2 (6)	100 (21)	100 (86)	99 (197)	
Limits on gatherings					
0 – no restrictions	91.8 (67)	0 (0)	0 (0)	0 (0)	p<.0001
1 – restriction on >1,000 people	0 (0)	0 (0)	0 (0)	10.5 (21)	
2 – restriction on between 101-1,000 people	8.2 (6)	100 (21)	34.9 (30)	0 (0)	
3 – restrictions on between 11-100 people	0 (0)	0 (0)	65.1 (56)	89.5 (178)	
Closing of public transport					
0 – no measures	100 (73)	33.3 (7)	65.1 (56)	30.7 (61)	p<.0001
1 – recommend closing	0 (0)	0 (0)	0 (0)	54.3 (108)	
2 – require closing	0 (0)	66.7 (14)	34.9 (30)	15.1 (30)	
Stay at home orders					
0 – no measures	100 (73)	33.3 (7)	0 (0)	1.0 (2)	p<.0001
2 – require not leaving home with certain exceptions	0 (0)	66.7 (14)	94.2 (81)	94.5 (188)	
3 – require not leaving home with minimal exceptions	0 (0)	0 (0)	5.81 (5)	4.5 (19)	
Movement restrictions between cities/regions					
0 – no measures	100 (73)	33.3 (7)	9.3 (8)	22.6 (45)	p<.0001
1 – recommend not to travel between regions/cities	0 (0)	0 (0)	33.7 (29)	9.1 (18)	
2 – internal movement restrictions in place	0 (0)	66.7 (14)	57 (49)	68.3 (136)	
Restrictions on international travel for foreign travelers					
0 – no restrictions	35.6 (26)	0 (0)	0 (0)	0 (0)	p<.0001
1 – screening arrivals	64.4 (47)	33.3 (7)	0 (0)	5.03 (10)	
2 – quarantine arrivals from some or all regions	0 (0)	0 (0)	0 (0)	62.8 (125)	
3 – ban arrivals from some regions	0 (0)	66.7 (14)	100 (86)	32.1 (64)	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n*:* number of days

Table 4.18c compares containment and closure NPI levels across case windows in Zambia. Zambia kept its stringency level for each containment and closure NPI relatively similar across the case windows. The only containment and closure NPI implemented during W_0 was moderate restrictions (level 2) on international travel for foreign travelers which was implemented for about a third (34%) of the case window. All schools were required to be closed during all of W_1 andW_2, but this was amended to close only certain schools during W_3. Workplaces were mainly only closed for certain sectors during W_1, W_2, and W_3. Similarly, cancelling of public events was not required for most of the case windows. During W_1 and W_2, public events were cancelled only for 23 days combined (41%). Limits on gatherings stayed relatively steady with restrictions placed on gatherings of 11-100 people. Restriction of movement between cities/regions varied depending on the case window but this was mostly only a recommendation (level 2). Restrictions on international travel for foreign travelers was the most stringent containment and closure NPI implemented during W_1 (level 4).

Table 4.18c. Comparison of the level of containment and closure NPIs levels across case windows using Fisher's Exact Test, Zambia

	W_0 (58 days) % (n)	W_1 (30 days) % (n)	W_2 (26 days) % (n)	W_3 (38 days) % (n)	Fisher's Exact Test
School closing					
0 – no measures	100 (77)	4.7 (2)	0 (0)	0 (0)	p<.0001
2 – require closing certain schools	0 (0)	0 (0)	0 (0)	94.1 (80)	
3 – require closing all schools	0 (0)	95.4 (41)	100 (27)	5.9 (5)	
Workplace closing					
0 – no measures	100 (77)	100 (43)	7.4 (2)	0 (0)	p<.0001
2 – require closing some sectors	0 (0)	0 (0)	70.4 (19)	100 (85)	
3 – require closing for all but essential workplaces	0 (0)	0 (0)	22.2 (6)	0 (0)	
Cancelling of public events					
0 – no measures	100 (77)	65.1 (28)	70.4 (19)	34.1 (29)	p<.0001
1 – recommend cancelling	0 (0)	0 (0)	0 (0)	65.9 (56)	
2 – require cancelling	0 (0)	34.9 (15)	29.6 (8)	0 (0)	
Limits on gatherings					
0 – no restrictions	100 (77)	18.6 (8)	0 (0)	0 (0)	p<.0001
3 – restrictions on between 11-100 people	0 (0)	46.5 (20)	70.4 (19)	100 (85)	
4 – restrictions of 10 people or less	0 (0)	34.9 (15)	29.6 (8)	0 (0)	
Movement restrictions between cities/regions					
0 – no measures	100 (77)	25.6 (11)	70.4 (19)	34.1 (29)	p<.0001
1 – recommend not to travel between regions/cities	0 (0)	37.2 (16)	0 (0)	65.9 (56)	
2 – internal movement restrictions in place	0 (0)	37.2 (16)	29.6 (8)	0 (0)	
Restrictions on international travel for foreign travelers					
0 – no restrictions	66.2 (51)	0 (0)	0 (0)	0 (0)	p<.0001
2 – quarantine arrivals from some or all regions	33.8 (26)	20.9 (9)	92.6 (25)	100 (85)	
4 – ban on all regions or total border closures	0 (0)	79.1 (34)	7.4 (2)	0 (0)	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days

Health system NPI item levels were also compared across total case windows using Fisher's exact test (Tables 4.19a, 4.19b, and 4.19c). The tables show the number of days each health system NPI was implemented and at what level across the case windows in each country. Public officials urging caution about COVID-19 was consistent throughout the first 10,000 cases in Nigeria. Nigeria's testing policy was consistently at a level 1—testing of only those who both have (a) symptoms and (b) meet specific criteria. Comprehensive contact tracing was done for all identified for all the case windows beginning in W_1 in Nigeria. Extensive restrictions for isolation and hygiene in LCTFs were implemented for 100% of both W_2 and W_3. In Rwanda, public officials urging caution about COVID-19 was also consistent throughout all case windows. For the majority of W_0 (41 days (56%)), there was no testing policy. However, for most of W_1 and the subsequent two case windows, there was open public testing (e.g., widespread PCR testing available, including for asymptomatic persons) available. Facial coverings were required in all case windows. Facial coverings were implemented at a level 3 beginning in W_2 and continued for most of W_3; however, there were two days during the last case window that facial coverings were only required in some specified shared/public spaces (level 2). Protective measures for elderly individuals? in LTCFs were implemented beginning in W_1 but the level of implementation varied during each case window. Unlike both Nigeria and Rwanda, Zambia had a coordinated public information campaign beginning in W_0 that continued during all case windows. Like Nigeria, Zambia's testing policy was at a level 1 beginning in W_1. Comprehensive contact tracing was implemented for 100% of the case windows

beginning in W_1. Facial coverings were required in Zambia in all shared/public spaces (level 3) beginning in W_1.

Table 4.19a. Comparison of health system NPI levels across case windows using Fisher's Exact Test, Nigeria

	W_0 (58 days) % (n)	W_1 (30 days) % (n)	W_2 (26 days) % (n)	W_3 (38 days) % (n)	Fisher's Exact Test
Presence of public information campaigns					
0- no measures	36.2 (21)	0 (0)	0 (0)	0 (0)	p<.0001
1- public officials urging caution about COVID-19	15.5 (9)	0 (0)	0 (0)	0 (0)	
2- coordinated public information campaign	48.3 (28)	100 (30)	100 (26)	100 (38)	
Testing policy					
0- no testing policy	55.2 (32)	0 (0)	0 (0)	0 (0)	p<.0001
1- only those who both have symptoms and meet specific criteria	44.8 (26)	100 (30)	100 (26)	100 (38)	
Contact tracing					
0- no contract tracing	100 (58)	0 (0)	0 (0)	0 (0)	p<.0001
2- comprehensive contact tracing	0 (0)	100 (30)	100 (26)	100 (38)	
Facial coverings					
0- no policy	100 (58)	100 (30)	73.1 (19)	0 (0)	p<.0001
1- recommended	0 (0)	0 (0)	26.9 (7)	2.6 (1)	
3- required in all shared/public spaces	0 (0)	0 (0)	0 (0)	97.4 (37)	
Elderly protection					
0- no measures	100 (58)	63.3 (19)	0 (0)	0 (0)	p<.0001
3- extensive restrictions for isolation and hygiene in LCTFs	0 (0)	36.7 (11)	100 (26)	100 (38)	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days

Table 4.19b. Comparison of health system NPI levels across case windows using Fisher's Exact Test, Rwanda

	W_0 (58 days) % (n)	W_1 (30 days) % (n)	W_2 (26 days) % (n)	W_3 (38 days) % (n)	Fisher's Exact Test
Presence of public information campaigns					
0- no measures	27.4 (20)	0 (0)	0 (0)	0 (0)	p<.0001
1- public officials urging caution about COVID-19	72.6 (53)	100 (21)	100 (86)	100 (199)	
Testing policy					
0- no testing policy	56.2 (41)	0 (0)	0 (0)	0 (0)	p<.0001
2- testing of anyone showing COVID-19 symptoms	43.8 (32)	33.3 (7)	0 (0)	0 (0)	
3- open public testing	0 (0)	66.7 (14)	100 (86)	100 (199)	
Contact tracing					
0- no contract tracing	91.8(67)	0 (0)	0 (0)	0 (0)	p<.0001
2- comprehensive contact tracing	8.2 (6)	100 (21)	100 (86)	100 (199)	
Facial coverings					
0- no policy	100 (73)	100 (21)	30.2 (26)	0 (0)	p<.0001
2- required in some specified shared/public spaces	0 (0)	0 (0)	0 (0)	1 (2)	
3- required in all shared/public spaces	0 (0)	0 (0)	69.8 (60)	99 (197)	
Elderly protection					
0- no measures	100 (73)	33.3 (7)	0 (0)	18.6 (37)	p<.0001
2- narrow restrictions for isolation and hygiene in LTCFs	0 (0)	0 (0)	65.1 (56)	81.4 (162)	
3- extensive restrictions for isolation and hygiene in LCTFs	0 (0)	66.7 (14)	34.9 (30)	0 (0)	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n*:* number of days

Table 4.19c. Comparison of health system NPI levels across case windows using Fisher's Exact Test, Zambia

	W_0 (58 days) % (n)	W_1 (30 days) % (n)	W_2 (26 days) % (n)	W_3 (38 days) % (n)	Fisher's Exact Test
Presence of public information campaigns					
0- no measures	66.2 (51)	0 (0)	0 (0)	0 (0)	p<.0001
2- coordinated public information campaign	33.8 (26)	100 (43)	100 (27)	100 (85)	
Testing policy					
0- no testing policy	100 (77)	0 (0)	0 (0)	0 (0)	p<.0001
1- only those who both have symptoms and meet specific criteria	0 (0)	100 (43)	100 (27)	100 (85)	
Contact tracing					
0- no contract tracing	100 (77)	18.6 (8)	0 (0)	0 (0)	p<.0001
2- comprehensive contact tracing	0 (0)	81.4 (35)	100 (27)	100 (85)	
Facial coverings					
0- no policy	100 (77)	67.4 (29)	0 (0)	0 (0)	p<.0001
3- required in all shared/public spaces	0 (0)	32.6 (14)	100 (27)	100 (85)	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days

Summary

This research objective examined the level in which individual NPIs were implemented leading up to 10,000 cases in each country, including how many days and at what level each NPI was implemented. Rwanda was the only country to begin implementing multiple containment and closure measures prior to the identification of the first index case. Zambia implemented one measure prior to the identification of the first case, which was to quarantine travelers arriving from some or all regions. In contrast, all three countries implemented some health system NPIs prior to identification of the first case, largely around public information campaigns. This research objective also utilized post-hoc

comparisons using ANOVA to assess differences in index scores across case windows. The mean government response index scores for all three countries were statistically different across all case windows indicating the level of response differed during each case window. For the indicators used to measure the containment and health index, there seemed to be similar levels of variation when comparing individual case windows. For example, the mean stringency scores were not statistically different for W_2 and W_3 in Nigeria. Similarly, in Rwanda, this was observed during W_1 and W_3, indicating that the last case window was as stringent as the first case window upon identification of the index case. Meanwhile there were no differences in implementation for Zambia in W_2 and W_3, compared to W1, indicating there were very little increases in the stringency level of measures between case windows in Zambia despite an increase in cases. The results of this objective indicate Rwanda had a robust and varied response compared to Nigeria and Zambia.

Research Objective Three: Core Goal Three

Core goal three of research objective three sought to examine the relationship between prior changes in the implementation of NPIs relative to rising COVID-19 cases and deaths. Seven day moving averages were computed for the three indices (stringency, government response, and containment and health), number of new COVID-19 cases, and number of new COVID-19 deaths. Weekly changes on these average NPIs, cases, and deaths were computed. Then, the lagged relationships between changes on NPIs and subsequent changes in COVID-19 cases and deaths were examined using Spearman correlations (ρ). Two time-lags were examined for the NPIs, 7-day and 14-day. For example, the 7-day time lags evaluated whether changes in the NPIs in the prior week (7

days) correlated with later changes in COVID-19 cases and deaths. Likewise, the 14-day time lags evaluated whether NPI changes 2-weeks earlier (14 days) were associated with later change in cases and deaths. Tables 4.20 shows the Spearman correlations (ρ) between changes in the stringency, government response, and containment and health index scores and subsequent changes in COVID-19 cases and death using 7-day and 14-day time lags for Nigeria, Rwanda, and Zambia.

Correlational analyses showed that prior week (7-day lag) changes on indices were not significantly associated with changes in new COVID-19 cases in Nigeria (ρ ranged from -0.01 to 0.04, p-value > 0.05 for all correlations). The associations between the stringency and government response indices and changes in COVID- 19 deaths were statistically significant (p-value = 0.03 and 0.01, respectively) and the correlation for containment and health index trended towards statistical significance (p-value = 0.06). These associations may indicate that more positive changes in the index scores may have been associated with an increase in deaths compared to the previous week. One hypothesis is that a rise in cases may have triggered an increase in response, but community transmission may have already led to an increase in deaths from the previous week. However, this is a relatively weak correlation as ρ ranged from 0.16 to 0.22. Seven-day lag correlation analysis for Rwanda and Zambia did not yield statistically significant associations with changes in new COVID-19 cases or deaths. Spearman correlation coefficients ranged from -0.06 to -0.01, p-value > 0.05 for all correlations in Rwanda, while the range for Zambia were much narrower 0.06-0.08, p > 0.05 for all correlations. This

indicates there was no monotonic relationship between change in index scores and changes in cases and deaths the next week.

Comparatively, correlational analyses showed that changes to containment and closure measures made in the preceding two-weeks were not significantly associated with changes in new COVID-19 cases in Nigeria ($\rho = -0.11$, p-value > 0.05), but there was a weak, negative monotonic relationship between changes in stringency index scores and COVID-19 cases, indicating that an increase in stringency index score 2-weeks prior may have led to a decrease in the seven-day moving average of cases ($\rho = -0.21$, p-value $= 0.02$). Like the 7-day time lag analysis, prior changes in? the indices were positively correlated with later changes in new COVID-19 deaths in Nigeria, indicating that greater increases in index scores were associated with more positive changes (i.e., an increase) in deaths (ρ ranged from 0.18 to 0.25, p-value < 0.05 for all). Conversely, changes 2-weeks prior in index scores were negatively correlated with later changes in new COVID-19 deaths in Rwanda (ρ ranged from -0.12 to -0.11), albeit this was a very weak correlation. In Zambia, changes 14-days prior in index scores were positively correlated with changes in new cases (ρ ranged from 0.19 to 0.20, p-value < 0.05 for all).

Table 4.20. Spearman correlations between indices and cases and deaths across 3 countries.

	Indices		Nigeria		Rwanda		Zambia	
			Change in New Cases	Change in New Deaths	Change in New Cases	Change in New Deaths	Change in New Cases	Change in New Deaths
7-Day Time Lag	Stringency	ρ	0.01	0.19	-0.01	-0.02	0.06	0.08
		p-value	0.87	**0.03**	0.88	0.65	0.41	0.27
	Government Response	ρ	0.04	0.22	-0.07	-0.04	0.07	0.07
		p-value	0.60	**0.01**	0.17	0.48	0.34	0.32
	Containment and Health	ρ	-0.01	0.16	-0.06	-0.04	0.07	0.07
		p-value	0.94	0.06	0.23	0.49	0.33	0.32
14-Day Time Lag	Stringency	ρ	-0.21	0.18	0.06	-0.11	0.19	0.00
		p-value	**0.02**	0.05	0.25	**0.04**	**0.01**	0.99
	Government Response	ρ	-0.05	0.25	0.03	-0.12	0.20	0.02
		p-value	0.59	**0.004**	0.53	**0.02**	**0.003**	0.81
	Containment and Health	ρ	-0.11	0.18	0.03	-0.12	0.20	0.02
		p-value	0.20	**0.04**	0.53	**0.02**	**0.004**	0.79

Note: 'change' refers to the change in the 7-day moving average of index scores and case/deaths from either 7-days prior or 14-days prior.

Summary

The results of core goal three examined the relationship between prior changes in implementation of NPIs and COVID-19 cases and deaths, using two-time lags and seven-day moving averages. Spearman's correlation coefficients allowed us to examine the monotonic relationships between the changes in 7-day moving averages of individual containment and closure, and health systems NPIs and COVID-19 cases and deaths in each country. Initially, the hypothesis was that there would be a monotonically decreasing relationship between NPIs and cases/deaths, where a positive change in NPI level would lead to a decrease in cases or deaths. However, this analysis did not reveal meaningful negative correlations between changes in the individual NPIs and cases and deaths using both the 7-day and 14-day time lags.

Research Objective Four

While the quantitative data shows the differences in stringency, government response, and different types of NPIs, the qualitative data allows for a deeper understanding of the nuances of public health and social measures in the three countries. In addition, the qualitative data provides rich information on the barriers and facilitators of implementing NPIs during the pandemic. The goal of research objective four was to understand the facilitators and barriers in implementing NPIs during the COVID-19 pandemic in Nigeria, Rwanda, and Zambia. To achieve this goal semi-structured interviews were conducted with decision makers and others involved in the COVID-19 response in Nigeria, Rwanda, Zambia, or at the regional level at WHO AFRO. Data were collected and analyzed using grounded theory approach.[171] Thematic analysis using inductive coding was used to systematically extract key themes as they emerged throughout analysis. An iterative process was used to develop a comprehensive codebook. During the initial coding phase, first-order codes were developed, while secondary coding allowed for grouping of first-order codes into themes. Quotes attributed to specific themes related to research objective 4 were extracted. A summary of the qualitative results can be found in Table 4.22.

Table 4.22. Outcome and themes from qualitative interviews	
Outcome	Themes
Types of NPIs implemented	• Mask mandate • Travel restrictions • Restrictions of gatherings • Movement restrictions • Lockdowns • Curfews • Closures of schools and businesses • Handwashing • Public health campaigns
Successes in implementation	• Capacity building • Coordination • Government leadership • Timing of implementation • Strong enforcement
Challenges in implementation	• Limited access to essential services • Lack of adherence and compliance to measures • COVID-19 fatigue • Perceived severity of COVID-19 • Socioeconomical impact of pandemic • Lack of enforcement
Lessons learned and recommendations for future epidemics or pandemics	• Engagement of community • Leveraging existing resources • Preparedness and capacity building

Types of NPIs Implemented

Participants were asked what types of NPIs were implemented in either Nigeria, Rwanda, Zambia, or larger African region for WHO AFRO participants. Participants in all three countries mentioned mask mandates, hand washing, physical distancing, school, and business closures, including the closure of markets, public information campaigns, and restrictions on movement and large gatherings.

> *"We have come up with what we're calling the five golden rules which involve handwashing, maintaining social distance from people, staying at home, and avoiding crowds, and masking itself." Participant 1, Zambia*

> *"…we had [school and business closures and travel restrictions] at the beginning, but it was not throughout the country. We had it in the epicenters, like two or three states where the epidemic was spreading widely. We had it there. Schools were closed. Markets were closed—but on and off, not really fully." Participant 1, Nigeria*

> *"If you may recall the countries in Africa tried to limit the first wave of the response by implementing some of these public health and social measures. For majority of the countries, they physically closed their borders, international airports, land crossings, and their seaports…some countries implemented what we call partial lockdown…they selected high risk areas and implemented lock downs in those places, and then the other places were left open." Participant 1, WHO AFRO*

Participants in Rwanda heavily emphasized the implementation of total lockdowns and strict curfews that were implemented throughout the pandemic when there were upticks in cases.

> *"People were told to remain at home and the markets were closed, those who were selling food were allowed to open at 50%. The transport was also stopped. There were no motor bikes allowed to operate in the country. Public transport was also not open sometimes. During a point of the confinement public transport was allowed at 50% capacity not at full capacity." – Participant 2, Rwanda*

> *"…it was just a total lockdown…there was no one outside…it was the police in every village…we have the local government, and everyone was involved in making sure that the lockdown was imposed…you could see on the road that there was no one, except for people who were going to buy food and they have to have a clearance from the village leader that they are going to the market, so it was very strict, the total lockdown.– Participant 1, Rwanda*

> *"…strict lockdown twice…first one was about for six weeks, second one was a bit softer but for about four weeks, curfews—the strict six weeks lockdown was replaced by curfew at 6pm, then it became 7pm, then 8pm, then 9pm, back to 7pm, now it's midnight. Since COVID hit the country, curfew has been in place. Complete closure of all the bars, discotheques, clubhouses." – Participant 3, Rwanda*

Participants in Zambia mentioned quarantine of international travelers in the early days of the pandemic, since Zambia never officially closed its borders to travelers, which varied from Rwanda and Nigeria who had both closed their borders for international travelers, especially those arriving by air. Participants from WHO AFRO discussed early measures undertaken in the region emphasizing travel restrictions and lockdowns, the latter of which Rwanda was the first country in Africa to implement.

> *"I must mention that Zambia never closed its borders to travelers we never did that and at no point said we've been closed. We've always had our borders open, but we've periodically update countries we deem as high-risk countries and travelers from these countries are required to quarantine." Participant 1, Zambia*

> *"…these countries [Nigeria, Rwanda, and Zambia], aside from Zambia, had closed their borders at one point or another to international travel—well including Zambia I guess, Zambia briefly closed and opened its border…this issue of national lockdown started with Rwanda... basically, limiting every movement within the country, in addition to the international travel restrictions…for countries that did the total lockdown you cannot even come out. There are police and military people outside, aside from essential health workers…if I'm a health worker, for instance, and I want to go to the hospital, you have to show your pass for you to move when they did the national lockdown in most of those countries." Participant 1, WHO AFRO*

> *"These include closure of the airport, all borders for quite some time…four or five months, if I'm not mistaken, Significant reduction in in-country and out-of-country travel. Any traveler arriving to Rwanda is required to do mandatory isolation in a hotel, until the PCR test on-arrival comes back negative. You know about the mandatory PCR tests across all countries in the world, and Rwanda is different because they do tests upon arriving at the airport and you're not released from the hotel unless your test is negative." Participant 3, Rwanda*

Participants mentioned travel and movement restrictions at land borders, which posed a challenge as African borders are porous with lots of cross-border crossings.

> *"And then our district (Burera, Rwanda) is bordering Uganda, so there was there is usually a tough moment at this moment, was talked about there were a lot of illegal crossings between Uganda and Rwanda, and there were a lot of cases" – Participant 1, Rwanda*

> *"…lockdown…especially Rwanda, it has locked down either between countries, or you know in Africa our borders are very much artificial. We live across borders. But also, the lockdown within the country." – Participant 2, WHO AFRO*

Successes in Implementation

Participants were asked to describe what they would classify as the top three successes in terms of NPI implementation. Themes that emerged from this question included capacity building, closure of social places to reduce spread, coordination, government leadership, mask mandates, and timing of NPI implementation. WHO AFRO participants and others noted that Africa and the countries of interest were able to delay the proliferation of COVID-19 compared to other parts of the world due to early timing in implementation of NPIs.

> *"…one of the successes, was the African leadership, especially at the country level, that national leaders showed their leadership in managing COVID. Why am I saying this? Because contrary to what happened in many other countries in other regions, African countries actually took these measures very earlier on in the response So, I always say, especially in the first phase of COVID, that Africa was, and still is now, among the least affected. Of course, there are many factors that may explain this, but I'm convinced that one of the reasons is because national authorities, took not only the right decision, but the right decision at the right moment."-Participant 2, WHO AFRO*

> *"…it gave Africa the opportunity to build or enhance capacity…basically they were able to buy time to build more capacity…you buy time, you're able to build more capacity, more beds, they were able to establish more isolation centers, while the cases were still building up across the continent. So, this was definitely a benefit." – Participant 1, WHO AFRO*

Countries like Rwanda were able to buy time by implementing and enforcing stringent measures that were aimed at limiting the importation and spread of cases. The delay allowed for countries to build up their capacity and avert overwhelming already fragile health systems. However, this was very different from what occurred later in the third wave

in Nigeria, Rwanda, and Zambia, as well as across the African region, where new variants and easing of restrictions led to massive spread and a drastic increase in cases and deaths that overwhelmed the health systems.

> *"I'm happy you mentioned countries like Rwanda, those are for me countries that took these measures very early in the response. Some of the countries took these measures before even getting a single case of COVID." – Participant 2, WHO AFRO*

> *"If you look at the epi curve before the second and third wave, you'll see that Africa was least affected during the first wave…despite the fact there was not much capacity for ICUs and all that…we did not have the health system overwhelmed during our first wave. The health system was still able to manage with those cases which is different from what we are seeing in the third wave, for instance…the health system was able to avert the condition we saw in the third wave—where the entire system was overwhelmed, ICU beds were full, and all that…we didn't see that during the first wave." – Participant 1, WHO AFRO*

Government leadership as well as overall coordination also emerged as themes. Rwanda was lauded by WHO AFRO participants as a country who took not only stringent measures but ensured that the measures were enforced. Participants in all three countries also identified multisectoral collaboration and coordination within government as a success. Two of the three participants from Zambia also emphasized the role of statutory instruments that were enacted by Parliament which allowed for public health officials to inspect public premises, such as bars and restaurants. Participant 1 talked about the statutory instruments which were enacted by the Minister of Health. They mentioned that the first statutory instrument made COVID-19 a notifiable disease which triggered other regulations under Zambia's Public Health Act while the second statutory instrument

> *"…provided specific guidelines that gave additional power to the government to enforce adherence to these measures, so for instance, gave power to the Minister*

> *to abolish congregate settings…to say for instance you may not meet as a public gathering unless you have been granted authority by a public health officer."*

However, the second statutory instrument was later amended by a third statutory instrument which amended a specific clause in the second secondary instrument.

> *"[There was] a clause in the second [statutory instrument] that had indicated that a gathering of more than 5 people needed to have permission from a public health official and that meant we couldn't hold our Parliament for instance because there are more than 5 members of Parliament, so that was in conflict, and it meant they were in breach of public health regulations. So, what it did was to correct that statement and say any public gathering must be authorized by public health official and removed the restriction of the number of people involved. That way, you could deal with any public gathering on a case-by-case basis, whether it is a church gathering, a wedding function, a kitchen party, bridal ceremony, they have to appear on a case-by-case basis, and then they could be granted authority to gather or not." – Participant 1, Zambia*

In Rwanda, the general public received updates from the Cabinet meetings on a regular basis. Notices of new or revised measures were published on social media, broadcasted on the radio, and published in other media. The announcement usually came as unified message from the Ministry of Health, Ministry of Local Government, and the police.

> *"All these non-pharmaceutical interventions are possible with a good communication strategy… Rwanda is a country between Burundi, Tanzania, and DRC, and in those three countries, apart maybe from DRC, there were no measures for COVID prevention. So, if your neighbors are not doing something but you are doing it then you have to make sure you are doing it the right way and explain why you are doing things that others are not doing." – Participant 2, Rwanda*

> *"I think one of the things I would say is a collaboration…multisectoral collaboration. It has been great…they publish the notification to social media, they go on the radio, they publish what are the revised measures. And it is usually from the Ministry of Health, Ministry of Local Government, and the police and all three go to the media then they say how these measures are going to be followed. That has been key. Because whenever we had a patient with COVID, we have the police car and they involve the mayor, they involve the executive secretary, I think the multi sectoral collaboration has been very key…" -Participant 1, Rwanda*

Similarly in Zambia, coordination using the Incident Management System as well as intra-government collaboration between the various Ministries allowed for unified messaging around new measures.

> *"The Incident Management System has been very crucial in ensuring that we have a coordinated response that incorporates the partners and serves as a communication platform where we are able to share information with our partners, identify any gaps we have in the response and assign roles amongst ourselves as to who will tackle what that's missing in the response." Participant 2, Zambia*

Participants also noted that capacity and coordinated efforts put in place for other diseases such as Ebola allowed them to capitalize on existing resources, including human resource and infrastructure. This also allowed for additional capacity building as the pandemic went on.

> *"For Zambia, we were privileged in that there were cases of Ebola in a neighboring country and because of that we had…this is prior to 2020 before COVID-19…we embarked on a mission to train rapid response teams in all the provinces in the country, and that became helpful when the pandemic struck because it meant we were at least one step ahead in our preparedness efforts, we had rapid response teams we could deploy at short notice. They had some basic trainings in PPE, IPC, they knew how to put on full PPE, and that was really helpful, and it made a big difference for us…" -Participant 1, Zambia*

> *"…when COVID broke out here, I think we had only 2-3 testing centers across the country. A country like Nigeria that has about 200 something million people, we had only about 2-3 testing centers. These testing centers were there because of the experience we had with Lassa Fever and Ebola." – Participant 2, Nigeria*

> *"One of the successes was the technical skills that we had as a country and our ability to be able to carry out capacity building…I would definitely say we've strengthened our systems; we've built our resilience as a country from being able to carry out this response. And I think the beauty of it is that the investments we've made the gains we've made do not only serve as beneficial for COVID, but for other public health priorities as well." – Participant 2, Zambia*

There were a couple of participants in Nigeria and Zambia who did not feel that there were any real successes because compliance and enforcement were major challenges.

> *"Although government claims a few successes that "oh we closed our borders as soon as we could" and we did this, and we did that. But it didn't last. It is one thing to say close the border or check all those who are coming in, and then people are receiving bribes and letting people go. Or some top people will force their way through. So, it was more like a porous border which didn't make any sense to anybody." – Participant 2, Nigeria*

> *"I think that at the national level, I wouldn't say we had successes. I mean really. A few states, until the government introduced the idea that you couldn't come into public places without your mask, nobody believed it. But then also as I mentioned, even though you put a notice "no mask, no entry", as soon as they enter, they remove the mask. So, I wouldn't call that success. I really don't think we had successes. It was purely not complied with…majorly not complied with at all." - Participant 1, Nigeria*

> *"I don't think it (closure of social places) had any impact in slowing down the epidemic because everything else was open, and the same people who didn't go to the bar, went to another event somewhere or were with friends without masks. So, in the grand scheme of things, I don't think they succeeded…you know what we claim as successes were not really success stories." – Participant 3, Zambia*

However, in Rwanda, enforcement was mentioned as a success several times. This success was attributed to both the strict enforcement by the government and the high compliance of the Rwandese people as a population that respects its government.

> *"Quarantine…it's quarantine full-stop…nobody goes out unless you apply online for a certification you have to download, reach out to the federal police, and you get permission—even to go for shopping. To go to the airport, you have to ask specific permission, they respond right away. So that's how they enforced it…it is the rule of the land. Full stop. You wear a mask; you wear a mask. You get vaccinated, you get vaccinated, unless there is a medical reason otherwise. There's a curfew, there's a curfew. Full stop." -Participant 3, Rwanda*

> *"…people are now clear that these things work. We have seen that all the time that when you have spike in cases they impose these partial lockdowns, they stop weddings, they decrease the number of people who go in public transport. It works. We see that there is a decrease in number of cases and is decreasing in death, so I think people have learned that these measures actually work. Because we have done this multiple times. All the time when you have a spike in COVID cases they impose the rules and then it goes down" – Participant 1, Rwanda*

> *"…the enforcement piece I could say that there were radio talks about any of the measures that were put in place by the government and local entities were in charge of making sure these measures are respected by the general population." – Participant 2, Rwanda*

> *"Number one, the culture of the country by itself. Rwandans obey the rule of law. Obey their government. If there's a policy, it's respected, generally. Even without an enforcer, without the involvement of the police, of law enforcement, it is generally accepted. That's the main thing. The second thing is they're very strict. Walking without a mask is I think $30. I've seen several people getting penalized right in front of my eyes in Kigali. So, they don't joke around. If you are caught past the curfew, you will be taken to the national stadium, you'll be kept there throughout the night—that's punishment in addition to $100 payment." – Participant 3, Rwanda*

> *"Like everyone had to be home at 7pm. Right now, the time is 7:45pm and if you go on the road, you won't find anybody. Just that move of respecting the guidelines and the level of cooperation is why I think we're successful." – Participant 1, Rwanda*

Participant 3 and others from Rwanda shared anecdotes about the national stadium, where people in Kigali were taken if they were found to be in breach of the COVID-19 public health and social measures.

> *"At a time, I think I saw the entire contingent…the bride, the groom, the bride's friends and family…I think about 50 people ended up overnight in the stadium. I think it was a non-authorized wedding...hidden somewhere in a hotel…but they were caught and penalized for it. So, they don't joke around, if a policy is made, if they make a certain law, it is generally respected…the government doesn't joke around…there is no carrot, but there is always a stick. [There was enforcement] one hundred percent. Without exception. Without exception. I really would be surprised if there is a single individual in Rwanda who walked outside without a mask and did not get penalized. I will really be surprised." – Participant 3, Rwanda*

> *"…people were asked to pay [a fine] if they trespassed the law…they would also take you somewhere where you would be educated on COVID and COVID consequences so that you don't do that again…of course, we cannot miss some of the people who were not abiding to the measures, and they were fined most of the time. And as I mentioned, each time someone got fined, there was an education session to that person so that he or she does not repeat the same mistake." – Participant 2, Rwanda*

> *"…there were a lot of consequences, I remember one of the consequences if you went out and they found that you don't have a clearance that you don't have a valid reason to be outside your home, in most of the cases they will take you to the [national] stadium and then you spend the night and then they say they're teaching you COVID rules, but you know spending a night at the stadium, I think you understand how hard that is…I think most of the people were at home, they were following the TV, so they wanted to show all the people who are at home what would happen if they went outside. So, whenever they catch people who are not following the rules, they will display that on the media, so that people at home, understand that going outside is not really good." – Participant 1, Rwanda*

Challenges in Implementation

Several themes emerged regarding challenges in implementing NPIs from participants. The socioeconomic impacts of the NPIs implemented was a major theme. Other challenges included lack of adherence and compliance to measures and perceived severity of COVID-19 by the community. A few sub-themes also emerged. Nearly all participants commented on the economic hardships that certain NPIs such as lockdowns and business closures created.

> *"… overall, the economy was affected, when businesses were closed, everywhere was closed, the economy was affected. Like we said earlier, there was also impact in accessing the services by the general population because of the movement restrictions. So, there are some of the things that were negatively impacted and has put the countries in a tight corner and made them start re-opening the economy and lifting some of those measures." – Participant 1, WHO AFRO*

> *"Businesses really suffered. All nightclubs are completely shut down now, they're completely out of the picture. Many restaurants shut down. And right after the lockdown was lifted, restaurants became very expensive. They had to compensate for the last one full year. That has been a challenge." – Participant 3, Rwanda*

The lack of economic and social support provided by the government were also raised as a major hurdle in implementation, especially in Nigeria and Zambia where measures were not uniformly implemented or enforced. Several participants noted a terrible choice many

citizens faced: do I die of hunger at home or die of COVID-19?

> *"…when you lock people down without providing for their means to survive. Because people were saying that it is better to die of COVID than to die of hunger. That was a common thing that people were saying here. "Oh, let me go and get this disease than die of hunger at home." – Participant 2, Nigeria*

> *"And also, you know the choice between I'm staying at home or going to hustle on the streets to make a living. It was easier for people to just choose to go and hustle on the streets so they could feed their families…" – Participant 3, Zambia*

> *"But again, taking the lesson from the first wave, what we said is we have to take into account the vulnerability of our people, because otherwise, if the measure themselves become a barrier for them because of their social economical vulnerabilities then we are making the situation even worse. We can make, the situation actually worse." – Participant 2, WHO AFRO*

> *"But it was also hard for people who are doing business, people who are making a living on daily basis. And it was very hard. Especially when we are talking about total lock down when no one was moving, there were cases of people who were really hungry and they have to call the government and the government had to assist them with finding food, so it was not easy." – Participant 1, Rwanda*

> *"…there is no social security system that caters for people's personal needs. People have to go out daily to work, to earn their living. So [lockdowns] met a steep resistance so after a while the government had to abandon that. As it is now, no one even talks about a lockdown. The attempt really is to restrict number of large gatherings." Participant 2, Nigeria*

Social determinants of health such as poverty, lack of access to water, overcrowding, and food insecurity were major sub-themes that emerged. Poverty was mentioned by nearly all participants as a major challenge in terms of both implementation and adherence.

> *"…the main challenge was the poverty of the population which made them want to go out and work for something, and sometimes people lacked food and the government tried to chip in and help those who are not able to get food on a daily basis." – Participant 2, Rwanda*

> *"…the challenges have been number one poverty. There are several people in Africa, Rwanda included, that depend on day-to-day wages. Take the earnings of motorcycle drivers, taxi drivers, day-laborers, farmers. Quarantine for them has been a huge, huge blow, a huge blow. Vis-a-vi other African countries did not*

implement quarantine. I think it was only Uganda and Kenya that did so. So that has been a big challenge." – Participant 3, Rwanda

"…the biggest problem really number one was poverty. I remember that people were asked to wash their hands every 20 seconds. But how do you wash your hands every 20 seconds if you don't even have running water and you can barely get 20 or 40 liters for your daily chores at home? …you have 20 liters of water you're not going to use water to be washing your hands in between every hour or so. You're going to use it for cooking or for drinking or for cleaning the house or something like that and not for washing your hands every hour." – Participant 3, Zambia

"And then you also want to look at the fact that when you tell me wash your hands, and there's no running water in your area, how are you going to wash your hands? Or when you say keep a safe distance and then you have a family of 6 living in a room, how are they going to keep a safe distance? And you have the whole block of single room apartments which is packed with so many people. Or in the marketplace, how do you keep distance in the market? So, some of the non-pharmaceutical interventions were not implementable because of the environment we are in." – Participant 1, WHO AFRO

"In the village if we need people to wash hands, then let us support them. Then let us support the community in washing hands. How are we going to support? By providing soap or providing even water in some communities. If we want them to wear a mask then let us support them, maybe providing masks because if you need to give children [going] to school masks, then that costs the parents, especially again or those earning the least, it is costly, if you put, I don't know $0.25 per day, that's a lot of money for several African households." – Participant 2, WHO AFRO

This also brought up a theme related to perceived severity of disease. Several noted that media outlets, especially in the West, had emphasized that when COVID-19 reached Africa, it would create complete catastrophe. When this was not the case in the first and second wave, many did not perceive COVID-19 to be a major threat and did not find the strict measures to be justified. These feelings were further intensified by misinformation, and in the case of Nigeria, major distrust in the government.

"…the governments to their credit saw the danger for the countries because our health system will not cope with the level of infection rate that we were seeing in other countries, so if that happened in Africa that would be catastrophic…because actually that's what we predicted, even WHO, we said we are likely going to see

dead bodies on the street so maybe the national authorities kind of put more emphasis on, we have to implement [these measures]." – Participant 2, WHO AFRO

"First of all, I'm sad to say that the major challenge was the people didn't trust the government. Two, they didn't believe there was COVID because people were not dying because the wrong impression was created that when COVID came to Africa it was going to kill everybody, and so when they didn't see any dead bodies then they just assumed that there was no COVID. And there was a lot of fake information and things about COVID, which people took as truth." – Participant 1, Nigeria

"…the number one challenge is the people's perception of the disease itself because despite all the government did to make people understand how the disease is caught, you will hear people say it is a scam, that it is an attempt for government to just make money out of donors, that there's no such disease as COVID… there was buy-in initially but because of these fear…the fear that the government cannot be trusted, because people think they had what they call "hidden agenda." They didn't believe that the disease was there. Government officials just want to make money, so they just brought this thing that there's a disease and all that. So, the buy-in is not like it was usually compared to HIV, or polio, or other preventative healthcare. COVID was completely different." – Participant 2, Nigeria

Lack of compliance and adherence to NPIs was also a major theme that emerged. A sub-theme was the issue of "COVID fatigue."

"We had quite a number of countries where hospitals got overwhelmed because all of these measures were relaxed, children have gone back to school, businesses have been opened, and the government was depending on the general population to observed the social measures to wear their mask, to keep their distance, keep up with hand hygiene, avoid mass gathering…but you know like I said, when the pandemic fatigue set in, the adherence to those measures was difficult" – Participant 1, WHO AFRO

"…everybody likes to care for their own health, so people will embrace anything that will prevent them from having a disease. But when the disease is open-ended…like when will this end? And we cannot live our lives. So, people started thinking, no. And resistance from organizations, like there are churches now that resist the non-pharmaceutical interventions against COVID." – Participant 2, Nigeria

"We did get instances of people being holed up and you could tell that the person wasn't at home. People would go back to the issue of livelihood so "I'm a

> *breadwinner I can't be home the whole time" and things like that., Similarly, even with the facilities, we still have some challenges with people leaving the facilities against medical advice, so I think part of it was due to people not being psychologically prepared for the experience." – Participant 2, Zambia*

In Zambia, the pandemic also coincided with a particularly tense election year, which brought its own challenges in terms of adherence to measures.

> *"…, it's been an election year for Zambia. This is unique to us so we had political gatherings that I think needed time…they didn't really adhere to us under our recommendations, or they said in principle they would accept that, and then just went ahead and did whatever they wanted to do. So, it was rather a challenging time. And we had large gatherings, political gatherings, that was a big challenge for us to manage adherence to COVID-19 regulations, as well as ensure that there is a democratic electoral process running side by side." – Participant 1, Zambia*

Whereas enforcement was a success in Rwanda, enforcement was a major challenge in Nigeria and Zambia. The length and protractedness of the response have had major consequences in terms of compliance and adherence to several public health and social measures that were being implemented at various points throughout the pandemic, not only by the community but some participants mentioned government figures themselves were not adhering to these measures they were supposed to be enforcing.

> *"Rwanda was the first country to implement the national lockdown. And when they implemented the national lockdown, they said there is no movement and there was no movement, and they were pretty much enforcing it. In Nigeria, they had a period of lockdown which was not very, very long. They also had closed inter-city travel but once they lifted those measures, people started moving around. Also, all the countries you have mentioned, had closed schools, businesses, restaurants. But they had to reopen because of the economy, and some of them had to close of those places again when they started having new waves. I will say Rwanda was more stringent definitely, comparing it with Nigeria or Zambia…more stringent and more effective I would say than the other countries." – Participant 1, WHO AFRO*

> *"I mean the way it was enforced was more of you know a political show because it's the politicians, like I remember vividly the Lusaka provincial Minister would go out and stage roadblocks and threaten people and bus drivers, but it was all just for the TV, you know for the cameras. By in large the enforcement did not work at*

all, it doesn't work even now. I mean the rule are there, everybody knows, we have a lot of publicity that we need to wear masks, social distance, you need to wash your hands. But then you know it's not been enforced. It's all dependent on people's good will." – Participant 3, Zambia

*"…there were not really [consequences for lack of adherence] …well they put it there…but complying with the law and enforcing is one thing…on a few cases here and there they did. But it didn't last. In about a week or two everybody had forgot, and they went back…even the guy who is supposed to be enforcing it is not wearing a mask *laughs*" – Participant 1, Nigeria*

"For places of worship, they are now back to their old, crowded form despite the regulations. Because the latest law was no gathering of 50 or more people, but I was in church on Sunday, and I think we were more than 2,000 in that gathering so that's how it is. So, there is no consistency or uniformity in the enforcement. Like every state or local government can do whatever they felt like implementing."– Participant 2, Nigeria

"…so, the community didn't outrightly protest these measures. We didn't have like protests where people went up in the streets and said no, but you could tell sometimes in their attitudes toward public health guidelines that they didn't really believe in what we were trying to achieve as a public health sector…and some of the large density populations in the peri urban areas, if you went there, they would just see blatant disregard of the regulations despite posters being around or motor vehicles with the speakerphone going around announcing what to do. You would essentially see nobody wearing for instance a mask, and that just shows you the defiance levels people had, and because we didn't really have people going around arresting you for not putting on a mask for instance, so that was some of the challenges we saw." – Participant 1, Zambia

"…we've been pushing for inspections of public premises and where we find that these are not compliant, they'll either get served a notice or in extreme cases, they will be closed. So, they get served a notice of improvement that outlines the things that they need to put in place for them to be considered compliant so things like having hand washing stations in place or things like that." – Participant 2, Zambia

Political structures and dynamics also played key roles in implementation of NPIs. In countries like Nigeria and Zambia, where there is a decentralized government, enforcement was much more difficult than in a country like Rwanda, which has a very centralized government.

> *"Over time, there was no consistency in the enforcement and no uniformity between States. Some States tended to take it more seriously than other States. But on the part of the Federal Government of Nigeria, the government had been the one really wielding the big stick. The States were left to do what they felt like doing because at first when the [federal] government tried to send down regulations right from the country's capital, some State governments saw it as upfront to their own rights because the body governance and the president were elected so they didn't like the idea of a [federal] government official trying to decide what happens at the State level. So, the States were left to do what they wanted to do. So, no uniformity across the country. Some States never had lockdowns even for one day, one or two states never had lockdown while a state like Lagos for example had severe lockdowns and up to now, I think there are some restrictions on how many people will be allowed in certain places… like I said, it is not uniform across the country, and the way it is enforced is different from one place to another." – Participant 2, Nigeria*

> *"It also depends on the political structure of the country. What do I mean by the political structure of the country? If you look first at the countries that are more centralized, and the national authorities have more power over the administrative and sub national entities, the measure was more likely to get applied in a uniform way across the country. Whereby when you have a country more decentralized, where sub-national entities have more power in terms of health and dealing with health, these measures kind of suffered a little bit with their application on the ground not being uniform. Of course, Nigeria. Nigeria is a very complex country where it has federal [territories] and states. The states have very much power in terms of dealing with the local issues, so the application and implementation of these measures at the local level was a little bit not much uniform in the country. Whereby in countries like Rwanda, it's most centralized, of course with good leadership, the implementation of these measures was very much uniform across the country." – Participant 2, WHO AFRO*

Some participants felt it was hard to control a disease like COVID-19 using just non-pharmaceutical interventions, especially given the social and economic dynamics at play in several African countries.

> *"…these pronouncements in my view were just on paper. On public transport it's very hard to social distance in those minibuses. And then people in the shanty compounds, at those markets it's very hard to social distance…if you have a significant population living in these conditions…even though they know what to do they do not have the means to do it…you have people in this town in some neighborhoods where seven, eight members of the family live in not two bedrooms but a two-room house. So, it is really, really hard to control an infectious disease*

> *like COVID with non-pharmaceutical interventions. I mean that is just my view. It just cannot be done, not in our environment." – Participant 3, Zambia*

> *"I would also like to mention that even though we have these non-pharmaceutical interventions, they can't be successful if you don't have correct treatment, correct education to use, correct sciences around it. If you have a 100 people with COVID and you just rely on non-pharmaceutical interventions, most of those people would probably die, because there is no medication. I would say that non-pharmaceutical interventions go together with pharmaceutical interventions as well." – Participant 2, Rwanda*

However, participant 3 in Rwanda, felt that it could be done but perhaps at a cost.

> *"One it can be done. It can be done. If you have a government that listened by its people then any, as you call it, non-pharmaceutical intervention can be done. It is not fully politicized like in the US. It's not Republican and Democrat. It is the rule of the land. It kind of puts democracy, human rights, and public safety into the picture, which one comes first? Rwanda has proven that such things cannot exist. Government has a duty to protect its people. Full stop."*

Lessons learned and recommendations for future epidemics or pandemics

There were several themes that emerged under lessons learned and recommendation for future epidemics or pandemics. The main themes that emerged were the need to engage communities early on, leveraging existing resources, the need to build capacity, and overall preparedness. The importance of engaging the community and creating buy-in was emphasized as a major lesson learned.

> *"You can enforce, but how long can we continue to enforce? We are better off having compliance when the people understand that this for me, this is going to protect me, and I need to do it, without somebody forcing it on them. So, this is one part that governments need to consider and really look at critically. Getting the people on board, let them understand that this is important for them, and this is a need for their good, and explaining why you're doing it so that they will take it upon themselves to comply with this…not feeling that the government is enforcing, and I have to do it, but let them do it as part of their own responsibility. And this will come when we engage the community, when we pass the right information, and they feel like part of the response. So that is important." – Participant 1, WHO AFRO*

> *"…you start preparing messages to send to communities; the communities should be educated consistently. Like I said before…we have been an epicenter for Lassa Fever, so most of the people here are kind of aware of some of these preventative measures against such diseases. So, the lesson from the past have been very helpful. Even though cases and deaths are going down now, we shouldn't let go of our guard. We should continue with the current tempo of information dissemination regarding prevention and control of disease, so we don't wait until another outbreak before we start." – Participant 2, Nigeria*

> *"But also, another lesson we need to learn is to have good information. I mean like have a strategy of communicating how the diseases spread and make sure that it can be delivered in a way that you to make a difference and people understand it." – Participant 3, Zambia*

> *"One of the biggest lessons to come out of this is around risk communication and community engagements. I think any gains and losses that have been made in this response have been based on how good a job or bad a job we have done around risk communication to the general public. When the perception changes, we've seen high levels of adherence…that speaks to what the role of risk communication really is and has continued to play in this pandemic. We've made strides. We're coming from a time when people believed COVID-19 was a hoax, and we've moved to a point of view where people say it is real, and I can actually die from COVID-19." – Participant 2, Zambia*

> *"When COVID started everyone was not wearing a mask, everyone was saying the masks should be given to the health care providers, but later on it was found that masks were helping people to stop COVID. So, when the leaders said please wear masks, and they put on the masks themselves, it showed that the things they are saying are working. Leadership was key in Rwanda. Also, the communication campaigns around COVID were very key." – Participant 2, Rwanda*

Leveraging existing resources was also noted as another lesson learned. Many participants noted how infrastructure and resources established during other outbreaks and epidemics, which had built capacity, were utilized in the response to COVID-19.

> *"Like we have seen in Africa, majority of the countries actually leveraging the capacities they had from responses to other emergencies, like Ebola and other outbreaks, to kickstart the COVID response. Even the interventions they started at the point of entry, they didn't start from zero, they already had thermal scanners in their airports, because of Ebola. The majority of the countries that were preparing for Ebola, had those things in place. Rwanda was neighboring DRC, so they had capacities in place. Nigeria had responded to Ebola, so they had those capacity in*

place. So quite a number of countries already had something there for leverage upon start." – Participant 1, WHO AFRO

"Then another thing is the health work force. There have been a lot of trainings now. That has helped us from Ebola outbreak of 2014, a lot of workers who were trained to take part in Ebola control, some of them who are still in service, were willing to lend a hand from their experience. It's always good to have people trained, to have your system equipped, so that you don't have crisis at hand." – Participant 2, Nigeria

The need to be prepared and build capacity was a major theme that emerged. Preparedness and capacity building in terms of robust surveillance systems, trained health workforce, and investing in research and development were discussed by participants.

"The lesson is that everyone is at risk if an emergency is happening, no matter how long or how far the emergency is, it will end up in your territory. It's just a matter of time. It is very important to build those capacity. This will include everything, including infrastructure, human resource capacity, and the capacity to have the systems in place for a response whether it is surveillance or whatever it is. We need to have those in place ahead of any emergencies…I hope that we have learned the lesson and we will now start prioritizing to invest in preparing before. Not this fire brigade approach of trying to extinguish the fire when the fire is already burning but anticipating because this gives you an opportunity for any containment." – Participant 2, WHO AFRO

"So, you know building up those surveillance systems where you can really positively determine what is the epidemiology, how is the prevalence and then related to that are the sequencing and probably do this at provincial levels. Such that at any given time you're not going to be second guessing how many cases you have, or what strain is circulating, you are on top of things as far as surveillance of cases is concerned. And that is not limited to COVID. This is now for everything else." – Participant 3, Zambia

"… to be prepared. It was COVID-19 last year, how about COVID-22 or COVID-25. So, it's a sign. It's a sign that anything can go wrong at any time. As a country, probably as a continent, Africa should be prepared, for a catastrophe. In fact, there is always a silver lining to major catastrophe. The country and the continent should probably compile what it has learned from the pandemic, what changes we have brought." – Participant 3, Rwanda

"I think when we think of future pandemics or epidemics, I think we should intrinsically look at from our perspective as a country. We need to invest more into

research and development, and also in emergency preparedness and response efforts." – Participant 1, Zambia

"Number one is to always be prepared. Get the system in place, have the right equipment, have the right trained staff, have communities be aware. So, it's not "oh there's an outbreak." – Participant 2, Nigeria

Summary

The qualitative interviews allowed for a deeper understanding of the facilitators and barriers that influenced the implementation of NPIs in all three countries. Various forces either facilitated or hindered adherence and compliance to these measures. Several challenges were highlighted by participants ranging from lack of enforcement to poverty. The socioeconomic consequences of the public health and social measures that were put in place, especially containment and closure NPIs, cannot be underscored. The protracted nature of COVID-19 with no clear end in sight, even two years later, made it particularly difficult to continue to enact certain measures such as lockdowns and closure of businesses and schools. While NPIs play a great role in minimizing spread of disease, interviews with participants highlighted the complexities at play when trying to implement these measures. Rwanda by far had the most consistent and stringent measures compared to Nigeria and Zambia. Their success in implementation was in part due to strong enforcement and having a population that generally obeys their government. There were several lessons learned which highlighted the need to engage communities early on and create buy-in, as well as the need to always be prepared so that response efforts are proactive rather than reactive when faced with an emergency.

CHAPTER FIVE

Manuscript

TARGET JOURNAL: PLoS Global Public Health

TITLE: Adherence to and enforcement of non-pharmaceutical interventions for COVID-19 prevention in Nigeria, Rwanda, and Zambia: A mixed methods analysis

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BACKGROUND

In a pandemic, non-pharmaceutical interventions (NPIs) are crucial in curbing disease spread, especially in the absence of vaccines and other pharmaceutical interventions.[1] It is widely accepted in public health that early interventions are an important step to halting the progression of a new communicable disease threat.[14] Prior to the COVID-19 pandemic, the impact of NPIs has been largely studied in controlling influenza outbreaks, including the 1918/1919 influenza pandemic.[1,2] NPIs include actions that can be taken by individuals and the larger community. These include frequent hand washing, covering coughs and sneezes, isolating sick persons, contact tracing, quarantining exposed persons, and physical/social distancing measures for the general population.[1,3,4] The latter includes containment strategies such as the closing of schools and workplaces, restricting public gatherings, curfews, quarantine, and maximizing telework (when applicable).

The success of NPIs is dependent on enforcement, political governments, and citizens' willingness to comply with the measures. Until recently, the effectiveness of NPIs

has not been tested systematically. Early measures of efficacy were explored mainly through the use of mathematical models, while few published studies have reviewed the historical evidence on NPI adoption during past pandemics.[1,2,38] A small number of studies have explored the impact of public health interventions and NPIs during the 1918-1919 influenza pandemic, in which NPIs played a critical role in delaying the temporal effects of the pandemic, in addition to reducing the overall and peak attack rate and the number of cumulative deaths.[2,38] How successful NPIs were in limiting disease spread in Africa, especially in the first year of the COVID-19 pandemic has been underexplored in the literature. The degree of implementation and the impact of these NPIs during the COVID-19 pandemic has largely been studied in high-income countries, and there has been limited data in the literature focused on low- and middle-income countries, especially in Africa.[78,81,172–175]

In the absence of treatment beyond supportive care and vaccination for the early parts of the COVID-19 pandemic, NPIs were implemented across the world to prevent and control transmission and spread of SARS-CoV-2. By early March 2020, several countries in Africa (affected and unaffected by COVID-19) began mobilizing in response to the pandemic. This included prompt case identification, information campaigns to sensitize citizens, and building laboratory capacity.[63,64] Some countries relied on innovative strategies such as using locally produced cloth masks, soaps, and hand sanitizers, developing inexpensive diagnostic tests, testing pooled COVID-19 samples, and using drones to transport test kits to and samples from hard-to-reach areas.[60–62] By the end of March 2020, many African Union Member States had imposed travel bans on flights

arriving from certain Asian and European countries.[60] In the following two months, almost two-thirds of African Union Member States had closed their borders to all international travelers, except for cargo, freight, and expatriation of foreign nationals.[60,61] Fifteen countries, including Nigeria and Rwanda implemented border closures before any COVID-19 cases were confirmed.[66] Other NPIs, such as restrictions of movement and public gathering, and closure of schools and workplaces were also implemented across the region.

The present study focuses on three countries in Africa: Nigeria in West Africa, Rwanda in East Africa, and Zambia in southern Africa. These countries were selected to provide variety in geo-political structures, population size, region, and World Bank income classification. This mixed methods study aims to examine adherence and enforcement of NPIs implemented to curb COVID-19 in Nigeria, Rwanda, and Zambia, leading up to the 10,000th recorded case of COVID-19 in each country. Additionally, we aim to broadly evaluate the relationship among the levels/changes in NPIs implemented and changes in COVID-19 cases and deaths.

METHODS

Study design

This mixed methods study utilized a mix of semi-structured interviews and a quantitative dataset constructed using multiple open data sources.

Qualitative method

To understand the potential barriers and facilitators in implementing and enforcing NPIs and how other epidemics within the countries may have affected compliance in NPIs, qualitative data were collected from decision-makers and experts involved in the COVID-

19 response using key informant interviews (KIIs). KIIs were conducted with officials of Ministries of Health, Africa CDC Regional Collaborating Centers, and WHO African Regional Office (AFRO). Recruitment utilized purposive and convenience sampling, including a snowball sampling approach. All KIIs provided verbal consent before the start of the interview. Each KII took on average 30 minutes to complete using Zoom. The audio recordings were downloaded from Zoom and then immediately uploaded to a secure database and deleted from the computer. Transcription took place upon completion of the interviews. Data were collected and analyzed using a grounded theory approach.[171] Thematic analysis using both inductive coding was used to systematically extract key themes in an iterative process as they emerged through the analysis process. An iterative process was used to develop a comprehensive codebook. During the initial coding phase, first-order codes were developed, while secondary coding allowed for grouping of first-order codes into themes. Quotes attributed to specific themes were extracted. Both coding and analysis were conducted using NVivo Release 1.6 Mac Edition.

Quantitative Methods

A time-series dataset was constructed using multiple open data sources. Observations for each variable were recorded daily beginning on January 1st, 2020, for each of the three countries (Nigeria, Rwanda, and Zambia) and ending on the date when each country surpassed its 10,000th case. While most studies exploring the effect of NPIs have focused on 100 cases as the outbreak threshold, this study uses four case windows to gain a broader picture: no cases (W_0), 1-100 cases (W_1), >101-1,000 cases (W_2), and >1,001-10,000+ cases (W_3)). New and cumulative cases during this time period were

obtained from the COVID-19 data repository by the Center for Systems Science and Engineering at Johns Hopkins University.[176] In addition to COVID-19 case and death aggregates, the dataset also includes variables from the University of Oxford COVID-19 Government Response Tracker (OxCGRT), which collects publicly available information on 20 indicators in different areas, such as containment policies, economic policies and health policies in more than 150 countries since January 2020.[97] Data are collected in real-time and from publicly available sources in each country. The OxCGRT dataset utilized in this paper was downloaded in March 2021.

This paper focuses on two policy indices calculated by the OxCGRT, the stringency index (SI) and the containment and health index (CHI). Table 5.1 shows which variables were included in each index. The SI records the strictness of closure and containment policies using 9 indicators, which include lockdown policies, primarily aimed at restricting certain behaviors, while the CHI includes all the ordinal variables from the stringency index and additional variables focused on mitigating the health consequences of COVID-19 (e.g., testing, use of facial coverings outside the home, and contact tracing).[97] The methods and calculation of indices are described elsewhere by Hale et al.[97] Broadly, both indices aggregate the data of individual policy measures into a single number, between 0 to 100, that reflects the level of a government's response along certain dimensions to measure the indicators upon which a government has acted, and to what degree.

Table 5.1. Non-pharmaceutical policy variables used in OxCGRT index calculation

Variable	Description	SI	CHI
C1	Record closings of schools and universities	X	X
C2	Record closings of workplaces	X	X
C3	Record cancelling public events	X	X
C4	Record limits on gatherings	X	X
C5	Record closing of public transport	X	X
C6	Record orders to "shelter-in-place" and otherwise confine to the home	X	X
C7	Record restrictions on internal movement between cities/regions	X	X
C8	Record restrictions on international travel (this records policy for foreign travelers, not citizens)	X	X
H1	Record presence of public info campaigns	X	X
H2	Record government policy on who has access to testing Note: this records policies about testing for current infection (PCR tests) not testing for immunity (antibody test)		X
H3	Record government policy on contact tracing after a positive diagnosis Note: Policies include only those that would identify all people potentially exposed to COVID-19		X
H6	Record policies on the use of facial coverings outside the home		X
H7	Record policies for vaccine delivery for different groups		
H8	Record policies for protecting elderly people (as defined locally) in Long Term Care Facilities and/or the community and home setting		X

To examine the degree of implementation of NPIs relative to the four case windows, we used plots and descriptive statistics (means and standard deviations) stratified by the case windows. Indices were compared across case windows using analysis of variance (ANOVA) models with post-hoc comparisons (p-values adjusted using Tukey's method). All analyses were performed using SAS statistical software version 9.4 (SAS Institute Inc., Cary, NC).[170]

Ethical Considerations

IRB exemption was granted on May 5, 2021, by the Boston University Medical Center Institutional Review Board (IRB number: H-41329).

RESULTS

Quantitative findings

It took Rwanda less time to surpass the first 100 cases (21 days) compared to Nigeria (30 days) and Zambia (43 days); however, it took Rwanda substantially longer to surpass 10,000 cases (379 days) than Nigeria and Zambia (152 and 232 days, respectively). All three countries experienced an exponential rise in cases after surpassing 1,000 cases of COVID-19.

An examination of SI scores from January 1st, 2020, until each country surpassed 10,000 cases, reveals several important differences across countries (Tables 5.2a–5.2c). In Rwanda, the average score of the SI from January 1st, 2020, until it surpassed 10,000 cases was 61.1 out of 100 (SD = 26.6, median=73.2) indicating sustained moderate stringency on measures. In contrast, Nigeria and Zambia had average scores of 42.1 (SD = 37.1, median=11.1) and 34.3 (SD = 22.3, median=43.5), respectively. In Nigeria, a Tukey post hoc test shows the mean SI scores in case windows W_2 (SI=83.0) and W_3 (SI=84.6) were statistically significantly different ($p<0.0001$) when compared to W_0 (SI=6.2). However, there was no difference between the mean SI scores between W_2 and W_3 ($p=0.85$), indicating stringency scores stayed relatively around the same level after the 100th case. In contrast, in Zambia, the mean SI scores in case windows W_1 (SI= 49.5), W_2 (SI=51.2), and W_3 (SI=47.4) were significantly different ($p<0.0001$) than W_0 (SI=5.6), indicating that Zambia's stringency levels varied post-identification of the index case compared to pre-identification. However, there was no difference between the mean SI scores across case windows W_1, W_2, and W_3, suggesting that the stringency levels in how the measures were

implemented stayed relatively stable despite cases increasing. In Rwanda, mean SI scores in W_1 (SI=73.2) and W_3 (SI=70.3) were statistically significantly different ($p<0.05$) when compared to W_2 (SI=79.5). However, there was no difference between the mean SI scores between W_1 and W_3 ($p=0.53$) suggesting that the stringency levels were similar in terms of which measures were implemented during W_1 and W_3.

Table 5.2a. One-Way Analysis of Variance of the Stringency Index Score by Case Window, Nigeria

				Tukey's Post-hoc Comparisons			
Case Window	*n*	Mean	*SD*	**W_0**	**W_1**	**W_2**	**W_3**
Pooled	152	42.1	37.1	-	-	-	-
W_0	58	6.2	5.1		<0.0001	<0.0001	<0.0001
W_1	30	22.3	16.3	<0.0001		<0.0001	<0.0001
W_2	26	83.0	0.6	<0.0001	<0.0001		0.85
W_3	38	84.6	0.6	<0.0001	<0.0001	0.85	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days, *SD:* standard deviation

Table 5.2b. One-Way Analysis of Variance of the Stringency Index by Case Window, Rwanda

				Tukey's HSD Comparisons			
Case Window	*n*	Mean	*SD*	**W_0**	**W_1**	**W_2**	**W_3**
Pooled	379	61.1	26.6	-	-	-	-
W_0	73	10.9	7.6		<0.0001	<0.0001	<0.0001
W_1	21	73.2	25.6	<0.0001		0.04	0.54
W_2	86	79.5	8.6	<0.0001	0.04		<0.0001
W_3	199	70.3	7.5	<0.0001	0.54	<0.0001	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days, *SD:* standard deviation

Table 5.2c. One-Way Analysis of Variance of the Stringency Index by Case Window, Zambia

				Tukey's HSD Comparisons			
Case Window	*n*	Mean	*SD*	**W_0**	**W_1**	**W_2**	**W_3**
Pooled	232	34.3	22.3	-	-	-	-
W_0	77	5.6	7.9		<0.0001	<0.0001	<0.0001
W_1	43	49.5	14.7	<0.0001		0.87	0.63
W_2	27	51.2	12.1	<0.0001	0.87		0.25
W_3	85	47.4	5.1	<0.0001	0.63	0.25	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days, *SD:* standard deviation

There were also major differences between countries when examining the degree of implementation of the CHI which measured all 14 ordinal containment and closure, and health system NPIs. In Rwanda the overall average score for the CHI was 58.5 (SD = 25.3, median=71.4) (Table 5.3a). In contrast, the average scores in Nigeria and Zambia were 38.3 (SD = 32.2, median=16.7) and 31.1 (SD = 20.8, median=40.5), indicating lower stringency and levels of implementation compared to Rwanda. When looking at differences in implementation between case windows, there were significant differences between the CHI scores across case windows in Nigeria indicating varying levels of implementation between the case windows. By comparison, in Rwanda the mean containment and health index scores in case windows W_1 (CHI=65.3) and W_3 (CHI=68.7) were significantly different ($p<0.001$) compared to W_2 (CHI=74.7). However, there was no difference between the mean CHI scores in W_1 and W_3, indicating that the implementation of measures calculated in the CHI were similar during W_1 and W_3. Lastly, in Zambia there was a statistically significant difference between the mean containment and health index scores in case windows W_1 (CHI=41.7), W_2 (CHI=47.8), and W_3 (CHI=45.3). However, there was no difference in the mean containment and health index scores between W_1 and W_2 compared to W_3 ($p>0.05$), which again indicates similar implementation of the measures calculated in the containment and health index during W_1, W_2, and W_3.

Table 5.3a. One-Way Analysis of Variance of the Containment and Health Index by Case Window, Nigeria

				Tukey's Post-hoc Comparisons			
Case Window	*n*	Mean	*SD*	**W_0**	**W_1**	**W_2**	**W_3**
Pooled	152	38.3	32.2	-	-	-	-
W_0	58	5.1	4.4		<0.0001	<0.0001	<0.0001
W_1	30	26.5	13.8	<0.0001		<0.0001	<0.0001
W_2	26	70.5	1.0	<0.0001	<0.0001		0.0065
W_3	38	76.1	0.4	<0.0001	<0.0001	0.0065	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days, *SD:* standard deviation

Table 5.3b. One-Way Analysis of Variance of the Containment and Health Index by Case Window, Rwanda

				Tukey's HSD Comparisons			
Case Window	*n*	Mean	*SD*	**W_0**	**W_1**	**W_2**	**W_3**
Pooled	379	58.5	25.3	-	-	-	-
W_0	73	9.7	8.0		<0.0001	<0.0001	<0.0001
W_1	21	65.3	21.0	<0.0001		<0.0001	0.24
W_2	86	74.7	4.6	<0.0001	<0.0001		<0.0001
W_3	199	68.7	6.2	<0.0001	0.24	<0.0001	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days, *SD:* standard deviation

Table 5.3c. One-Way Analysis of Variance of the Containment and Health Index by Case Window, Zambia

				Tukey's HSD Comparisons			
Case Window	*n*	Mean	*SD*	**W_0**	**W_1**	**W_2**	**W_3**
Pooled	232	31.1	20.8	-	-	-	-
W_0	77	3.6	5.1		<0.0001	<0.0001	<0.0001
W_1	43	41.7	13.7	<0.0001		0.005	0.05
W_2	27	47.8	7.8	<0.0001	0.005		0.43
W_3	85	45.3	3.3	<0.0001	0.05	0.43	

Note: W_0: 0 cases, W_1: 1-100+ cases, W_2: >101-1,000+ cases, W_3: >1,001-10,000+ cases
n: number of days, *SD:* standard deviation

Qualitative Findings

A total of ten (n=10) KIIs were conducted. Interviewees represented different agencies involved in the response including Ministries of Health, WHO AFRO, academic

institutions, and non-governmental organizations. There were several themes that emerged regarding challenges in implementing NPIs from participants. The socioeconomic impact of the NPIs was a major theme. Other challenges included lack of adherence and compliance to measures and perceived severity of COVID-19 by the community. Several notable sub-themes were also identified. These are discussed below in more detail, along with illustrative statements

Nearly all participants commented on the economic hardships that certain NPIs such as lockdowns and business closures have created.

> *"… overall, the economy was affected, when businesses were closed, everywhere was closed, the economy was affected. Like we said earlier, there was also impact in accessing the services by the general population because of the movement restrictions. So, there are some of the things that were negatively impacted and has put the countries in a tight corner and made them start re-opening the economy and lifting some of those measures." – Participant 1, WHO AFRO*

> *"Businesses really suffered. All nightclubs are completely shut down now, they're completely out of the picture. Many restaurants shut down. And right after the lockdown was lifted, restaurants became very expensive. They had to compensate for the last one full year. That has been a challenge." – Participant 3, Rwanda*

Social determinants of health such as poverty, lack of access to water, overcrowding, and food insecurity were major sub-themes that emerged. Poverty was mentioned by nearly all participants as a major challenge in both implementation and adherence to NPIs.

> *"…the challenges have been number one poverty. There are several people in Africa, Rwanda included, that depend on day-to-day wages. Take the earnings of motorcycle drivers, taxi drivers, day-laborers, farmers. Quarantine for them has been a huge, huge blow, a huge blow. Vis-a-vi other African countries did not implement quarantine. I think it was only Uganda and Kenya that did so. So that has been a big challenge." – Participant 3, Rwanda*

> *"And then you also want to look at the fact that when you tell me wash your hands, and there's no running water in your area, how are you going to wash your hands? Or when you say keep a safe distance and then you have a family of 6 living in a*

> *room, how are they going to keep a safe distance? And you have the whole block of single room apartments which is packed with so many people. Or in the marketplace, how do you keep distance in the market? So, some of the non-pharmaceutical interventions were not implementable because of the environment we are in." – Participant 1, WHO AFRO*

An additional theme was perceived severity of disease. Several noted that media outlets, especially in the West, had emphasized that when COVID-19 reached Africa, it would create complete catastrophe. When this was not the case in the first and second wave, KII participants noted that citizens did not perceive COVID-19 to be a major threat and did not find the strict measures to be justified. KII participants mentioned that this view was further intensified by misinformation, and, in the case of Nigeria, major distrust in the government.

> *"First of all, I'm sad to say that the major challenge was the people didn't trust the government. Two, they didn't believe there was COVID because people were not dying because the wrong impression was created that when COVID came to Africa it was going to kill everybody, and so when they didn't see any dead bodies then they just assumed that there was no COVID. And there was a lot of fake information and things about COVID, which people took as truth." – Participant 1, Nigeria*

> *"…the number one challenge is the people's perception of the disease itself because despite all the government did to make people understand how the disease is caught, you will hear people say it is a scam, that it is an attempt for government to just make money out of donors, that there's no such disease as COVID… there was buy-in initially but because of these fear…the fear that the government cannot be trusted, because people think they had what they call "hidden agenda."" – Participant 2, Nigeria*

Lack of compliance and adherence to NPIs was also a major theme that emerged. In Zambia, the pandemic also coincided with a particularly tense election year, which brought its own challenges in terms of adherence to measures.

> *"… it's been an election year for Zambia. This is unique to us so we had political gatherings that I think needed time…they didn't really adhere to us under our recommendations, or they said in principle they would accept that, and then just went ahead and did whatever they wanted to do. So, it was rather a challenging time. And we had large gatherings, political gatherings, that was a big challenge*

> *for us to manage adherence to COVID-19 regulations, as well as ensure that there is a democratic electoral process running side by side." – Participant 1, Zambia*

Enforcement was a common theme among participants. In Rwanda, enforcement was mentioned as a success several times, and it was attributed to both the malleability of the Rwandese people as a population that respects its government and strict enforcement by the government.

> *"Rwandans obey the rule of law. Obey their government. If there's a policy, it's respected, generally. Even without an enforcer, without the involvement of the police, of law enforcement, it is generally accepted. That's the main thing. The second thing is they're very strict. Walking without a mask is I think $30. I've seen several people getting penalized right in front of my eyes in Kigali. So, they don't joke around. If you are caught past the curfew, you will be taken to the national stadium, you'll be kept there throughout the night—that's punishment in addition to $100 payment." – Participant 3, Rwanda*

> *"Like everyone had to be home at 7pm. Right now, the time is 7:45pm and if you go on the road, you won't find anybody. Just that move of respecting the guidelines and the level of cooperation is why I think we're successful." – Participant 1, Rwanda*

> *"…the enforcement piece I could say that there were radio talks about any of the measures that were put in place by the government and local entities were in charge of making sure these measures are respected by the general population." – Participant 2, Rwanda*

Whereas enforcement was a success in Rwanda, enforcement was a major challenge in Nigeria and Zambia. KII participants noted that the length and protracted nature of the response have had major consequences in terms of compliance and adherence to several public health and social measures that were being implemented at various points throughout the pandemic, not only by the community but some KIIs mentioned government figures themselves were not adhering to precisely the measures they were responsible for enforcing.

> *"…there were not really [consequences for lack of adherence] …well they put it there…but complying with the law and enforcing is one thing…on a few cases here and there they did. But it didn't last. In about a week or two everybody had forgot, and they went back…even the guy who is supposed to be enforcing it is not wearing a mask *laughs*" – Participant 1, Nigeria*

> *"For places of worship, they are now back to their old, crowded form despite the regulations. Because the latest law was no gathering of 50 or more people, but I was in church on Sunday, and I think we were more than 2,000 in that gathering so that's how it is. So, there is no consistency or uniformity in the enforcement. Like every state or local government can do whatever they felt like implementing."– Participant 2, Nigeria*

> *"…in some of the large density populations in the peri urban areas, if you went there, they would just see blatant disregard of the regulations despite posters being around or motor vehicles with the speakerphone going around announcing what to do. You would essentially see nobody wearing for instance a mask, and that just shows you the defiance levels people had, and because we didn't really have people going around arresting you for not putting on a mask for instance, so that was some of the challenges we saw." – Participant 1, Zambia*

In the opinion of KII participants, political structures and dynamics also played a factor as a barrier in implementation of NPIs. In countries like Nigeria and Zambia, where there is a decentralized government, enforcement was much more difficult than in a country like Rwanda, which has a very centralized government.

> *"Over time, there was no consistency in the enforcement and no uniformity between States. Some States tended to take it more seriously than other States. But on the part of the Federal Government of Nigeria, the government had been the one really wielding the big stick. The States were left to do what they felt like doing because at first when the [federal] government tried to send down regulations right from the country's capital, some State governments saw it as affront to their own rights because the body governance and the president were elected so they didn't like the idea of a [federal] government official trying to decide what happens at the State level. So, the States were left to do what they wanted to do." – Participant 2, Nigeria*

> *"It also depends on the political structure of the country. Nigeria is a very complex country where it has federal [territories] and states. The states have very much power in terms of dealing with the local issues, so the application and implementation of these measures at the local level was a little bit not much uniform in the country. Whereby in countries like Rwanda, it's most centralized, of course*

with good leadership, the implementation of these measures was very much uniform across the country." – Participant 2, WHO AFRO

Discussion

To the best of our knowledge, this study is the first to focus on understanding the degree of implementation and facilitators and barriers to enforcement in sub-Saharan Africa. In the early stages of the pandemic, many countries in sub-Saharan Africa including Nigeria, Rwanda, and Zambia replicated NPIs, such as travel restrictions and shelter-in-place orders, as implemented by Western countries in Europe and the United States. However, approaches that were effective in countries outside of Africa were not necessarily appropriate for the African region. Given the heterogeneity in populations, health systems, and governments in the region, blanket NPI measures such as restrictions on movement proved challenging to implement. Almost three-fourths (71%) of Africans work in the informal sector and thus encountered severe economic hardship with the enforcements of lockdowns and border closures.[50,62,67] With the implementation of certain measures, some countries had food shortages, social unrest, and economic instability.[61,62] Economic instability was felt across the African continent; however, Zambia became the first African country to default on its Eurobond national debt during the pandemic.[168] The pandemic caused the Zambian economy to enter its deepest recession in history with the economy shrinking by 4.2% in 2020.[165–167] An assessment of the Zambian economy a year into the pandemic claimed that the "recession goes beyond the containment measures (which were moderate) and reflects vulnerabilities to external shocks and unfavorable internal macroeconomic decisions, with potential long-term implications."[158]

Additionally, as key informants noted, enforcement of NPIs was met with resistance and noncompliance in countries where governmental authority was weak or contested, or misinformation was high.[68–71] Similarly, physical, or social distancing measures were also difficult to enforce and implement. Aside from the high population density in many communities in Africa, social interaction is a key aspect of life. In urban areas in Africa, public transportation systems are often overcrowded, dense shanty towns and informal settlements are part of the physical infrastructure, and many people do not have the luxury to self-isolate even if they are positive, as many homes face overcrowding. For example, Makoko in Lagos, Nigeria has 300,000 people whose homes are built on stilts in a lagoon.[69] In rural areas, many households share sanitation facilities and have only access to water from a communal tap. Ekumah et al. (2020) used demographic and health survey data from 25 countries in sub-Saharan Africa to explore how vulnerability to COVID-19 was affected by access to basic necessities (sanitation, water, and food) within a household.[75] They found that 46% of sampled households (except South Africa) lacked access to any of these three basic necessities, and only 8% had access to all three.[75] Thus, physical distancing measures, including shelter-in-place measures, were unrealistic in overcrowded areas with inadequate sanitation as pointed out by KIIs.

In addition to several long-term effects of implementing NPIs, timing plays a crucial role in the implementation of NPIs. Several KIIs including those at WHO AFRO pointed out early measures undertaken by countries. However, experts may find it challenging to determine the optimal time to implement different interventions. If governments wait too long, this may lead to the proliferation of disease at a rapid rate and

overwhelm health systems quickly. Consequently, the roll-out of NPIs that are too premature or uniform across an entire country may also increase the risk of a "second wave" of infections once the initial measures are halted or pandemic fatigue sets in. [8,77] The implementation of NPIs, especially over a long period of time, can have significant detrimental consequences in terms of social and economic costs as was the case in Nigeria, Rwanda, and Zambia. While NPIs are generally effective in reducing the burden of disease and alleviating pressure on health infrastructures, studies have found that a longer duration of NPI implementation may have consequences such as increased unemployment, economic hardship, and social disruption.[78] Resource-poor settings are at an especially increased risk, with some data showing income reduction as great as 70% and reduction in consumption expenditure by 30%. [78–80] The Africa Research, Implementation Science, and Education (ARISE) Network conducted a telephone survey in Burkina Faso, Ethiopia, and Nigeria between July and November 2020 to understand COVID-19 knowledge, attitudes, practices and their impacts on health, nutrition, and education.[72,73] The education sector was profoundly affected by school closures. Food shortages and insecurity were rampant across the three sites in the study. Consumption of a range of staple foods in all three countries declined, while the prices of staples, legumes, vegetables, fruit, and animal-source foods rose.[72,74] Additionally, with increased unemployment and decreased crop production, respondents described reductions in general food intake and dietary diversity.[72,74]

Compliance is also a major factor of NPI implementation. NPIs are dependent on enforcement and citizens' willingness to comply with the measure. Compliance generally

wanes the longer measures are in effect.[81] Poverty and economic dislocation also reduce compliance especially with NPIs focused on containment (i.e., shelter-in-place) which again was supported by KIIs in our study.[82] In Rwanda, compliance with public health measures, including mask-wearing, was governed strictly by police and an anti-corona task force. Anecdotal reports detailed police pulling over cars with unmasked drivers and/or passengers, hand-washing stations and sanitizer dispensers were monitored for use before entering businesses, and arrests were made of those violating the country-wide curfew.[140] The strictness with which measures were implemented in Rwanda was supported by claims made by KIIs. This was also supported by the quantitative data where the pooled average SI and CHI scores for Rwanda were much higher than that of Nigeria and Zambia. Additionally, despite a robust public information campaign to dispel misinformation, many residents in Nigeria did not initially adhere to the recommendations aimed at reducing the spread of COVID-19. This caused high tension between the civilians and armed forces who became violent when trying to enforce certain protocols.[104,109] To enforce lockdown and curfew measures, policy, paramilitary, and military personnel were deployed to various areas in the country. Among the challenges in this implementation were persistent corruption and political distrust.[104,109] There were also multiple reports of unlawful use of force and misconduct of the Nigerian police while enforcing COVID-19 measures.[110,111] Implementation and enforcement were marred by a lack of compliance from the public, which limited the outcomes of the government response to COVID-19. An article in The Guardian described Nigerians defying the stay-at-home orders which some attributed to distrust in the government and rising reports of hunger.[68] There were also reports of

security operatives being susceptible to bribes from those choosing to defy lockdown measures.[104] This weakened the impact of travel restrictions and lockdown measures on the slowing down of COVID-19 in the country which was also supported by KIIs.

The study has several limitations. First, given the fluidity of the COVID-19 pandemic and the time it took each of the three countries to get there, external factors such as variants, holiday season, etc., could have affected the degree of implementation. For example, Nigeria reached 10,000 cases in May 2020 while Rwanda reached that point in January 2021. The state of the pandemic and global guidance had changed significantly in between that time. There are also specific limitations in the OxCGRT dataset itself. The dataset does not measure implementation or compliance,[97] nor does it provide subnational measures for almost all countries apart from adding a flag denoting whether the restriction was national or subnational.[97] Thus, our nation-focused analysis may miss some variation of policies implemented at the sub-national level. Additionally, our sample size of KIIs is relatively small, therefore there may be other diverse opinions about what worked and what did not during NPI implementation, that are not captured here.

During pandemics, apart from effective vaccine strategies, NPIs are one of the most important tools that individuals and communities can utilize to limit disease spread and reduce deaths. In addition, the timing of NPI implementation is crucial. Delayed implementation of NPIs will lead to unchecked proliferation of disease in the community and overwhelm health systems.[3,7,8] However, in addition to timing, the success of NPIs depends critically on the fidelity of implementation and the willingness of individuals to

comply with the NPIs.[9–12] Careful consideration to tailored NPI measures for the specific community context may lead to less resistance and improved compliance.

CHAPTER 6

Recommendations: Policy Memo

To : Dr. John Nkengasong, Africa CDC Director

From : Hiwote Solomon

Date : 12 April 2022

Subject : **Recommendations for the implementation of non-pharmaceutical interventions for the management of COVID-19**

Thank you for your willingness to discuss the implementation of non-pharmaceutical interventions (NPIs) during the COVID-19 pandemic. As you are aware, in the absence of pharmaceutical interventions, NPIs are key to mitigate the spread of disease. Throughout the pandemic, several NPIs have been implemented by Member States with varying levels of stringency, success, and challenges. The implementation of NPIs for outbreak control is not uncommon for many countries in Africa who have dealt with epidemics and outbreaks of infectious disease. However, the protracted nature of COVID-19 has proven to be a challenge in implementing certain NPIs, such as mask mandates and movement restrictions.

As previously discussed, my analysis examines adherence and enforcement of NPIs implemented to limit the spread of COVID-19 in Nigeria, Rwanda, and Zambia. The lessons learned and recommendations gleaned through interviews with experts involved in the COVID-19 pandemic and quantitative analysis of NPI implementation can be applied to future outbreaks, epidemics, and pandemics. The top three recommendations include engaging communities, using a risk-based approach to implement containment and closure

NPIs, and providing social and economic support to citizens during periods of lockdowns and other measures that interrupt the ability to make a living.

One of the most important lessons learned, and a key recommendation for continued and/or future implementation of NPIs, is the early engagement of communities in the response. The success of NPIs is largely dependent upon the willingness and compliance of citizens to adopt control measures. Ideally, community engagement should begin during the preparedness stage. Listening to communities, understanding their concerns, and providing them with the right information will all be critical in ensuring high compliance and building trust. Secondly, a risk-based approach should be used in order to implement containment and closure measures especially those that restrict people's behaviors. A risk-based approach to implementation was strongly advocated by WHO AFRO personnel consulted during this analysis. A risk-based approach utilizes surveillance and epidemiological data to inform experts where measures should be implemented, rather than the implementation of blanket measures (e.g., national lockdown). This approach was undertaken in countries like Kenya and South Africa, where containment and closure measures were guided by surveillance data and were targeted at communities with high rates of transmission rather than at the national level. Lastly, providing economic and social support to communities is crucial, especially during the implementation of measures that include the closure of schools and businesses and movement restrictions that limit the ability of individuals to access education or to leave their homes to earn a living. For example, innovative financial strategies in Rwanda included supporting workers and vulnerable persons through food relief efforts to the

hardest-hit households living in Kigali and other urban centers, zero charges on mobile money transfers, and removing the maximum transaction limit on mobile payments. Additionally, the government was able to support businesses by establishing a fund to support access to capital for small and medium enterprises and extending the deadline for businesses to file and pay income taxes. These interventions were able to alleviate some of the economic consequences of lockdowns and closure of businesses for the Rwandese people.

Given the success of engaging communities during early stages of the response, implementing measures using a risk-based approach, and providing social and economic support to citizens, Africa CDC should consider incorporating these strategies in guidance offered to all Member States.

CHAPTER SEVEN

Conclusion

This mixed-methods study allowed for a deeper understanding of the implementation of NPIs in Nigeria, Rwanda, and Zambia throughout the COVID-19 pandemic. Two years into the pandemic and with the introduction of vaccines, we are in a drastically different place than we were at the beginning. However, one cannot underscore the essential role of NPIs throughout this pandemic. Poor vaccine availability and acceptability has been a major barrier in several African countries who are relying on donations of vaccines and having to curb misinformation.[177–179] There continues to be a risk for recurrent waves of infection (unless population level immunity is attained) which may necessitate further implementation of NPIs to mitigate spread. Measures such as lockdowns and closure of businesses and schools have had an extremely negative effect on the lives of people, as well as economic and social consequences that will reverberate throughout the next few years. Other measures such as mask-wearing have become the standard and relatively well accepted—transcending cultural norms. However, it is important to note that approaches that were effective in countries outside of Africa were not necessarily appropriate for the African region. Careful consideration to tailored NPI measures for the specific community context may lead to less resistance and improved compliance. Additionally, social and economic support would alleviate consequences such as economic hardship, unemployment, and social disruption, often associated with prolonged, blanket measures.

As key informants emphasized during their interviews, poverty and inequity must

be addressed to support our ability to build a health system that is resilient and has the necessary tools to respond to a myriad of emergencies. This dissertation highlights several social, economic, political, and cultural factors that have played a role in how NPIs were introduced and implemented in communities in Nigeria, Rwanda, and Zambia. Public health emergencies, especially outbreaks of infectious disease, are not an anomaly in Africa. The dissertation has highlighted the use of existing infrastructure and capacity built as result of previous emergencies to respond to COVID-19 pandemic. The ability to prevent, detect, and respond early and efficiently to public health emergencies cannot be emphasized enough. Proactivity is far more desirable and effective than reactivity in emergency preparedness and response. The lessons learned by countries and as a global community should be documented and frequently reviewed to ensure the necessary systems are ready for the next emergency.

Appendix A: Description and Sources of Variables in Quantitative Dataset

VARIABLE	DESCRIPTION	SOURCE
iso_code	ISO 3166-1 alpha-3 – three-letter country codes	International Organization for Standardization
date	Date of observation	Our World in Data
total_cases	Total confirmed cases of COVID-19	COVID-19 Data Repository by the CSSE at Johns Hopkins University
new_cases	Total confirmed cases of COVID-19	COVID-19 Data Repository by the CSSE at Johns Hopkins University
total_deaths	Total deaths attributed to COVID-19	COVID-19 Data Repository by the CSSE at Johns Hopkins University
new_deaths	New deaths attributed to COVID-19	COVID-19 Data Repository by the CSSE at Johns Hopkins University
total_cases_per_million	Total confirmed cases of COVID-19 per 1,000,000 people	COVID-19 Data Repository by the CSSE at Johns Hopkins University
new_cases_per_million	New confirmed cases of COVID-19 per 1,000,000 people	COVID-19 Data Repository by the CSSE at Johns Hopkins University
total_deaths_per_million	Total deaths attributed to COVID-19 per 1,000,000 people	COVID-19 Data Repository by the CSSE at Johns Hopkins University
new_deaths_per_million	New deaths attributed to COVID-19 per 1,000,000 people	COVID-19 Data Repository by the CSSE at Johns Hopkins University
reproduction_rate	Real-time estimate of the effective reproduction rate (R) of COVID-19	Arroyo Marioli et al. (2020). https://doi.org/10.2139/ssrn.3581633
population	Population in 2020	United Nations, Department of Economic and Social Affairs, Population Division, World Population Prospects 2019 Revision
population_density	Number of people divided by land area, measured in square kilometers, most recent year available	World Bank World Development Indicators, sourced from Food and Agriculture Organization and World Bank estimates
median_age	Median age of the population, UN projection for 2020	UN Population Division, World Population Prospects, 2017 Revision
aged_65_older	Share of the population that is 65 years and older, most recent year available	World Bank World Development Indicators based on age/sex distributions of United Nations World Population Prospects 2017 Revision
aged_70_older	Share of the population that is 70 years and older in 2015	United Nations, Department of Economic and Social Affairs,

		Population Division (2017), World Population Prospects 2017 Revision
gdp_per_capita	Gross domestic product at purchasing power parity (constant 2011 international dollars), most recent year available	World Bank World Development Indicators, source from World Bank, International Comparison Program database
cardiovasc_death_rate	Death rate from cardiovascular disease in 2017 (annual number of deaths per 100,000 people)	Global Burden of Disease Collaborative Network, Global Burden of Disease Study 2017 Results
diabetes_prevalence	Diabetes prevalence (% of population aged 20 to 79) in 2017	World Bank World Development Indicators, sourced from International Diabetes Federation, Diabetes Atlas
female_smokers	Share of women who smoke, most recent year available	World Bank World Development Indicators, sourced from World Health Organization, Global Health Observatory Data Repository
male_smokers	Share of men who smoke, most recent year available	World Bank World Development Indicators, sourced from World Health Organization, Global Health Observatory Data Repository
handwashing_facilities	Share of the population with basic handwashing facilities on premises, most recent year available	United Nations Statistics Division
life_expectancy	Life expectancy at birth in 2019	James C. Riley, Clio Infra, United Nations Population Division
human_development_index	United Nations Development Programme (UNDP)	United Nations Development Programme (UNDP)
Codebook for the Oxford Covid-19 Government Response Tracker NPIs		
COLUMN	**DESCRIPTION**	**Coding**
stringency_index	All containment and closure policies (C1-C8) and one health system policy (H1)	Score of 0-100
government_response_index	All 16 ordinal policy indicators (C1-C8, H1-H3, H6-H8), and economic relief (E1-E2) indicators	Score of 0-100
containment_health_index	All 14 ordinal containment and closure (C1-C8) and health system (H1-H3, H6-H8) policies	Score of 0-100
c1_school_closing	Record closings of schools and universities	0 - no measures 1 - recommend closing or all schools

		open with alterations resulting in significant differences compared to non-Covid-19 operations 2 - require closing (only some levels or categories, e.g. just high school, or just public schools) 3 - require closing all levels Blank - no data
c1_flag	Binary flag for geographic scope	0 - targeted 1- general Blank - no data
c2_workplace_closing	Record closings of workplaces	0 - no measures 1 - recommend closing (or recommend work from home) or all businesses open with alterations resulting in significant differences compared to non-Covid-19 operation 2 - require closing (or work from home) for some sectors or categories of workers 3 - require closing (or work from home) for all-but-essential workplaces (e.g. grocery stores, doctors) Blank - no data
c2_flag	Binary flag for geographic scope	0 - targeted 1- general Blank - no data
c3_cancel_public_events	Record cancelling public events	0 - no measures 1 - recommend cancelling 2 - require cancelling Blank - no data
c3_flag	Binary flag for geographic scope	0 - targeted 1- general Blank - no data
c4_restrictions_on_gatherings	Record limits on gatherings	0 - no restrictions 1 - restrictions on very large gatherings (the limit is above 1000 people) 2 - restrictions on gatherings between 101-1000 people 3 - restrictions on gatherings between 11-100 people 4 - restrictions on gatherings of 10 people or less Blank - no data
c4_flag	Binary flag for geographic scope	0 - targeted 1- general Blank - no data

c5_close_public_transport	Record closing of public transport	0 - no measures 1 - recommend closing (or significantly reduce volume/route/means of transport available) 2 - require closing (or prohibit most citizens from using it) Blank - no data
c5_flag	Binary flag for geographic scope	0 - targeted 1- general Blank - no data
c6_stay_at_home_requirements	Record orders to "shelter-in-place" and otherwise confine to the home	0 - no measures 1 - recommend not leaving house 2 - require not leaving house with exceptions for daily exercise, grocery shopping, and 'essential' trips 3 - require not leaving house with minimal exceptions (e.g. allowed to leave once a week, or only one person can leave at a time, etc.) Blank - no data
c6_flag	Binary flag for geographic scope	0 - targeted 1- general Blank - no data
c7_movementrestrictions	Record restrictions on internal movement between cities/regions	0 - no measures 1 - recommend not to travel between regions/cities 2 - internal movement restrictions in place Blank - no data
c7_flag	Binary flag for geographic scope	0 - targeted 1- general Blank - no data
c8_internationaltravel	Record restrictions on international travel (this records policy for foreign travelers, not citizens)	0 - no restrictions 1 - screening arrivals 2 - quarantine arrivals from some or all regions 3 - ban arrivals from some regions 4 - ban on all regions or total border closure Blank - no data
h1_public_information_campaigns	Record presence of public info campaigns	0 - no Covid-19 public information campaign 1 - public officials urging caution about Covid-19 2- coordinated public information campaign (e.g. across traditional and social media) Blank - no data

h1_flag	Binary flag for geographic scope	0 - targeted 1- general Blank - no data
h2_testing_policy	Record government policy on who has access to testing Note: this records policies about testing for current infection (PCR tests) not testing for immunity (antibody test)	0 - no testing policy 1 - only those who both (a) have symptoms AND (b) meet specific criteria (e.g. key workers, admitted to hospital, came into contact with a known case, returned from overseas) 2 - testing of anyone showing Covid-19 symptoms 3 - open public testing (e.g. "drive through" testing available to asymptomatic people) Blank - no data
h3_contact_tracing	Record government policy on contact tracing after a positive diagnosis Note: we are looking for policies that would identify all people potentially exposed to Covid-19; voluntary Bluetooth apps are unlikely to achieve this	0 - no contact tracing 1 - limited contact tracing; not done for all cases 2 - comprehensive contact tracing; done for all identified cases
h6_facial_coverings	Record policies on the use of facial coverings outside the home	0 - No policy 1 - Recommended 2 - Required in some specified shared/public spaces outside the home with other people present, or some situations when social distancing not possible 3 - Required in all shared/public spaces outside the home with other people present or all situations when social distancing not possible 4 - Required outside the home at all times regardless of location or presence of other people
h6_flag	Binary flag for geographic scope	0 - targeted 1- general Blank - no data
h8_protection_of_elderly_people	Record policies for protecting elderly people (as defined locally) in Long Term Care Facilities and/or the community and home setting	0 - no measures 1 - Recommended isolation, hygiene, and visitor restriction measures in LTCFs and/or elderly people to stay at home 2 - Narrow restrictions for isolation, hygiene in LTCFs, some limitations on external visitors and/or restrictions

		protecting elderly people at home 3 - Extensive restrictions for isolation and hygiene in LTCFs, all non-essential external visitors prohibited, and/or all elderly people required to stay at home and not leave the home with minimal exceptions, and receive no external visitors Blank - no data
h8_flag	Binary flag for geographic scope	0 - targeted 1- general Blank - no data

Appendix B: Interview Guide

Date: _____
Start time: _____
Stop time: _____

My name is Hiwote Solomon and I am a Doctor of Public Health Candidate in Leadership, Management, and Policy at the Boston University School of Public Health.

Thank you so much for taking part in this interview which aims to understand the potential barriers and facilitators in implementing and enforcing non-pharmaceutical interventions during the COVID-19 pandemic in Africa. While the study is specifically interested in Nigeria, Rwanda, and Zambia, it is also crucial to understanding how non-pharmaceutical interventions were implemented and enforced throughout the continent. The study also aims to understand how other epidemics within countries in Africa may have affected compliance in implementing and enforcing non-pharmaceutical interventions.

I am interviewing decision-makers and others involved in the COVID-19 pandemic response across the continent. These include those at Ministries of Health, National Public Health Institutes, WHO AFRO Office, and the Africa CDC Secretariat and Regional Collaborating Centers.

During this brief discussion, I will ask you to share your role in the COVID-19 pandemic response and your perception of the overall response in either Nigeria, Rwanda, and/or Zambia or the larger Africa region. Next, I will ask you to tell me about some facilitators and barriers of implementing and enforcing non-pharmaceutical interventions including school closures, quarantine/isolation, business closures, and travel restrictions. You are the expert here and your responses will allow me to think critically about the on-the-ground response efforts and be better able to triangulate the quantitative data with your responses. ***(pause)***

Being part of this interview is optional and you may stop me at any time. We understand you are busy thus this interview will take only about 20-30 minutes of your time. In order to make sure I do not miss any details and make sure I can keep up with you, I would like to seek your verbal permission to record the interview. The recording will not be shared with anyone and will be destroyed upon completion of transcription. If you do not wish to be identified, you will remain completely anonymous in all parts of the dissertation. If you do not want to be recorded, I will not record you.

*Do you have any initial questions for me? (**pause**). Thank you very much, we can begin.*

Note: verbal consent will be sought and recorded before beginning the discussion.

Warm Up Questions

1. In what capacity have you been involved in the COVID-19 response in *(insert country)?* How long have you been part of the response?

Non-Pharmaceutical Interventions—Key Questions:

1. What were some of the non-pharmaceutical interventions that were put in place by the country?
2. How were these interventions enforced by the government or other entities? (Probe: what were consequences of lack of adherence?)
3. What would you describe as the top three (3) successes in how the NPIs were implemented?
4. What would you describe as the top three (3) challenges in implementing the NPIs?
5. How were these NPIs received by the community? (Probe: what were the challenges in creating buy-in with communities?)
6. What would you say are some of the biggest lessons learned by decision-makers throughout the COVID-19 response in (*insert country*)?
7. Knowing what we know about COVID-19 today, what are some measures you would recommend for future epidemics or pandemics in (*insert country*)?

Moving Forward – Closing Questions

"Thank you very much! We'll now end with a few general questions"

1. Do you have anything else to tell me today about what we've talked about?

"Thank you very much for your time and for chatting with me. I appreciated the chance to learn more about the COVID-19 response in (insert country). Have a wonderful day!"

[Interviewer: Please return to the first page and record the stop time of the interview.]

----STOP----

Appendix C: NVivo Final Codebook

Name	Description	Files	References
Type of NPIs implemented	Answer to question: what were some of the NPIs put in place?	0	0
Closures		1	1
Business closures		3	8
School closures		4	6
Curfews		3	4
Handwashing		3	3
Lockdowns		5	16
Mask Mandate		6	5
Movement restrictions		6	7
Public information campaigns	Sensitization and building knowledge	6	9
Restrictions on gatherings		5	3
Travel restrictions	International and within country	7	10
Successes	Participants were asked to describe the top 3 successes on NPI implementation	1	4
Capacity Building	Includes infrastructure, technical knowledge, and human resources	4	8
Coordination	Includes utilization of rapid response teams	4	7
Government leadership	Includes mentions of strong government leadership including the enactment of public health laws	6	16
No successes	Responses that there were no success	2	2
Timing of implementation	The timing of when NPIs were implemented and how that was a facilitator to controlling spread	4	8

Name	Description	Files	References
Strong enforcement	Strong enforcement to ensure adherence and compliance (Rwanda)		
Challenges		2	2
Lack of adherence and compliance	Mentions of challenges with adherence and compliance of measures	7	10
Adherence to mask wearing	Lack of adherence to mask mandate	5	8
COVID Fatigue	Phenomenon of “covid fatigue”	5	5
lack of adherence by public figures	Mentions of lack of adherence to measures by public figures	4	4
Perceived severity	How the community perceived the severity of COVID-19 in Africa compared to what was happening in other parts of the world	6	5
Government distrust	How trust or distrust in the government affected implementation of NPIs	2	8
Misinformation	The role of misinformation in adherence and compliance	6	8
No buy-in	Lack of buy-in from community	6	5
Social support	Lack of social support and effect on implementation/uptake	2	4
Socioeconomical impact	The effect of certain measures on populations	5	13
Effect on economy	The negative effect of certain measures on the country’s economy	6	6
Social determinants	Social determinants of health that were a barrier to implementation of NPis	2	4
Access to water	Lack of access to sufficient water	4	2
Food insecurity & hunger	Mentions of food insecurity or hunger as a barrier	5	4
Poverty	Mentions of poverty as a systemic barrier to uptake	6	8
Lack of enforcement	Mentions of lack of enforcement by government and other entities	10	37

Name	Description	Files	References
Malleability of population	How the malleability of population affected whether enforcement was successful or not	3	11
Uniformity of implementation	Uniform/blanket measures vs. targeted measures	4	8
Lessons Learned	Responses to questions on the biggest lessons learned throughout the COVID-19 and recommendations for future epidemics and pandemics	3	4
Engagement of communities	Importance of engaging communities and creating buy-in	6	11
Leveraging existing resources	Building upon existing resources	3	3
Preparedness and capacity building	Comments around preparedness and capacity building as lessons learned	6	11
Recommendations for future epidemics or pandemics	Recommendations for future epidemics or pandemics	5	5

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