

HOW DO IMMUNIZATION PROGRAMS IN LMICS ADAPT TO AN INFECTIOUS DISEASE CRISIS?

A Thesis submitted as a requirement for the
MSc. International Public Health (Planning &
Management) course



SEPTEMBER 2020

LIVERPOOL SCHOOL OF TROPICAL MEDICINE

Adaptions by Immunization Programs in LMICs to an Infectious Disease Crisis: A
Rapid Evidence Assessment

Fransuave Moore

September 2020

Liverpool School of Tropical Medicine

Word Count = 13,242

Table of Contents

List of tables and illustrative material.....	5
Acknowledgements.....	5
Abstract.....	6
Background	6
Methods.....	6
Findings	6
Conclusions	6
Abbreviations.....	7
Organization of Thesis.....	8
Introduction	8
Health System Shocks	8
History of Infectious Disease Crises and Shocks	9
Health Systems Resilience During Shocks.....	12
Immunization programs.....	13
Purpose of study	15
Current state of knowledge and appraisal of existing knowledge	15
Problem to be addressed.....	15
Aim & Objectives.....	16
Methods.....	16
Search.....	20
Identification of relevant literature	20
Screening of literature	21
Data Extraction.....	23
Data Analysis.....	24
Data synthesis	25
Results.....	25
Included Literature.....	25
Synthesis of Main Findings.....	26
Themes.....	26
Discussion.....	40
Limitations.....	40
Pulling together findings and evaluating	40

Bias, Reliability, and the Unexpected	42
Implications.....	42
Conclusion.....	44
References.....	46

List of tables and illustrative material

Figure 1 - Adaptive Definition

Figure 2 - Literature search flowchart

Table 1 - Conceptual framework

Table 2 - Inclusion criteria

Table 3 - Exclusion criteria

Table 4 - Search terms

Table 5 - Infectious disease crises

Table 6 - Included infectious disease crises

Table 7 - Types of data extracted

Table 8 - Adapted strategy to the epidemiological or social context

Table 9 - Adapted with electronic technology

Table 10 - Adapted how communities were engaged

Table 11 - Adapted how multiple actors coordinated

Acknowledgements

Supervisors: Russell Dacombe & Laura Dean

Abstract

Background

Infectious disease crises can shock a health system, which can decrease the amount of resources available for specific health services. When an infectious disease crisis occurs in a resource-poor health system, there can be a greater impact on the health services provided. Immunization programs are critical health services that can prevent the spread of infectious diseases and therefore outbreaks. How immunization programs adapted in anticipation of, during, and after an infectious disease crisis is critical to understand. This study evidences how this critical health service for preventing infectious disease outbreaks was maintained or improved in the past.

Methods

Medline Complete, The Cumulative Index to Nursing and Allied Health Literature (CINHL), Global Health, and grey literature were searched to identify non-impact studies that described changes or adaptations made by immunization programs during and after an infectious disease crisis to maintain a similar level of health services prior to the crisis. A total of 5,806 articles were screened, 92 of which were semi-relevant and once fully screened, 19 met the inclusion criteria to be included in this Rapid Evidence Assessment.

Findings

Key themes that emerged included (a) adaptations made that involved adjusting the strategy of a campaign to the epidemiological or social context; (b) adaptations made that involved the use of technology such as electronic mapping; (c) adaptations where community engagement enabled a successful program; and (d) adapting the inter-actor dynamics related to the campaign staff, community leaders, community health workers, and other actors involved in an immunization program

Conclusions

Evidence exists that showed how immunization programs have adapted to an infectious disease crisis to maintain or expand immunization services. It is important to adapt strategy to an epidemiological or social context, and keyways to do this are through the use of technology and community engagement. When an infectious disease crisis occurs, it is implied that community leaders, community health workers, and community members should be formally included in the campaign process. Overall, these adaptations have enabled immunization programs to maintain or expand immunization services during an infectious disease crisis.

Word count = 340

Abbreviations

AIDS = Auto Immune Deficiency Syndrome

ART = Artemisinin-based treatment

CDC = Centers for Disease Control and Prevention

CINHL = Complete Index for Nursing and Allied Health Literature

COVID-19 = Corona Virus Disease 2019

EPPI-Centre = Evidence for Policy and Practice Information and Co-ordinating Centre

EVD = Ebola Virus Disease

GAPS = Geographic Assessment and Planning Services

GPS = Global positioning system

HIV = Human immunodeficiency virus

MDA = Mass drug administration

MTS = Multi-team system

LMICs = Low-and-middle-income countries

PHEIC = Public Health Emergency of International Concern

REA = Rapid Evidence Assessment

SARS = Severe Acute Respiratory Syndrome

SARS-CoV-2 = Severe Acute Respiratory Syndrome-Corona Virus-2

TB = Tuberculous

UK = United Kingdom

VPD = Vaccine Preventable Disease

WHO = World Health Organization

Organization of Thesis

At first, I introduce the concepts of health system shocks and infectious disease crises; resilience and adaptation; and immunization programs. Then, the study is justified primarily through the explanation of why there is a need for greater shared knowledge on how immunization programs in LMICs adapt to maintain or expand services following an infectious disease crisis.

The aims and objectives of this study will then be presented, followed by the research methods taken to achieve these aims and objectives. The results from this REA and the discussion of these results will then be presented. For the discussion, in depth commentary is inclusive of the implications of the results and how they relate to the wider literature and field of public health. This REA ends with the conclusions from this evidence assessment.

Introduction

Immunization when vaccines are utilized is the most cost-effective preventative measure for reducing child mortality from infectious diseases (CDC, 2006; Hadler, 2013). When a population is under-vaccinated for a vaccine preventable disease (VPD), or a new disease is introduced to a population that has no built-up immunity, an infectious disease outbreak is likely to occur (Reid and Goldberg, 2012). Infectious disease outbreaks can directly affect the health outcomes of a population. In addition, the health of a population can be indirectly affected if an infectious disease diminishes a health system's ability to maintain the delivery of health services, including routine immunization campaigns (CDC, 2020; WHO, 2020a).

Health System Shocks

A shock is a sudden event that displaced a health systems ability to delivery services (Fridell *et al.*, 2020). In addition, shocks can limit access to health services or reduce demand, both of which contribute to negative health outcomes of a population (Kruk *et al.*, 2015; Blanchet *et al.*, 2017). An infectious disease outbreak can shock a health system. Infectious disease outbreaks can be intensified based on context, such as following a natural disaster, during conflict, among populations of displaced persons, during a humanitarian crisis, or during or following another outbreak. A crisis can be defined as an event of greater difficulty where both preparedness and response are a part of a possibly insidious process with varying layers of intensity that is not limited by time (WHO, 1998).

An intensified infectious disease outbreak can be a major shock to a health system and should be viewed as an infectious disease crisis. For the purpose of this study, an infectious disease crisis is an outbreak that had the potential to become a large regional or national

epidemic; occurred in the context of a humanitarian crisis, conflict, natural disaster, or another outbreak; or the disease could have become endemic in a new population.

History of Infectious Disease Crises and Shocks

The causes of infectious disease crises are all fairly inter-related, with one thing causing another or one cause intensifying another. Infectious disease crises have resulted from natural disasters, human interaction with wildlife, poverty, conflict, and lack of proper hygiene and sanitation infrastructure. They have been recurrent through the history of humanity and continue to negatively impact the health of populations.

Natural disasters have been increasing in the last two decades due to the effects of the changing global climate, and the intensity and rate of these events will only accelerate in the coming decades (Van Aalst, 2006). Natural disasters such as earthquakes, flooding, hurricanes, and tsunamis incite outbreaks due to things such as damaged water infrastructure increased interaction with unclean water (Stanislas *et al.*, 2013). Lack of access to clean water and proper hygiene and sanitation solutions has been a contributing factor to infectious disease outbreaks such as Cholera outbreaks (Peter, 2009; Webster, 2011). Climate change has been increasing the incidence of Cholera around the world (WHO, 2011). In addition, natural disasters can displace populations, which can increase the amount of contact humans have with wildlife and therefore increase the incidence of various infectious disease (Ivers and Ryan, 2006; Ligon, 2006). Infectious disease crises occurring out of natural disasters will likely increase as the climate continues to change unless actions are taken to improve the planning, implementation, and response for these types of events.

In 2010, Haiti experienced a series of earthquakes that damaged infrastructure, devastated the population, incited multiple Cholera outbreaks across four years, and created a situation of crisis (Webster, 2011). Due to the intensity of the event, the situation became an infectious disease crisis. From 2010 to the end of 2013, Haiti became the hotspot for the largest Cholera epidemic for a single country, accounting for 54% of all cholera cases and 41% of all Cholera deaths during this four-year period (WHO, 2010; 2011; 2012; 2013). This outbreak was a major shock to Haiti's health system and showcased the potential impact natural disasters, exacerbated by the changing climate, could have on health systems that are vulnerable to infectious diseases such as Cholera.

Natural disasters, conflict, political crises, economic crises, and economic gaining activities can all increase human interaction with wildlife. This interaction has led to infectious disease outbreaks, as well as situations of crisis. Interaction between human and wildlife

populations has contributed to major disease outbreaks such as EVD, COVID-19, HIV/AIDs, and Influenza A H1N1 (Smith *et al.*, 2014).

In the late 20th century, HIV/AIDS showcased how some infectious diseases can spread largely undetected through populations and become pervasive in specific communities (De Cock, Mbori-Ngacha and Marum, 2002; Fauci and Lane, 2020). There was a stigma around immunization programs because of the uncertainties around the route of transmission for HIV/AIDS (Mills *et al.*, 2004; Mahajan *et al.*, 2008). A lot of this stigma can still be seen, especially in communities where HIV/AIDS still has a high incidence (Sian, 2013). In the 1980s, many immunization programs were scaled back across the world after the realization that HIV/AIDs had spread through needles during mass vaccination campaigns (Hausman, 2019). This led to a stark decrease in demand from populations not wanting to put themselves at risk for infection for HIV/AIDS (Hausman, 2019). While it is important to note the HIV/AIDS epidemics for the historical background of this REA, the research on this infectious disease crisis, as well as most infectious disease crises prior to 2002, is very limited in scope. Therefore, the HIV/AIDs epidemics and other infectious disease crises prior 2002 were not included in the literature search for this REA.

In 2002, SARS spread across the world, showcasing the modern world's increased vulnerability to the rapid spread of an infectious disease (deLisle, 2003). Airports closed, disease surveillance increased, and health systems waited, however, the virus and the modes of transmission it chose were not conducive for uninterrupted spread and within person community transmission (WHO, 2006). Health systems were on edge and some, particularly those in Southeast Asia, paused or reduced routine services including those for immunization (Gopalakrishna *et al.*, 2004).

Conflict, displaced populations, and economic gaining activities were major contributing factors to why the EVD outbreak began in Guinea in 2014 and quickly spread into Sierra Leone and Liberia (WHO, 2019c). Due to conflict in the 1990s, populations were displaced and began to settle Meliandou, a forested region on the borders of Guinea, Liberia, and Sierra Leone. These settlements began to interact with the forested region, creating farmland and such, and then in 2013, the first index case for the EVD outbreak was identified in Meliandou (WHO, 2019c). The outbreak then spread out from this settlement due to cross-border work. This EVD epidemic was a major shock to health systems in the region. The health systems effected reduced all non-essential or related health services, and demand for health services also decreased (WHO, 2019b). Flights to the region were halted, and most internal migration and regional migration was paused in attempts to contain the outbreak to the West Africa region

(Poletto *et al.*, 2014). The EVD outbreak gave a sudden glimpse of an infectious and highly deadly disease, with few proven therapeutics and no vaccine at the time, spreading in a region with resource-poor health systems (Kieny *et al.*, 2014). In addition, the crisis showed what could be left in the aftermath, where vulnerable populations distrusted the health system and health actors associated with it, which affected the health system's ability to serve those populations (Yamanis, Nolan and Shepler, 2016).

In addition, this EVD outbreak led immunization programs to pause (Takahashi *et al.*, 2015; Cancedda *et al.*, 2016). Due to this, once the outbreak began to subside, there were reports of diminished coverage for VPDs such as Cholera and Measles (Takahashi *et al.*, 2015; Wilhelm and Helleringer, 2019). The decrease in VPD coverage increased the likelihood outbreaks for these diseases occurring. If a VPD outbreak were to have occurred as an indirect result of the EVD outbreak, either during or immediately following, the negative health effect on population likely would have been significant. However, toward the tail-end of the EVD outbreak, adaptations were made to adequately 'catch-up' the population in terms of immunity (Dunbar *et al.*, 2017; Sun *et al.*, 2017; Gupta, Collier and Feinberg, 2018). (Armocida *et al.*, 2020)

In 2018, an EVD outbreak began in the Democratic Republic of Congo (DRC) and threatened to spread in neighboring countries (WHO, 2019d). The DRC has been in a state of civil conflict from 1997 - 2016, and continues to face challenges in reaching a state of peace (Karbo and Mutisi, 2012; Shears and Garavan, 2020). The DRC has one of the most resource-limited health systems in the world and a bottlenecked budget for immunization programs (Le Gargasson *et al.*, 2014). This makes the spread of any highly infectious disease (such as EVD) likely to lead to a crisis, one that could go undetected, especially in more rural populations (Nguyen, 2019). This is what has been happened in the DRC from 2018 onwards with the EVD outbreak being declared a Public Health Emergency of International Concern (PHEIC) as it neared urban populations (WHO, 2019a). However, in 2020, this EVD outbreak was declared over in Equateur province (WHO, 2020c).

In 2019, SARS-CoV-2 began to spread out of China eventually leading to the COVID-19 pandemic that started in 2020 (Shereen *et al.*, 2020). Immunization programs were advised to halt or pause, and many did, inclusive of those in high-income countries (CDC, 2020; WHO, 2020f). This pandemic has led many countries to reimagine how the world works: from how to travel, work, attend school, and provide health services (Chinazzi *et al.*, 2020). The number of people who lost access, or chose not to access health services during the initial months of the pandemic was substantial (Robertson *et al.*, 2020; WHO, 2020b). The pause in immunization activities across European countries and the United States was significant, and the decrease in

access to services in low-income countries largely varied (Robertson *et al.*, 2020). However, low-income, or middle-income countries such as Ethiopia continued to run immunization activities as they saw the benefit of preventing other infectious disease outbreaks far outweighed the burden of COVID-19 on their population (WHO, 2020d). It is important to note that countries that continued to run immunization activities, or resumed them relatively quickly after pausing them, experienced less health burdens from COVID-19 compared to VPDs such as Cholera (Lloyd-Sherlock *et al.*, 2020). Despite this, the health systems of most countries in the world experienced a series of intense shocks as a result of COVID-19.

Health systems around the world have experienced infectious disease crises in one form or another, so how have they adapted or failed to adapt to these crises?

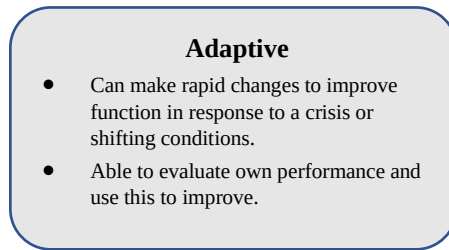
Health Systems Resilience During Shocks

What has happened to health systems that have faced an infectious disease crisis and experienced significant shocks? Across many outbreaks, epidemics, and crisis situations, the WHO and health system coordinating bodies have recommended countries pause or scale back immunization programs to decrease the likelihood of the disease spreading via the typically close interaction needed for these programs (WHO, 2020f). However, many health systems have continued to offer services where available and after an infectious disease crisis ended. During these events, health systems have experienced significant shocks and have made significant adjustments, some more than others.

Most health systems have limited resources, and when additional needs are required of the health system like during a shock, it can be difficult for a health system to meet the needs asked of it (Barasa, Cloete and Gilson, 2017). Health services such as immunization services are important as they are proven to save lives now and in the future through the prevention of disease outbreaks (Lernout *et al.*, 2014). When an immunization program has experienced a significant shock such as an infectious disease crisis, it is important to identify how it adapted to maintain routine services or expand immunization services for a VPD-caused crisis.

An adaptation can be defined as a health system's ability to evaluate its performance then make rapid functional improvements in response to a crisis (Kruk *et al.*, 2015). When a health system, or a particular health service such as an immunization program, is able to adapt to an infectious disease outbreak, it can reduce the effects on a population in both the short-term and the long-term (Ling *et al.*, 2017). See *figure 1* for adaptive defined within the resilience framework by Kruk *et al.* (2015).

Figure 1 - Adaptive Definition



Adaptations by immunization programs to an infectious disease outbreak is a way a health system strengthens itself, making it more resilient. To learn how a health system or immunization program adapted to an infectious disease outbreak can allow a health system to improve.

Immunization programs

A vaccine is a well-known and cost-effective preventative measure for certain diseases. When an infectious disease crisis occurs, it can be caused by a VPD or a novel infectious disease. In the cause of an outbreak is a VPD, it is important for immunization programs to maintain or expand immunization services related to the VPD. Otherwise, it is likely the shock on the health system would have greater negative health effects on the population. If the cause of an outbreak is a novel disease, it is important for immunization programs to maintain services for VPDs to prevent further outbreaks and to allow an immunization program to build resilience so that if a vaccine for the novel disease is developed, a campaign can be successfully implemented. However, it takes time to develop a vaccine for a novel disease. In that time, pausing immunization programs can prove maleficent, as these programs lose resources, they also begin to lose infrastructure and human resources that need to be scaled back up to deliver a vaccine. To effectively address an infectious disease crisis, it is critical for immunization programs to make adaptations to maintain or expand services.

Resource-poor health systems exist all over the world, at regional and national levels. Low- and middle-income countries (LMICs) typically have resource poor health systems, showing that their health system does not have enough resources to adequately deliver health services in accordance with WHO recommendations (UN, 2015). If the immunization program that serves a population lacks resources prior to an infectious disease outbreak, then an outbreak would have particularly negative consequences on how that health system delivers services (Wilhelm and Helleringer, 2019; WHO, 2020a). Adjustments, adaptations, and capacity building would likely need to take place, potentially at a rapid pace, if a health system aims to minimize how its services are diminished, paused, or halted by an infectious disease

outbreak (Cancedda *et al.*, 2016; Ling *et al.*, 2017; Wilhelm and Helleringer, 2019; CDC, 2020).

Countries with minimal resources to address potential outbreaks, or prevent them, are left vulnerable. If a health system is left under-resourced and unable to address the infectious disease crisis and immunization programs are left paused, other infectious disease outbreaks are likely to occur, extrapolating the health burdens on a population. Infectious disease crises have greatly affected health services, diminishing the overall ability of a health system to positively impact the health of the population it serves. Immunization campaigns are an important health service to address infectious disease outbreaks caused by VPDs. Routine immunization services can prevent or minimize the likelihood of an outbreak from occurring. If an outbreak does occur, immunization services in response to that outbreak are critical to prevent the spread of that disease. If immunization services do not exist for an infectious disease, such is the case when a disease is novel or a health system lacks access to vaccines for a disease, maintaining immunization services for other diseases can prove critical in preventing other infectious disease outbreaks from occurring simultaneously.

Organizations such as the WHO and the U.S. Centers for Disease Control and Prevention (CDC) have advised health systems facing an infectious disease crisis to halt or pause non-related immunization activities (WHO, 2020e). Halting or pausing non-related immunization activities enables a health system to divert resources to the particular disease that is the cause of the crisis. For example, if there are immunization or therapeutic activities related to the particular disease, it is assumed that these would likely continue and could receive more resources to address the outbreak. However, if there are no immunization or therapeutic activities related to the particular disease that caused the crisis, then resources would likely be diverted to non-immunization prevention activities, such was the case during the initial shocks of the EVD outbreak in West Africa or COVID-19 pandemic.

When health systems move resources away from immunization activities, the amount of people in a population immune to VPDs begins to decrease as coverage decreases and newborn or young children are not vaccinated. This increases the likelihood of an infectious disease outbreak occurring from a VPD. In addition, when populations become displaced due to conflict, famine, a natural disaster, or other events, their vulnerability to experience a negative health outcome from an infectious disease increases (Lam, McCarthy and Brennan, 2015). Oftentimes, displaced populations can be underserved, increasing the likelihood of an infectious disease outbreak occurring and due to potential low-levels of displaced population immunity, a crisis can emerge (Lam *et al.*, 2017).

However, immunization programs can adapt to an infectious disease crisis. These adaptations allow a program to maintain immunization services, VPD coverage, or expand immunization services in response to an outbreak.

Purpose of study

The research question this study sought to answer was, “How do immunization programs in LMICs adapt to an infectious disease crisis to maintain or expand immunization services?” The purpose of this study is to assess the current available evidence related to this question. It is important because of the lack of synthesized or shared knowledge on the subject, and infectious disease crises cause negative health outcomes.

Current state of knowledge and appraisal of existing knowledge

Studies exist that discuss adaptations made by immunization programs in LMICs in anticipation of, during, and following an infectious disease crisis. However, despite the recurrent nature of infectious disease outbreaks becoming situations of crisis, there is no assessed, reviewed, or collated evidence on this topic. Understanding the successes, as well as the failures of adaptations made by immunization programs would prove critical toward protecting improving health outcomes. This knowledge would allow health systems and immunization programs in LMICs to be better equipped to adapt to an infectious disease crisis.

The most comprehensive review or appraisal of infectious disease outbreaks in LMICs that discussed immunization programs is written by Walldorf *et al.* (2017). However, there is no discussion on adaptations made to maintain or expand immunization services. The article addressed the need for building capacity of in-country surveillance and how this, along with adaptations made by a few health systems during previous major outbreaks, would bolster global health security. The comprehensive appraisal this study makes on health systems facing infectious disease outbreaks of varying sizes is useful. The article puts into perspective the challenges different infectious diseases can create given the context of an outbreak, however the discussion and experiences of immunization programs is minimal.

Problem to be addressed

Research and reflected on experiences have shown that there is a need for rapid vaccination following events such as humanitarian emergencies, sociopolitical conflicts, and large-scale disease outbreaks to prevent the significant loss of life across the short-term and the long-term (Walldorf *et al.*, 2017). Implementing immunization programs in anticipation of, during, or following an infectious disease crisis have been met by many challenges. Some of those challenges include understanding resource needs and constraints, community sentiment, location of vulnerable and target populations, and organizational capacity.

Organizations such as the WHO and CDC currently provide guidance to pause or reduce non-related immunization services during an infectious disease outbreak (CDC, 2020; WHO, 2020f). This is likely due to the lack of shared knowledge and proven evidence on best practices of how immunization programs have adapted to an infectious disease crisis to maintain non-related services or expand related services. If the knowledge gap related to this topic were filled, it is likely health systems, and immunization programs in particular, would become more resilient to infectious disease outbreaks.

This Rapid Evidence Assessment (REA) will provide insight into the lack of knowledge on the topic of adaptations made by immunization programs in LMICs to an infectious disease crisis. This will likely prove useful during the time of this study and in the future.

Aim & Objectives

The aim of this study was to rapidly assess the evidence related to changes or adaptations made to immunization programs and MDA programs in LMICs to maintain service delivery following an infectious disease crisis.

Objective One: To determine if immunization programs in LMICs make adaptations to maintain service delivery following an infectious disease crisis.

Objective Two: To synthesize the existing information on adaptations made by immunization programs in LMICs during and after an infectious disease crisis.

Objective Three: To assess the methods taken by immunization programs in LMICs to maintain or expand service delivery following an infectious disease crisis.

Methods

A rapid evidence assessment (REA) was the methodology used for this research study. A REA is a form of literature review that is both rapid and rigorous. It is rapid through limiting the scope of the search and methods. It is rigorous due to the quality of data screening and extraction that is taken.

A REA was the best research method given the topic and nature of the study. Due to this project being a master's dissertation, the study needed to be conducted in a relatively short time frame, especially given the changes and shifts in context under which this study was conducted. In addition, due to the subject of the study being about the adaptations immunization programs undertake following an infectious disease crisis, and the context this research is being conducted within (during a global infectious disease crisis), it was essential that newly released literature and information could be assessed rapidly and added to this study. This REA sought

to answer the non-impact question of, “what have immunization programs in LMICs done to adapt to an infectious disease crisis?”

The conceptual framework for this REA lays out the key concepts, what the concept means in relation to this study, how the concept could be measured, and associated terminology for a particular concept. See *table 1* for the conceptual framework for this study.

Table 1 - Conceptual Framework

Concept	What does this concept mean?	How is this concept measured?	Terminology
Immunization program	An immunization program consists of a cold chain, a vaccine supply, a population at risk and aims to prevent a disease in a population.	Quantity and quality of programs; coverage of target population	“vaccination programs” “Vaccines” “Immunize”
Infectious disease crisis	An epidemic at least at the national level that created an unstable situation post-2002.	Number of actual or estimated cases/deaths; geographical spread; DALYs actual or estimated	“crisis” “disease outbreak” “Ebola” “COVID” “Flu” “Cholera” “Measles” “Zika Virus Infection” “Middle East Respiratory Syndrome” “Ebola Virus Disease” “Influenza A H1N1” “Severe Acute Respiratory Syndrome” “Coronavirus Infections”
Low-and-middle income countries	Countries that have low or middle amounts of income per capita as defined by the World Bank.	GDP; GNI; Income per capita	“developing countr*” “low to middle income” “low-to-middle income” LMIC “low income” “middle income” “least developed countr*” “less developed countr*” “under developed countr*” “under developed nation*” “poor countr*” “third world countr*” “third world nation*” “least developed nation*” “less developed nation” “Global South”
Conflict	Civil or between country armed dispute.	Number of disputes; intensity of violence	“conflict” “war” “armed conflict”
Adaptation	In reference to a MDA or immunization program making a change in preparation, response, or recovery for an infectious disease event.	Quality of change(s) made; level of response needed; level of change(s) made	“change” “adjustment”

All sources had to be electronic. These were further limited to peer-reviewed literature and grey literature published by health systems, governments, and international organizations. Other inclusion criteria were that the literature had to be written in English, the place of focus had to be a low-income or middle-income country, and it had to discuss or showcase an adaptation made by an immunization program to maintain or expand service delivery following an infectious disease crisis (or the likelihood of one). Literature was excluded from this study if it was published before 2002 or if it focused on epidemics that did not, or were not likely to, become a national, international, or global infectious disease crisis. Inclusion criteria for studies are listed in *table 2*. Exclusion criteria are listed in *table 3*.

Table 2 - Inclusion criteria

Inclusion Criteria
Electronically available
Academic and grey literature including reports

Written in English language only
Country of focus for the literature must be a low-income or middle-income country
Content of literature focused on immunization program in anticipation of, during, or following an infectious disease crisis.
Infectious disease outbreaks that had the ability to be at least a large-regional epidemic; occurred in the context of a humanitarian crisis, conflict, or natural disaster; or were largely disruptive due to the lack of resources available for a health system to address it.
Literature clearly discusses lesson(s) learned, recommendation(s), or showcases at least one adaptation or change made by an immunization program to maintain or expand service delivery.

Table 3 - Exclusion criteria

Exclusion Criteria
Infectious disease crisis with literature published before 2002.
Literature that focused on epidemics that did not or were not likely to become a national, international, or global crisis
Letters and editorials
Literature not written in English
Literature not available in Medline Complete, Global Health, or the CINHL databases.

Keywords were used for the database search are listed in *table 4*. The table includes key concepts needed to answer the question of this research study. It also includes subject terms such as “immunization programs”, “vaccines”, “disease outbreaks”, or “Ebola virus disease”. These subject terms are based on the Medical Subject Headings (MeSH) set by the National Library of Medicine (NLM). In addition, free-language terms were used to expand the terminology for the search. This also included free-language terms such as, “vaccine campaign”, “flu shot”, “disease spread”, or “Ebola”. The free-language terms are based on less normalized and more contextual terminology that could be used for a specific concept. Subject terms and free-language terms were used in combination with each other when appropriate during the literature search.

Table 4 - Search terms

Concept	Subject Term(s) (controlled vocabulary)	Free language term(s)
Immunization programs	“Immunization programs” “Mass Vaccination” “Vaccination”	“vaccination programs” “vaccines”
Infectious disease crisis	“Disease outbreaks” “Cholera” “Measles” “Zika Virus Infection” “Middle East Respiratory Syndrome” “Ebola Virus Disease” “Influenza A H1N1” “Severe Acute Respiratory Syndrome” “Coronavirus Infections”	“crisis” “disease outbreak” “Ebola” “COVID” “Flu”
Low-and-middle-income countries	“Developing countries”	“developing countr*” “low to middle income” “low-to-middle income” LMIC “low income” “middle income” “least developed countr*” “less developed countr*” “under developed countr*” “under developed nation*” “poor countr*” “third world countr*” “third world nation*” “least developed nation*” “less developed nation” “Global South”
Conflict	“Conflict”	“war” “armed dispute” “coup”
Adaptation	“Adaptation”	“change” “adjustment”
Health Intervention Services	“Health interventions”	“health interv*”

The infectious diseases that resulted in an infectious disease crisis that fit the criteria for inclusion in this study can be found in *table 2*. These events were largely selected based on the scale of the crisis, if it was caused by an infectious disease, if the outbreak had high likelihood or did cause a highly unstable situation that was difficult for the health system to address, even with additional resources. This list was created based on subjective criteria. For this study, infectious disease outbreaks were only considered if they occurred after 2002. This year provided a relevant start point for this study, which focused on recent events where technology and practice can be properly assessed across studies.

If a piece of literature did not discuss an infectious disease outbreak that was list in *table 5*, the particular outbreak was reviewed to see if it fit the parameters laid out by this study to be a crisis. If the literature did, then the list of infectious disease crises was expanded.

Table 5 - Infectious disease crises

Disease	Origin	Area(s) Affected	Year(s)
Measles	Afghanistan	Afghanistan	2001-2002
Severe Acute Respiratory Syndrome (SARS)	China	China, Canada, Hong Kong, Taiwan Singapore, , Viet Nam	2002-2004
Measles	Sudan	Sudan	2003-2004
Cholera	Zimbabwe	Zimbabwe	2008-2009
Influenza A H1N1 (Swine Flu)	North America (Mexico/United States)	World	2009
Cholera	Malawi	Malawi	2010
Measles	Democratic Republic of Congo (DRC)	Democratic Republic of Congo (DRC)	2010-2014
Cholera	Haiti	Haiti	2010-2014
Cholera	Guinea	Guinea, Sierra Leone	2012-2013
Cholera	South Sudan	South Sudan	2012-2015
Cholera	Malawi	Malawi	2015-2016
Ebola Virus Disease (EVD)	Guinea	Guinea, Liberia, Sierra Leone	2014-2016
Cholera	Iraq	Iraq	2015
Zika Virus	Brazil	Americas	2016
Cholera	Yemen	Yemen	2016-2020
Cholera	Zambia	Zambia	2017-2018
Ebola Virus Disease (EVD)	Democratic Republic of Congo (DRC)	Democratic Republic of Congo (DRC)	2018-2020
Measles	Democratic Republic of Congo (DRC)	Democratic Republic of Congo (DRC)	2019-2020
COVID-19	China	World	2019-2020

However, after the search and screening the literature, only some of the infectious disease crises listed in *table 5* had relevant literature available based on the search paraments. The infectious disease crises that had relevant literature on the topic of this REA can be found in *table 6*. These events had relevant literature written about the experiences of the immunization programs and met the inclusion criteria for this study.

Table 6 - Included infectious disease crises

Disease	Origin	Area(s) affected	Year(s)
Measles	Afghanistan	Afghanistan	2001-2002
Measles	Sudan	Sudan	2003-2004
Cholera	Zimbabwe	Zimbabwe	2008-2009
Cholera	Malawi	Malawi	2010
Measles	Democratic Republic of Congo (DRC)	Democratic Republic of Congo (DRC)	2010-2014
Cholera	Haiti	Haiti	2010-2014
Cholera	Ghana	Ghana	2012
Cholera	Guinea	Guinea, Sierra Leone	2012-2013
Cholera	South Sudan	South Sudan	2012-2015
Cholera	Malawi	Malawi	2015-2016
Ebola Virus Disease (EVD)	Guinea	Guinea, Liberia, Sierra Leone	2014-2016
Cholera	Iraq	Iraq	2015
Cholera	Yemen	Yemen	2016-2020
Cholera	Zambia	Zambia	2017-2018
Measles	Democratic Republic of Congo (DRC)	Democratic Republic of Congo (DRC)	2019-2020

Search

Due to the rapid nature of the methodology of the study, restraints were placed on the search parameters. Restraints such as limiting to electronic literature that was published after 2002 and literature that was peer-reviewed allowed for the rapid search. However, to compensate for the limited search parameters, the sensitivity of the search was high. The high sensitivity meant the search was comprehensive through the expanded use of relevant terminology and the number of searches to identify as much relevant literature as possible. In addition, while the high sensitivity inherently caused the specificity to be low and led to an increased number of literature that needed to be sorted through, it did allow for a high number of relevant literature to be identified. This was needed to ensure the study was high quality despite the rapid methods.

The high sensitivity and low specificity of the search created the need for an iterative search approach to be taken. This allowed the search to naturally flow into the direction of the topic of the study without becoming entrenched in non-related literature. There were multiple cycles of search, some that were longer than others dependent upon the relevancy of the literature that was identified during an iterative step. This process allowed a wide-variety of literature to be searched rapidly to identify the most relevant literature to achieve the aims of this study.

Identification of relevant literature

Relevant literature was identified through the use of three databases, (1) Medline Complete, (2) Global Health, and (3) The Complete Index for Nursing and Allied Health Literature (CINHL). Due to the rapid nature of this study, the scope of the search was limited and well-defined. However, to ensure the quality of the search, an initial search was conducted with a broad scope to identify that relevant literature in relation to key concepts of this study existed, that as

much potentially relevant literature as possible, and to narrow down the topic for the main search. Additional concepts and search terms outside of *table 2* and *table 3*, respectively were used for the initial search. This included concepts such as “health intervention services”, “campaign-based”, and “fragile states”. Additional search terms for the initial search were included such as “health interventions”, “vaccine campaign”, and “unstable countries”.

The main search was conducted with a heavy focus on the specific topic discussed of this paper with narrow search parameters. These parameters included: only literature published from 2002–2020, full-text available online, written in English, located in Medline Complete, Global Health, or CINHL databases listed or grey literature, and peer-reviewed literature only. Only the search terms listed in *table 3* were used during this search.

Additional searches following the main search included the loosening of subject terms into free-language terms. This broadened the search and allowed for literature that, though it did not include the controlled subject terms, still fit within the context of the topic of this study. Further searches were conducted after the screening and data extraction of included literature as new themes and topics emerged that could be probed through a literature search. Finally, relevant literature was identified through the screening of the references and citations of literature that was already identified to fit the inclusion criteria of this study.

Screening of literature

Relevant literature was screened to ensure it met the inclusion criteria and that it did not contain any exclusion criteria. An initial search was conducted, then following this, the main search was conducted with subsequent searches when relevant terms emerged. The screening of data from the initial search, main search, and subsequent searches consisted of three parts:

- (1) systematically using key concepts and subject terms to search the selected databases.
- (2) temporarily including any studies that were relevant based off the title and abstract of the paper.
- (3) reading through each of these papers in entirety to decide if they truly met the inclusion criteria for this study.

The use of an initial search, which was then followed by the main search, increased the quality of the screening process by making it more critical and reflexive. In addition, through first screening the results of the literature via title and abstract, an initial overview was provided of each article to decide if it was likely to meet the inclusion criteria of this study. Furthermore, the full-text reading of pieces of literature that were likely to be included, allowed these pieces of

literature to be thoroughly screened which increased the quality of the studies that were included in this REA.

Literature from an initial search was screened, however this was limited. Only the literature of the first fifty results per search term combination were screened through the reading of titles and abstracts. Since some search term combinations had a high volume of results, the purpose of the initial search was to rapidly identify if a search term combination was likely to yield relevant results. While the initial search yielded 11,143 results, only 528 of these were screened. Of these 528, only 39 articles were semi-relevant. This semi-relevant literature was screened then read in full, and 4 of these papers were included in the study.

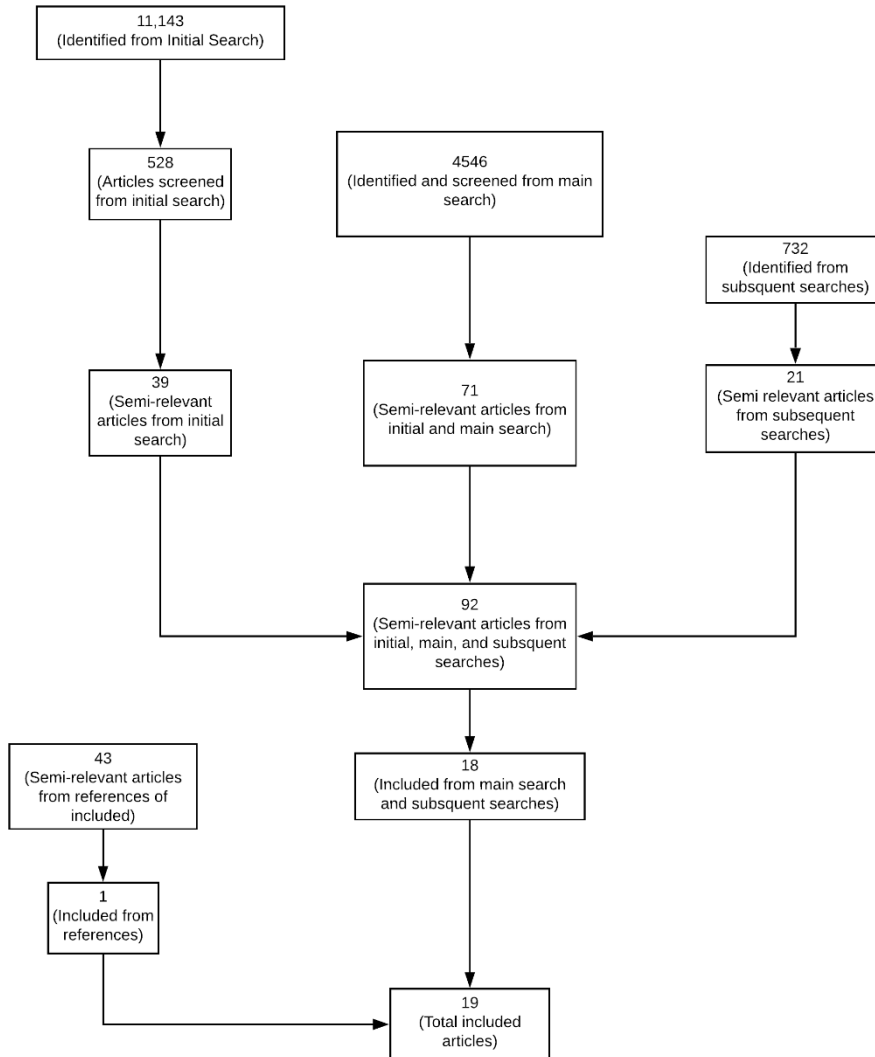
Upon completion of the initial search, the main search was conducted using a refine list of search terms based off the key concepts of this study and yielded higher volumes of relevant literature in the initial search. From the main search, 4,546 articles were identified and screened based off the title and abstract to determine if they met the inclusion criteria. Upon completion of this, 92 pieces of literature were found to be semi-relevant. These papers were read in full to determine if they truly met the inclusion criteria for this study. From this step, 12 pieces of literature were found to be entirely relevant. These 12 pieces of literature were set to be included in this study.

Throughout the main search, new terms emerged that were related to the concepts of this study. This led to subsequent searches being conducted. A total of 732 results were identified and screened through the reading of titles and abstracts. From this, 21 papers were found to be semi-relevant. These papers were read in full to determine if they truly fit the criteria for this study. Of these 21, only 2 studies were found to be completely relevant and were included in this study.

Following the initial search, main search, and subsequent searches, a total 18 pieces of literature fully met the inclusion criteria for this study. The citations of these 18 studies were screened for semi-relevant literature through reading the title of each. Upon the screening of these citations, 43 pieces of literature were found to be semi-relevant. The abstracts and discussion sections of these papers were then read to determine if they fully met the inclusion criteria of this REA. Following this, 1 piece of literature was found to be entirely relevant and was included in this study.

In total, 19 pieces of literature had data extracted from them and were included in the study (see *figure 2* for literature search and screening flowchart).

Figure 2 - Literature search flowchart



Data Extraction

Data was extracted based on a template modified from the EPPI-Centre for systematic reviews. The articles that were selected for inclusion in this study were read in full and relevant data such as the methods, results, conclusions, and adaptations or recommendations of a particular study were coded and extracted. This process allowed for data to be systematically extracted after it was screened.

Through utilizing a template from the EPPI-Centre for systematic reviews, the rigor of the data extraction process was increased. However, since this study is rapid, the template was modified and trimmed down to the essentials, quality control elements, and key elements related to information about the immunization program discussed in each piece of literature. A

key element that was extracted were the lessons learned, or unique insights an article provided on an immunization program that was ran in anticipated of, during, or after an infectious disease crisis. The data extraction form also included the methods of the literature, results, recommendations, adaptations, and quality checks. See *table 7* for a full list of the types of data that were extracted from included studies.

Table 7 - Types of data extracted

Data Extracted
Publication Date
Placed Published
Methodological approach
Purpose of literature
Aim of literature
How the study was funded
Setting
Country/ies where study took place
Population of interest
Details on the topic studied
Program or intervention name
Format of results
Results
Recommendations
Adaptations
Conclusions
Immunization campaign timing
Quality check: Have sufficient attempts been made to justify the conclusions drawn from the findings?
Quality check: Considering all quality assessment issues, can the study findings be trusted in answering the study questions?
Quality check: Appropriateness of research design and analysis for addressing the question, sub-questions, of this specific REA
Quality check: Relevance of particular focus of the study for addressing the question, or sub-questions, of this REA
Quality check: Overall weight of evidence?
Relevant references

Data Analysis

Since this is a non-impact REA, the purpose of data analysis was to assess the available evidence from the studies in relation to what was done to adapt, and not necessarily the degree of impact of the adaptations. The key similarities and differences of the extracted data was compared and assessed. Data was put into a conceptual framework to create a map to identify emerging themes that were representative and to identify unique yet critical concepts. When common concepts were found, they were synthesized into themes.

The themes that emerged were assessed based on the importance and weight that a particular paper gave an adaptation. Themes and extracted data were assessed based on subjective measures, specifically prioritizing data and themes that had a strong relation to the adaptations made by an immunization program. The relationships were identified and

described. In addition, the methods of the coinciding adaption(s) made by the immunization program was described.

Quality of a study was assessed by the quality of the methodological approach a study used, the relevance of the research design for answering the non-impact question for this REA, and the relevance of the study focus for answering the non-impact question for this REA. This created a critical appraisal process from which 0 studies were removed. All included studies met the quality standards for this REA. The qualitative studies included in this REA were appraised using the EEPI-Centre's "Weight of Evidence" framework. Four elements were extracted from the qualitative studies to determine this information.

Data synthesis

The data synthesis process was iterative. Upon the development of the conceptual framework for this study, review questions such as "does this fit the original assumptions?" were asked. Reflection was done on the answer to this question for any particular concept. This led to considerations of the initial topic, its relevance, and the likelihood of the search parameters and methods having covered the original or new assumptions about the direction the topic was taking.

Any existing patterns in the data that were extracted and fit the assumptions held thus far in the synthesis were integrated into the overall synthesis. However, if new patterns from the data extraction emerged or the data did not fit the previous underlying synthesis, the overall synthesis would then be expanded or re-directed. This process repeated for all of the included articles and the data extracted for them until a coherent and meaningful synthesis of data and themes was created.

In short, similarities between pieces of literature were categorized into themes and therefore synthesized. Key differences were also noted to create a wholistic picture. This process generated the findings of this REA which answer the original non-impact questions of this study: What happens to immunization programs during and after an infectious disease crisis? Do you they adapt? If so, how? The answers to these questions yielded the results of this study.

Results

Included Literature

In total, 19 pieces of literature were included in this REA. All of which were peer-reviewed studies. Overall, the density of the literature on the topic of this REA was very scarce. Overall, the quality of the literature found can said to be medium, based on the EPPI-Centre framework

of trustworthiness. 1 piece of literature was low quality, 15 were medium quality, and 1 was high quality.

Synthesis of Main Findings

Overall, this REA showed that immunization programs can adapt through changes in strategy, the use of electronic technology, how they engage with the community, and how the campaign adapted the various dynamics and roles that existed between the multiple actors carrying out the campaign. With each of these adaptations, an immunization campaign would make a specific changes during either the planning, implementation, or evaluation phase of the campaign, or they would utilize a specific adaptation would help during all or two of the phases.

Adaptations were broken down into categories based on the adaptation(s) made by an immunization program. This included (a) adaptations made that involved adjusting the strategy of a campaign to the epidemiological or social context; (b) adaptations made that involved the use of technology such as electronic mapping; (c) adaptations were community engagement enabled a successful program; and (d) adapting the inter-actor dynamics related to the campaign staff, community leaders, community health workers, and other actors involved in an immunization program. Within each of these categories, immunization campaigns adapted during the planning, implementation, and evaluation phases of a particular campaign.

Themes

Adapted Vaccination Strategy to Epidemiological or Social Context

To effectively adapt immunization programs following an infectious disease crisis, it is important to know the epidemiological or social context of the community, region, or country. Studies such as (ting et al.) stress the importance of this to be able to run a successful immunization program during an infectious disease crisis. This stresses the importance of including local and community actors who know the epidemiological and social context when planning, conducting, or evaluating immunization activities.

In Malawi in 2010, a large measles outbreak began with 134,000 cases and the outbreak continued to grow until a vaccination campaign was conducted (Minetti *et al.*, 2013). The outbreak was unexpected since previous campaigns had mostly estimated high population immunity among children 12-23 months but low coverage for children >12 months and 15-19 years of age. For this unexpected outbreak of measles, to make the campaign successful, Minetti *et al.* stated that:

“Control programs need to be adapted to the epidemiological context including age range for routine vaccination” (2017).

Adaptation through improved risk assessment and vaccine coverage estimates for certain populations played a large role in this campaign being effective during an infectious disease outbreak that was set to become a crisis. Minetti *et al.* stated that:

“At-risk and affected groups should be targeted for immunization activities of that particular VPD if they have high epidemic risk” (2017).

In addition, it was concluded that the choice of population to vaccinate and the timeliness of the response played a large role in adapting to the outbreak.

According to Dadgar *et al.* (2003) during a measles campaign in Afghanistan following 23 years of conflict that had disrupted many health services and immunization campaigns, it was important to understand that certain hard-to-reach communities can become the epicenter of a measles outbreak if they were not reached. Therefore, it was important to identify these communities ahead of the campaign and give them special attention for measles vaccination to ensure similar levels of vaccination to the rest of the target population. They discussed the importance of other epidemiological knowledge about the disease in the area, such as the populations it affected. This knowledge can enable a campaign to adjust things such as the age range if a high proportion of cases affected a population that would not typically be targeted for a vaccination campaign of that disease. During their measles campaign in Afghanistan, they extended the target population age range upon the realization that a high proportion of the cases affected children closer to the age of 5 years old. This enabled them to greatly improve the effectiveness and coverage of the campaign, which likely reduced the intensity of the outbreaks.

The studies conducted by Minetti *et al.* (2013) and Dadgar *et al.* (2003) showcased the importance of adaptations made to how the target population is set. This is further elaborated by Abubakar *et al.* (2015) when they stated that:

“More work is needed in understanding how to target appropriate populations if OCV [Oral Cholera Vaccination] is to become more integrated into standard cholera control and prevention”.

The integration of vaccination campaigns and other health services is also discussed by Takahashi *et al.* (2015) in their study which looked at the risk of measles and other childhood infections post-EVD in West Africa. They suggested that key public health interventions, such as vitamin A supplements and insecticide-treated bed nets (ITNs), could be adapted with immunization campaigns following an infectious disease crisis. This would prove critical in

adapting to the epidemiological context of the outbreak. However, Sodha and Dietz (2015) noted the following in regard to the EVD outbreak in West Africa in 2014-2016:

“Additional interventions integrated into an immunization program can sometimes put burdens on resource-limited health systems.”

Sodha and Dietz (2015) discussed how these additional burdens could make either the immunization program less effective or the additional interventions less effective.

With regard to social context, the use of outreach strategies (e.g. door-to-door vaccination) along with fixed strategies (e.g. a stationary vaccination post) proved to be a useful adaptation or change to improve the coverage and feasibility of an immunization campaign as discussed by multiple studies.

During an OCV campaign in Malawi during a Cholera outbreak that had been suspected of becoming nested in hard-to-reach communities, Grandesso *et al.* (2018) conducted a survey to evaluate their adaptive strategic approach. Overall, they found that the use of novel distribution strategies was associated with a high level of vaccination coverage. Due to the communities being hard-to-reach, Grandesso *et al.* (2018) found it important to focus on “home based deliveries”.

In anticipation of a large-scale Cholera epidemic after a Cholera outbreak in Guinea in 2012, Ciglenecki *et al.* (2013) found that the simultaneous utilization of two different strategies improved target population coverage for OCV. Fixed posts were used to vaccinate populations that entered more high-trafficked areas, while door-to-door vaccination was used to reach populations and demographics that were more likely to remain in communities on the periphery of fixed posts.

During an immunization campaign in 2015, post-EVD outbreak in Liberia, Bedford *et al.* (2017) maintained a fixed post vaccination strategy due to high stigmatization of health workers following the EVD crisis. However, they discussed the importance of reaching into the target population when deciding on a vaccination strategy, which can be better understood when a campaign engaged with a community. This is evidenced through a qualitative interview conducted by Bedford *et al.* (2017) where a participant stated:

“If people are farming it will be difficult to get them at their homes or in the village, so we suggest you go to the farms, particularly during Khoo, the time when everybody goes to one person’s farm to help them on the land, and then we eat and drink. That would be the best time, because then people would be in the right mood and would listen to you.”

Adaption through the use of novel strategies for vaccinating a target population is further exemplified by Porta *et al.* (2014) where they utilized two vaccination strategies in response to a potential high-risk Cholera outbreak among refugee and IDP populations in South Sudan in 2012. They found it useful when they utilized a fixed post strategy and a door-to-door vaccination strategy. They further adapted the fixed strategy to the social context by creation of outreach points in areas identified by community leaders and health authorities. These fixed posts were in the markets and the periphery of the refugee camps, which contributed to the high coverage of the OCV campaign. In addition, during a cholera outbreak in Iraq, amid a humanitarian crisis, Lam *et al.* (2017) also found it useful to use a mix of fixed posts and door-to-door Cholera vaccination strategies when the target population was IDPs in and around camps.

Other examples of mixed vaccination strategies included emergency measles control in Sudan in 2003, Hadler *et al.* (2004) discussed how the campaign team found a combination of fixed posts and outreach immunization teams to be effective in increasing measles vaccination coverage. In addition, in 2012, following Cholera outbreaks in Haiti that were a result of the crisis created from the 2010 earthquakes, Teng *et al.* (2014) found that the use of fixed posts, mobile posts, or door-to-door enabled them to vaccinate target rural populations with OCV. They found that leveraging electronic technology allowed them to adapt their strategy daily through the review of the previous day's coverage. This is described when Teng *et al.* (2014) stated:

“Nightly review of community coverage aided in determining the following day's vaccination strategy, whether fixed, mobile, or door-to-door within each locality.”

To contrast this, Poncin *et al.* (2018) found that during a large Cholera outbreak in Zambia, it was more efficient and cheaper to only utilize static vaccination posts. This showcases how the social context of infectious disease crises can vary, and that sometimes it is better to setup outposts and let the target population access static sites.

Lastly, Walldorf *et al.* (2017) found that during the EVD epidemic in Guinea, Liberia, and Sierra Leone, it was important to adapt to the social context and figure out ways to increase a target population's access to a vaccine before the situation escalated to an emergency. This was particularly relevant for at-risk populations, in which case figuring out ways to rapidly deliver a vaccine was critical. This was important because in a resource-limited setting, additional stressors and shocks can further set back an immunization campaign. In addition, they found that the use of geographic targeting can be a particularly useful strategy when an infectious

disease is affecting a well-defined and dense population. To complement this, a study conducted by Ajayi and Smith (2019) found that during a Cholera outbreak, mapping of target populations enabled a more effective and strategic response to an outbreak.

See *table 8* for a full list of literature that discussed adaptation of strategy to the epidemiological or social context and the problem or change that incited the adaptation to occur.

Table 8 - Adapted strategy to the epidemiological or social context

Title	Author(s)	Problem	Adaptation/recommendation
Lessons and Challenges for Measles Control from Unexpected Large Outbreak, Malawi	Minetti et al.	The epidemiological context of a crisis can differ, making a one-size fits approach ineffective.	Expanded the age range of the target population based on a risk assessment.
Implementation of a Mass Measles Campaign in Central Afghanistan, December 2001 to May 2002	Dadgar et al.	Hard-to-reach communities can fuel ongoing outbreaks and future outbreaks.	Give special attention to hard-to-reach communities. Made plans ahead of time to ensure these communities were reached. Expand age range if communities are unlikely to be reached in again in the near future for measles vaccination.
The First Use of the Global Oral Cholera Vaccine Emergency Stockpile: Lessons from South Sudan	Abubaker et al.	The target populations of OCV and other Cholera control and prevention activities differ, which made integration difficult.	There needs to be a better understanding of how to target for OCV populations when OCV is integrated with other Cholera control and prevention activities.
Reduced vaccination and the risk of measles and other childhood infections post-Ebola	Takahashi et al.	Following an infectious disease crisis, many health services can be limited, which is likely to increase the incidence of disease.	Integration of immunization programs and public health interventions relevant to the epidemiological context should be carried out following and infectious disease crisis to minimize health burdens.
Strengthening routine immunization systems to improve global vaccination coverage	Sodha and Dietz	Integration of health interventions and immunization programs can increase costs, especially in a resource-limited setting	Avoid the integration of health interventions and immunization programs during an infectious disease crisis if it is not cost-effective.
Oral cholera vaccination in hard-to-reach communities, Lake Chilwa, Malawi	Grandesso et al.	Communities can be hard-to-reach which can lead to diseases to become endemic in these communities and potentially creating a situation of crisis.	Novel vaccination strategies prevented outbreaks and crisis from occurring through prevention of endemic Cholera in hard-to-reach communities.
Feasibility of Mass Vaccination Campaign with Oral Cholera Vaccines in Response to an Outbreak in Guinea	Ciglenecki et al.	A target population can consist of persons who are unlikely to enter densely populated areas.	Utilization of two strategies (fixed posts and door-to-door) for vaccination proved effective in vaccinating a mixed rural and urban target population.
Community Engagement in Liberia: Routine Immunization Post-Ebola	Bedford et al.	Following an infectious disease outbreak, vaccination strategies that were once effective may not be effective anymore.	To better understand the epidemiological context to be able to adapt, engage with community leaders and local health authorities to better decide on strategic approaches for vaccination.
Feasibility of a preventative mass vaccination campaign with two doses of oral cholera vaccine during a humanitarian emergency in South Sudan	Porta et al.	Despite refugee camps and IDP camps tending to have high population density, there are still individuals who remain on the periphery of these areas.	Vaccination campaign used fixed posts and door-to-door vaccination strategies to increase the coverage of a Cholera vaccination campaign.
Oral Cholera Vaccine Coverage during an Outbreak and Humanitarian Crisis, Iraq, 2015	Lam et al.	Despite refugee camps and IDP camps tending to have high population density, there are still individuals who remain on the periphery of these areas.	Vaccination campaign used fixed posts and door-to-door vaccination strategies to increase the coverage of an OCV campaign.
Emergency Measles Control Activities -- Darfur, Sudan, 2004	Hadler et al.	An epidemiological context with an urban and rural target population can make it difficult for a more traditional vaccination strategy to be effective.	Vaccination campaign used fixed posts and door-to-door vaccination strategies to increase the coverage of a measles campaign.
Using Mobile Health (mHealth) and Geospatial Mapping Technology in a	Teng et al.	An epidemiological context with an urban and rural target population can	Vaccination campaign used fixed posts, mobile posts, and door-to-door vaccination

Mass Campaign for Reactive Oral Cholera Vaccination in Rural Haiti		make it difficult for a more traditional vaccination strategy to be effective.	strategies to increase the coverage of an OCV campaign.
Implementation research: reactive mass vaccination with single-dose oral cholera vaccine, Zambia	Poncin et al.	Resource-limited settings require tighter budgets for immunization campaigns.	Use of static vaccination sites was cheaper and more efficient than house-to-house visits.
Lessons Learned from Emergency Response Vaccination Efforts for Cholera, Typhoid, Yellow fever, and Ebola	Walldorf et al.	Members of a target population can be left unvaccinated, especially during a crisis.	(1) It is important to identify and anticipate how a campaign can increase vaccine access prior to an outbreak becoming an emergency. (2) Can utilize geographic targeting if an outbreak is well-defined and densely populated.
Recurrent Cholera Epidemics in Africa: Which way forward A literature review	Ajayi and Smith	It can be difficult for an immunization campaign to properly plan a campaign if they do not know where the target population is located and how to effectively reach them.	Found that it would be useful for immunization campaigns to map out target populations prior to a campaign to be able to reach a target population effectively and strategically.

Adapted with electronic technology

Electronic technology played a critical role in the planning process for an immunization program following an infectious disease crisis, which allowed staff to be effective and rapidly target, plot, and review vaccination data, strategies, and coverage. Electronic technology can allow an immunization program to rapidly vaccinate a target population while maintaining high levels of coverage.

In a study conducted by Sodha and Dietz (2015), they found that mobile technologies and electronic information systems improved how immunization campaigns were conducted. This is observed through their statement of:

“At more operational levels, innovative means to implement and manage immunization programs, through improved use of information systems and mobile technologies, will be necessary to improve efficiencies.”

In 2010, an earthquake devastated Haiti, disrupting its health system, damaging infrastructure, and sending the country into a crisis. From 2010-2013, Haiti experienced immense health burdens from Cholera outbreaks. Beginning in February 2012, a reactive immunization campaign using OCV was planned and implemented in Haiti. The campaign utilized mobile health (mHealth) software, 40 electronic tablets, and geospatial mapping technology to vaccinate rural populations (Teng *et al.*, 2014). Electronic tablets enabled the usability of mHealth, which allowed campaign staff to quickly enter, review, and confirm data. The mHealth software consisted of a data-hosting contract, mobile licenses for the tablets, and a custom-built analysis tool for case-finding reports. mHealth enabled the campaign to pre-register individuals quickly, providing them with easy to access data to see when pre-registered individuals had yet to be reached by the vaccination campaign. This registration process and the use of mHealth,

which allowed the rapid review of registration data, allowed the campaign to accurately and quickly plan the next day's vaccination strategy based on their target population and what areas had been covered in the day(s) prior. Geospatial mapping was used to plot where fixed vaccination posts were in relation to each other, where out-reach vaccination teams were, and most importantly, where pre-registered yet unvaccinated members of the target population were. Geospatial mapping was used throughout the implementation process to plan where to put fixed vaccination points after each day, based on what populations had been vaccinated or reached the day prior.

In addition, the mHealth solution described by Teng *et al.* (2014) enabled the campaign team to directly enter electronic data while rapidly vaccinating populations with OCV in rural Haiti. The ability to directly enter data allowed them to track fieldwork progress more effectively and give feedback directly to each team member. This was critical for them to continuously adapt their strategy based on new information. The use of geospatial mapping improved quality control, such as seamlessly correcting a team member that appeared to be behind in administration, in the wrong location, or entering data incorrectly. Lastly, the use of electronic tablets enabled the entire campaign staff to enter data in whichever language that were most comfortable with as it could be quickly translated via the tablet later. This improved the quality of the data given the diverse languages present in this context.

The use of electronic tablets, mHealth, and geospatial mapping also enabled the campaign described by Teng *et al.* (2014) to increase the evaluation capacity of the immunization program. They were able to conduct surveillance post-vaccination and improve the follow-up rates of the campaign much more efficiently with electronic technology. Due to the electronic nature of the mHealth solution, all the data recorded from the vaccination campaign was stored in a way that was fairly accessible for future use by the multiple actors involved in this campaign. Through this electronic data, they could monitor the estimated cholera incidence more accurately based on the rates of coverage achieved by this campaign. In addition, the use of geospatial mapping by this campaign also created a digital footprint that could then be used to view exactly the populations the vaccination campaign reached since they were tracked with GPS and plotted onto an electronic map.

In a study conducted by Lam *et al.* (2017), electronic tablets were used by the campaign staff to quickly enter data similar to the study conducted by Teng *et al.* (2014). However, the setting of the study by Lam *et al.* (2017) was during a large-scale Cholera outbreak in Iraq that primarily affected internally displaced persons (IDPs) and refugees in and around Displaced Persons camps. This context increased the need for a rapid and impactful response given the

fragility of the general health of such populations. Electronic tablets enabled the campaign staff to have the quality of data quickly reviewed remotely, and for immediate feedback when incorrect actions were taken. In addition, Lam *et al.* (2017) used GPS to monitor vaccination teams for things such as: how close campaign staff were to each other and if they were at the correct target population. With this knowledge, immediate corrective action was provided, which improved the quality and coverage of the immunization campaign

The use of global positioning system (GPS) to geographically target populations for an immunization program can prove useful to increase coverage and make the program more cost-effective as modelled by Lee *et al.* (2019). The study focused on Sub-Saharan African countries with high Cholera incidence and potential to experience outbreaks, that if left under-vaccinated, would continue to cause infectious disease crises such as the DRC, Nigeria, Somalia, and Sierra Leone. Their modeling showed that geographic targeting can significantly reduce Cholera cases by 859,980 and Cholera deaths by 33,011 from 2018-2030 dependent on the strategy implemented (Lee *et al.*, 2019).

See *table 9* for a full list of literature where an immunization program adapted with electronic technology and the problem or change that incited the adaptation.

Table 9 - Adapted with electronic technology

Title	Author(s)	Problem(s)	Adaptation(s)/Recommendation(s)
Strengthening routine immunization systems to improve global vaccination coverage	Sodha and Dietz	Adaptive implementation and management of immunization programs is needed to improve efficiency.	Mobile technologies and information systems will play a large role in the effectiveness of a vaccination campaign.
Oral Cholera Vaccine Coverage during an Outbreak and Humanitarian Crisis, Iraq, 2015	Lam et al.	(1) Manual review and hard copy entry of data can be time consuming and requires the campaign team to all be in the same location which can slow the vaccination campaign. (2) Campaign staff can survey the wrong populations, households, or communities.	(1) Used electronic tablets for data collection and entry which enabled remote review of data and the quality of the data. (2) Tracked survey teams with GPS to identify their spatial relations to each other to provide feedback.
Using Mobile Health (mHealth) and Geospatial Mapping Technology in a Mass Campaign for Reactive Oral Cholera Vaccination in Rural Haiti	Teng et al.	The campaign was time sensitive due to the nature of the recurrent outbreaks in Haiti. (1) Manual and hard copy entry of data can be time consuming to collate and review. (2) It can be difficult and time-consuming to collate hard copy data into an existing surveillance. (3) It can be time-consuming to identify individuals who are a part of a target population to confirm if they have been vaccinated or not.	They adapted and used technology to speed up the time to reach a site, and how long they spent collecting information from each person vaccinated. (1) Direct electronic data entry created an iterative feedback capability. (2) Use mHealth solution to vaccinate reactively with efficiency. Conducted surveillance post-vaccination with electronic data, active case-finding during implementation, and increased coverage and follow-up rates. (3) Electronic data allowed the campaign to rapidly identify individuals who were pre-registered but still unvaccinated. Further sped up

		(4) When a campaign team consists of individuals of with various native languages, it can be time consuming and inefficient to manually translate data.	the process through scanning barcodes that identified if someone was preregistered or not. (4) Electronic data allowed quick and cost-effective translation of multiple languages to greatly improve communication among a language diverse campaign team.
The projected impact of geographic targeting of oral cholera vaccination in sub-Saharan Africa: A modeling study	Lee et al.	It can be difficult to tell if cholera vaccination campaigns are targeting the right population in relation to level of risk of developing Cholera	Geographic targeting was critical to ensure that extended cholera vaccination campaigns across sub-Saharan Africa had a measurable impact.

Adapted how they engaged with communities

Community engagement played a large part immunization programs to adapt to an infectious disease crises. Community members and leaders play a large role when immunization programs are vaccinating a population, especially when the target population are children. Encouragement of communication between the campaign staff who provide the vaccination and the community members can allow the shared goal of reduced disease burden to be accomplished.

In Sudan in 2004, low measles coverage among the urban populations of Darfur and reported measles outbreaks among IDPs in this urban area led multiple actors to begin a vaccination campaign against measles. As described by Hadler *et al.* (2004), taking adaptive methods to engage communities played a large part in the success of the measles vaccination campaign. Primarily, the campaign used mass media and community-level activities to socially mobilize populations, which lead to the improvement of coverage as well as general measles education.

In addition, in 2015 in Iraq during an measles outbreak and humanitarian crisis among refugees and IDPs, Lam *et al.* (2017) learned that clearer messaging would have improved campaign coverage. This was stated through:

“However, given that one of the most frequent reasons for not being vaccinated was that vaccination teams did not visit residential structures, clearer messaging may be needed for the dual strategy of providing vaccine door-to-door and at fixed posts.”

During an unexpected measles outbreak in Malawi in 2010, Minetti *et al.* (2013) learned that it was important to adapt community engagement as they received feedback from communities throughout the campaign. They adapted and provided clear messaging on the age for the measles vaccination. In addition, it was noted that it implementing routine immunization services can improve the overall program’s ability to engage with communities as they can begin to

foster trust over time in the advent an infectious disease does occur, immunization levels are less likely to be affected by community interest.

Following the EVD outbreak in Guinea, Liberia, and Sierra Leone in 2014-2016, Bedford *et al.* (2017) learned that it was better to visit a community leader and inform them of vaccination activities as opposed to going directly to the community members (2017). Adapting communication pathways would have been key for immunization activities while the EVD outbreak following the crisis and while it was ongoing. This was expressed through qualitative data:

“The gCHV (general Community Health Volunteers) came first and said the vaccine was coming, but some people argued. Then the gCHV called the town chief and he said to bring the children. You shouldn’t go directly to the people, it is better you go to a person that they trust and know, and that person, like the chief tells the people himself” (Bedford *et al.*, 2017).

In 2012 in response to early reports of Cholera cases in Guinea, heightened predictions for a large-scale epidemic, and the start of a Cholera outbreak, a mass vaccination campaign for OCV was conducted. Working with community leaders and health authorities to decide on the location of fixed posts for vaccination was a critical change made discussed by Ciglenecki *et al.* (2013). This adaption enabled the immunization campaign to greatly increase its coverage and ability to increase access to OCV.

See *table 10* for a full list of literature where an immunization program adapted how communities were engaged and the problem or change that incited the adaptation.

Table 10 - Adapted how communities were engaged

Title	Author(s)	Problem(s)	Adaptation(s)/Recommendation(s)
Emergency Measles Control Activities -- Darfur, Sudan, 2004	Hadler et al	Following an infectious disease crisis, communities can be resistant to health workers or hesitant toward health services.	Used extensive social mobilization via community-led activities and mass media.
Oral Cholera Vaccine Coverage during an Outbreak and Humanitarian Crisis, Iraq, 2015	Lam et al.	Communities might find it difficult to understand why a vaccination campaign exists or they might have trouble knowing it exists.	Created clear campaign messages explaining the purpose and importance of vaccination as well as locations to get vaccinated.
Lessons and Challenges for Measles Control from Unexpected Large Outbreak, Malawi	Minetti et al.	Communities might not understand why a target age range exists or may be unfamiliar with immunization activities, and therefore might be hesitant.	Immunization program learned that it is important to provide clear messaging on the age for vaccination. In addition, to foster community acceptance of vaccination, it is important to implement routine vaccination when feasible, especially for areas that have a historical high risk of developing an infectious disease.

Community Engagement in Liberia: Routine Immunization Post-Ebola	Bedford et al.	Communities might be resistant or hesitant toward a campaign if the community leader is not involved.	Through community engagement, the campaign learned that it is important to adapt and first talk to the community leader and then let the community leader inform the community about the campaign.
Feasibility of Mass Vaccination Campaign with Oral Cholera Vaccines in Response to an Outbreak in Guinea	Ciglenecki et al.	Deciding on locations for fixed vaccination posts or what population to target is important and requires contextual knowledge	The campaign team worked with community leaders and local health authorities to decide on the locations for fixed vaccination posts.

Adapted how multiple actors coordinated

Evidence emerged that it was important adapt how multi-actors or sectors coordinated during an infectious disease crisis to be able to maintain or expand immunization services.

Following a measles outbreak in Sudan in 2004, Hadler *et al.* (2004) found that it was critical for them to gain commit from all stakeholders across multiple sectors. The outbreak and subsequent immunization campaign occurred in the midst of conflict. This led the immunization program to find ways to coordinate around the conflict and the lack of stability or pre-existing immunization coordination structures which had become mostly obsolete.

These experiences are backed by Sodha and Dietz (2015) who looked at the importance of strengthening routine vaccination services even in the midst of conflict. They found that it is important for immunization programs to work with other health sectors, especially when an outbreak has to the potential to become an infectious disease crisis. This included things such as immunization programs improving communication and coordination with caregivers when planning and implementing an immunization campaign.

From 2001-2002, Afghanistan faced a measles outbreak among refugee populations, and Dadgar *et al.* (2003) found that the measles campaign set to vaccinate these populations lacked critical information to enable a rapid response. Through improved communication and coordination with other immunization actors, the campaign was able to utilize the pre-existing knowledge from National Immunization Days (NID). This enabled the measles campaign to save time by using the NID processes for identifying supplies, personnel, transport needs, and setting up a training plan.

Following the EVD outbreak in Liberia from 2014-2016, Ling *et al.* (2017) discussed how the resilience of a health system needs to be built before a crisis. In particular, it was stated that the resilience priorities of the multiple actors involved with the health system has to discussed if that health system is to build and sustain resilience, an aspect inclusive of adaption. They concluded that throughout the course of the outbreak, Liberia's health system made significant adaptations, one being that multiple actors were able to coordinate activities more seamlessly due to the aligned goal of preventing and minimizing the spread of EVD.

In addition, Cancedda *et al.* (2016) found that it was critical to scale up the health system during the EVD outbreak in Sierra Leone. The EVD outbreak presented a significant shock to the region and many under-resourced health systems and immunization programs were left ill-equipped to address the crisis. Despite a pause in the immunization activities, the health system was able to restart vaccination campaigns. In particular, improved coordination between international organizations and local health workers enabled this. As they discuss in the paper, the immunization program was able to restart because it:

“Improved coordination with between donors and implementing partners and was able to mobilize what scant financial and human resources [that] were available in the country.”

During the first use of the global OCV emergency stockpile in South Sudan in 2014, Abubakar *et al.* (2015) found that good coordination contributed to their adaptive capacity in anticipation of an infectious disease crisis. This campaign utilized multisite, multi-partner approach to deliver OCV, which underscored the importance of adaptive coordination between multiple actors when conducting an immunization campaign in anticipation of an infectious disease crisis. They found that:

“Strong leadership from the MoH and WHO, pre-existing coordination structures, clearly defined roles and responsibilities for the different actors, and previous use of the vaccine enabled the success of the campaign.”

During a humanitarian crisis and Cholera outbreak in Iraq in 2015, Lam *et al.* (2017) also found adaptive coordination between multiple stakeholders to be critical. While working to vaccinate a large target population consisting of mostly refugees and IDPs, the campaign improved coordination and collaboration between multiple stakeholders during implementation and evaluation.

In 2012, Ghana experienced a wide-spread Cholera outbreak across multiple regions of the country, and Ohene, Klenyuie and Sarpeh (2016) assessed the outbreak in two districts that were in two separate regions. They found that the adaptive coordination carried out enabled by a multiple sector approached proved advantageous in being able to effectively vaccinate the target populations against Cholera. One way this was done was through:

“Extensive health education avenues some of which involved using community volunteers to impart information on preventative measures.”

Following the 2014-2016 EVD outbreak in Liberia, Bedford *et al.* (2017) found that coordination with community leaders, local health authorities, and community members played a significant role in enabling an immunization campaign to effectively vaccinate against Polio and Measles. They interviewed community members and found that:

“We need somebody from our community to convince us. The community must select the person, it can’t just be anybody, it must not be an arrogant person, you can’t just select them. Due to our brothers and sisters sensitizing ourselves, we protect ourselves and we live through their advice.”

“We trust our own people. Some of them went for training, so we believe them. You should use the same people in the future because we took our children as they told us to and by the grace of God, they are fine.”

The study further showcased the impact improvements in coordination with communities can be with the statement:

“You have to have people to tell people: neighbors to neighbors, friends to friends, mothers to mothers.”

In a study conducted by Matapo *et al.* (2016), they found that improving the coordination between multiple actors allowed them to effectively response to one a Cholera outbreak in urban areas in Zambia. This study was critical as it showed the success of a multi-partner response as well as what it enables, namely that a more effective multi-intervention approach can be taken against a Cholera outbreak.

See *table 11* for a full list of literature where an immunization program adapted how multiple actors coordinated and the problem or change that incited the adaptation.

Table 11 - Adapted how multiple actors coordinated

Title	Author(s)	Problem(s)	Adaptation(s)/Recommendation(s)
Emergency Measles Control Activities -- Darfur, Sudan, 2004	Hadler et al.	It can be difficult to achieve high levels of vaccination coverage in areas of conflict, especially when multiple sectors needed to run a campaign are divided due to the conflict.	Gained commitment from multiple sectors to run a large-scale measles vaccination campaign rapidly and effectively in an area of conflict.
Strengthening routine immunization systems to improve global vaccination coverage	Sodha and Dietz	Immunization programs in resource limited settings can be ineffective when they do not have the proper funding and are unable to have the needed range of activities needed.	Immunization programs can work with other health sectors to strengthen the overall health system.
The First Use of the Global Oral Cholera Vaccine Emergency Stockpile: Lessons from South Sudan	Abubakar et al.	Poor coordination among multiple actors can slow outbreak and crisis response.	Through using pre-existing coordination structures, clearly defining roles and responsibilities of multiple actors, this

			campaign was able to successful vaccinate the target population.
Strengthening Health Systems While Responding to a Health Crisis: Lessons Learned by a Nongovernmental Organization During the Ebola Virus Disease Epidemic in Sierra Leone	Cancedda et al.	The initial shock of EVD, lack of resources, and poor coordination between multiple actors led the immunization program to pause activities.	Through improved coordination between multi-actors, the immunization program was able to restart immunization activities, primarily through a partnership between an NGO and local health professionals.
Beyond the crisis: did the Ebola epidemic improve resilience of Liberia's health system?	Ling et al.	The priorities for resilience among communities and local governments can differ, which makes coordination among these actors difficult. This ultimately can slow adaptations.	Important to establish resilience priorities among health system actors so that actors can better coordinate how to adapt following an infectious disease crisis. Introducing new systems such as an incident management system improved the coordination between all actors.
Oral Cholera Vaccine Coverage during an Outbreak and Humanitarian Crisis, Iraq, 2015	Lam et al.	Poor coordination among multiple actors can slow outbreak and crisis response.	This campaign adapted to improve collaboration and coordination between multiple actors which contributed to a successful implementation and evaluation of the vaccination campaign.
Assessment of the response to cholera outbreaks in two districts in Ghana	Ohene, Klenyuie, and Sarpeh	Poor coordination among multiple actors can slow outbreak and crisis response.	Improved coordination among multiple actors to improve the outbreak response and vaccination campaign.
Implementation of a Mass Measles Campaign in Central Afghanistan, December 2001 to May 2002	Dadgar et al.	During an outbreak response, a lack of previous campaigns conducted in the region or context can make it difficult and time-consuming to start a campaign from the ground up.	This campaign used information and systems designed by the national immunization day program in the country, which enabled a rapid and effective response to a measles outbreak.
Community Engagement in Liberia: Routine Immunization Post-Ebola	Bedford et al.	Communities can be resistant to immunization campaigns if community leaders and members are not coordinate with properly.	During and after an infectious disease crisis it was apparent that the coordination with community leaders and members played a significant role in the success of an immunization campaign.
Feasibility of a preventative mass vaccination campaign with two doses of oral cholera vaccine during a humanitarian emergency in South Sudan	Porta et al.	Communities can be resistant or avoidant of health services during an infectious disease crisis, making improved coordination with communities important.	Worked with community leaders and health authorities to plan a cholera immunization campaign.
Successful Multi-partner Response to a Cholera Outbreak in Lusaka, Zambia 2016: A Case Control Study	Matapo et al.	It can be difficult to coordinate multiple actors, rapidly, and in response to an infectious disease crisis.	The campaign found that multiple partners were able to adapt and coordinate to effectively respond to a Cholera outbreak.

Additional adaptations

Additional and notable adaptations that do not fully fit the themes presented above include those related to cost-effectiveness and human resources.

Electronic technology such as the tablets and mHealth solution used by Teng *et al.* (2014) resulted in a significant reduction in cost. This was due to the elimination of the expenses for services such as mass printing and manual data entry, both of which require additional time or staff to complete. In addition, mapping tools discussed by Teng *et al.* (2014) and Lee *et al.* (2019) reduced the cost of an immunization program during a particular campaign and long-term for routine services and outbreaks. For example, Lee *et al.* discussed how geospatial mapping is projected to significantly reduced the time an immunization campaign has to spend to verify coverage rates over time.

From an emergency measles immunization campaign in Sudan in 2004, Hadler *et al.* (2004) attributed the ability for the campaign to be able to adapt to the emergency and rapidly train vaccinators, team leaders, and supervisors in under two weeks as a contributing factor for the success of the campaign.

Discussion

Limitations

This study was limited by only selecting studies that were written in the English language despite most of the context of the evidence aimed to be assessed by this study were in countries where English is not the primary language. Also, the scarcity of the published literature on this topic made it difficult to identify relevant grey literature. Both of these limited the studies that were included in this REA.

In addition, through limiting literature to electronic, published articles or grey literature, this study was limited in its ability to assess evidence from non-published literature. It was difficult to account for this due to the limitations imposed by the context in which this study was conducted, where access to non-electronic literature was not feasible.

Lastly, this study was limited further through the context it was conducted in where the non-ordinary circumstances limited the timeframe and ability for the researcher (myself) to conduct this study. However, this was somewhat accounted for through the design of this study, which made it rapid in nature.

Pulling together findings and evaluating

In anticipation of, during, and after an infectious disease crisis in a LIMC, it can be difficult for a resource-limited health system to maintain or expand services for immunization activities. As the number and intensity of natural disasters are predicted to increase, and have been occurring, there is a need for understanding how immunization programs have adapted in the past to crisis. In addition, as long as humans and animals continue to interact, there is always the risk of zoonotic diseases emerging, which is particularly evident from the COVID-19 pandemic. The shocks that have resulted from these situations of infectious disease crisis have been significant. However, as evidenced by the results of this study, these health systems have made adaptations and are likely more resilient because of them.

This research study was important due to the interconnectedness of the world and how a disease outbreak is able to spread across the globe or entrench itself in remote and isolated communities. The aim of this study was to rapidly assess the evidence related to immunization

programs in LMICs that made changes or adaptations when faced with an infectious disease crisis. This aim was achieved through the methods of this study.

From this REA, there is clear evidence that immunization programs in LMICs have adapted to maintain or expand immunization services in situations of crisis through the creation vaccination strategies based on the epidemiological context, the use of electronic technology, improved and unique ways of engaging with target communities, and learnt ways to improve coordination between multiple actors or sectors.

A key relationship was the use of tablets and mapping services to further adapt to the context of an outbreak and rapidly identify target populations, track campaign teams, and archive data for future evaluation. This relationship is important because it showcased the need for adaptation and how electronic technology can further improve adaptations made with regard to the epidemiological context. This is exemplified by Teng *et al.* (2014) when they used geospatial mapping in response to a Cholera outbreak in Haiti to map out populations and their campaign staff daily, and at the end of each this data was used to prioritize a strategy for the following day. The use of technology improved how the campaign could use more accurate and real-time data to effectively adapt to the epidemiological context of an outbreak.

Another key relationship was when immunization campaigns worked with community leaders to be able to adapt to an epidemiological or social context. Lam *et al.* (2017) found that when their community engagement was not adapted, it prevented their adaption to the social context where they used a door-to-door strategy and a fixed post strategy. The door-to-door strategy was less effective and the need for clearer messaging about the dual strategy became clear. When community engagement is adapted alongside vaccination strategies, such as was the case in South Sudan in 2012 during a Cholera outbreak where Porta *et al.* (2014) found it useful to work with community leaders to decide on the locations of fixed posts as well as outreach points around displaced persons camps. From this relationship, it can be derived that community leaders, community health workers, and community members are important elements of an immunization campaign, especially in the context of an infectious disease crisis. Therefore, it would be logical to formally include such actors within immunization programs. The implications of this will be discussed later in this section.

A third key relationship was between community engagement and improved coordination among multiple actors or sectors. When an immunization campaign viewed community, leaders, community health workers, and community members as actors within the larger immunization program, it enabled the immunization campaign to improve its overall coordination and vaccination coverage. This was evidenced by This relationship is further strengthened by the

relationship between community engagement and adaptation of a strategy to the epidemiological and social context.

[Bias, Reliability, and the Unexpected](#)

Bias was likely introduced to this study due to the limitations placed on where literature could be searched. This could have introduced bias through locating studies. However, this was accounted for by through searching three databases (Medline Complete, Global Health, and the CIHNL) and grey literature. Bias was also likely introduced through the synthesis of the data. While a protocol for a REA does not need to be as rigorous as a protocol for a systematic review, the level of rigor could have been useful in synthesis. However, this bias was necessary and accounted for through the selection of a more rapid evidence assessment methodology.

The reliability of the evidence from this REA is high, and the quality of this evidence is medium. The quality was determined through the EPPI-Centre's framework for trustworthiness where literature was critical reviewed and assigned a quality of low, medium, or high. The reliability of the evidence from this REA is high, because of the methods taken to select the literature were rigorous, highly sensitive, and comprehensive.

Overall, the results from this study were unexpected as the literature on the specific topic is scarce and there are not any pre-existing synthesis, review, or assessment. It was anticipated that there would be more literature on the COVID-19 pandemic and how health systems have adapted immunization programs to maintain or expand services. However, this was only a slight expectation as this study took place shortly after the start of the COVID-19 pandemic, so it was fairly unlikely that there would be comprehensive literature on the subject.

[Implications](#)

This REA discovered that immunization programs have adapted to infectious disease crises in significant ways such as adapting strategy to epidemiological or social context, through the use of electronic technology, how communities are engaged, and how multi-actors or sectors are coordinated. This study was important due to the lack of existing assessment, review, or synthesis of how immunization programs in LMICs adapted to an infectious disease crisis.

[Who is likely to benefit from this study?](#)

Health systems that serve populations that have a history of infectious disease outbreaks are likely to benefit from this study. To learn from the adaptations taken by these immunization programs, health systems could improve resilience and strengthen their immunization programs by proxy. Populations that are affected by infectious disease outbreaks could benefit if the health system that serves them.

In addition, populations that are likely to experience the consequences of climate change, and the anticipated infectious disease outbreaks that will occur as a result of these events, would also greatly benefit from a strengthened health system. Lastly, since infectious disease outbreaks that become crises have the potential to affect the world at large, the sharing of adaptations by health systems who have faced similar events could prove useful in benefiting the entire world if these outbreaks can be adequately prevented or minimized by immunization programs.

[What is the new contribution made?](#)

How immunization programs adapted to an infectious disease crisis is not a topic that has been reviewed or assessed across multiple immunization campaigns and contexts. The key new contribution that is made by this study is that it provides a synthesized assessment of evidence related to immunization programs in LMICs adapting to infectious disease crises.

[What does this imply for immunization programs?](#)

The implications of the results of this study show that there is evidence related to how immunization programs have adapted to infectious disease crises in the past, and that these adaptations proved significant in improving the effectiveness of a program. In addition, it is implied that these adaptations improved the resilience of a health system, which ultimately strengthened it.

The relationship between tablets and mapping services being used rapidly to identify target populations, target campaign teams, and archive data for future evaluation, which ultimately allowed a campaign discussed by Teng *et al.* (2014) to adapt to the epidemiological context was significant. There are many implications with this relationship. First, this campaign created a map of where disease outbreaks occurred, which could lead to the identification of vulnerable populations and where to target immunization campaigns in the future for VPDs. In addition, since mapping services are electronic, it could enable immunization programs, health systems, and other health actors to be able to archive the data for future immunization program use. This could greatly increase an immunization programs ability to rapidly and effectively identify high risk areas for VPD outbreaks when faced with a novel infectious disease crisis. This knowledge could also prove useful in identifying areas that have a high incidence of VPDs to anticipate infectious disease outbreaks more effectively and therefore prevent these outbreaks.

Another implication of the results of this study is that community leaders, community health workers, and community members (here forth all of these groups will be referred to simply as community members) should be formally included in immunization programs,

especially during an infectious disease crisis. Bedford *et al.* (2017) showcased the need for immunization programs following the EVD outbreak in Liberia to adapt and view immunization campaigns as a partnership with community members. These groups all shared the goal of reduced health burden on the target population.

To not formally include community members had adverse outcomes for campaigns. This is described in the results of this study where the literature showed that not working with community members led people to trust or avoid the immunization campaign.

Coordinating, and formally working with community members is an impactful way for immunization campaigns to adapt to an infectious disease crisis. An infectious disease crisis can create stigma around health workers, especially if they have no ties to a community. It is important to establish trust with communities a vaccination campaign aims to reach if the campaign is to be effective and achieve high levels of coverage. A trusted community member being formally included in an immunization campaign would have significant positive impacts on an immunization campaign.

There is a need for having community health workers/volunteers/leaders work with immunization campaigns at a higher level. In addition, there is a need to properly compensate these individuals. Important to view immunization campaigns, especially following an outbreak or infectious disease crisis, as a campaign that works with the community and brings communities onto the process and within key leadership positions, even if temporarily. As evidenced by this study, are essential for a campaign to adapt and be successful. Overall, formally including community members in immunization campaigns and compensating them for their work would increase an immunization campaigns ability to adapt during an infectious disease crisis.

Conclusion

There was evidence that immunization programs have adapted to an infectious disease crisis, and that this occurred through adaptive strategies based on epidemiological or social context, adaptive use of electronic technology, adaptive community engagement, and adaptive coordination between multiple actors. It is important to adapt strategy to an epidemiological or social context, and keyways to do this are through the use of technology and community engagement. When an infectious disease crisis occurs, it is implied that community leaders, community health workers, and community members should be formally included in the campaign process. Overall, these adaptations proved effective in minimizing the extent of an outbreak and the negative health effects on a population. Health systems can learn from each

other, especially in relation to adapting to infectious disease outbreaks. Ultimately, this shared knowledge will improve how immunization programs in LMICs adapt to infectious disease crises.

References

- Abubakar, A., Azman, A. S., Rumunu, J., Ciglenecki, I., Helderma, T., West, H., Lessler, J., Sack, D. A., Martin, S., Perea, W., Legros, D. and Luquero, F. J. (2015) 'The First Use of the Global Oral Cholera Vaccine Emergency Stockpile: Lessons from South Sudan', *Plos Medicine*, 12(11), pp. 1-8. doi: 10.1371/journal.pmed.1001901. Available at: <http://search.ebscohost.com/login.aspx?direct=true&db=ccm&AN=128193003&site=ehost-live>.
- Ajayi, A. and Smith, S. I. (2019) 'Recurrent cholera epidemics in Africa: which way forward? A literature review', *Infection*, 47(3), pp. 341-349. doi: 10.1007/s15010-018-1186-5. Available at: <http://search.ebscohost.com/login.aspx?direct=true&db=ccm&AN=136714629&site=ehost-live>.
- Armocida, B., Formenti, B., Ussai, S., Palestra, F. and Missoni, E. (2020) 'The Italian health system and the COVID-19 challenge', *The Lancet Public Health*, 5(5), p. e253.
- Barasa, E. W., Cloete, K. and Gilson, L. (2017) 'From bouncing back, to nurturing emergence: reframing the concept of resilience in health systems strengthening', *Health Policy And Planning*, 32(Suppl. 3), pp. iii91-iii94. Available at: <https://lstmed.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&AuthType=cookie.ip,uid&db=llh&AN=20183149022&site=eds-live&scope=site>
<https://academic.oup.com/heapol/> email: edwinebarasa@gmail.com.
- Bedford, J., Chitnis, K., Webber, N., Dixon, P., Limwame, K., Eleassawi, R. and Obregon, R. (2017) 'Community Engagement in Liberia: Routine Immunization Post-Ebola', *Journal of health communication*, 22(sup1), pp. 81-90. doi: 10.1080/10810730.2016.1253122. Available at: <http://search.ebscohost.com/login.aspx?direct=true&db=mdc&AN=28854140&site=ehost-live>.
- Blanchet, K., Nam, S. L., Ramalingam, B. and Pozo-Martin, F. (2017) 'Governance and Capacity to Manage Resilience of Health Systems: Towards a New Conceptual Framework', *International Journal of Health Policy and Management*, 6(8), pp. 431-435. doi: 10.15171/ijhpm.2017.36. Available at: <https://pubmed.ncbi.nlm.nih.gov/28812842>
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5553211/>.
- Cancedda, C., Davis, S. M., Dierberg, K. L., Lascher, J., Kelly, J. D., Barrie, M. B., Koroma, A. P., George, P., Kamara, A. A., Marsh, R., Sumbuya, M. S., Nutt, C. T., Scott, K. W., Thomas, E., Bollbach, K., Sesay, A., Barrie, A., Barrera, E., Barron, K., Welch, J., Bhadelia, N., Frankfurter, R. G., Dahl, O. M., Das, S., Rollins, R. E., Eustis, B., Schwartz, A., Pertile, P., Pavlopoulos, I., Mayfield, A., Marsh, R. H., Dibba, Y., Kloepper, D., Hall, A., Huster, K., Grady, M., Spray, K., Walton, D. A., Daboh, F., Nally, C., James, S., Warren, G. S., Chang, J., Drasher, M., Lamin, G., Bangura, S., Miller, A. C., Michaelis, A. P., McBain, R., Broadhurst, M. J., Murray, M., Richardson, E. T., Philip, T., Gottlieb, G. L., Mukherjee, J. S. and Farmer, P. E. (2016) 'Strengthening Health Systems While Responding to a Health Crisis: Lessons Learned by a Nongovernmental Organization During the Ebola Virus Disease Epidemic in Sierra Leone'. Available at: <https://lstmed.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&AuthType=cookie.ip,uid&db=edswsc&AN=000386148800008&site=eds-live&scope=site>.
- CDC, C. f. D. C. a. P. (2006) 'Vaccine Preventable Deaths and the Global Immunization Vision and Strategy, 2006–2015', *Morbidity and Mortality Weekly Report*, 55(18), p. 511. Available at: <https://lstmed.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&AuthType=cookie.ip,uid&db=edsjsr&AN=edsjsr.23316827&site=eds-live&scope=site>.
- CDC, C. f. D. C. a. P. (2020) *Vaccination Guidance During a Pandemic*. Available at: <https://www.cdc.gov/vaccines/pandemic-guidance/index.html>.

- Chinazzi, M., Davis, J. T., Ajelli, M., Gioannini, C., Litvinova, M., Merler, S., y Piontti, A. P., Mu, K., Rossi, L. and Sun, K. (2020) 'The effect of travel restrictions on the spread of the 2019 novel coronavirus (COVID-19) outbreak', *Science*, 368(6489), pp. 395-400.
- Ciglenecki, I., Sakoba, K., Luquero, F. J., Heile, M., Itama, C., Mengel, M., Grais, R. F., Verhoustraeten, F. and Legros, D. (2013) 'Feasibility of mass vaccination campaign with oral cholera vaccines in response to an outbreak in Guinea', *Plos Medicine*, 10(9), pp. e1001512-e1001512. doi: 10.1371/journal.pmed.1001512. Available at: <http://search.ebscohost.com/login.aspx?direct=true&db=ccm&AN=104098037&site=ehost-live>.
- Dadgar, N., Ansari, A., Naleo, T., Brennan, M., Salama, P., Sadozai, N., Golaz, A., Lievano, F., Jafari, H., Mubarak, M., Hoekstra, E., Paganini, A. and Feroz, F. (2003) 'Implementation of a Mass Measles Campaign in Central Afghanistan, December 2001 to May 2002', *The Journal of Infectious Diseases*, 187(Supplement_1), pp. S186-S190. doi: 10.1086/368335. Available at: <https://doi.org/10.1086/368335> (Accessed: 8/28/2020).
- De Cock, K. M., Mbori-Ngacha, D. and Marum, E. (2002) 'Shadow on the continent: public health and HIV/AIDS in Africa in the 21st century', *The Lancet*, 360(9326), pp. 67-72. doi: [https://doi.org/10.1016/S0140-6736\(02\)09337-6](https://doi.org/10.1016/S0140-6736(02)09337-6). Available at: <http://www.sciencedirect.com/science/article/pii/S0140673602093376>.
- deLisle, J. (2003) 'SARS, Greater China, and the Pathologies of Globalization and Transition', *Orbis*, 47(4), pp. 587-604. doi: 10.1016/S0030-4387(03)00076-0. Available at: <https://pubmed.ncbi.nlm.nih.gov/32287394>
- <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7130713/>.
- Dunbar, N. K., Richards, E. E., Woldeyohannes, D., Bergh, R. v. d., Wilkinson, E., Tamang, D. and Owiti, P. (2017) 'Knockdown and recovery of malaria diagnosis and treatment in Liberia during and after the 2014 Ebola outbreak', *Public Health Action*, 7(Suppl. 1), pp. S76-S81. Available at: <http://lstmed.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=lhs&AN=20173369004&site=eds-live&scope=site&custid=ns241346>
<http://ingentaconnect.com/contentone/iatld/pha/2017/00000007/A00101s1/art00014;jsessionid=1lzlz2xrhi8h.x-ic-live-03#> email: nelsonichd2013@gmail.com
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5515568/pdf/i2220-8372-7-s1-S76.pdf>.
- Fauci, A. S. and Lane, H. C. (2020) 'Four Decades of HIV/AIDS — Much Accomplished, Much to Do', *New England Journal of Medicine*, 383(1), pp. 1-4. doi: 10.1056/NEJMp1916753. Available at: <https://www.nejm.org/doi/full/10.1056/NEJMp1916753>.
- Fridell, M., Edwin, S., von Schreeb, J. and Saulnier, D. D. (2020) 'Health System Resilience: What Are We Talking About? A Scoping Review Mapping Characteristics and Keywords', *International Journal of Health Policy and Management*, 9(1), pp. 6-16. doi: 10.15171/ijhpm.2019.71. Available at: <https://pubmed.ncbi.nlm.nih.gov/31902190>
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6943300/>.
- Gopalakrishna, G., Choo, P., Leo, Y. S., Tay, B. K., Lim, Y. T., Khan, A. S. and Tan, C. C. (2004) 'SARS transmission and hospital containment', *Emerging Infectious Diseases*, 10(3), p. 395.
- Grandesso, F., Rafael, F., Chipeta, S., Alley, I., Saussier, C., Nogareda, F., Burns, M., Lechevalier, P., Page, A.-L., Salumu, L., Pezzoli, L., Mwesawina, M., Cavailler, P., Mengel, M., Javier Luquero, F. and Cohuet, S. (2018) 'Oral cholera vaccination in hard-to-reach communities, Lake Chilwa, Malawi', *Bulletin Of The World Health Organization*, 96(12), pp. 817-825. doi: 10.2471/BLT.17.206417. Available at: <http://search.ebscohost.com/login.aspx?direct=true&db=ccm&AN=133397220&site=ehost-live>.

- Gupta, S. B., Collier, B.-A. and Feinberg, M. (2018) 'Unprecedented pace and partnerships: the story of and lessons learned from one Ebola vaccine program', *Expert review of vaccines*, 17(10), pp. 913-923. doi: 10.1080/14760584.2018.1527692. Available at: <http://search.ebscohost.com/login.aspx?direct=true&db=mdc&AN=30269612&site=ehost-live>.
- Hadler, J. H., J., Weiss, D. O., B., Hoffman, J., Dail, K., Hawkins, D. and Nguyen, D. S., S. (2004) 'Emergency measles control activities--Darfur, Sudan, 2004', *MMWR. Morbidity and mortality weekly report*, 53(38), pp. 897-899. Available at: <http://search.ebscohost.com/login.aspx?direct=true&db=mdc&AN=15457146&site=ehost-live>.
- Hadler, S. (2013) 'Vaccination programs in developing countries', *Vaccines*. [St. Louis, Mo.]: Saunders.
- Hausman, B. L. (2019) *Anti/Vax: Reframing the Vaccination Controversy*. Ilr Press.
- Ivers, L. C. and Ryan, E. T. (2006) 'Infectious diseases of severe weather-related and flood-related natural disasters', *Current Opinion in Infectious Diseases*, 19(5). Available at: https://journals.lww.com/co-infectiousdiseases/Fulltext/2006/10000/Infectious_diseases_of_severe_weather_related_and.3.aspx.
- Karbo, T. and Mutisi, M. (2012) 'Ethnic conflict in the Democratic Republic of Congo (DRC)', *Handbook of Ethnic Conflict*: Springer, pp. 381-402.
- Kieny, M.-P., Evans, D. B., Schmets, G. and Kadandale, S. (2014) 'Health-system resilience: reflections on the Ebola crisis in western Africa'. SciELO Public Health.
- Kruk, M. E., Myers, M., Varpilah, S. T. and Dahn, B. T. (2015) 'What is a resilient health system? Lessons from Ebola', *The Lancet*, 385(9980), pp. 1910-1912. doi: 10.1016/S0140-6736(15)60755-3. Available at: [https://doi.org/10.1016/S0140-6736\(15\)60755-3](https://doi.org/10.1016/S0140-6736(15)60755-3) (Accessed: 2020/09/10).
- Lam, E., Al-Tamimi, W., Russell, S. P., Butt, M. O.-U. I., Blanton, C., Musani, A. S. and Date, K. (2017) 'Oral Cholera Vaccine Coverage during an Outbreak and Humanitarian Crisis, Iraq, 2015', *Emerging Infectious Diseases*, 23(1), pp. 38-45. doi: 10.3201/eid2301.160881. Available at: <https://lstmed.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&AuthType=cookie,ip,uid&db=mdc&AN=27983502&site=eds-live&scope=site>.
- Lam, E., McCarthy, A. and Brennan, M. (2015) 'Vaccine-preventable diseases in humanitarian emergencies among refugee and internally-displaced populations', *Human vaccines & immunotherapeutics*, 11(11), pp. 2627-2636.
- Le Gargasson, J.-B., Mibulumukini, B., Gessner, B. D. and Colombini, A. (2014) 'Budget process bottlenecks for immunization financing in the Democratic Republic of the Congo (DRC)', *Vaccine*, 32(9), pp. 1036-1042.
- Lee, E. C., Azman, A. S., Kaminsky, J., Moore, S. M., McKay, H. S. and Lessler, J. (2019) 'The projected impact of geographic targeting of oral cholera vaccination in sub-Saharan Africa: A modeling study', *Plos Medicine*, 16(12), pp. 1-17. doi: 10.1371/journal.pmed.1003003. Available at: <http://search.ebscohost.com/login.aspx?direct=true&db=ccm&AN=140292426&site=ehost-live>.
- Lernout, T., Theeten, H., Leuridan, E. and Van Damme, P. (2014) 'Do vaccines save lives? Yes they do!', *Acta medica portuguesa*, 27(2), pp. 160-162. Available at: <https://lstmed.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&AuthType=cookie,ip,uid&db=mdc&AN=24813482&site=eds-live&scope=site>.
- Ligon, B. L. (2006) 'Infectious Diseases that Pose Specific Challenges After Natural Disasters: A Review', *Seminars in Pediatric Infectious Diseases*, 17(1), pp. 36-45. doi: <https://doi.org/10.1053/j.spid.2006.01.002>. Available at: <http://www.sciencedirect.com/science/article/pii/S1045187006000033>.
- Ling, E. J., Larson, E., Macauley, R. J., Kodl, Y., VanDeBogert, B., Baawo, S. and Kruk, M. E. (2017) 'Beyond the crisis: did the Ebola epidemic improve resilience of Liberia's health system?', *Health Policy And Planning*, 32(suppl_3), pp. iii40-iii47. doi: 10.1093/heapol/czx109. Available at:

<http://lstmed.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=mdc&AN=29149311&site=eds-live&scope=site&custid=ns241346>
https://watermark.silverchair.com/czx109.pdf?token=AQECAHi208BE49Ooan9kkhW_Ercy7Dm3ZL_9Cf3qfKAc485ysgAAAmwwggJlBgkqhkiG9w0BBwagggJZMIICVQIBADCCAk4GCSqGSIb3DQEHATAeBglgkgBZQMEAS4wEQQMJCqipVPY317OHOQAgEQgIICh2xdn2XD1z5tziia5BZpgCz89gDGXQO49IFtB3cz-qpz-xnFaT6wiw6eR0KHGzzqbVFmVsvUufwLP2gTmrVQ88H00S0C977VchXtaU_8R5OYZwCy5AiW8kblvjE2jpoPU9BX-RV_0X_iWTePcrWgQVBmkFZu_j4BgfhFaARMtztGLg2s1LL_KEjtyrbXOWwCoMW5lc2FLbfVcGDDPaz3XtCsYHgTstlbKsrzC82iBXVpHqoB6gnTPaUmOyewKBdkx5cn43ggON_xOAC6NfFB56tLfpXO5XT3bMyusT-pTBXyHZ4V-IILvdesPqBqFG-j6HlyydDHOwJ74PRIQl-X6tT4GXL895clRJfQnYamgYfvzljfHaoQY0h5eW9whYAoy2oWvx1EpiU5jyLuvbFYEToeVbXAexGHLQCQRzVbMfEQKgtSDLGFq0jRxmQF7Q5hE1-pS6KVIEOMbnivb6bYkYiq-vgRhPjeaNUJ1SWJBhzotejvC4W9_tijePluOWwBNt9DHDymrX8ofLwyQ_88oiLFK0dyrnTk0X80bglQobiV1ZkSL-33ADh6bndLjix-dvf1giD61xVGASwsdicYFUQUHXYaJrF4vgM9FfDzoKWPNYWz7SHXJkBSN-uV2-i6uZcJeA-SrpgVSWLeDPw2pwMQV0Rnr9xhDVnqFxO7qebQvqDq8YYcuOBxJnugmNEKy_TPMZ5tfR5gZYfrxkhEag

- Lloyd-Sherlock, P., Ebrahim, S., Geffen, L. and McKee, M. (2020) 'Bearing the brunt of covid-19: older people in low and middle income countries'. British Medical Journal Publishing Group.
- Mahajan, A. P., Sayles, J. N., Patel, V. A., Remien, R. H., Sawires, S. R., Ortiz, D. J., Szekeres, G. and Coates, T. J. (2008) 'Stigma in the HIV/AIDS epidemic: a review of the literature and recommendations for the way forward', *AIDS (London, England)*, 22 Suppl 2(Suppl 2), pp. S67-S79. doi: 10.1097/01.aids.0000327438.13291.62. Available at:
<https://pubmed.ncbi.nlm.nih.gov/18641472>
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2835402/>.
- Matapo, B., Chizema, E., Hangombe, B. M., Chishimba, K., Mwiinde, A. M., Mwanamwalye, I., Zulu, G., Malama, K., Mufunda, J., Muzongwe, C. M., Kabinga, F. M., Chewa, O. and Vwalika, B. (2016) 'Successful Multi-partner Response to a Cholera Outbreak in Lusaka, Zambia 2016: A Case Control Study', *Medical Journal of Zambia*, 43(3), p. 116. Available at:
<https://lstmed.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&AuthType=cookie.ip,uid&db=edb&AN=122982105&site=eds-live&scope=site>.
- Mills, E., Cooper, C., Guyatt, G., Gilchrist, A., Rachlis, B., Sulway, C. and Wilson, K. (2004) 'Barriers to participating in an HIV vaccine trial: a systematic review', *AIDS*, 18(17), pp. 2235-2242. Available at:
https://journals.lww.com/aidsonline/Fulltext/2004/11190/Barriers_to_participating_in_an_HIV_vaccine_trial.3.aspx.
- Minetti, A., Kagoli, M., Katsulukuta, A., Huerga, H., Featherstone, A., Chiotcha, H., Noel, D., Bopp, C., Sury, L., Fricke, R., Iscla, M., Hurtado, N., Ducombe, T., Nicholas, S., Kabuluzi, S., Grais, R. F. and Luquero, F. J. (2013) 'Lessons and challenges for measles control from unexpected large outbreak, Malawi', *Emerging Infectious Diseases*, 19(2), pp. 202-209. doi: 10.3201/eid1902.120301. Available at:
<http://search.ebscohost.com/login.aspx?direct=true&db=ccm&AN=104301033&site=ehost-live>.
- Nguyen, P.-Y. (2019) 'Ebola Outbreaks in the Democratic Republic of Congo (DRC), 2017-2019', *Global Biosecurity*, 1(2).
- Ohene, S.-A., Klenyue, W. and Sarpeh, M. (2016) 'Assessment of the response to cholera outbreaks in two districts in Ghana'. Available at:

- <https://lstmed.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&AuthType=cookie,ip,uid&db=edsWSC&AN=000387749300001&site=eds-live&scope=site>.
- Peter, R. M. (2009) 'Zimbabwe experiences the worst epidemic of cholera in Africa', *The Journal of Infection in Developing Countries*, 3(02). doi: 10.3855/jidc.62. Available at: <https://jidc.org/index.php/journal/article/view/19755746> (Accessed: 2020/09/10).
- Poletto, C., Gomes, M., y Piontti, A. P., Rossi, L., Bioglio, L., Chao, D. L., Longini Jr, I., Halloran, M. E., Colizza, V. and Vespignani, A. (2014) 'Assessing the impact of travel restrictions on international spread of the 2014 West African Ebola epidemic', *Eurosurveillance*, 19(42), p. 20936.
- Poncin, M., Zulu, G., Voute, C., Ferreras, E., Mbwili Muleya, C., Malama, K., Pezzoli, L., Mufunda, J., Robert, H., Uzzeni, F., Luquero, F. J., Chizema, E. and Ciglenecki, I. (2018) 'Implementation research: reactive mass vaccination with single-dose oral cholera vaccine, Zambia', *Bulletin Of The World Health Organization*, 96(2), pp. 86-93. doi: 10.2471/BLT.16.189241. Available at: <http://search.ebscohost.com/login.aspx?direct=true&db=ccm&AN=132310758&site=ehost-live>.
- Porta, M. I., Lenglet, A., de Weerd, S., Crestani, R., Sinke, R., Frawley, M. J., Van Herp, M. and Zachariah, R. (2014) 'Feasibility of a preventive mass vaccination campaign with two doses of oral cholera vaccine during a humanitarian emergency in South Sudan', *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 108(12), pp. 810-815. doi: 10.1093/trstmh/tru153. Available at: <https://lstmed.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&AuthType=cookie,ip,uid&db=mdc&AN=25311798&site=eds-live&scope=site>.
- Reid, D. and Goldberg, D. (2012) 'Epidemiology and control of community infections' In: Greenwood, D., Barer, M., Slack, R. & Irving, W. (eds.). *Medical microbiology: a guide to microbial infections: pathogenesis, immunity, laboratory investigation and control*. Edinburgh; UK: Churchill Livingstone. Available at: <https://lstmed.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&AuthType=cookie,ip,uid&db=lhh&AN=20123402517&site=eds-live&scope=site>.
- Roberton, T., Carter, E. D., Chou, V. B., Stegmuller, A. R., Jackson, B. D., Tam, Y., Sawadogo-Lewis, T. and Walker, N. (2020) 'Early estimates of the indirect effects of the COVID-19 pandemic on maternal and child mortality in low-income and middle-income countries: a modelling study', *The Lancet Global Health*, 8(7), pp. e901-e908. doi: [https://doi.org/10.1016/S2214-109X\(20\)30229-1](https://doi.org/10.1016/S2214-109X(20)30229-1). Available at: <http://www.sciencedirect.com/science/article/pii/S2214109X20302291>.
- Shears, P. and Garavan, C. (2020) 'The 2018/19 Ebola epidemic the democratic republic of the Congo (DRC): Epidemiology, outbreak control, and conflict', *Infection Prevention in Practice*, 2(1), p. 100038.
- Shereen, M. A., Khan, S., Kazmi, A., Bashir, N. and Siddique, R. (2020) 'COVID-19 infection: Origin, transmission, and characteristics of human coronaviruses', *Journal of Advanced Research*.
- Sian, C. (2013) 'Stigma related to HIV and AIDS as a barrier to accessing health care in Thailand: a review of recent literature', *WHO South-East Asia Journal of Public Health*, 2(1), pp. 12-22. Available at: <https://apps.who.int/iris/handle/10665/329765>.
- Smith, K. F., Goldberg, M., Rosenthal, S., Carlson, L., Chen, J., Chen, C. and Ramachandran, S. (2014) 'Global rise in human infectious disease outbreaks', *Journal of The Royal Society Interface*, 11(101), p. 20140950. doi: doi:10.1098/rsif.2014.0950. Available at: <https://royalsocietypublishing.org/doi/abs/10.1098/rsif.2014.0950> %X To characterize the change in frequency of infectious disease outbreaks over time worldwide, we encoded and analysed a novel 33-year dataset (1980–2013) of 12 102 outbreaks of 215 human infectious diseases, comprising more than 44 million cases occurring in 219 nations. We merged these records with ecological characteristics of the causal pathogens to examine global temporal trends in the total number of outbreaks, disease richness (number of unique diseases), disease diversity (richness and outbreak evenness) and per capita cases. Bacteria, viruses, zoonotic

- diseases (originating in animals) and those caused by pathogens transmitted by vector hosts were responsible for the majority of outbreaks in our dataset. After controlling for disease surveillance, communications, geography and host availability, we find the total number and diversity of outbreaks, and richness of causal diseases increased significantly since 1980 ($p < 0.0001$). When we incorporate Internet usage into the model to control for biased reporting of outbreaks (starting 1990), the overall number of outbreaks and disease richness still increase significantly with time ($p < 0.0001$), but per capita cases decrease significantly ($p = 0.005$). Temporal trends in outbreaks differ based on the causal pathogen's taxonomy, host requirements and transmission mode. We discuss our preliminary findings in the context of global disease emergence and surveillance.
- Sodha, S. V. and Dietz, V. (2015) 'Strengthening routine immunization systems to improve global vaccination coverage', *British Medical Bulletin*, 113, pp. 5-14. Available at: <http://search.ebscohost.com/login.aspx?direct=true&db=lhh&AN=20153113356&site=ehost-live> <http://bmb.oxfordjournals.org/content/113/1/5.full> email: ssodha@cdc.gov.
- Stanislas, R., Bertrand, S., Benoît, F. and Renaud, P. (2013) 'Environmental Determinants of Cholera Outbreaks in Inland Africa: A Systematic Review of Main Transmission Foci and Propagation Routes', *The Journal of Infectious Diseases*, 208, p. S46. doi: 10.1093/infdis/jit195. Available at: <https://lstmed.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&AuthType=cookie,ip,uid&db=edsjrs&AN=edsjrs.42569607&site=eds-live&scope=site>.
- Sun, X., Samba, T. T., Yao, J., Yin, W., Xiao, L., Liu, F., Liu, X., Zhou, J., Kou, Z., Fan, H., Zhang, H., Williams, A., Lansana, P. M. and Yin, Z. (2017) 'Impact of the Ebola outbreak on routine immunization in western area, Sierra Leone - a field survey from an Ebola epidemic area', *BMC Public Health*, 17(1), p. 363. doi: 10.1186/s12889-017-4242-7. Available at: <http://search.ebscohost.com/login.aspx?direct=true&db=mdc&AN=28446173&site=ehost-live>.
- Takahashi, S., Metcalf, C. J. E., Ferrari, M. J., Moss, W. J., Truelove, S. A., Tatem, A. J., Grenfell, B. T. and Lessler, J. (2015) 'Reduced vaccination and the risk of measles and other childhood infections post-Ebola', *Science*, 347(6227), pp. 1240-1242. doi: 10.1126/science.aaa3438. Available at: <https://science.sciencemag.org/content/sci/347/6227/1240.full.pdf>.
- Teng, J. E., Thomson, D. R., Lascher, J. S., Raymond, M. and Ivers, L. C. (2014) 'Using Mobile Health (mHealth) and geospatial mapping technology in a mass campaign for reactive oral cholera vaccination in rural Haiti', *PLoS neglected tropical diseases*, 8(7), p. e3050. doi: 10.1371/journal.pntd.0003050. Available at: <http://search.ebscohost.com/login.aspx?direct=true&db=mdc&AN=25078790&site=ehost-live>.
- UN, U. N. (2015) *Sustainable Development Goals*. Available at: <https://sdgs.un.org/goals>.
- Van Aalst, M. K. (2006) 'The impacts of climate change on the risk of natural disasters', *Disasters*, 30(1), pp. 5-18. doi: 10.1111/j.1467-9523.2006.00303.x. Available at: <https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1467-9523.2006.00303.x>.
- Walldorf, J. A., Date, K. A., Sreenivasan, N., Harris, J. B. and Hyde, T. B. (2017) 'Lessons Learned from Emergency Response Vaccination Efforts for Cholera, Typhoid, Yellow Fever, and Ebola', *Emerging Infectious Diseases*, 23, pp. S210-S216. doi: 10.3201/eid2313.170550. Available at: <http://search.ebscohost.com/login.aspx?direct=true&db=mdc&AN=EPTOC126568514&site=ehost-live>.
- Webster, P. C. (2011) 'Lack of clean water exacerbates cholera outbreak in Haiti', *Canadian Medical Association Journal*, 183(2), pp. E83-E84. doi: 10.1503/cmaj.109-3764. Available at: <https://www.cmaj.ca/content/cmaj/183/2/E83.full.pdf>.
- WHO, W. H. O. (1998) *Humanitarian Health Action*. Definitions: emergencies. Available at: <https://www.who.int/hac/about/definitions/en/>.

- WHO, W. H. O. (2006) *SARS: how a global epidemic was stopped*. Manila: WHO Regional Office for the Western Pacific.
- WHO, W. H. O. (2010) *Weekly Epidemiological Record, Cholera 2010*.
- WHO, W. H. O. (2011) *Weekly Epidemiological Record, Cholera 2011*.
- WHO, W. H. O. (2012) *Weekly Epidemiological Record, Cholera 2012*.
- WHO, W. H. O. (2013) *Weekly Epidemiological Record, Cholera 2013*.
- WHO, W. H. O. (2019a) 'Ebola outbreak in the Democratic Republic of the Congo declared a Public Health Emergency of International Concern'. Available at: <https://www.who.int/news-room/detail/17-07-2019-ebola-outbreak-in-the-democratic-republic-of-the-congo-declared-a-public-health-emergency-of-international-concern>.
- WHO, W. H. O. (2019b) 'Essential health services situation reports: Background'.
- WHO, W. H. O. (2019c) *Ground zero in Guinea: the Ebola outbreak smoulders - undetected - for more than 3 months*. Available at: <https://www.who.int/csr/disease/ebola/ebola-6-months/guinea/en/>.
- WHO, W. H. O. (2019d) 'WHO Director-General Press briefing on Ebola outbreak and response in DRC'. Available at: <https://www.who.int/news-room/detail/14-03-2019-who-director-general-press-briefing-on-ebola-outbreak-and-response-in-drc>.
- WHO, W. H. O. (2020a) *COVID-19 significantly impacts health services for noncommunicable diseases*. Available at: <https://www.who.int/news-room/detail/01-06-2020-covid-19-significantly-impacts-health-services-for-noncommunicable-diseases>.
- WHO, W. H. O. (2020b) *COVID-19: operational guidance for maintaining essential health services during an outbreak: interim guidance, 25 March 2020*, World Health Organization.
- WHO, W. H. O. (2020c) *Ebola virus disease – Democratic Republic of the Congo*. Available at: <https://www.who.int/csr/don/03-June-2020-ebola-drc/en/>.
- WHO, W. H. O. (2020d) *Ethiopia vaccinates nearly 15 million children against measles despite COVID-19 challenges*. Available at: <https://www.afro.who.int/news/ethiopia-vaccinates-nearly-15-million-children-against-measles-despite-covid-19-challenges>.
- WHO, W. H. O. (2020e) *Guiding Principles for immunization activities during the COVID-19 pandemic*.
- WHO, W. H. O. (2020f) *Guiding principles for immunization activities during the COVID-19 pandemic: interim guidance, 26 March 2020*, World Health Organization.
- Wilhelm, J. A. and HELLERINGER, S. (2019) 'Utilization of non-Ebola health care services during Ebola outbreaks: a systematic review and meta-analysis', *Journal of Global Health*, 9(1), pp. 1-13. doi: 10.7189/jogh.09.010406. Available at: <http://search.ebscohost.com/login.aspx?direct=true&db=ccm&AN=138488179&site=ehost-live>.
- Yamanis, T., Nolan, E. and Shepler, S. (2016) 'Fears and misperceptions of the Ebola response system during the 2014-2015 outbreak in Sierra Leone', *PLoS neglected tropical diseases*, 10(10), pp. e0005077-e0005077. Available at: <https://lstmed.idm.oclc.org/login?url=https://search.ebscohost.com/login.aspx?direct=true&AuthType=cookie,ip,uid&db=lhh&AN=20173059093&site=eds-live&scope=site> <http://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0005077> email: yamanis@american.edu\ nina.yamanis@gmail.com.