Health System Drivers of Universal Health Coverage in Mozambique: Scrutinization of Service Delivery and Human Resources for Health building blocks

Quinhas F. Fernandes

A dissertation

submitted in partial fulfillment of the

requirements for the degree of

Doctor of Philosophy

University of Washington

2023

Reading Committee:

Kenneth Sherr, Chair

Stephen Gloyd

James Pfeiffer

Program Authorized to Offer Degree:

Global Health

University of Washington

Abstract

Health System Drivers of Universal Health Coverage in Mozambique: Scrutinization of Service Delivery and Human Resources for Health building blocks

Quinhas F. Fernandes

Chair of the Supervisory Committee:

Kenneth Sherr, PhD, MPH

Department of Global Health, Epidemiology, and Industrial and Systems Engineering

Achieving Universal Health Coverage (UHC) is the most sustainable way to establish social justice and contribute to the well-being of all. Strong and resilient health systems are the foundation for achieving and sustaining UHC. Six building blocks of the health systems have been identified by the World Health Organization (WHO). Understanding health system building blocks challenges remains an essential step for achieving UHC. This dissertation analysis two of the six building blocks, service delivery and human resources for health.

The first study focuses on understanding the impact of an important weather event – the Idai cyclone – on measures of health service utilization. Mozambique is vulnerable to extreme weather events; therefore, describing the immediate impacts of such events, as well as post-event recovery patterns, can inform efforts to improve health system resilience. We used routine data capturing

health service utilization, aggregated to the district level, from pre- and post-event periods to perform an uncontrolled interrupted time series analysis and describe changes in 10 maternal and child health indicators across 25 districts. Overall, we demonstrated a negative impact on several indicators immediately after Idai, including 23% (95% CI: 0.62, 0.96) and 25% (95% CI=0.64, 0.87) reductions in antenatal care and measles vaccination, respectively. However, promising signs of recovery were evident three months later.

The second study focused on assessing the health workforce landscape in Mozambique. We used a longitudinal design to assess two measures of health workforce (density of personnel and the ratio of male to female health workers) in all districts between 2016 and 2020. In Mozambique, in January 2016, the average district-level workforce density was estimated at 75.8 per 100,000 population (95% CI: 65.9, 87.1) and was increasing at an annual rate of 8.0% (95% CI: 6.00, 9.00) through January 2018, declining to 3.0% (95% CI: 2.00, 4.00) after that point. Sex ratio imbalances were evident in this study, with northern provinces reporting twice the sex ratio relative to Maputo province.

Guided by the Consolidated Framework for Implementation Research (CFIR), the third study deepens the analysis of human resources to describe the individual and institutional drivers of health worker satisfaction. We conducted 63 In-Depth Interviews (IDIs) and seven Focus Group Discussions (FGDs) with health workers in five districts of Manica province. The results of the study suggest that poor working conditions, lack of clear criteria to select health workers for trainings and workshops, and scarcity of housing are among the most relevant determinants of dissatisfaction. Overall, CFIR proved helpful in identifying and summarizing the determinants of job satisfaction.

Together, the results presented in this dissertation describe important challenges that Mozambique's health system should address to accelerate progress toward UHC. The methods applied in this study are replicable and could inspire other countries to conduct similar analyses.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

I am deeply indebted to my dissertation committee, Kenneth Sherr, Stephen Gloyd, James Pfeiffer, and Marco Carone, for their remarkable support throughout the dissertation journey. In particular, I am thankful to my chair and tireless advisor, Kenneth Sherr, for the friendship, excellent guidance, and constant encouragement. I am forever grateful to you!

I extend my heartfelt appreciation to the human resources for health observatory team at the Ministry of Health in Mozambique for allowing me to access the data and your willingness to participate and provide essential insights that proved instrumental in finalizing my dissertation. I express my gratitude particularly to Ana Machai for your unconditional support.

I am thankful to my Ph.D. cohort, who provided valuable feedback, engaging discussions, and many unforgettable memories which shall be cherished for the rest of my life.

Thank you, Orvalho, for the days, hours, minutes, and seconds of your life you put into helping with the analysis. I am grateful for the moments of fun you provided us playing guitar wonderfully.

I am thankful to Braiton Maculuve and Celestino Sinai, for the time and energy you put into interviewing health workers in Manica.

A big thank you to those at the Doris Duke Charitable Foundation, particularly to Lola Adedokun, for the encouragement and support during the Ph.D. journey. You made my dream come true.

Mom, I appreciate the gracious amount of love and dedication you and Dad gave to me. May god keep blessing you! Dad, I wish you would be here to appreciate this lifelong dream.

To my brothers and sisters, for your permanent encouragement and motivation. You have always been there when I needed you.

To my wife (Naziat) and sons (Denilson and Ivans), my pillars of support. Without you, the journey would have been a million times harder. You were always there for me. I am proud of your resilience. I have no words to express my deepest appreciation and love!

DEDICATION

To my dad, in memory

To my mother, for the infinite love

To my wife and sons, for the endless love

CHAPTER 1: Introduction

As the clock to 2030 – the year Sustainable Development Goals (SDGs) and Universal Health Coverage (UHC) are set to be met – moves on, efforts to achieve SDGs and UHC are accelerating "*to make the world's dream come true."* Strong and resilient health systems are important determinants of achieving UHC. Countries that have made significant investments in strengthening their health systems are more likely to succeed in addressing persistent threats, including the impact of extreme weather events, epidemics, and pandemics such as cholera, polio, Ebola, COVID-19, among others.[1–6] These and other public health threats have led to substantial setbacks for health systems and have worsened health outcomes, and continue to occur more frequently and with higher magnitude impact. Furthermore, low- and middle-income countries (LMIC) are particularly vulnerable to health system shocks and are disproportionally affected.[7–13] Unless urgent and evidence-informed measures are taken to strengthen health systems, LMICs will likely not achieve the global goal of UHC. Science, particularly implementation research, represents an opportunity to provide critical guidance to inform policies and strategies on how to strengthen health systems, particularly in LMICs facing resource scarcity.[14,15]

No unique formula is perfect or applies to strengthening health systems everywhere; however, a deeper understanding of the specific challenges and context in which health systems are situated is a critical step to taking evidence-based and appropriate measures to improve system delivery across contexts. Mozambique, a southern African country, has progressively invested in building a robust health system grounded on primary health care (PHC).[16,17] Indeed, since its foundation, Mozambique's health system has been based on the principles of PHC and equity.[13,18–20] Mozambique's health system improvements have translated to substantial gains in population-

level health measures, including child survival, maternal mortality, and chronic malnutrition, which have all improved dramatically.[21–29] Nevertheless, the lack of resources and recurrent external shocks negatively impact the continued progress in these priority areas.

Given its location, Mozambique is highly vulnerable to extreme weather events, which negatively impact health infrastructures and, ultimately, service delivery.[30,31] During the last decade, more than ten cyclones and several major flooding events have been reported, destroying partially or completely more than 200 health facilities. Similar to other LMICs, Mozambique's health system is underfunded, has structural inefficiencies, and faces a substantial shortage of human resources for health, ranking behind most sub-Saharan African countries.[32] These challenges should be methodically addressed to ensure consistent progress toward UHC. Deepening our understanding of how external shocks impact service delivery, the system recovery process, and the availability and distribution of the workforce are important to support the country's efforts to strengthen the health system and meet the health needs of the population. This dissertation bolsters the analysis of two health system building blocks – service delivery and human resources for health – and provides essential evidence for policymakers to use in developing and monitoring progress on the roadmap to UHC.

Because of the country's vulnerability to extreme weather events, in Aim 1, we used the example of cyclone Idai to provide evidence of how this type of threat impacts service delivery. Idai, a grade four cyclone that made landfall in Beira City, affected four provinces in Mozambique in March 2019. Idai was the deadliest cyclone in the last decade in Mozambique, with 603 deaths recorded.[30,31] It caused disruption of essential services and significant damage to public infrastructure, including approximately 90 health facilities. In this study, we assessed the impact of Idai on ten maternal and child health service indicators across 25 districts of the two most

affected provinces. We performed an uncontrolled interrupted time series analysis to estimate the immediate losses from the cyclone and the subsequent overall recovery. Overall, this analysis describes a worrisome scenario whereby external shocks threaten service delivery in Mozambique and should be accounted for in the country's efforts to achieve UHC.

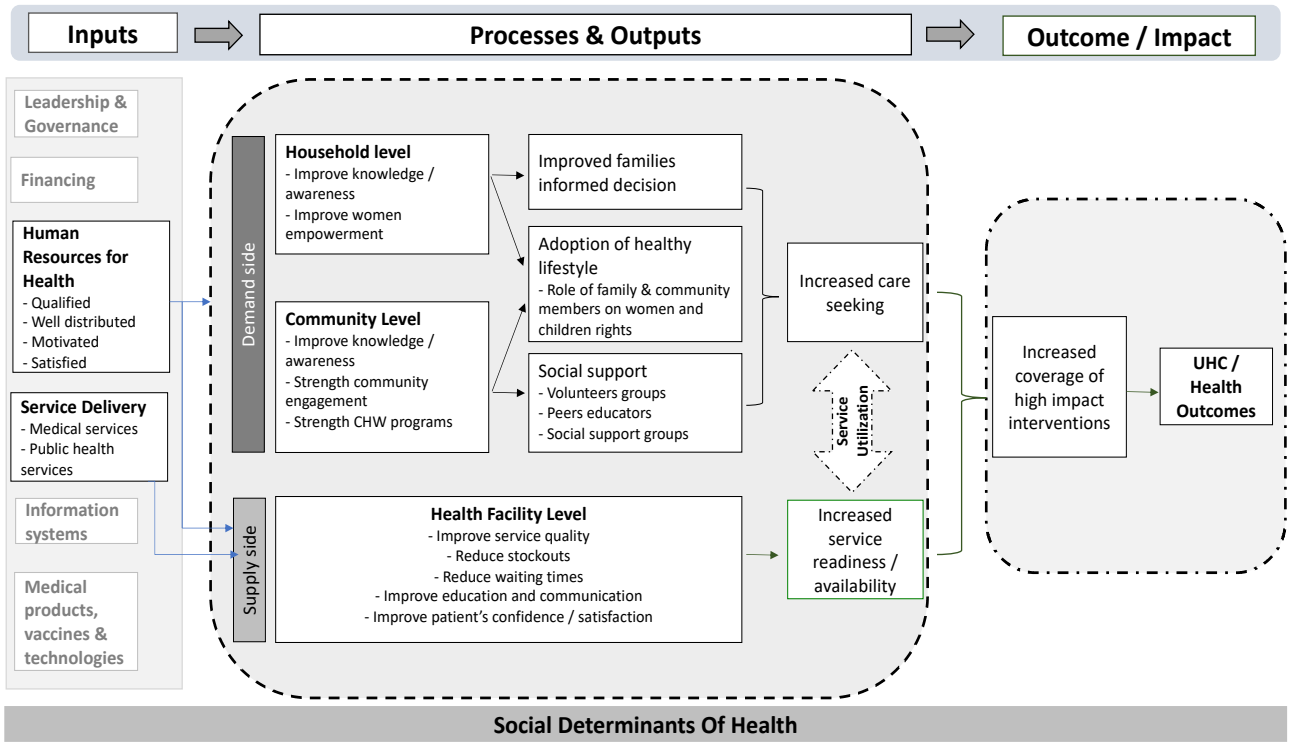
PHC offers an excellent opportunity to strengthen the health system since it is the most cost-effective approach to delivering quality healthcare services, reducing health disparities, and contributing to better health outcomes.[18–20,33,34] However, like other strategies, it relies on the availability and appropriate distribution of human resources. In Aim 2, our analysis focuses on understanding, at the subnational level, health workforce availability, its distribution, and gender equity. Despite the significant improvements observed in the last decade, Mozambique still has a tremendous shortage of human resources and ranks far below the WHO minimum threshold of 2.8 physicians, nurses, and midwives per thousand population.[32] Additionally, Mozambique (like many countries globally) has critical inefficiencies in the distribution of human resources between provinces, and between urban and rural areas.[35] These workforce challenges impact service delivery, and therefore impede progress towards UHC. Our Aim 2 provides detailed evidence, at the district level, of health workforce density, distribution, and trends before and after 2018 (at which point significant restrictive measures were implemented). This analysis identifies provinces that are chronically underprivileged and opportunities to improve workforce distribution even in the context of limited resources. Furthermore, it provides essential information on gender imbalances between provinces, which must also be addressed.

Local health system leaderships are essential for creating effective organizations that promote staff accountability and performance. Effective leadership and management practices contribute to a positive organizational climate that affects frontline staff's motivation and satisfaction levels.[36–

40] Other factors that affect motivation and satisfaction include levels of trust, wages, individual expectations, promotion and housing policies, and organization structure. Many of these factors are context-specific and are interrelated. Understanding the interplay between these factors, and patterns across individuals and levels of the health system, is critical to establishing human-centered and context-adjusted policies. In Aim 3, we assess health workers' perception of satisfaction, as well as individual and institutional factors that influence these perceptions, focusing on Manica province in central Mozambique. Understanding the determinants of health worker satisfaction can lead to policy changes that ultimately improve health service quality and coverage.

Together, the three dissertation aims provide critical evidence to support Mozambique's progress towards UHC. The dissertation's conceptual framework relies on primary and well-grounded knowledge that to deliver clinical and public health interventions with quality and coverage, health systems need available, qualified, and motivated health workers (Figure 1).[41–43] The methods applied in all studies are replicable to other settings and utilize routine data, which are frequently overlooked.

Figure 1: Conceptual model


Inputs
Processes & Outputs
Outcome / Impact
Leadership & Governance
Financing
Human Resources for Health
- Qualified
- Well distributed
- Motivated
- Satisfied
Service Delivery
- Medical services
- Public health services
Information systems
Medical products, vaccines & technologies
Demand side
Household level
- Improve knowledge / awareness
- Improve women empowerment
Community Level
- Improve knowledge / awareness
- Strength community engagement
- Strength CHW programs
Improved families informed decision
Adoption of healthy lifestyle
- Role of family & community members on women and children rights
Social support
- Volunteers groups
- Peers educators
- Social support groups
Supply side
Health Facility Level
- Improve service quality
- Reduce stockouts
- Reduce waiting times
- Improve education and communication
- Improve patient's confidence / satisfaction
Increased care seeking
Service Utilization
Increased service readiness / availability
Increased coverage of high impact interventions
UHC / Health Outcomes
Social Determinants Of Health

CHAPTER 2: Maternal and Child Health Care Service Disruptions and Recovery in Mozambique After Cyclone Idai: An Uncontrolled Interrupted Time Series Analysis

Quinhas Fernandes[1, b], Orvalho Augusto[2,3], Sérgio Chicumbe[4], Laura Anselmi[5], Bradley H. Wagenaar[2,6], Rosa Marlene[1], Sãozinha Agostinho[7], Sarah Gimbel[8], James Pfeiffer[2,9], Celso Inguane[2], Dorlim Uetela[2,4], Jonny Crocker[2], Isaías Ramiro[10], Benigna Matsinhe[1], Stélio Tembe[1,2], Naziat Carimo[2], Stephen Gloyd[2], Ivan Manhiça[1], Esperança Tavede[11], Priscila Filimone[12], Kenneth Sherr[2]

1. National Directorate of Public Health, Ministry of Health, Mozambique.
b. Department of Global Health, University of Washington, Seattle, WA, USA.
c. Eduardo Mondlane University, Maputo, Mozambique.
d. Instituto Nacional de Saúde, Ministry of Health, Mozambique.
e. Centre for Primary Care and Health Services Research, University of Manchester, Manchester, United Kingdom.
f. Department of Epidemiology, University of Washington, Seattle, WA, USA.
g. Mozambique Permanent Mission, Geneva Switzerland.
h. National Directorate of Planning and Cooperation, Ministry of Health, Mozambique.
i. Department of Child, Family, and Population Health Nursing, School of Nursing, University of Washington, Seattle, WA, USA.
j. Department of Anthropology, University of Washington, Seattle, WA, USA.
k. Comité para a Saúde de Moçambique, Maputo, Mozambique.
l. Provincial Social Affairs Services, Manica, Mozambique.
m. Provincial Social Affairs Services, Sofala, Mozambique.
n. Department of Industrial & Systems Engineering, University of Washington.

Corresponding Author: Quinhas Fernandes (ferq09@gmail.com)

ABSTRACT

Introduction: Climate change-related extreme weather events have increased in frequency and intensity, threatening people's health, particularly in places with weak health systems. In March 2019, Cyclone Idai devastated Mozambique's central region, causing infrastructure destruction, population displacement, and death. We assessed the impact of Idai on maternal and child health services and recovery in the Sofala and Manica provinces.

Methods: Using monthly district-level routine data from November 2016 to March 2020, we performed an uncontrolled interrupted time series analysis to assess changes in 10 maternal and child health indicators in all 25 districts before and after Idai. We applied a Bayesian hierarchical negative binomial model with district-level random intercepts and slopes to estimate Idai-related service disruptions and recovery.

Results: Of the 4.44 million people in Sofala and Manica, 1.83 (41.2%) million were affected. Buzi, Nhamatanda, and Dondo (all in Sofala province) had the highest proportion of people affected. After Idai, all 10 indicators showed an abrupt substantial decrease. First antenatal care visits per 100,000 women of reproductive age decreased by 23% (95% confidence interval [CI]=0.62, 0.96) in March and 11% (95% CI=0.75, 1.07) in April. BCG vaccinations per 1,000 children under age five years declined by 21% (95% CI=0.69, 0.90) and measles vaccinations decreased by 25% (95% CI=0.64, 0.87) in March and remained similar in April. Within 3 months post-cyclone, almost all districts recovered to pre-Idai levels, including Buzi, which showed a 22% and 13% relative increase in the number of first antenatal care visits and BCG, respectively.

Conclusion: We found substantial health service disruptions immediately after Idai, with greater impact in the most affected districts. The findings suggest impressive recovery post-Idai,

emphasizing the need to build resilient health systems to ensure quality health care during and after natural disasters.

INTRODUCTION

Increasingly, extreme weather events such as floods, storms, and cyclones present a permanent threat to health systems and individual health outcomes, particularly in low- and middle-income countries.[44] Worldwide, roughly 7,300 natural disasters occurred between 2000 and 2019, resulting in 1.2 million deaths (yearly average of 35,000) and an economic loss of US$2.97 trillion.[44,45] Floods and storms are the most frequent events, accounting for 44% and 28% of natural disasters, respectively.[44] Exposure to extreme weather events leads to immediate service disruptions, increased burden of infectious and non-infectious diseases, and poor long-term health outcomes.[46–51] A systematic review from 2012 found a 47% to 50% increase in the population mortality at all ages and a 40% increase in mental health disorders among individuals older than age 14 years in the first year after a severe flood episode. [45,52–54]

After being exposed to an extreme weather event, older adults are 2.1 times more likely than younger people to experience post-traumatic stress and 1.7 times more likely to develop a subsequent adjustment disorder;[55] pregnant women are at increased risk of pre-term delivery and low birth weight;[56,57] and children may experience an 18% increase in diarrhea and a 15% increase in acute respiratory infections.[58] Regardless of the magnitude of the event, women and children are most vulnerable to disruptions in health care (e.g., immunization and maternal and child health services). Antenatal care (ANC) visits, institutional deliveries, and postpartum care visits for both mothers and newborns are significantly reduced in areas recurrently affected by floods, as suggested by a study conducted in Bangladesh.[59]

The impact of extreme weather events on public infrastructure is expected, leading to reduced accessibility, availability, and quality of health care services, particularly with higher-magnitude events.[47,49] Power outages frequently occur and are consistently associated with poor patient

outcomes, as they affect quality of care for both chronic and acute conditions.[60] Regardless of severity, resilient health systems are expected to maintain essential services while responding to initial shocks and recover quickly.[1] The speed of recovery is related to the shock's magnitude, its characteristics, the population's baseline vulnerability, and the health system's level of resilience.[44] Health system resilience is defined as the capacity to absorb external shocks and adequately and promptly adjust to respond effectively, while maintaining all essential functions, including recovering any observed losses.[1,61–63]

Because of its geographic location, Mozambique is highly vulnerable to floods and cyclones. On March 14, 2019, category 4 Cyclone Idai hit Mozambique's central region (Zambezia, Tete, Sofala, and Manica Provinces), directly affecting 2.1 million people and causing 603 deaths, 1,641 injuries, and the displacement of 400,000 people.[30,31] Even though neighboring provinces (Tete and Zambézia) experienced high-speed winds and rains, the cyclone magnitude there was substantially lower and resulted in fewer fatalities, less destruction, and fewer health service disruptions were reported. No meaningful impacts from Idai were observed in any other provinces.

With the disruption of essential services (e.g., water, electricity, and communications) and significant damage to public infrastructure (including 90 health facilities and 3,145 health workers' homes, particularly in Manica and Sofala), the effects of Idai exacerbated ongoing challenges in sanitation, water supply, and food security in these two provinces.[64,65] One month after the cyclone, a cholera outbreak affected four districts in Sofala Province (Beira City, Dondo, Nhamatanda, and Buzi), with 6,768 reported cases and 8 deaths (0.12% case fatality).[31] Given the extent of the destruction, the budget needed to rebuild the health infrastructure was estimated at US$202 million over five years, with the first half needed in the first year (unpublished data). Domestic and international solidarity in the aftermath of Idai was impressive. The national

government, bilateral organizations, and multilateral international institutions played a critical role in saving lives, bridging gaps in health service disruptions, and mobilizing resources for a comprehensive response plan to address immediate and long-term needs.

There is limited evidence on health service continuity and the speed of recovery during and after an extreme weather event, especially in low- and middle-income countries. Routine health information system (RHIS) data, which are frequently disparaged due to quality issues, might be the best source to describe health service impacts with high resolution, granularity, and availability; therefore, these systems provide a critical opportunity to understand how health systems adjust to external shocks and guide policy makers' decisions. However, they can also be affected during external shocks, which may impede efforts to distinguish whether disruptions reflect service discontinuity or simply a lack of data.

In the 3 years since Idai, Mozambique has made significant progress toward rebuilding its health infrastructure and ensuring the provision of primary health care services. Mozambique's experience with Idai has offered a unique opportunity to understand the nature of health service disruptions after an extreme weather event and the speed of the health system's recovery to pre-disaster levels. In this study, we aimed to assess Idai's impact on district-level maternal and child health care services in the two most affected provinces (Sofala and Manica), as well as evaluate the health system's recovery. We also intend to demonstrate the relevance of frequently overlooked RHIS data and propose a method to assess service disruptions and inform emergency response and preparedness plans. No other study has comprehensively investigated the effects of Idai on immediate health service utilization or Mozambique's recovery process. Furthermore, to the best of our knowledge, no other study has investigated health system recovery after an extreme weather event by applying the methods used in this study.

METHODS

Study Design

Using a quasi-experimental design, we performed an uncontrolled interrupted time series analysis to assess monthly changes from November 2016 to March 2020 in 10 selected indicators.[2,66–68] These indicators covered the continuum of maternal and child health service delivery in 25 districts across two provinces (Manica and Sofala) before and after Cyclone Idai.

Setting

We assumed 10% as the cut-off value for the percentage of people affected by Idai. Manica and Sofala provinces were selected due to the percentage of people (41.2%) affected in those provinces, a proxy measure of Idai's impact. Zambezia and Tete provinces were excluded because less than 5% of the total province population was affected.

Sofala and Manica are neighboring provinces located in the central region of Mozambique (Figure 2). Sofala is situated along the coast of the Indian Ocean, whereas Manica borders Zimbabwe to the west. Sofala is among the poorest of Mozambique's 11 provinces. In 2017, Sofala's population was 2.3 million, of which 60% were living in rural areas; Manica's population was 1.9 million, with 66% living in rural areas. In both provinces, the under-5 mortality rate was higher than 100 deaths per 1,000 live births in 2011.[64,69] For administrative purposes, the cities of Beira and Chimoio are considered districts.

Maternal and Child Health Service Delivery Outcomes

Ten indicators available through the RHIS were selected to reflect a range of maternal and child services at the primary health care level. Together they were used to assess Idai's impact on service

utilization. The following indicators were assessed using monthly aggregated counts at the district level: (1) first antenatal care visits; (2) women completing at least 4 doses of intermittent preventive treatment for malaria during pregnancy (IPTp4); (3) institutional deliveries; (4) postpartum care visits within 3 to 7 days after delivery; (5) new users of modern contraceptives; (6) bacillus Calmette-Guerin (BCG) vaccinations; (7) diphtheria, pertussis, tetanus, and *Haemophilus influenzae* type b (DPT-Hib3) vaccinations; (8) measles vaccinations; (9) fully immunized children under age 1; and (10) first consultations for pediatric at-risk services.

Cyclone Idai

Cyclone Idai was characterized by high-speed winds reaching more than 118 miles (190 kilometers) per hour and heavy rains (200 mm per day). The cyclone led to destruction and flooding in districts and communities surrounding Buzi, a prominent regional river. On its trajectory, Idai inflicted the most damage to Sofala and Manica provinces. Within the provinces, seven districts (4 in Sofala and 3 in Manica) experienced the highest impact. Beira City, where Idai made landfall in Sofala province, was mostly affected by high-speed winds. However, Buzi District, also in Sofala, suffered from both high-speed winds and dramatic floods that covered almost the entire district.

Given the heterogeneity in the levels of destruction, we characterized Idai's severity based on the proportion of people affected in each district (estimated as the number of people affected among the total district population). We defined this as the "resident population whose homes were affected by shelter damage and have not left the assessed locality."[70] We created 3 strata of districts: I) least affected, II) moderately affected, and III) highly affected. All districts with no

affected people were included in strata I. We used the median (of the proportion of affected people) to separate strata II and strata III (Table 1).

Data Collection and Processing

Data on selected indicators were sourced from the health information system (Sistema de Informação de Saúde para Monitoria e Avaliação, or SISMA), based on the District Health Information Management System 2 (DHIS-2), from November 2016 to March 2020. Population data (including the total number of women of reproductive age and children under 5) were sourced from the 2007 Population and Housing Census, using district-level projections for 2017. After 2017, Manica District was divided into two districts (Manica and Vanduzi), and Gondola District was divided into Gondola and Macate districts. Data from the 2017 census were used to distribute the projected population of Manica and Gondola districts proportionately into these new districts.

We collected and analyzed data for 25 districts (13 in Sofala Province and 12 in Manica Province) in Mozambique over a period of 42 consecutive months from November 2016 to March 2020. Of the 25 districts, we classified ten as least affected (strata I), 7 as medium affected (strata II), and 8 as highly affected (strata III) by Cyclone Idai, based on the number of people affected.[70]

Statistical Analysis

We explored the data to assess completion and the presence of potential outliers to inform the analysis. Furthermore, we assessed district-specific time series plots to identify the parametrization of the models. For district comparisons, we used descriptive statistics (mean, standard deviation, coefficient of variation [CV], minimum, and maximum). We modeled the monthly counts of service provision, accounting for yearly estimated population and potential overdispersion through

a negative binomial regression with district-specific random effects (intercepts and slopes) using the following equation.

$$\log(count_{dt}) = \left(\beta_0 + b_0^{*d}\right) + \left(\beta_{post} + b_{post}^{*d}\right) \cdot I(time \geq March2019) + \left(\beta_{March2019} + b_{March2019}^{*d}\right) \cdot I(time = March2019) + \left(\beta_{April2019} + b_{April2019}^{*d}\right) \cdot I(time = April2019) + \left(\beta_{pre} + b_{pre}^{*d}\right) \cdot time + \left(\beta_{postslope} + b_{postslope}^{*d}\right) \cdot time^{*} + Season(time) + 1 \cdot \log(Population_{dt})$$

where *count* is the count of services delivered from a district *d* at time *t*. The subscript *t* and the variable *time* indicate time in months since November 2016, and for the variable *time** since March 2019 (taking value zero otherwise). The *I(time ≥ March2019)*, *I(time = March2019)*, and *I(time = April2019)* represent dummy indicators for time past March 2019, only March 2019, and only April 2019, respectively. Their coefficients capture the overall immediate impact post-Cyclone Idai (β_{post}) on the health system, and specific March ($\beta_{March2019}$) and April 2019 ($\beta_{April2019}$) impacts. *Season(time)* represents a function of time to capture seasonal trends, here chosen as 11 dummy indicators for each month with January as reference. The yearly projected population (women ages 15 to 49 or children under 5) was added as an offset.

β_0 is the intercept (overall log-mean count on November 2016), β_{pre} is the overall monthly change in log counts for all 25 districts before the cyclone, β_{post} is the immediate overall change in log counts for all districts since March 2019 (affecting the overall post-Cyclone Idai period), $\beta_{March2019}$ and $\beta_{April2019}$ are March- and April 2019-specific deviations from the overall β_{post}, $\beta_{postslope}$ is the overall monthly change in log counts during the post-cyclone period, and b^* coefficients are district-specific deviations from the respective β coefficient. The above model works on counts per population; therefore, the exponentiated coefficients are to be interpreted as relative changes in the count services per population. So immediately after Idai, there was $e^{\beta post}$, $e^{\beta post + \beta Mach2019}$ and $e^{\beta post + \beta April2019}$ for overall months, specific to March 2019, and specific to April 2019, respectively, associated level change in count services per population. We focus on these 2 months as they represent the period of greatest impact.

We computed the relative losses as the ratio between the observed counts for Idai and the expected counts for a district in a particular month since March 2019. The predicted counts are estimated from the model above with the on and off Idai scenarios set by the indicators I() terms as 1 or 0, respectively. The calculations are done at the district level. We assessed the relative loss by aggregating districts into their respective strata of cyclone damage.

The above equation is estimated as generalized linear mixed model (GLMM)[71] with negative binomial family and log link for each of the 10 service provision indicators. GLMMs are an extension of GLM to include random effects to address the nested and clustered nature of the data (e.g., 1 district has monthly counts making 42 observations). The GLMMs can be estimated through Maximum-Likelihood (ML), restricted ML (REML), and Bayesian approaches.[72] Due to numeric estimation challenges (multiple random effects and issues of estimation convergence) and less bias on the variance of the random effects, we chose to use the Bayesian approach.[73] All regression models were estimated using Stan programming language through the brms package in RStudio version 3.6.3 (RStudio).[74,75] As priors, we chose for fixed effects coefficients univariate normal distribution with 0 mean and 100 variance, for each standard deviation of the random effects a half Student-t with 3 degrees of freedom and scale parameter that is minimally 10, and for the negative binomial shape parameter a gamma distribution with 0.01 for shape and rate parameter. For correlations, the default priors were left unchanged. Four parallel chains were fit with 16,000 iterations, of which the first 1,000 were discarded as burn-in. We used Gelman-Rubin diagnostics (less than 1.02), trace plots, and autocorrelations to assess convergence, good mixing, and iteration autocorrelation. We applied a thin of 5, resulting in 12,000 iterations remaining for the posterior estimation. These were used to estimate the relative loss of service delivery in March, April, and May 2019 and to assess the immediate losses due to the cyclone and

the subsequent overall recovery. We focused the analysis on 3 months to capture the first month of returning to pre-Idai levels. The exponentiated parameters β_{jump} and β_{post} indicate the overall relative changes across 25 districts in the months after Cyclone Idai.

Ethics Approval

We used monthly district-level aggregated data, with approval from the Ministry of Health. We extracted data from the health information system devoid of individual-level identifiers.

RESULTS

Of the 4.44 million people living in Sofala and Manica provinces, 41.2% (1.83 million) were affected by the cyclone. Overall, the greatest impact was observed in Buzi, Dondo, and Nhamatanda, where almost all district inhabitants were affected.[71,76] Table 1 shows the district-specific population and the proportion of affected people.

District Characteristics Before Cyclone Idai

In 2017, for each of the 10 selected indicators, the cities of Beira and Chimoio (provincial capitals) had substantially higher average monthly counts than their respective provinces. The average number of first ANC visits was 847 (CV: 0.51) in Manica and 813 (CV: 0.61) in Sofala. Across the 25 districts, the monthly average number of first ANC visits ranged from 304 (CV: 0.05) in Machanga to 2,015 (CV: 0.12) in Beira City. The monthly average number of institutional deliveries was similar in both provinces: 562 (CV: 0.73) in Sofala and 558 (CV: 0.53) in Manica. The monthly mean number of new users of modern contraceptives was higher in Manica (2,150; CV: 1.24) than in Sofala (1,663; CV:1.12). In Manica, the monthly average number of children who completed all vaccines within the first year of life fluctuated from 192 (CV: 0.31) in Tambara to 1,096 (CV: 0.18) in Chimoio City, while in Sofala, it ranged from 124 (CV:0.31) in Muanza to

1,201 (CV:0.22) in Beira City. Compared to the number of institutional deliveries, the mean number of postpartum visits was lower than expected—less than one-sixth of the mean institutional deliveries for both provinces. Table 2 shows the monthly average counts for each indicator per district.

Regression Results

In November 2016, across all 25 districts, the average number of pregnant women per 100,000 women of reproductive age (WRA) who had completed a first ANC visit was 934 (95% CI, 867–1,007); of those, an average of 310 (95% CI, 246–392) women per 100,000 WRA completed at least 4 doses of IPTp and another 601 (95% CI, 556–649) per 100,000 WRA had delivered in a health facility. The average number of new users of modern contraceptives was 2,531 per 100,000 WRA (95% CI, 2,107–3,050) in November 2016. In the same month, on average, 2,293 (95% CI, 2,080–2,524) children per 100,000 children younger than one year were vaccinated against BCG, and another 2,113 (95% CI, 1909–2,342) had been vaccinated against measles.

Between November 2016 and February 2019, the period before Cyclone Idai, all indicators—except first ANC visits and postpartum visits—showed consistent and positive trends, although with significant heterogeneity across districts. Institutional deliveries per 100,000 WRA showed a significant monthly increase of 0.5%; (95% CI, 1.00–1.01), leading to an annual increase of 5.78% between the study baseline and February 2019. Similarly, pregnant women who completed at least 4 doses of IPTp (1.3%: 95% CI, 1.01–1.02) and new users of modern contraceptives (1.3%: 95% CI, 1.01–1.02) revealed significant monthly increases, culminating with annual gains of 16.9% and 17.0%, respectively, in the same period. Immunization trends before Idai (November 2016 to February 2019) were positive, with monthly increases of 0.4% (95% CI, 1.00–1.01) for measles

vaccinations and 0.3% (95% CI, 1.00–1.01) for DPT-Hib3 vaccinations, corresponding to yearly gains of 5.3% and 3.0%, respectively. Before Idai, only postpartum visits had a significant negative trend, with a monthly loss of 3.4% (95% CI, 0.95–0.98).

When Cyclone Idai hit Mozambique in March 2019, all 10 district-level service delivery indicators showed a significant decline, which continued through April 2019 for most indicators. First ANC visits per 100,000 WRA decreased by 23.0% (95% CI, 0.62–0.96) in March 2019 and 11.0% (95% CI, 0.75–1.07) in April 2019. BCG and measles vaccinations per 1,000 children under 5 decreased by 21.0% (95% CI, 0.69–0.90) and 25.0% (95% CI, 0.64–0.87), respectively, and remained similar in April 2019. Statistically significant seasonal effects were seen across all indicators (except for IPTp4), but with different patterns; for example, every year, immunization services performed better in January, ANC services in April, and institutional deliveries in November. Table 3 shows the regression coefficients for each model. Figure 3 shows the overlap of the regression observed vs. fitted values.

Relative Losses

Compared to model estimates without Cyclone Idai, all maternal health service delivery indicators showed immediate relative losses in March 2019 followed by recovery to levels before Idai in May (except IPTp4) and maintained these levels for the observation period. However, there was substantial variability across districts, with the most substantial losses observed in strata III districts. The overall immediate relative loss for first ANC visits was 11.0% in March (95% CI, 0.72–1.11), with 17% in Sofala and 5.0% in Manica. The following 3 districts showed the most significant relative losses in first ANC visits: 90.0% in Buzi (95% CI, 0.07–0.14), 28.0% in Machanga (95% CI, 0.56–0.93), and 23.0% in Tambara (95% CI, 0.60–0.99). Three months later

(May 2019), almost all districts had recovered to pre-Idai levels, including Buzi, which showed a 22.0% (95% CI, 1.05–1.43) significant relative increase in first ANC visits. Overall, the number of new contraceptive users showed a relative decline of 14.0% (95% CI, 0.56–1.34), with 15.0% in Sofala and 13.0% in Manica; however, this was not significant. All districts recovered by May 2019. Regarding institutional deliveries, Manica showed a 9.0% (95% CI, 0.78-1.06) reduction in March 2019, while Sofala had a 15.0% (95% CI: 0.73 –0.99) relative decrease.

Child health service delivery indicators showed similar results during the post-cyclone period, with service disruptions in March 2019, recovery to pre-Idai levels by May, and substantial variability across districts. Overall BCG vaccines dropped 10.0% (95% CI, 0.71–1.14) in March 2019, with 6.0% in Manica and 14.0% in Sofala. Buzi lost the most, with a 48.0% (95% CI, 0.34–0.82) decrease; however, by May 2019, Buzi had returned to pre-Idai levels with a 13.0% (95% CI, 0.98–1.31) relative increase. Concerning the measles vaccine, Buzi had a relative loss of 38.0% (95% CI, 0.36–0.92) in March 2019. Table 4 presents model-based estimates for the relative losses by selected indicators.

Two months after Idai, strata I districts were already returning to positive trends in all but 3 indicators (DPT-Hib3, IPTp4, and family planning); in contrast, highly affected strata III districts still had greater losses for all indicators except ANC visits and institutional deliveries.

Among strata III districts, the relative loss in institutional deliveries was 20.0% (95% CI, 0.69–0.94) in March 2019 and only 3.0% in May 2019. However, Buzi showed the most significant immediate relative loss in institutional deliveries, estimated at 55.0% (95% CI, 0.36–0.56) in March 2019. Despite its impressive recovery, Buzi still showed a 14.0% (95% CI, 0.76–0.97) relative loss in institutional deliveries in May 2019. The relative decline of BCG and measles

vaccinations in March 2019 was 18.0% (95% CI, 0.64–1.06) and 18.0% (95% CI, 61–1.07), respectively. The 2 districts that showed the most significant projected relative losses in immunization were Buzi and Dondo. Model estimates for Buzi showed a loss of 48.0% (95% CI, 0.34–0.82) for BCG vaccinations and 38.0% (95% CI, 0.36–0.92) for measles vaccinations, and Dondo had a loss of 23.0% (95% CI, 0.57–0.95) and 22.0% (95% CI, 0.56–0.99), respectively, all in March 2019. Figure 4 shows the relative loss by strata.

DISCUSSION

To determine disruptions to maternal and child health service delivery indicators after Cyclone Idai, we conducted an analysis that simultaneously accounted for annual population growth at the district level, seasonality, and historical trends using RHIS data. Overall, the results showed significant relative losses in all 10 selected indicators in the 2 months following Idai (March and April 2019), and a quick recovery within 3 months back to or higher than levels seen before the cyclone. Not surprisingly, strata III districts that were most seriously affected showed higher disruptions. These results corroborate previous findings from similar studies[59,77,78] and are consistent with what could have been expected due to the massive destruction of the public health service infrastructure.[45,57,78]

Even though returns to pre-Idai service delivery levels were observed by May 2019, this may not represent a full recovery, considering the need to recuperate losses from March and April. This is particularly true for indicators such as immunization, family planning, or antenatal care (for which care seeking could have been delayed), though not for other indicators that cannot be postponed (such as institutional deliveries). Therefore, studying the recovery process deserves special attention to the type of service disrupted; prospective studies may help researchers understand the full scope of recovery when service delivery trends return to levels before the shock. A study from

Liberia quantified the cumulative losses to capture not only the return to expected trends but also to track whether losses from shock periods had been recovered.[2] While this approach could help better describe the recovery, limitations persist—particularly when using aggregated data, as in this article. With aggregated data, it is difficult to disentangle whether specific groups recovered, particularly for chronically underperforming services, as higher than expected performance may not represent a full recovery but could instead be a consequence of increased demand due to targeting new groups or community mobilization activities.

The number of first consultations for at-risk child services was least affected in March and April 2019, particularly in strata I and II districts; however, this indicator showed the highest relative increase in May 2019 across all districts (Manica: 36%, Sofala: 22%), regardless of their level of destruction. This pattern might be due to increased demand for services for acute conditions, particularly malnutrition, which is predictable following an extreme weather event. Most at-risk child consultation visits are for children exposed to HIV or tuberculosis, or children being treated for malnutrition. In fact, 6 months after the cyclone, Sofala Province reported 600 cases of pellagra—a chronic B3 vitamin deficiency—after decades with no episodes, which signals a critical nutrition issue following Idai.[79] Nutritional insecurity worsens after natural disasters, and vulnerable populations, particularly displaced people, face significant difficulties in securing daily meals due to possible increases in disruptions to travel, infrastructure destruction, and increased food prices, among others. Vulnerable groups often must rely on support from local and international organizations, which lacked resources or were delayed in some study areas.[80]

Several factors may have contributed to a quick health system recovery. Because the catastrophic impact of Idai captured widespread international attention, we assume that the aid received might have contributed to minimizing the initial shock and speeding up the recovery process. Domestic

and international support contributed to swiftly addressing essential health system needs, including drugs, supplies, and materials. Furthermore, significant support existed to restore water supplies, electricity, and infrastructure rehabilitation—all critical service readiness determinants—though most support did not continue for an extended period and was focused on high-demand areas. Mozambique's health sector has a well-established coordination mechanism with donors and implementing partners. Robust leadership and collaboration, together with massive individual solidarity, appear to have played an essential role in efficiently responding to Idai (at least during the initial shock period).[81,82]

To the best of our knowledge, no other studies have focused on understanding how a health system recovers after the shock of an extreme weather event such as Cyclone Idai. Despite health system resilience being increasingly discussed in the field of global health, its definition, characteristics, and indicators of measurement are still subjects of debate.[80] Notwithstanding, definitions of health system resilience have reached consensus in their inclusion of a health system's ability to respond effectively to shocks and to maintain primary health system functions in the presence of external shocks or crises.[1] Resilience is context-specific, adaptive, and builds on new learnings and knowledge translation into the health delivery system.[1,61,80–83] The rapid and steady recovery seen across nearly all study indicators after the cyclone showcases critical signs of Mozambique's health system resilience, particularly in Sofala and Manica. The substantial gains recorded within 3 months after the cyclone (by May 2019) reinforce the evidence for resilience — as the immediate international aid, in some cases, did not appear to continue beyond this timeframe.[17] These findings are not surprising, since Mozambique has accumulated experience from previous cyclone responses (Dineo [2017], Hellen [2014], Funso [2012], and Leon-Eline [2000]), which has strengthened its preparedness to deal with shocks.

This study provides important lessons, particularly for low- and middle-income countries vulnerable to extreme weather events. First, the finding that highly affected areas had the most significant impact on services uptake reinforces the need to establish systems that quickly detect these areas during shock periods so that aid can be immediately channeled to support recovery plans. Second, even though we were able to observe a recovery to pre-Idai levels, this may not be enough since disruptions can be severe—as observed in Buzi—and a full recovery of the accumulated losses may take longer; therefore, robust monitoring mechanisms should be developed to continue tracking these losses. Third, external shocks can trigger acute conditions and create space for the emergence of related diseases, as seen in the cholera outbreak and resurgence of pellagra; in anticipation of this, RHIS data should be prioritized since it can facilitate rapid detection as conditions emerge and guide an informed response. Indeed, the level of granularity achieved with RHIS data is useful to understand district-level variability, as well as identify highly affected services. RHIS provides a unique opportunity to track the recovery process, particularly for indicators such as family planning or immunization for which a full recovery (not only returning to pre-shock levels but also recovering the losses accrued during periods of disruption) is a programmatic goal. Fourth, effective coordination mechanisms and strong leadership are critical in an emergency, mainly when massive solidarity exists and new stakeholders come in. We have learned that the existing tools between government agencies and partners were essential to avoid or minimize anarchy in the response and to direct aid to the most vulnerable areas during Idai.

LIMITATIONS

This study has some notable limitations. First, districts could have experienced disruptions to service delivery after the cyclone even without significant levels of destruction. Because districts

were classified by severity level based on the number of people affected, some districts could have been misclassified when estimating relative losses. Second, we relied on routine data, which may have quality issues, including missing data. Indeed, our analysis included a small number of outliers; however, these were not influential. Third, we were not able to track aid directed to each district; therefore, we missed understanding whether the recovery had any association with the resources allocated. Fourth, given the study design (uncontrolled ITSA) and lack of covariates at the district level, causal inference should be avoided and result interpretation should be conservative. Fifth, although we did not statistically test for lead and lagged effects, our data exploration (by plotting individual district time series) did not suggest such patterns. Despite the limitations, the results presented are robust and are consistent with what could have been expected after an external shock of Idai's magnitude, with the added advantage of quantifying the effects across a set of essential service delivery indicators, using routine data that are frequently overlooked to track health system performance during and post shocks.

CONCLUSION

This study provides evidence of the negative impacts of extreme weather events on women's and children's ability to access essential evidence-based interventions. It also showcases how routine data is useful for tracking health system performance and resilience during and after shocks; therefore, it should be used and prioritized to guide decision making. Overall, Cyclone Idai led to massive disruptions in health service delivery, with all elements of maternal and child health services showing meaningful and statistically significant decreases immediately following the cyclone. Recovery to pre-Idai trends occurred quickly for most indicators, although highly affected districts took relatively much longer. However, describing the specific characteristics that most influenced the health system's recovery and accumulated losses should be investigated to more

fully picture the recovery process. Finally, despite the focus on a single dimension of system resilience (ability to recover), this study contributes to evidence on features of health system resilience and alternative methods for assessing them.

Acknowledgments: The authors would like to acknowledge the health workers from Sofala and Manica provincial health directorates who provided relevant information for this paper.

Funding: This work was supported by the African Health Initiative of the Doris Duke Charitable Foundation, the UKRI University of Manchester (UoM) Research England Global Challenges Research Fund (GCRF) QA Allocation, and by the Eunice Kennedy Shriver National Institute of Child Health and Development of the National Institutes of Health under award R01HDHD092449. The content is solely the responsibility of the authors and does not represent the funder's views.

Author contributions: QF, OA, LA, SC, and KS conceptualized the research question, the study design, and the analytic strategy. QF and SA provided the data. OA and QF performed the analysis with substantial inputs from BW and KS. QF developed the first draft with creative inputs from OA, LA, and KS. All authors provided substantial inputs, reviewed, and approved the final version.

Competing interests: None declared.

Table 1: Population and Level of Cyclone Idai Destruction in 25 Districts of Manica and Sofala Provinces, Mozambique, 2019

Districts	2019 Population[a]			Cyclone Idai Impact[b]	
	Total Population	Women Aged 15–49 Years, %	Children Aged Younger Than 5 Years, %	Affected People, No. (%)	Strata[c]
Manica Province	2,056,037	30.2	17.9	414,977 (20.2)	
Bárue	205,756	30.6	17.6	-	I
Chimoio City	417,954	31.8	16	1,603 (0.4)	II
Gondola	212,930	30	17.7	104,528 (49.1)	III
Guro	105,906	29.6	18.4	-	I
Macate	92,059	28.7	18.4	51,284 (55.7)	III
Machaze	137,857	31.9	18.3	21,576 (15.7)	II
Macossa	50,294	29.7	18.4	-	I
Manica	241,122	30.3	17.2	10,234 (4.2)	II
Mossurize	222,078	31	18.3	51,068 (23.0)	II
Sussundenga	185,790	30.3	17.8	139,889 (75.3)	III
Tambarra	58,324	29.9	18.4	-	I
Vanduzi	125,967	29	18.4	34,795 (27.6)	II
Sofala Province	2,388,902	30.6	16.8	1,416,690 (59.3)	
Búzi	191,693	30.7	17.1	247,193 (129.0)	III
Caia	171,334	30.5	16.9	-	I
Chemba	89,784	30.5	17.4	-	I
Cheringoma	62,586	30.7	16.3	-	I
Chibabava	145,778	31.5	17.4	41,204 (28.3)	II
Beira City	651,313	31.7	14.6	575,077 (88.3)	III
Dondo	210,742	30.5	16	211,266 (100.2)	III
Gorongosa	191,565	30.6	16.8	-	I
Machanga	60,223	30.8	17.4	20,004 (33.2)	II
Maríngue	102,833	30.8	17.4	-	I
Marromeu	167,791	30.3	16.3	-	I
Muanza	41,179	28.7	17.5	34,202 (83.1)	III
Nhamatanda	302,081	30	16.9	287,744 (95.3)	III
Total	4,444,939	30.4	17.3	1,831,667 (41.2)	

[a] Projected population based on National Institute of Statistics (INE) 2007 Census[32]

[b] National Institute for Disaster Management (INGD) reports[29]

[c] Based on the number of people affected (percentage) after Cyclone Idai, strata I districts were the least affected, strata II were medium affected, and strata III were highly affected.

Table 2: Monthly Averages for Each Study Indicator in 25 Districts of Manica and Sofala Provinces, Mozambique, 2017

District/Province	First ANC Visits	IPTp4	Institutional Deliveries	New FP User	Measles Vaccination	BCG Vaccination	DPT-Hib3	Fully Immunized Children Under Age 1 Year	First At-Risk Children's Consultation	Postpartum Care Visit (3–7 days)
	Mean (CV)[a]	Mean (CV)[a]	Mean (CV)[a]	Mean (CV)[a]	Mean (CV)[a]	Mean (CV)[a]	Vaccination Mean (CV)[a]	Mean (CV)[a]	Mean (CV)[a]	Mean (CV)[a]
Manica Province[b]	847 (0.51)	371 (0.68)	558 (0.53)	2,150 (1.24)	607 (0.57)	681 (0.67)	604 (0.56)	574 (0.64)	74 (0.75)	86 (1.06)
Bárue	952 (0.20)	290 (0.35)	675 (0.16)	3,953 (1.32)	764 (0.36)	901 (0.29)	801 (0.36)	779 (0.78)	101 (0.32)	71 (0.77)
Chimoio City	1,708 (0.17)	935 (0.19)	1,282 (0.07)	4,200 (0.65)	1,150 (0.16)	1,455 (0.11)	1,191 (0.10)	1,096 (0.18)	214 (0.11)	319 (0.27)
Gondola	1,064 (0.08)	482 (0.12)	660 (0.04)	3,215 (1.24)	610 (0.36)	688 (0.21)	580 (0.31)	586 (0.35)	72 (0.30)	117 (0.42)
Guro	514 (0.07)	324 (0.22)	347 (0.10)	985 (1.13)	351 (0.14)	389 (0.12)	355 (0.14)	323 (0.16)	46 (0.52)	100 (0.40)
Macate	598 (0.41)	327 (0.16)	369 (0.11)	1,217 (0.95)	436 (0.46)	462 (0.44)	435 (0.49)	426 (0.46)	46 (0.25)	35 (1.12)
Machaze	612 (0.11)	101 (0.39)	420 (0.10)	1,317 (0.74)	548 (0.50)	682 (0.81)	528 (0.34)	514 (0.44)	56 (0.26)	37 (0.49)
Macossa	222 (0.15)	84 (0.31)	166 (0.05)	598 (0.77)	184 (0.39)	167 (0.20)	166 (0.15)	159 (0.45)	10 (0.81)	33 (1.56)
Manica	1,077 (0.08)	612 (0.12)	672 (0.08)	2,069 (0.66)	744 (0.16)	781 (0.13)	771 (0.10)	705 (0.19)	115 (0.11)	126 (0.26)
Mossurize	1,346 (0.12)	561 (0.13)	803 (0.04)	2,988 (0.41)	1,171 (0.22)	1,131 (0.69)	1,076 (0.25)	1,092 (0.22)	52 (0.41)	45 (1.25)
Sussundenga	953 (0.09)	260 (0.24)	601 (0.08)	2039 (1.04)	598 (0.16)	692 (0.18)	601 (0.17)	558 (0.16)	67 (0.38)	79 (0.47)
Tambarra	364 (0.31)	54 (0.18)	195 (0.15)	1,722 (1.81)	230 (0.25)	252 (0.23)	232 (0.20)	192 (0.31)	17 (0.22)	40 (0.47)
Vanduzi	713 (0.11)	371 (0.23)	510 (0.08)	1,494 (1.34)	504 (0.20)	576 (0.13)	506 (0.16)	460 (0.21)	47 (0.15)	12 (1.28)
Sofala Province[b]	813 (0.61)	289 (0.84)	562 (0.73)	1,663 (1.12)	579 (0.67)	653 (0.66)	597 (0.67)	493 (0.65)	125 (1.19)	67 (1.06)
Búzi	938 (0.12)	315 (0.15)	697 (0.09)	2,737 (0.87)	750 (0.27)	784 (0.13)	810 (0.27)	687 (0.22)	139 (0.27)	51 (0.92)
Caia	884 (0.07)	307 (0.14)	650 (0.07)	2,395 (1.34)	715 (0.51)	788 (0.35)	747 (0.51)	607 (0.45)	138 (0.26)	90 (0.43)
Chemba	445 (0.14)	41 (0.90)	275 (0.08)	1,099 (0.58)	286 (0.18)	341 (0.12)	296 (0.20)	243 (0.19)	33 (0.39)	23 (0.90)
Cheringoma	362 (0.09)	54 (0.26)	245 (0.08)	379 (1.01)	241 (0.37)	295 (0.30)	267 (0.33)	211 (0.37)	20 (0.45)	32 (0.35)
Chibabava	704 (0.09)	213 (0.21)	403 (0.13)	854 (0.87)	555 (0.19)	571 (0.11)	552 (0.16)	462 (0.15)	87 (0.21)	80 (0.19)
Beira City	2,015 (0.12)	872 (0.11)	1,657 (0.18)	3,889 (0.54)	1,479 (0.11)	1,668 (0.16)	1,510 (0.11)	1,201 (0.22)	574 (0.21)	197 (0.82)
Dondo	955 (0.14)	333 (0.16)	563 (0.12)	1961 (0.77)	603 (0.14)	694 (0.36)	637 (0.09)	565 (0.12)	145 (0.21)	98 (0.27)
Gorongosa	1,113 (0.17)	449 (0.30)	626 (0.11)	2,154 (0.32)	596 (0.11)	815 (0.16)	632 (0.12)	512 (0.10)	174 (0.47)	98 (0.27)
Machanga	304 (0.05)	136 (0.20)	242 (0.10)	522 (1.00)	240 (0.29)	248 (0.15)	228 (0.20)	224 (0.30)	43 (0.38)	22 (0.76)
Maríngue	526 (0.15)	119 (0.22)	308 (0.10)	858 (0.85)	321 (0.51)	354 (0.24)	311 (0.48)	218 (0.39)	40 (0.26)	40 (0.55)
Marromeu	759 (0.10)	250 (0.44)	493 (0.16)	2,167 (0.89)	557 (0.23)	642 (0.10)	604 (0.22)	504 (0.27)	60 (0.24)	36 (0.35)

Muanza	193 (0.15)	52 (0.23)	114 (0.11)	393 (1.10)	138 (0.36)	140 (0.24)	132 (0.21)	124 (0.31)	9 (0.53)	6 (0.71)
Nhamatanda	1,374 (0.09)	601 (0.13)	1,037 (0.10)	2,208 (1.05)	1,041 (0.25)	1,155 (0.17)	1,028 (0.25)	850 (0.22)	161 (0.15)	64 (0.77)
Total	829 (0.56)	329 (0.76)	560 (0.64)	1,896 (1.21)	592 (0.62)	667 (0.66)	600 (0.62)	532 (0.65)	101 (1.17)	76 (1.07)

Abbreviations: ANC, antenatal care visit; BCG, bacillus Calmette-Guerin; CV, coefficient of variation (ratio of standard deviation to the average); DPT-Hib3, diphtheria, pertussis, tetanus, and *Haemophilus influenzae* type b immunization; FP, family planning; IPTp4, at least 4 doses of intermittent preventive treatment prophylaxis.

[a] Means and CV for the districts in the province.
[b] The averages and the CV are computed per district for the months of 2017.

Table 3: Exponentiated Regression Coefficient for Each Study Indicator Before and After Cyclone Idai, Manica and Sofala Provinces, Mozambique

Indicator	Intercept[a]	Post[b]	Pre-Slope[c]	Post-Slope Change[d]	March 2019[e]	April 2019[f]
	Exponentiated Regression Coefficient (95% CI)					
First ANC visit	934 (867, 1,007)	1.08 (1.02–1.16)	0.998 (0.9965–1.0011)	1.00 (0.99–1.00)	0.77 (0.62–0.96)	0.89 (0.75–1.07)
IPTp4	310 (246, 392)	0.94 (0.85–1.04)	1.013 (1.0080–1.0183)	1.00 (0.98–1.01)	0.90 (0.73–1.11)	0.88 (0.69–1.11)
Institutional delivery	601 (556, 649)	1.00 (0.96, 1.05)	1.005 (1.0024, 1.0069)	0.99 (0.98, 0.99)	0.87 (0.80, 0.94)	0.90 (0.84, 0.97)
New FP user	2,531 (2,107, 3,050)	1.34 (1.12, 1.60)	1.013 (1.0058, 1.0207)	0.91 (0.89, 0.93)	0.64 (0.48, 0.85)	0.69 (0.53, 0.92)
Measles vaccination	2,113 (1909, 2,342)	1.15 (1.06, 1.26)	1.004 (1.0016, 1.0069)	0.98 (0.97, 0.99)	0.75 (0.64, 0.87)	0.76 (0.62, 0.92)
BCG vaccination	2,293 (2,080, 2,524)	1.13 (1.06, 1.21)	1.001 (0.9991, 1.0035)	0.98 (0.98, 0.99)	0.79 (0.69, 0.90)	0.79 (0.65, 0.97)
DPT-Hib3 vaccination	2,121 (1910, 2,354)	1.09 (1.02, 1.17)	1.003 (1.0003, 1.0047)	0.99 (0.98, 0.99)	0.83 (0.73, 0.95)	0.77 (0.62, 0.95)
Fully immunized children under age 1 year	1,926 (1,722, 2,152)	1.13 (1.03, 1.24)	1.006 (1.0029, 1.0086)	0.98 (0.96, 0.99)	0.76 (0.65, 0.89)	0.79 (0.66, 0.94)
First at-risk children's consultation	244 (187, 319)	1.27 (1.13, 1.42)	1.003 (0.9967, 1.0091)	1.01 (0.99, 1.02)	0.75 (0.63, 0.90)	0.73 (0.55, 0.95)
Postpartum visit within 3–7 days	103 (76, 139)	1.50 (1.13, 1.99)	0.966 (0.9538, 0.9781)	0.96 (0.92, 1.01)	0.57 (0.35, 0.94)	0.58 (0.37–0.92)

Abbreviations: ANC, antenatal care; BCG, bacillus Calmette-Guerin; DPT-Hib3, diphtheria, pertussis, tetanus, and Haemophilus influenzae type b; FP, family planning; IPTp4, at least 4 doses of intermittent preventive treatment prophylaxis.

[a] Intercept ($e^{\beta 0}$) is a model estimate of the count of service deliveries per 100,000 people in November 2016 (e.g., for "first ANC visit," there were an estimated 934 first ANC visits per 100,000 women of reproductive age in November 2016).
[b] Post ($e^{\beta post}$) is the multiplicative change of the intercept since Cyclone Idai (e.g., compared to November 2016, there was an 8% increase in first ANC visits among women of reproductive health age in the post-Idai period [after March 2019]).
[c] Pre-slope ($e^{\beta pre}$) is the monthly multiplicative increase in the ratio of indicator count to 100,000 people before Cyclone Idai (e.g., there was a 0.2% relative decrease in first ANC visits in women of reproductive health age per month).
[d] Post-slope ($e^{\beta postslope}$) change is the multiplicative change in the pre-slope coefficient (e.g., after Cyclone Idai, the monthly trend in first ANC visits was unchanged).
[e] March 2019 is the specific change relative to the post-level ($e^{\beta March2019}$) change. This is a multiplicative deviation from the overall post-Idai level in March 2019 (e.g., during the month when Cyclone Idai occurred, the ratio of first ANC visits to the population of women of reproductive health age was 23% lower than during the entire post-Idai period).
[f] April 2019 is the specific change relative to the post-level ($e^{\beta April2019}$) change. This is a multiplicative deviation from the overall post-Idai level in April 2019 (e.g., during the month following Cyclone Idai, the ratio of first ANC visits to the population of women of reproductive health age was 11% lower relative to the entire post-Idai period).

Table 4: Model Estimates and Relative Losses for Each Study Indicator After Cyclone Idai, Manica and Sofala Provinces, Mozambique, 2019

Indicator	Observed Count			Model Expected Without Cyclone Idai Count (CI)			Model Expected With Cyclone Idai Count (CI)			Relative Loss[a] (CI)		
	March	April	May	March	April	May	March	April	May	March	April	May
First ANC visit	761	865	1,019	850 (780; 927)	836 (764; 914)	872 (794; 958)	771 (602; 986)	862 (683; 1,086)	933 (826; 1,053)	0.89 (0.72; 1.11)	1.00 (0.80; 1.26)	1.08 (0.95; 1.23)
IPTp4	391	411	422	423 (348; 513)	437 (356; 536)	440 (356; 544)	397 (256; 617)	415 (251; 685)	415 (345; 500)	0.88 (0.61; 1.31)	0.88 (0.57; 1.38)	0.94 (0.79; 1.11)
Institutional delivery	567	621	645	645 (598; 694)	689 (637; 744)	669 (617; 725)	569 (485; 666)	623 (536; 723)	657 (611; 706)	0.88 (0.75; 1.02)	0.90 (0.77; 1.05)	0.98 (0.90; 1.07)
New FP user	1,676	1,627	4,526	1921 (1,423; 2,594)	1,879 (1,375; 2,566)	2,520 (1,818; 3,493)	1,694 (1,000; 2,870)	1,615 (1,014; 2,575)	2,808 (2,092; 3,768)	0.86 (0.56; 1.34)	0.85 (0.56; 1.29)	1.12 (0.86; 1.45)
Measles vaccination	565	532	722	650 (569; 743)	606 (529; 695)	640 (556; 736)	566 (424; 756)	536 (350; 821)	701 (605; 813)	0.87 (0.67; 1.14)	0.87 (0.61; 1.29)	1.10 (0.97; 1.25)
BCG vaccination	591	646	775	659 (592; 733)	695 (623; 776)	706 (631; 789)	591 (457; 764)	655 (447; 960)	772 (690; 863)	0.90 (0.71; 1.14)	0.92 (0.67; 1.29)	1.10 (1.00; 1.21)
DPT-Hib3 vaccination	578	526	668	631 (567; 703)	602 (539; 673)	618 (551; 693)	579 (445; 754)	531 (368; 767)	654 (581; 736)	0.92 (0.72; 1.18)	0.87 (0.64; 1.23)	1.06 (0.96; 1.18)
Fully immunized children under age 1 year	532	503	634	615 (534; 709)	570 (493; 659)	575 (496; 666)	533 (395; 718)	508 (340; 759)	618 (537; 712)	0.86 (0.66; 1.12)	0.88 (0.63; 1.27)	1.07 (0.96; 1.20)
First at-risk children's consultation	92	101	129	105 (81; 137)	108 (82; 143)	105 (78; 142)	96 (65; 142)	103 (54; 198)	130 (101; 168)	0.95 (0.72; 1.27)	0.97 (0.60; 1.65)	1.29 (1.04; 1.59)
Postpartum visit within 3–7 days	42	53	57	48 (22; 102)	53 (24; 117)	44 (19; 102)	44 (11; 174)	48 (13; 182)	60 (28; 130)	0.86 (0.40; 1.88)	0.84 (0.43; 1.64)	1.40 (0.95; 2.06)

Abbreviations: ANC, antenatal care; BCG, bacillus Calmette-Guerin; CI, confidence interval; DPT-Hib3, diphtheria, pertussis, tetanus, and Haemophilus influenzae type b; FP, family planning; IPTp4, at least 4 doses of intermittent preventive treatment prophylaxis.

[a] Relative loss is computed at the district level by dividing the Model Expected With Cyclone Idai scenario by the Model Expected Without Cyclone Idai scenario. Averages of these ratios are then computed for overall relative loss. The confidence intervals are computed from Markov Chain Monte-Carlo (MCMC) posterior realizations.

Figure 2: Map of Sofala and Manica Provinces in Mozambique

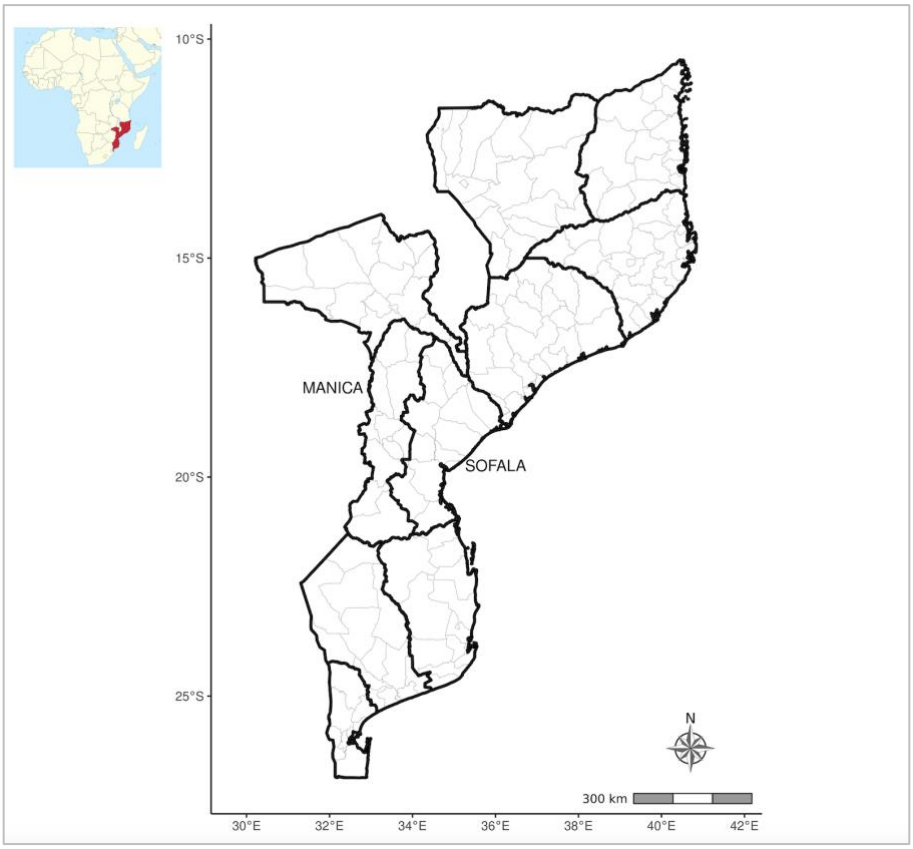
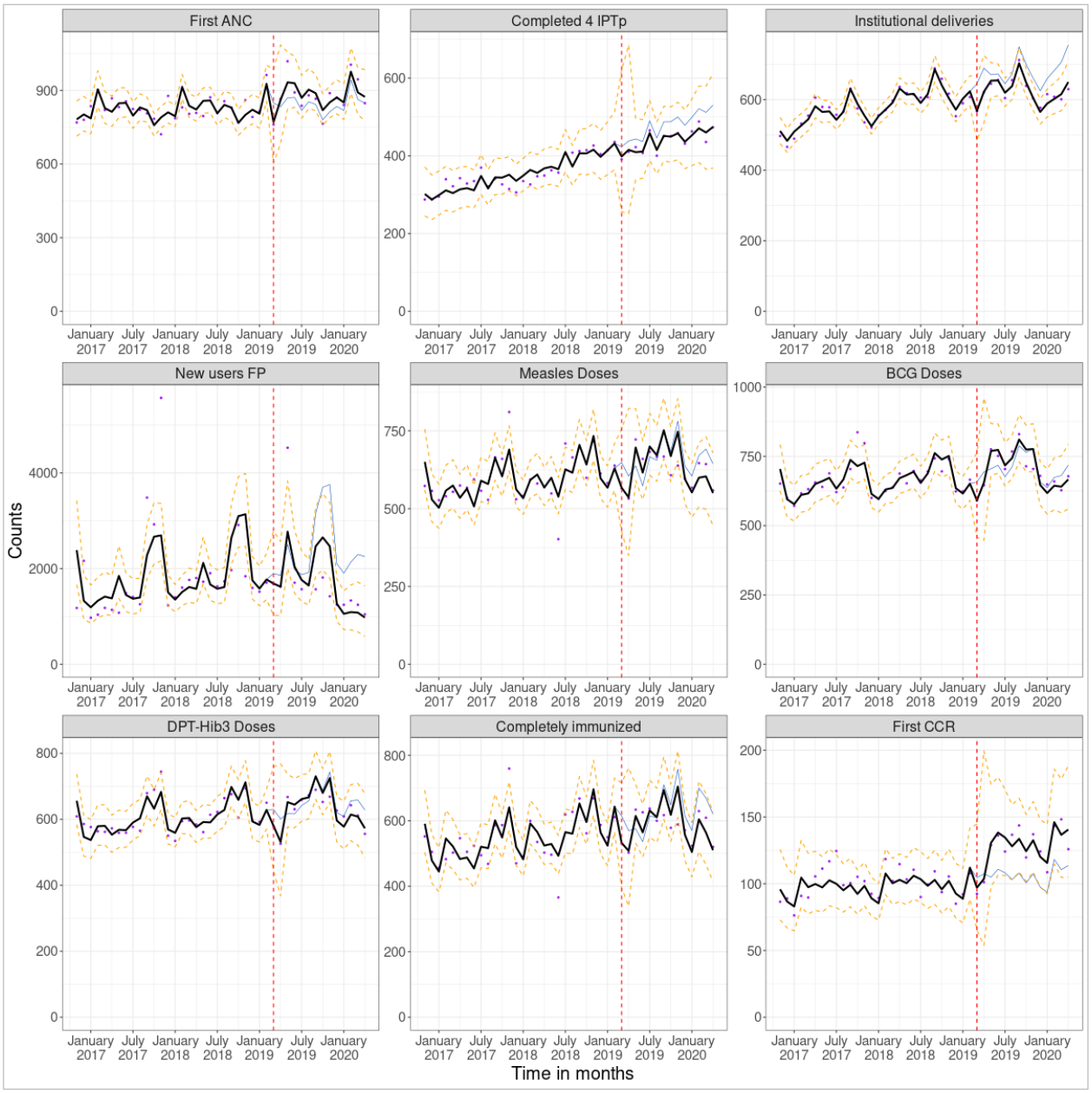
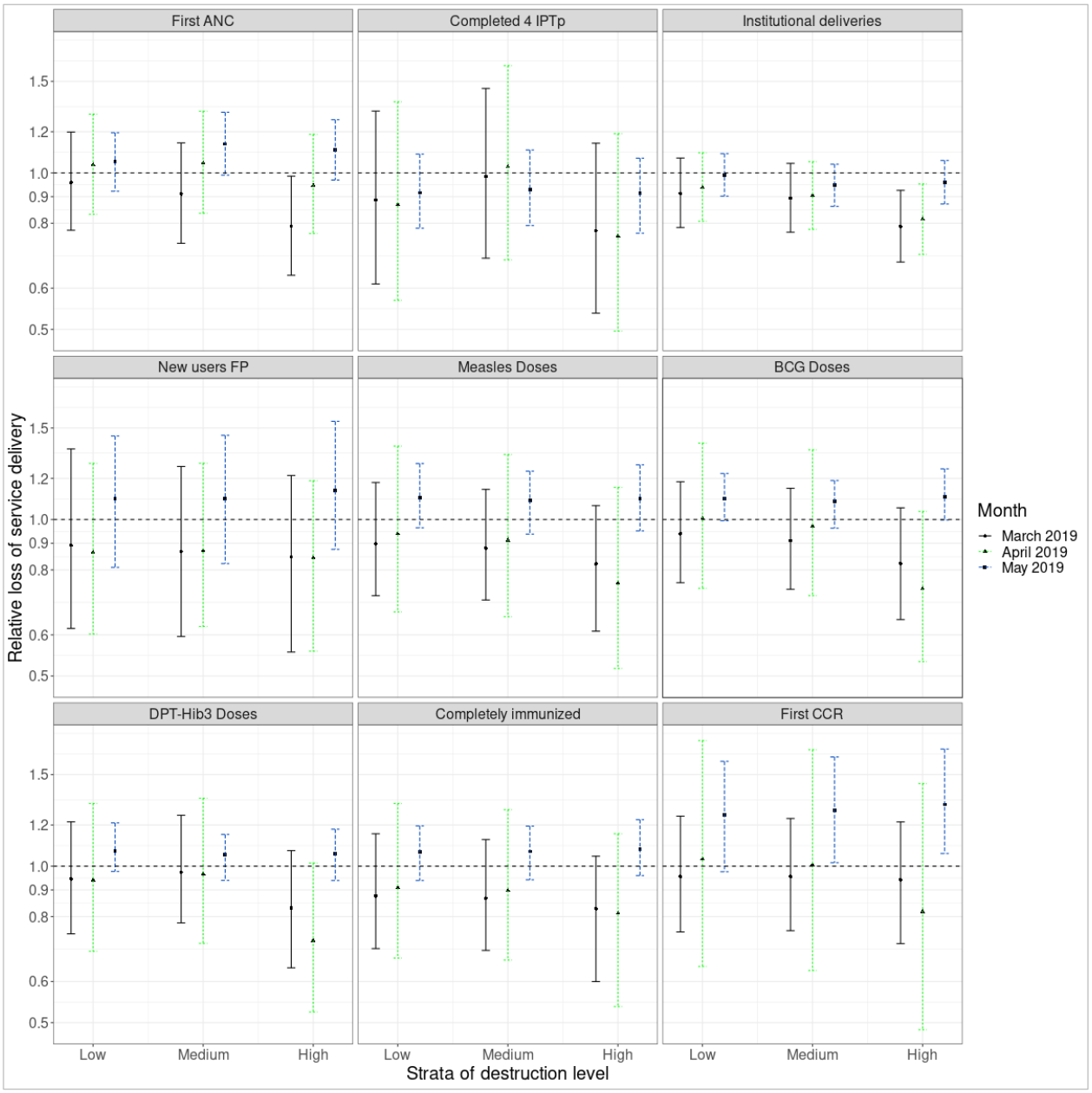


Figure 3: Average Counts for Service Delivery Indicators in 25 Districts Before and After Cyclone Idai in Sofala and Manica Provinces, Mozambique[a]



[a] Cyclone Idai March 2019 (dashed red line); observed counts (dots); model expected under Idai (solid thick line) and its 95% confidence interval (dashed lines); counterfactual model expected without Idai (solid thin line).

Figure 4: Relative Losses After Cyclone Idai, by Service Delivery Indicator and District-Level Destruction Strata, Sofala and Manica Provinces, Mozambique



Abbreviations: ANC, antenatal care; BCG, bacillus Calmette-Guerin; CCR, child at risk consultation; DPT-Hib3, diphtheria, pertussis, tetanus, and Haemophilus influenzae type b; FP, family planning; IPTp4, at least 4 doses of intermittent preventive treatment prophylaxis.

CHAPTER 3: Scrutinizing Human Resources for Health Availability and Distribution in Mozambique Between 2016 and 2020: A Subnational Descriptive Longitudinal Study.

Quinhas Fernandes[1,2], Orvalho Augusto[2,3], Helena Machai[4], James Pfeiffer[2,5], Marco Carone[6], Norton Pinto[4], Naziat Carimo[2], Isaías Ramiro[7], Stephen Gloyd[2], Kenneth Sherr[2,8,9]

1. National Directorate of Public Health, Ministry of Health, Mozambique.
2. Department of Global Health, University of Washington, Seattle, WA, USA
3. Eduardo Mondlane University, Maputo, Mozambique.
4. Directorate of Human Resources, Ministry of Health, Mozambique.
5. Department of Anthropology, University of Washington, Seattle, WA, United States
6. Department of Biostatistics, School of Public Health, University of Washington, Seattle, WA, USA
7. Comité para a Saúde de Moçambique, Maputo City, Mozambique
8. Department of Industrial & Systems Engineering, University of Washington, Seattle, USA
9. Department of Epidemiology, University of Washington, Seattle, USA

Corresponding author: Quinhas Fernandes (ferq09@gmail.com)

ABSTRACT

Introduction: Overall, resilient health systems build upon sufficient, qualified, well-distributed, and motivated health workers; however, this precious resource is limited in numbers to meet people's demands, particularly in LMICs. Understanding the subnational distribution of health workers from different lens is critical to ensure quality healthcare and improving health outcomes.

Methods: Using data from Health Personnel Information System, facility-level Service Availability and Readiness Assessment, and other sources, we performed a district-level longitudinal analysis to assess health workforce density and the ratio of male to female health workers between January 2016 and June 2020 across all districts in Mozambique.

Results: 22,011 health workers were sampled, of whom 10,405 (47.3%) were male. The average age was 35 years (SD: 9.4). Physicians (1,025, 4.7%), maternal and child health nurses (4,808, 21.8%), and nurses (6,402, 29.1%) represented about 55% of the sample. In January 2016, the average district-level workforce density was 75.8 per 100,000 population (95% CI: 65.9, 87.1), and was increasing at an annual rate of 8.0% (95% CI: 6.00, 9.00) through January 2018. The annual growth rate declined to 3.0% (95% CI: 2.00, 4.00) after January 2018. Two provinces, Maputo City and Maputo Province, with 268.3 (95% CI: 186.10, 387.00) and 104.6 (95% CI: 84.20, 130.00) health workers per 100,000 population, respectively, had the highest workforce density at baseline (2016). There were 3,122 community health workers (CHW), of whom 72.8% were male, in January 2016. The average number of CHWs per 10,000 population was 1.33 (95% CI: 1.11, 1.59) in 2016 and increased by 18% annually between January 2016 and January 2018. This trend reduced to 11% (95% CI: 0.00, 13.00) after January 2018. The sex ratio was twice as high for all provinces in the central and northern regions relative to Maputo Province. Maputo City (OR: 0.34; 95% CI: 0.32, 0.34) and Maputo Province (OR: 0.56; 95% CI: 0.49, 0.65) reported the

lowest sex ratio at the baseline. Encouragingly, important sex ratio improvements were observed after January 2018, particularly in the northern and central regions.

Conclusion: Mozambique made substantial progress in health workers' availability during the study period; however, with a critical slow-down after 2018. Despite the progress, meaningful shortages and distribution disparities persist.

Keywords: Workforce density, HRH availability and distribution, longitudinal analysis, Mozambique.

INTRODUCTION

Human Resources for Health (HRH), an essential pillar of any health system, are frequently limited in supply to meet population health needs, particularly in low- and middle-income countries (LMICs). Despite the lack of consensus on the ideal number of HRH for primary health care (PHC), the World Health Organization (WHO) defines fewer than 2.8 physicians, nurses, and midwives per thousand population as an unequivocal sign of a critical shortage of HRH.[84–86] Globally meaningful progress has been achieved in closing the HRH gap; nevertheless, by 2016, 76 countries had fewer than one physician per thousand population.[87] Most of these were sub-Saharan African (sSA) countries,[9] which had only 2-3% of the global number of physicians.[88] Lurking under this worrisome scenario, other important subnational concerns exist, including asymmetrical distribution, absenteeism, and poor quality training.[89,90]

Several factors in the literature have been associated with HRH shortages, including resource challenges to produce, hire, and retain qualified health workers.[9,91] HRH shortages disproportionally affect LMICs as a result of chronic reduced fiscal space related to austerity policies and unsustainable debts. Furthermore, when evidence-based distribution criteria are lacking or are poorly implemented, challenges arise to equitably apportion health workers, improve motivation, and minimize internal and external brain drain.[42] Together, these factors lead to lower staff availability and acceptability, disproportional facility-level staff completeness, and ultimately the systematic inability to deliver quality care.[43] Scrutinizing how these contextual factors interact and affect HRH availability at the point of care is critical to ensuring efficient HRH management.

Routine information systems are primarily designed to monitor health service delivery rather than tracking human resources, financing, stockouts, and other planning and management indicators.

Therefore, these systems fail to detect critical features of systems inefficiencies, including workforce availability and disparities.[92,93] Frequently, routine statistics rely on aggregated data which hinders the ability to track individual health workers and study temporal dynamics related to individual movements within and between administrative areas.[94] Encouragingly, contemporary and robust analytic approaches can help understand and address HRH management complexities and generate solid evidence to guide equitable HRH distribution.[93] However, barriers to obtaining the data (when it exists) and poor data quality limit the ability to close the knowledge gap on HRH.[95] Addressing these issues is critical to improving HRH management, particularly in LMICs.

In Mozambique, public and private training institutions produce more health workers than can be absorbed. However, like many other LMICs, Mozambique continues to struggle to hire and equitably distribute adequate numbers of health workers to staff PHC services.[35] Furthermore, the private health sector is limited in availability and is concentrated in large urban areas; therefore, it is not an alternative for the vast majority of people.[65] Between 2014 and 2016, less than 50% of the budget needed to hire new health workers was allocated to the health sector.[35] Despite financial barriers, the Mozambique health system increased the overall number of health workers between 2006 to 2015 (from 69 to 100 per 100.000 people), for key PHC cadres, including physicians (from 4 to nearly 8 per 100.000 people) and midwives (from 34 to 48 per 100.000 people).[35] While this increase is notable, progress has been insufficient to accomplish the ambitious goals defined in the Mozambique Ministry of Health Strategic Plan nor meet the WHO minimum HRH threshold. Furthermore, weak compliance with distribution criteria contributes to persistent disparities (gender and location) between and within country administrative areas.[35] For example, the absolute difference in HRH availability in urban *versus* rural areas was 111 per

hundred thousand people in 2015 (176 per hundred thousand people in urban areas compared with 65 per hundred thousand people in rural areas). If evidence-based measures are not urgently taken, efforts to address the overall availability gap may fail, jeopardizing the achievement of national goals.

This study aimed to provide a detailed picture of HRH availability and distribution trends between 2016 and 2020. Furthermore, it provides an alternative and replicable approach to generate evidence on HRH by combining and validating available data sources and applying robust analytical methods to describe distribution trends.

METHODS

Study design

We performed a district-level longitudinal analysis, using data generated by the Health Personnel Information System (eSIP-Saúde), to describe patterns in health workforce density (HWD) and the ratio of male to female health workers between January 2016 and June 2020 across all districts in Mozambique.

Study setting

In 2023, Mozambique has around 32.4 million people and is divided into 11 provinces (admin level 2) and 154 districts (admin level 3), including the capital city, Maputo.[75] In 2018, Mozambique had 1,643 health facilities, of which 1,575 were primary-level, 54 secondary, seven tertiary, and seven quaternary – all hierarchically organized to ensure a comprehensive referral system and continuum of care. Typically, tertiary and quaternary health facilities are provincial or regional referral hospitals located in densely populated urban areas. The type II health center is the

smallest health facility providing PHC services in rural areas with essential staffing that should include a clinician (basic or mid-level technician), a maternal and child health nurse (MCH-N), and a public health technician or nutritionist (Ministerial Diploma No.127, July 31, 2002). The 1,170 existing type II health centers represent 71.2% of the total health facilities.

Mozambique's health system has multiple health worker cadres; however, not all are comparable to other countries in terms of years of training and core competencies. In this manuscript, physicians were defined as all doctors regardless of being generalist medical doctors or specialist medical doctors, according to the international classification of health workers (based on ISCO, revision 2008).[96] Maternal and child health nurses are midwifery professionals, and they plan, manage, provide, and evaluate maternal and child health care services before, during and after pregnancy and childbirth. Table 5 summarizes core competencies and training duration for selected cadres, including for community health workers (CHWs, in the Ministry of Health known as *Agente Polivalente Elementar* - *APE*). It also provides the International Standard Classification of Occupations (ISCO) code for the analogy to other settings.

Data sources, processing, and quality control

Data were sourced and aggregated from the eSIP-Saúde database, which contains monthly excel-spreadsheets with individual-level data by month for all Ministry of Health personnel. The spreadsheets were made available by the Human Resources for Health Observatory. The eSIP-Saúde database has evolved over the years from including only annual provincial-level aggregated data (between 2000 and 2014) to annual individual-level data (2015) and later to monthly individual-level data (since 2016). After June 2020, when broader decentralization policies were introduced, notable data availability and completeness gaps arose because health workers were

split between two institutions, the provincial health service and the provincial health directorate. Therefore, we only included data through June 2020. Between January 2016 and June 2020, individual personnel records were identified using unique identifiers. For this period, essential information was extracted, including demographics (age and sex), place of work, source of salary, and category – all by month.

In addition, we included data from the district-level community health worker database (gender, location, and starting year); the 2007 and 2017 Mozambique Population and Housing Census for yearly population forecasts;[75] the 2018 Service Availability and Readiness Assessment (SARA) survey for data on facility and district locations;[97] and the Ministry of Health's routine health information system (SIS-MA) for data on health facility type. These data sources were merged with the eSIP-Saúde database to construct a consolidated dataset.

Data cleaning and quality control proceeded as follows. First, we developed an R-based algorithm to identify unusual health worker transitions across districts, defined as health worker movement from one district (district A) to another (district B) with a return to the later district (district A) within a period of fewer than four months. For these cases, we assumed that the health worker permanently stayed in district A. We chose four months based on our experience since transitions with returns less than this interval are highly unexpected. Second, we investigated unexpected category changes, particularly from higher to lower levels (for example, from physician to nurse) to ensure that every health worker was classified in the correct category across time. We also assessed potential misclassification between MCH-N and nurses. Third, we triangulated the SARA and eSIP-Saúde data to ensure that the place of work corresponded to the right district and province. Fourth, we cross-checked the type of health facility between SARA and SIS-MA data, using the former as the gold standard. Regular meetings were held with the eSIP-Saúde team over

a six-month period to double-check all inconsistencies and cross-validate data with provincial and district managers. The few remaining observations with inconsistent data were excluded from the analysis.

Outcomes and explanatory factors

We assessed, at the district level, two primary outcomes: health workforce density and health worker's sex ratio. HWD is the number of health workers per 100,000 population, and sex ratio refers to the number of male to female health workers at the district level. Health workers were defined as those practicing clinical activities, professionally active in clinical activities, and licensed to practice clinical activities in the public sector.[98] It includes physicians, MCH-N, nurses, clinicians (medicine, surgery, psychiatric, laboratory, pharmacy, and dentistry technicians), and public health technicians. We excluded all clinicians primarily hired in a non-clinical setting (ex: ministry of health offices and training institutions) or holding a leadership position that conflicts with clinical activity. CHWs were excluded from the HWD calculation since they provide a limited-service package.

Two main predictors were considered. First, infrastructure availability, defined as the number of health facilities per ten thousand people measured at the district level. Second, the type of referral hospital available in each district (primary, secondary, tertiary, or quaternary).

Study Sample

Based on the study inclusion criteria (being a clinician or public health worker, holding a leadership position without conflict with clinical activity, and being hired in a clinical setting), 34,120 health workers were identified in the eSIP-Saúde database between January 2016 and June 2020, of whom 1,702 health workers were excluded since we could not clearly identify their

workplace after completing the data cleaning process. An additional 90 health workers were excluded for being older than 70 years of age, as the legal working age limit is 65 years for males and 60 for females (the new regulation sets 60 years for both), with few exceptions given the HRH shortage. The final sample included 32,328 health workers.

Statistical analysis

We conducted a district-level analysis with results presented as provincial and national averages. Initial district-specific plots were constructed to visualize the data, search for suspected outliers, investigate missingness, and guide decisions on model parameterization and sensitivity analysis strategy. Summary statistics – mean and standard deviation for continuous characteristics and absolute values and relative frequencies for categorical variables – were produced to describe baseline (January 2016) health worker characteristics.

Maputo City, the country's capital, was considered a particular case since it is the only city with urban districts. This city hosts the country's largest referral hospital (Maputo Central Hospital), which simultaneously is the major physicians' training center. We excluded one urban district (Khamphumo District) from the trend analysis since it is where the country referral hospital is located and is an influential outlier.

Due to several factors, including data quality across provinces (completeness and delays to remove retired health workers), comparison based on observed densities is not conservative. Therefore, we modeled the health workforce densities adjusting for infrastructure availability, type of existing referral hospital, and calendar months. Thus, to estimate health worker availability, we computed the HWD for each district time-point (month) using the number of health workers and the district population for the year of interest, multiplied by 100,000. We performed a generalized estimation

equation (GEE) linear regression model with robust standard errors, a first-order autoregressive (AR1) working correlation matrix, and clustering at the district level to model the HWD.[99] Given the high skewness to the right of the density and to allow interpretation of the association on a multiplicative scale, outcomes were log-transformed. After examining the correlation matrix between successive time periods, the working correlation structure was determined (model equations). Because Mozambique follows a calendar year budgetary cycle (January to January), typically, the first quarter has fewer personnel contracts; therefore, we accounted for seasonal-time effects by adding months as dummy indicators. We added a linear-spline term to accommodate hidden deviation, allowing trends to differ before and after January 2018, to estimate trends before and after this cut-off. This cut-off was preferred as it matches the beginning of a period of acute budget restrictions – from the International Monetary Fund, bilateral, and multilateral donors – to hire new health workers because of the debt scandal. Infrastructure availability was centered at one health facility per ten thousand people to allow a meaningful intercept interpretation. We let each province have its own trajectory by adding an interaction term between time and province before and after 2018. Physicians, nurses, MCH-N, and CHWs densities were also assessed individually following a similar approach. The ratio of males to females and its trend before and post 2018 was estimated using a logistic regression model performed under GEE and accounting for clustering, autocorrelations of errors, secular trends, and existing district type of referral hospital.

We repeated the analysis using linear mixed-effect models.[100,101] Overall, the two models provided approximate results, with the GEE being more conservative. All analyses were performed in R version 4.0.3.[73] We used a model-based approach to estimate densities and the uncertainty (95% Confidence Intervals) rather than reporting the densities from the raw data for several

reasons, including i) exclusion of around 5% of the total health workers; ii) human resources databases being prone to delays to removing deceased or retired health workers, and iii) need to adjusting for critical variables and estimate differences between and within provinces.

Model equation 1: HR Density

$$log(count_{dt}) = \beta_0 + \beta_1 time\_sinceJan2016_t + \beta_2 time\_sinceJan2018_t + \beta_3 HF\_type.CS_d + \beta_4 HF\_type.HP_d + \beta_5 HF\_type.HC_d + \sum_{p=1}^{10} \gamma_p I(p = province_d) + \sum_{p=1}^{10} \gamma_{10+p} I(p = province_d) \cdot time\_sinceJan2016_t + \sum_{p=1}^{10} \gamma_{20+p} I(p = province_d) \cdot time\_sinceJan2018_t + \sum_{m=2}^{12} \beta_{5+m} \cdot I(m = month_t) + 1 \cdot (log(population_{dt}/100000) + \epsilon_{dt}$$

for a d district at t time (in months since 2016 January):

- count is the number of health workers
- time_sinceJan2016 and time_sinceJan2018 are the number of months since January 2016 and January 2018, respectively
- The HF terms are dummy indicators for health facility type
- p indexes the provinces in Mozambique. There are 11. One of the is a reference so we add 10 dummy indicators to the models as $\sum_{p=1}^{10} \gamma_p I(p = province)$
- the terms with terms including the multiplication $I(p = province) \cdot time\_sinceJan2016$ are interactions between time and province dummy indicators
- the terms containing $I(m = month)$ are month dummy indicators. There are 12 months and January is used as reference so we have 11 terms.
- the $1 \cdot (log(population_{dt}/100000)$ is the offset included in the model so the outcome becomes the ratio between counts of health care workers to the 100000 inhabitants
- ϵ_{dt} is the error term and it follows a normal distribution with mean 0 and a variance to be estimated in the model.

Model equation 2: Sex Ratio

$$log\left(\frac{count\_males_{dt}}{count\_females_{dt}}\right) = \beta_0 + \beta_1 time\_sinceJan2016_t + \beta_2 time\_sinceJan2018_t$$
$$+\beta_3 HF\_type.CS_d + \beta_4 HF\_type.HP_d + \beta_5 HF\_type.HC_d + \sum_{p=1}^{10} \gamma_p I(p = province_d)$$
$$+\sum_{p=1}^{10} \gamma_{10+p} I(p = province_d) \cdot time\_sinceJan2016_t + \sum_{p=1}^{10} \gamma_{20+p} I(p = province_d) \cdot time\_sinceJan2018_t$$
$$+\sum_{m=2}^{12} \beta_{6+m} \cdot I(m = month_t) + \epsilon_{dt}$$

for a d district at t time (in months since 2016 January):

- count is the number of health workers
- time_sinceJan2016 and time_sinceJan2018 are the number of months since January 2016 and January 2018, respectively
- The HF terms are dummy indicators for health facility type
- p indexes the provinces in Mozambique. There are 11. One of the is a reference so we add 10 dummy indicators to the models as $\sum_{p=1}^{10} \gamma_p I(p = province)$
- the terms with terms including the multiplication $I(p = province) \cdot time\_sinceJan2016$ are interactions between time and province dummy indicators
- the terms containing $I(m = month)$ are month dummy indicators. There are 12 months and January is used as reference so we have 11 terms
- ϵ_{dt} is the error term and it follows a normal distribution with mean 0 and a variance to be estimated in the model.

RESULTS

Descriptive

At the baseline (January 2016), Mozambique had 22,011 health workers who fulfilled the study criteria, of whom 10,405 (47.3%) were male. The mean age was 35 years (SD: 9.4). Physicians

(1,025, 4.7%), MCH-N (4,808, 21.8%), and nurses (6,402, 29.1%) together represented roughly 55% of the total study sample. Overall, 19,455 (88.4%) of the health workers were government paid. Furthermore, at baseline, there were 3,122 CHWs, of whom 72.8% were male (Table 6).

HRH availability and distribution

Despite the substantial between-province variation, the average baseline district-level HWD nationwide was 75.8 per 100,000 population (95% CI: 65.9, 87.1), which increased at an annual rate of 8.0% (95% CI: 6.00, 9.00) through January 2018, after which it declined to an annual growth rate of 3.0% (95% CI: 2.00, 4.00) (Figure 5). On average, Maputo City, with 268.3 health workers per 100,000 population (95% CI: 186.10, 387.00), and Maputo Province, with 104.6 health workers per 100,000 population (95% CI: 84.20, 130.00), had the highest HWD at baseline (Table 7). Excluding Maputo City, six out of ten provinces had lower HWD compared to Maputo Province in January 2016, including Tete (45.0%), Zambézia (40.2%), Nampula (38.8%), Niassa (38.4%), Manica (31.3%), and Cabo Delgado (25.5%). All provinces but Maputo province and Manica observed significant annual improvements between January 2016 and January 2018, ranging from 3.0% in Sofala to 24.0% in Maputo City (Figure 6-7). Relative to districts with a secondary referral hospital, districts with a tertiary referral hospital had 3.9 times higher HWD (95% CI: 3.13, 4.85). Furthermore, every year, HWD was consistently higher from April to August and in the last two months of the year, relative to January.

The disaggregated analysis demonstrates that Zambézia, Tete, Manica, Nampula, and Niassa had lower baseline densities in essential health worker categories, including physicians, MCH-N, and nurses. For example, Tete, a chronically underprivileged province, had the lowest MCH-N density at baseline (37.7; 95% CI: 31.30, 45.20) and had a null slope from 2016 to 2018. Similarly,

Zambézia, the second most populated province, had 36.6 (95% CI: 30.70, 43.80) MCH-N per 100,000 population in January 2016, which had been increasing at an annual rate of 5.0% (95% CI: 0.40, 10.00) from 2016 to 2018; however, this positive trend did not continue after 2018 (Table 8).

The disproportional distribution was also evident among physicians. Tete and Zambézia provinces had 58.1% (95% CI: 38.20, 71.70) and 53.9% (95% CI: 36.10, 66.80) lower physician density relative to Maputo province. Although Maputo Province had the second highest increase in the annual rate of change prior to January 2018 (1.12; 95% CI: 0.98, 1.28), this rate maintained and became significant after 2018 (1.12; 95% CI: 1.01, 1.24) (Table 8). Not surprisingly, districts with a tertiary referral hospital observed 8.2 times higher physician density than those with a secondary hospital (95% CI: 6.60, 10.23). All provinces experienced positive changes in the density of nurses before 2018. Nevertheless, after 2018, a substantial reduction in the rate of change was observed in most provinces, with Gaza (0.9; 95% CI: 0.80, 1.02) and Zambézia (4.0%; 95% CI: 2.00, 6.00) reporting important reductions (Table 8).

The average number of CHWs per 10,000 population in Mozambique was 1.33 (95% CI: 1.11, 1.59) in 2016 and increased by 18% annually between January 2016 to January 2018. The baseline CHW density ranged from 0.93/10,000 population in Tete to 2.02/10,000 population in Cabo Delgado. Tete and Zambézia, the two provinces with the lowest baseline CHW density, had the most notable annual increase between January 2016 and January 2018, estimated at 46.1% (95% CI: 35.80, 57.20) and 47.3% (95% CI: 49.90, 54.00), respectively, leading to an equitable distribution across provinces in January 2018. (Figure 7 and Table 7).

HRH sex ratio (male to female)

Substantial gender imbalances were observed in staffing between provinces located in the southern region compared with the rest of the country. Overall, Maputo City (OR: 0.34; 95% CI: 0.32, 0.34), Maputo Province (OR: 0.56; 95% CI: 0.49, 0.65), Gaza (OR: 0.71; 95% CI: 0.58, 0.87), and Inhambane (OR: 0.67; 95% CI: 0.58, 0.78) had significantly lower sex ratios at the baseline (Table 9). The sex ratio is more than twice as high for all provinces in the central and northern regions relative to Maputo Province. To illustrate, in January 2016, for every 100 female health workers, there were 56 males in Maputo Province [sex ratios of 0.56 (95% CI: 0.45, 0.65)] while in Niassa, there were 173 [sex ratios of 1.73 (95% CI: 1.47, 2.05)].

No important changes in the sex ratio were observed between 2016 and 2018, except in Manica, Nampula, and Zambezia; however, after 2018, the sex ratio continued to decrease at an annual rate of 5.0% (95% CI: 1.00, 9.00) in Maputo City and Province, and 3.0% (95% CI: 0.00, 6.00) in Gaza Province.

DISCUSSION

This study used nationally representative, granular data to describe district-level HRH availability and distribution in Mozambique. Overall, substantial improvements have been achieved in HRH availability nationwide. Despite the progress made, there was a notable slowdown in progress after 2018. The HRH availability trends after 2018 suggest a critical influence of the debt scandal since international support restrictions exacerbated the already limited fiscal space. After removing non-practicing clinicians from the analysis, the HRH gap is even more prominent than what has been officially reported. Except for Maputo City, no other province was close to the minimum HWD

(2.8 per thousand people).[86,91] Indeed, compared to the neighboring countries, Mozambique still ranks far below the average.[32]

While HRH shortages are anticipated, given current and past economic restrictions and austerity measures, critical equitable distribution issues are evident, including the following. First, the variability across provinces is unacceptably high, with some provinces having almost double the HWD compared with others. Provinces in the southern region consistently reported better HWD relative to others across time. This inequity may be due to failures in the HRH allocation criteria and/or including personnel choices, as historically, the southern region has performed better in most socio-economic indicators and is, therefore, more attractive to qualified staff.[65,75] However, we cannot rule out a selective privilege in the allocation given to southern, particularly to Maputo City, where for example, physician density was the highest in January 2016 (more than ten times de national average) and remained with the highest increment over time. Second, gender imbalances were prominent, with the southern region predominantly staffed by females and the remaining provinces by males. Several factors could explain gender imbalances within the health sector, including poor implementation of gender equity policies in staff allocation and the countrywide implementation of public sector marriage protection policies (where a female nurse, for example, has the right to request to be hired in the same area as where her husband works).[102] Third, even though the southern region had higher HWD levels, this did not translate into equitable distribution between districts with tertiary or quaternary-level referral hospitals and those with secondary hospitals. Indeed, this reflects another critical issue – the imbalances between the urban and rural areas – which have not been assessed directly in this study but have been described in other studies.[103] If we consider that the provincial capital cities all have a tertiary or quaternary-level referral hospital and are urbanized areas, our findings demonstrate that these areas have

around four times higher HWD compared to districts with a secondary referral hospital. Therefore, the higher levels of the HWD in the southern region truly reflect the absorption of health workers in urban areas with tertiary or quaternary-level hospitals, which obscures insufficient health worker availability in rural areas.[90,104–106]

Previous studies have reported similar findings including inefficiencies in distribution criteria; disparities between production capacity and restricted absorptive capacity; weak attraction policies; poor implementation of retention policies; and internal and external migration.[90,107–109] Nevertheless, improvements can be achieved if informed decisions and actions are taken to address inefficient HRH distribution. An example from this study is with CHWs, whose gaps have consistently decreased because the new training approach has directed resources explicitly to underprivileged provinces.

This study also demonstrates the relevance of investing in HRH databases that allow for longitudinal analysis. Although there has been a push for routine health information systems that capture outputs and outcomes such as health service provision, insufficient attention has been given to building data systems that track inputs such as human resources. Unlike aggregate monthly counts of systems outputs or outcomes, HRH databases must be designed to track individual health workers across time, requiring unique identifiers and rigid security protocols. Understanding this gap, our study leveraged a unique Ministry of Health database (eSIP-Saúde) that included a monthly census of all health workers, which was developed for record-keeping purposes to build a comprehensive database for analysis. As such, this study provides an excellent model for using existent and overlooked data sources to generate evidence to guide policymakers. As populations continue to rapidly expand in many LMICs, combined with internal migration patterns, evidence-informed decisions will be increasingly important to guide allocation and

retention practices and ultimately ensure that human resources – the backbone of health systems – are in place to meet the societal health needs. Therefore, our analytic approach provides a crucial model for evidence generation.

This study has some limitations. First, we relied on routine data subject to human errors. However, our quality assessment procedures greatly improved data accuracy and reliability. Second, we excluded approximately 5% of health workers in the dataset due to the inability to clarify working locations, which could have introduced some degree of selection bias. However, the small number and the sensitivity analysis performed minimized this concern. Third, we failed to include some important factors in the model, including disease burden, development index, and health facility catchment population, leading to insufficient control of confounding. Despite these limitations, our analytic approach was robust, and results were stable in all models, enhancing our confidence in the reliability of our results.

CONCLUSION

Despite the improvements in HRH availability in Mozambique, we demonstrated persistent subnational chronic disparities and gender imbalances. Importantly, our findings demand urgent changes, including 1) increases in fiscal space to allow hiring additional health workers, particularly in areas underserved; 2) updates in the distribution criteria to reduce inequalities on HRH availability and gender balance; 3) appropriate incentives and support to motivate health workers to work in rural areas; and 4) implementation of new analytic approaches to effectively track HRH trends at the subnational level and study health worker's movements within and between administrative areas. Furthermore, this study provides a replicable model to maximize

existing routine data to conduct robust analysis and provide policymakers with the information needed to drive evidence-based decisions.

Abbreviations

CHW: Community Health Worker

GEE: Generalized Estimation Equation

HRH: Human Resources for Health

HWD: Heath Workforce Density

MCH-N: Maternal and Child Health Nurses

LMIC: Low- and Middle-Income Countries.

PHC: Primary Health Care

SARA: Service Availability and Readiness Assessment survey

WHO: World Health Organization

Ethics approval and consent to participate.

The Ministry of Health in Mozambique approved the data for this study. The study was exempt from ethical review since the analysis did not include individual identification.

Availability of data and materials.

Data are available upon request to the Ministry of Health Mozambique

Competing interests.

The author declares no competing interests.

Funding

The research reported in this publication was supported by the African Health Initiative of the Doris Duke Foundation and the Eunice Kennedy Shriver National Institute of Child Health and Development of the National Institutes of Health under award R01HDHD092449. Neither funding entity had any role in the design of the study, collection, analysis, and interpretation of the data, nor in writing the manuscript.

Authors' contributions

QF, KS, SG, JP, and MC conceptualized the research question, the study design, and the analytic strategy. QF, NP, HM provided the data. QF did the data curation with inputs from HM. QF performed the analysis with substantial inputs from OA and KS. QF developed the first draft manuscript. All authors provided substantial inputs, reviewed, and approved the final version.

Acknowledgements

The authors would like to acknowledge the Human Resources for Health Observatory team for the support provided and for extraordinary work to cross-check and validate the data.

Table 5: Training Duration, Core and Non-Core Competencies for Health Worker Main Cadres in the Mozambique Health System

Cadre	ISCO code	Training Duration	Core Competences	Additional Competences
Physician	2211 (Generalist doctor)	6 years	- Diagnose, treat and prevent illness, disease, injury, and other physical and mental impairments - Supervise and evaluate the implementation of care and treatment plans	- Training health workers - Health promotion -Leadership and management
	2212 (Specialist doctor) *	+ 4-5 years	- Diagnose, treat and prevent illness, disease, injury and other physical and mental impairments using specialized testing, diagnostic, medical, surgical, physical and psychiatric techniques - Specialized in certain disease categories, types of patient or methods of treatment - Perform medical education and research activities	- Health promotion -Leadership and management
MCH Nurse	2222	2.5 years	-Family planning, antenatal care, and postpartum care -Performing institutional deliveries (basic emergency obstetric care) -Integrated management of child illnesses care	-Immunization -Basic nutritional assessment -Health promotion
Nurse	2221	2 years	-Inpatient-centered monitoring and care -Nursing care planning, management and leadership	-Nursing education -Health promotion
Nutrition Technician	2265	2.5 years	-Nutritional status assessment, habits and eating practices -Health and nutritional education at the health facility and community levels (e.g. cooking demonstrations) -Supplementation for children and women, deworming -Outpatient nutritional rehabilitation (moderate and uncomplicated cases)	-Health promotion
Medicine Technician **	2269	2.5 years	-Diagnosis and treatment for chronic diseases and infectious diseases -Pediatric and adult HIV management -Sexual and reproductive health care -Nutritional status assessment and treatment (acute and chronic malnutrition)	-Health promotion -Leadership and management
Surgery Technician	2240	4 years	-Performing complicated institutional deliveries (advanced emergency obstetric care) - Performing surgeries (e.g. cesarean section, appendectomy and other basic obstetric and general surgical procedures)	-Health worker education -Health promotion
Community Health Worker (APEs)	3253	6 months	-Health Promotion -Integrated management of child illnesses care (community level package) -Malaria treatment -Basic nursing care (small and uncomplicated injuries) -Family planning distribution (oral and injectable contraceptives)	-Home-based visits

* Specialist medical doctor complete a 4-5 residence program after becoming a generalist doctor
**Medicine Technician qualify also for a four-year training to become a surgery technician

Table 6: Baseline Health Worker Characteristics in Mozambique (January 2016)

	Cabo Delgado	Gaza	Inhambane	Manica	Maputo City	Maputo Province	Nampula	Niassa	Sofala	Tete	Zambezia	Mozambique
Number of Health Workers	**1553**	**1446**	**1721**	**1653**	**2538**	**1292**	**3386**	**1349**	**2569**	**1579**	**2925**	**22011**
Age (mean (SD))	34.94 (9.39)	33.81 (9.15)	33.87 (9.37)	34.47 (9.52)	37.10 (10.68)	34.99 (9.05)	36.03 (9.56)	36.36 (9.46)	34.56 (10.07)	35.22 (9.61)	35.00 (9.68)	35.24 (9.73)
Age Category (N, (%))												
< 30 years	525 (33.8)	554 (38.3)	694 (40.3)	560 (33.9)	721 (28.4)	408 (31.6)	902 (26.6)	343 (25.4)	977 (38.0)	530 (33.6)	942 (32.2)	7156 (32.5)
30-50 years	848 (54.6)	737 (51.0)	845 (49.1)	925 (56.0)	1348 (53.1)	746 (57.7)	2061 (60.9)	845 (62.6)	1291 (50.3)	879 (55.7)	1624 (55.5)	12149 (55.2)
>50 years	179 (11.5)	155 (10.7)	182 (10.6)	168 (10.2)	469 (18.5)	138 (10.7)	422 (12.5)	161 (11.9)	301 (11.7)	169 (10.7)	359 (12.3)	2703 (12.3)
Male (%)	909 (58.5)	531 (36.7)	656 (38.1)	845 (51.1)	751 (29.6)	416 (32.2)	1765 (52.1)	796 (59.0)	1251 (48.7)	780 (49.4)	1705 (58.3)	10405 (47.3)
Category (N, (%))												
MCH Nurses	351 (22.6)	304 (21.0)	467 (27.1)	363 (22.0)	449 (17.7)	305 (23.6)	796 (23.5)	330 (24.5)	532 (20.7)	357 (22.6)	554 (18.9)	4808 (21.8)
Nurses	368 (23.7)	436(30.2)	441 (25.6)	477 (28.9)	892 (35.1)	278 (21.5)	945 (27.9)	393 (29.1)	852 (33.2)	414 (26.2)	906 (31.0)	6402 (29.1)
Physicians	45 (2.9)	53 (3.7)	73 (4.2)	58 (3.5)	304 (12.0)	75 (5.8)	122 (3.6)	44 (3.3)	112 (4.4)	48 (3.0)	91 (3.1)	1025 (4.7)
Dentists	23 (1.5)	39 (2.7)	37 (2.1)	31 (1.9)	39 (1.5)	46 (3.6)	70 (2.1)	19 (1.4)	47 (1.8)	33 (2.1)	45 (1.5)	429 (1.9)
Pharmacists	116 (7.5)	67 (4.6)	110 (6.4)	114 (6.9)	186 (7.3)	80 (6.2)	243 (7.2)	104 (7.7)	185 (7.2)	131 (8.3)	199 (6.8)	1535 (7.0)
Laboratorians	100 (6.4)	76 (5.3)	127 (7.4)	115 (7.0)	181 (7.1)	87 (6.7)	233 (6.9)	69 (5.1)	169 (6.6)	157 (9.9)	217 (7.4)	1531 (7.0)
Medical Technicians	272 (17.5)	255 (17.6)	181 (10.5)	232 (14.0)	122 (4.8)	164 (12.7)	467 (13.8)	201 (14.9)	349 (13.6)	192 (12.2)	434 (14.8)	2869 (13.0)
Public Health Technicians	151 (9.7)	114 (7.9)	159 (9.2)	121 (7.3)	72 (2.8)	155 (12.0)	270 (8.0)	85 (6.3)	157 (6.1)	111 (7.0)	293 (10.0)	1688 (7.7)
Other Technicians	127 (8.2)	102 (7.1)	126(7.3)	142 (8.6)	293 (11.5)	102 (7.9)	240 (7.1)	104 (7.7)	166 (6.5)	136 (8.6)	186 (6.4)	1724 (7.8)
Salary Source (N, (%))												
Government	1489 (95.9)	1332 (92.1)	1655 (96.2)	1486 (89.9)	2118 (83.5)	1025 (79.3)	2976 (87.9)	1235 (91.5)	2074 (80.7)	1216 (77.0)	2849 (97.4)	19455 (88.4)
PROSAUDE*	62 (4.0)	93 (6.4)	66 (3.8)	167(10.1)	365 (14.4)	255 (19.7)	408 (12.0)	114 (8.5)	495 (19.3)	362(22.9)	57 (1.9)	2444 (11.1)
Others	2 (0.1)	21 (1.5)	0 (0.0)	0 (0.0)	55 (2.2)	12 (0.9)	2 (0.1)	0 (0.0)	0 (0.0)	1 (0.1)	19 (0.6)	112 (0.5)
Number of CHW	**362**	**232**	**246**	**270**	**0**	**158**	**637**	**322**	**212**	**213**	**470**	**3,122**
Male (%)	292 (80.7)	54 (23.3)	127 (51.6)	234 (86.7)	-	50.0 (31.6)	519 (81.5)	258 (80.1)	197 (92.9)	200 (93.9)	343 (73.0)	2,274 (72.8)

*PROSAUDE: Donor funds channeled through a common budget/Sector Wide Approach; MCH-N=Maternal and Child Health Nurse

Table 7: Overall Estimated Workforce Density per 100,000 Population in Mozambique, January 2016 and January 2018

	Estimated* workforce density per 100,000 Pop. (95% CI)		Estimated* physicians' density per 100,000 Pop. (95% CI)		Estimated* MCH-N density per 100,000 Pop. (95% CI)		Estimated* Nurses' density per 100,000 Pop. (95% CI)		Estimated* CHW density per 10,000 Pop. (95% CI)	
	January 2016	January 2018	January 2016	January 2018	January 2016	January 2018	January 2016	January 2018	January 2016	January 2018
Mozambique	**75.8 (65.90, 87.10)**	**88.0 (76.2, 102.0)**	**2.31 (1.87, 2.84)**	**2.5 (2.03, 3.07)**	**51.70 (44.70, 59.80)**	**56.5 (48.5, 65.9)**	**21.8 (19.00, 25.10**	**25.4 (22.1, 22.1)**	**1.33 (1.11, 1.59)**	**1.86 (1.55, 2.24)**
Cabo Delgado	78.0 (64.1, 94.9)	99.8 (82.5, 120.8)	2.2 (1.63, 3.01)	2.2 (1.7, 2.9)	51.0 (42.9, 60.6)	55.8 (47.7, 65.3)	18.8 (14.7, 24.0)	26.1 (20.7, 32.8)	2.0 (1.52, 2.68)	2.0 (1.5, 2.7)
Gaza	100.2 (85.0, 118.2)	109.5 (92.0, 130.3)	3.6 (2.60, 4.97)	3.9 (2.9, 5.1)	63.5 (54.6, 73.8)	68.0 (57.1, 81.0)	30.4 (24.0, 38.3)	30.6 (23.1, 40.5)	1.6 (1.16, 2.14)	1.5 (1.1, 2.1)
Inhambane	98.7 (83.9, 116.0)	117.8 (100.7, 137.8)	3.8 (3.03, 4.87)	3.6 (2.8, 4.7)	80.5 (67.9, 95.5)	94.9 (80.6,111.6)	25.2 (21.1, 30.2)	29.0 (24.0, 34.9)	1.3 (1.05, 1.72)	1.4 (1.1, 1.8)
Manica	71.8 (58.1, 88.8)	77.3 (62.3, 95.9)	1.8 (1.42, 2.34)	1.9 (1.5, 2.5)	47.7 (38.2, 59.6)	46.7 (36.5, 59.7)	21.2 (16.5, 27.1)	23.0 (17.7, 29.8)	1.7 (1.11, 2.73)	2.3 (1.5, 2.6)
Maputo City**	268.3 (186.1, 387.0)	411.4 (256.5, 659.9)	25.9 (14.72, 45.67)	41.0 (24.1,69.8)	197.6 (132.3, 295.1)	193.3 (123.9, 301.8)	58.8 (34.1, 101.6)	113.3 (55.1, 233.0)	-	-
Maputo Province	104.6 (84.2, 130.0)	111.9 (87.2, 143.6)	3.9 (2.96, 5.00)	4.8 (3.9, 5.9)	76.5 (58.0, 100.9)	79.8 (59.1,107.7)	24.5 (19.6, 30.6)	25.4 (20.3, 31.9)	1.4 (1.03, 2.02)	1.7 (1.2, 2.5)
Nampula	64.0 (50.4, 81.0)	76.2 (61.0, 95.1)	1.9 (1.29, 2.68)	2.1 (1.5, 2.9)	43.4 (36.0, 52.4)	48.8 (40.3, 59.2)	18.7 (14.4, 24.2)	22.3 (17.8, 28.0)	1.6 (1.22, 2.22)	3.3 (2.4, 4.5)
Niassa	64.5 (53.6, 77.5)	78.7 (64.1, 96.7)	2.0 (1.35, 2.93)	2.3 (1.7,3.0)	47.3 (40.3, 55.4)	56.6 (46.4,59.0)	20.7 (17.0, 25.3)	23.4 (18.7, 29.2)	1.9 (1.46, 2.56)	2.0 (1.5, 2.6)
Sofala	96.2 (83.8, 110.5)	102.2 (89.9, 116.1)	2.8 (2.15, 3.54	2.9 (2.2, 3.7)	62.0 (52.7, 73.0)	63.5 (56.1, 71.9)	30.2 (26.0, 35.2)	31.8 (26.7, 37.9)	1.1 (0.81, 1.45)	1.8 (1.4, 2.3)
Tete	57.5 (46.9, 70.6)	63.9 (50.7, 80.7)	1.6 (1.15, 2.25)	1.7 (1.1, 2.5)	37.6 (31.3, 45.2)	39.7 (31.8, 49.7)	16.2 (12.7, 20.7)	18.5 (14.1, 24.2)	0.9 (0.63, 1.37)	2.0 (1.3, 3.0)
Zambézia	62.6 (51.7, 75.7)	67.7 (55.2, 83.1)	1.8 (1.36, 2.31)	2.1 (1.5,2.9)	36.6 (30.7, 43.8)	40.6 (33.2, 49.7)	19.8 (16.2, 24.3)	21.5 (17.3, 26.7)	1.0 (0.69, 1.34)	2.1 (1.5, 2.9)

* The densities were estimated from a GEE model after adjusting for infrastructure availability, type of existing referral hospital and calendar months

** Maputo City intercept includes the coefficient for general hospitals (corresponds to a district hospital in this setting)

Table 8: Workforce Density Annual Rate of Change in Mozambique, Before and After 2018.

	Physicians' density annual rate of change (95% CI)		MCH-N density annual rate of change (95% CI)		Nurses' density annual rate of change (95% CI)	
	Before 2018	**After 2018**	**Before 2018**	**After 2018**	**Before 2018**	**After 2018**
Mozambique	**1.04 (0.99, 1.08)**	**1.07 (1.05, 1.11)**	**1.05 (1.03, 1.06)**	**1.04 (1.02, 1.05)**	**1.08 (1.06, 1.10**	**1.02 (1.00, 1.04**
Cabo Delgado	0.99 (0.91, 1.10)	1.07 (1.00, 1.16)	1.05 (1.01, 1.08)	1.14 (1.09, 1.18)	1.18 (1.14, 1.22)	1.10 (1.06, 1.13)
Gaza	1.03 (0.92, 1.16)	0.95 (0.82, 1.10)	1.04 (1.00, 1.08)	1.03 (0.99, 1.07)	1.00 (0.97, 1.04)	0.90 (0.80, 1.02)
Inhambane	0.97 (0.86, 1.09)	1.01 (1.00, 1.20)	1.09 (1.05, 1.12)	1.00 (0.98, 1.02)	1.07 (1.05, 1.10)	1.02 (0.98, 1.06)
Manica	1.02 (0.91, 1.16)	1.15 (1.05, 1.26)	0.99 (0.93, 1.05)	1.01 (0.98, 1.05)	1.04 (1.00, 1.09)	1.06 (1.02, 1.11)
Maputo City*	1.26 (1.10, 1.44)	1.06 (0.98, 1.13)	0.99 (0.85, 1.15)	0.97 (0.93, 1.01)	1.39 (1.04, 1.85)	1.01 (0.98, 1.05)
Maputo Province	1.12 (0.98, 1.28)	1.12 (1.02, 1.24)	1.02 (0.97, 1.08)	1.04 (1.02, 1.07)	1.02 (0.97, 1.07)	1.04 (1.02, 1.06)
Nampula	1.05 (0.90, 1.22)	1.13 (1.05, 1.23)	1.06 (1.01, 1.11)	1.08 (1.05, 1.12)	1.09 (1.05, 1.13)	1.06 (1.03, 1.09)
Niassa	1.07 (0.92, 1.23)	1.05 (0.97, 1.14)	1.09 (1.02, 1.17)	0.99 (0.96, 1.01)	1.06 (1.02, 1.11)	1.03 (0.99, 1.07)
Sofala	1.02 (0.90, 1.16)	1.04 (0.92, 1.17)	1.01 (0.98, 1.04)	1.01 (0.98, 1.03)	1.03 (0.99, 1.06)	0.97 (0.94, 1.00)
Tete	1.0 (0.91, 1.16)	1.11 (0.99, 1.24)	1.03 (0.98, 1.08)	1.07 (1.02, 1.12)	1.07 (1.03, 1.11)	1.03 (1.00, 1.06)
Zambézia	1.09 (0.97, 1.22)	0.99 (0.95, 1.05)	1.05 (1.00, 1.10)	0.99 (0.97, 1.01)	1.04 (1.01, 1.08)	0.96 (0.94, 0.98)

- The annual rate of change was estimated from a GEE model after adjusting for infrastructure availability, type of existing referral hospital and calendar months

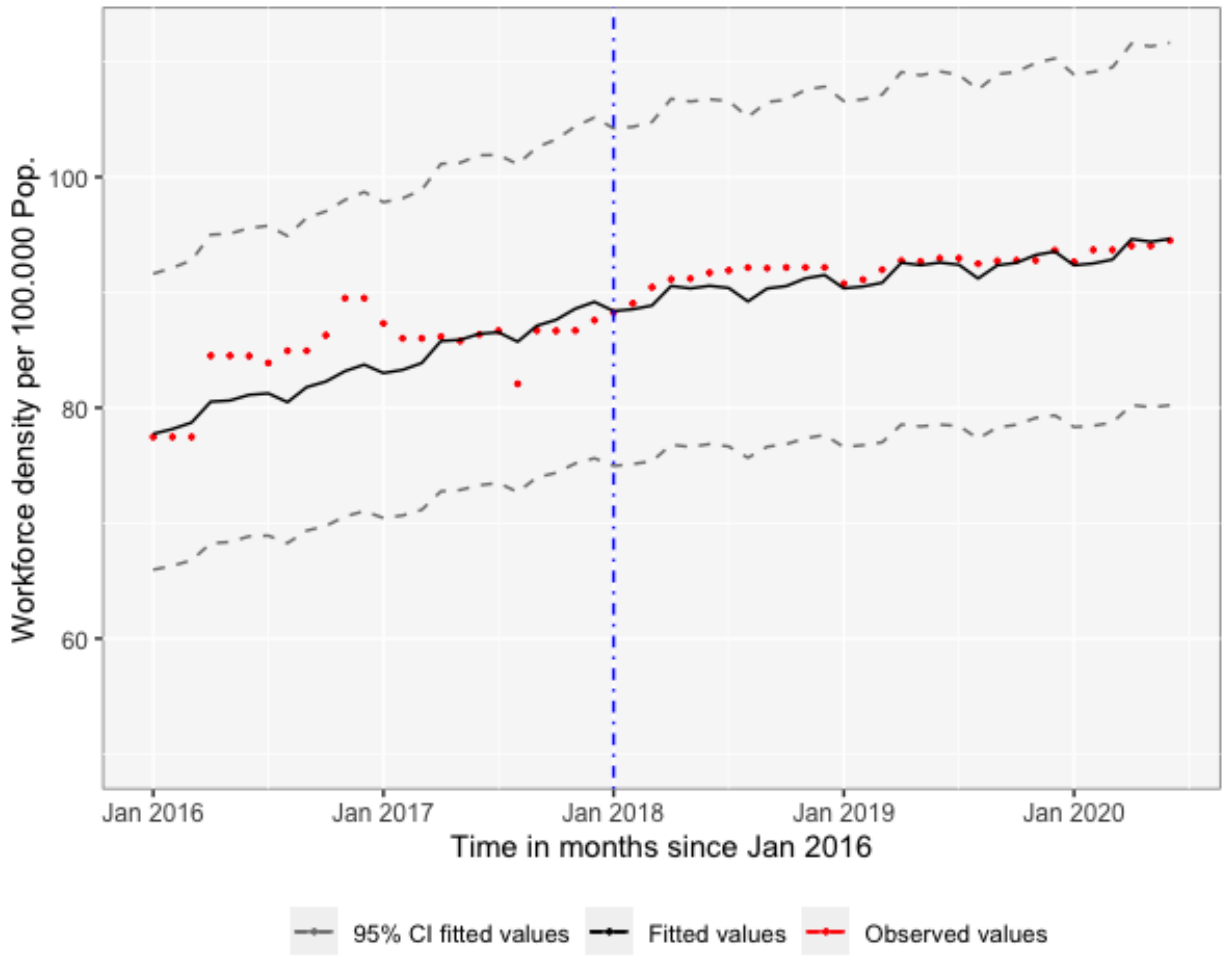
* Maputo City intercept includes the coefficient for general hospitals (corresponds to a district hospital in this setting)

Table 9: Annual Rate of Change (Sex Ratio) and Rate of Change in Mozambique, January 2016 and January 2018

	Adjusted Odds of the Sex Ratio		**Annual rate of change of the Sex ratio (95% CI)**	
	January 2016	January 2018	2016 to 2018	After 2018
Cabo Delgado	1.63 (1.46, 1.81)	1.66 (1.47, 1.88)	1.01 (0.98, 1.04)	0.94 (0.91, 0.97)
Gaza	0.71 (0.58, 0.87)	0.72 (0.59, 0.87)	1.01 (0.96, 1.06)	0.97 (0.94, 1.00)
Inhambane	0.67 (0.58, 0.78)	0.64 (0.53, 0.78)	0.98 (0.94, 1.01	0.99 (0.97, 1.02)
Manica	1.30 (1.12, 1.49)	1.18 (0.99, 1.40)	0.95 (0.92, 0.98)	0.94 (0.91, 0.99)
Maputo City	0.34 (0.32, 0.36)	0.35 (0.32, 0.39)	1.02 (0.97, 1.06)	1.00 (0.98, 1.03)
Maputo Province	0.56 (0.49, 0.65)	0.54 (0.47, 0.61)	0.98 (0.96, 1.00)	0.95 (0.91, 0.99)
Nampula	1.29 (1.16, 1.44)	1.14 (1.03, 1.26)	0.94 (0.92, 0.96)	0.95 (0.91, 0.99)
Niassa	1.73 (1.47, 2.05)	1.67 (1.41, 1.97)	0.98 (0.95, 1.01)	0.98 (0.97, 0.99)
Sofala	1.18 (1.02, 1.37)	1.22 (1.07, 1.39)	1.02 90.98, 1.05)	0.94 (0.93, 0.95)
Tete	1.16 (0.91, 1.47)	1.12 (0.89, 1.41)	0.98 (0.96, 1.01)	0.97 (0.95, 0.98)
Zambézia	1.46 (1.29, 1.66)	1.29 (1.12, 1.50)	0.94 (0.90, 0.99)	0.95 (0.93, 0.96)

- Results adjusted for existing type of referral hospital

Figure 5: Mozambique workforce density trend from January 2016 to June 2020.



- The blue dotted line represents the interruption placed to assess density trends before to after 2018.
- The red dotted points and the black line represent the observed and the estimated from the model workforce density, respectively.
- The dashed dark-gray lines are the 95% confidence intervals for the estimated workforce density.

Figure 6: Province specific workforce density trend January 2016 to June 2020)

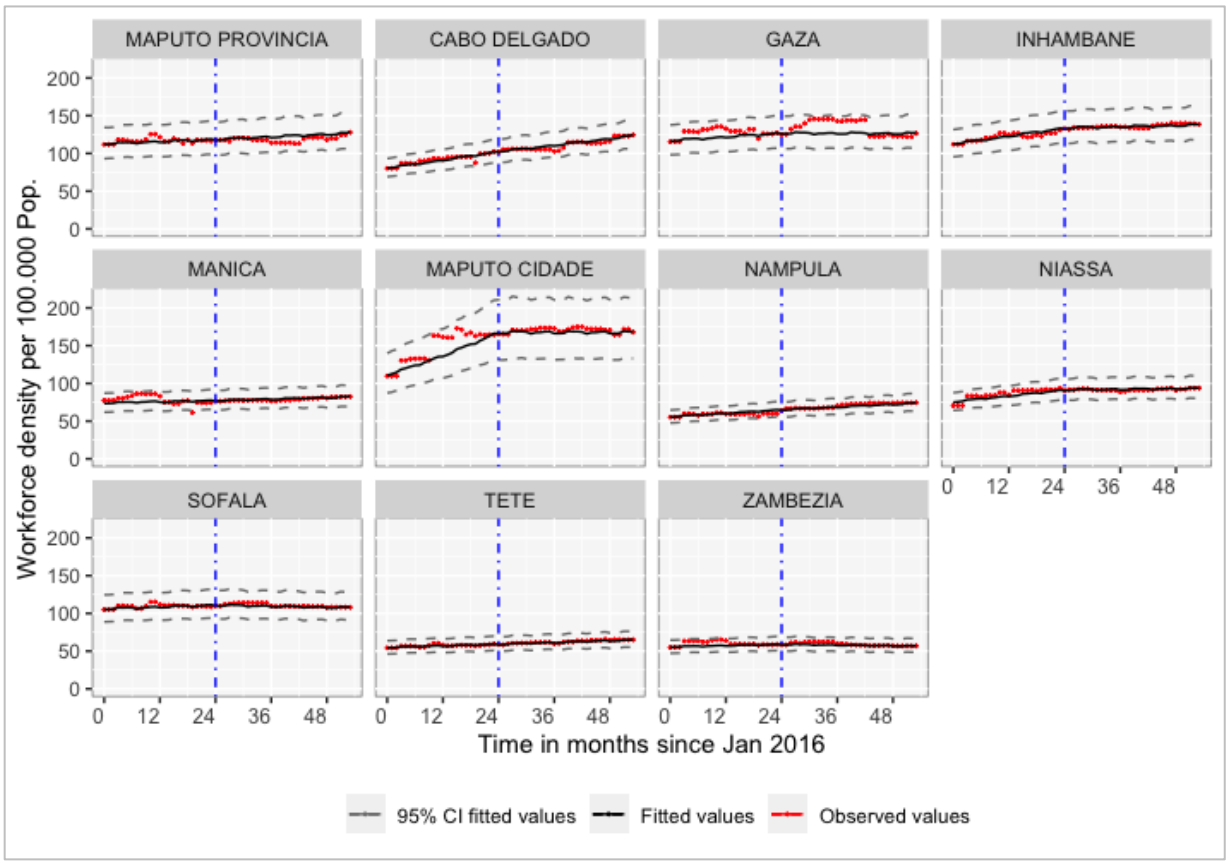
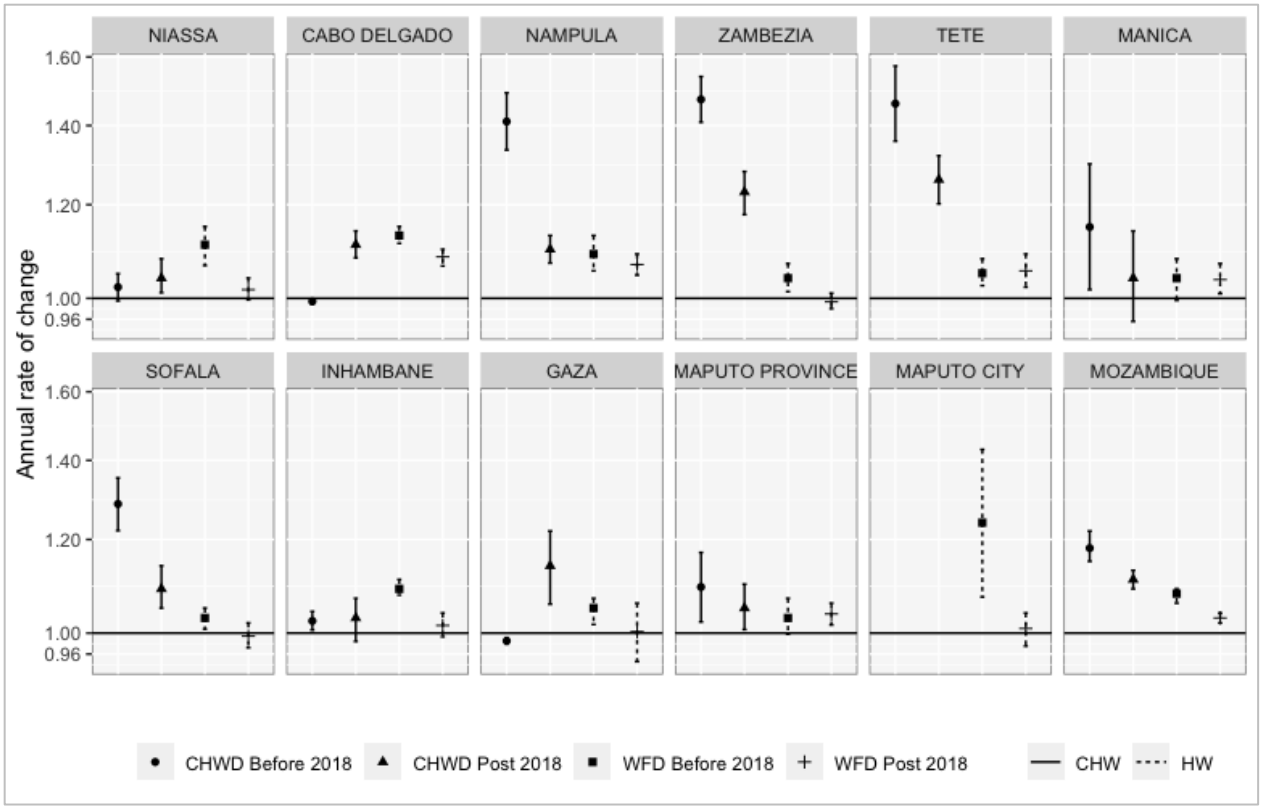


Figure 7: Annual rate of change of the workforce density, before and after 2018, for Community Health Workers (CHWD) and for Health Workers (HWD).



- There are no community health workers in Maputo City.

CHAPTER 4: Applying the Consolidated Framework for Implementation Research to understand health workers' perception of job satisfaction in Mozambique. A facility-level analysis from Manica Province.

Quinhas Fernandes[1,2], Celestino Sinai[3], Braiton Maculuve[1], Naziat Carimo[2], Orvalho Augusto[2,4], Isaías Ramiro[5], Stephen Gloyd[2], Marco Carone[6], Kenneth Sherr[2,7,8] & James Pfeiffer[2,9]

10. National Directorate of Public Health, Ministry of Health, Mozambique.
11. Department of Global Health, University of Washington, Seattle, WA, USA
12. Instituto Nacional de Saúde, Marracuene, Maputo, Mozambique
13. Eduardo Mondlane University, Maputo, Mozambique.
14. Comité para a Saúde de Moçambique, Maputo City, Mozambique
15. Department of Biostatistics, School of Public Health, University of Washington, Seattle, WA, USA
16. Department of Industrial & Systems Engineering, University of Washington, Seattle, USA
17. Department of Epidemiology, University of Washington, Seattle, USA
18. Department of Anthropology, University of Washington, Seattle, WA, United States

Corresponding author: Quinhas Fernandes (ferq09@gmail.com)

ABSTRACT

Introduction: Job motivation and satisfaction are essential drivers of health workers' productivity and quality of work. Only half of doctors and nurses are estimated to be satisfied in Africa. Understanding the determinants of job satisfaction is critical and may lead to policy changes to accelerate progress towards Universal Health Coverage.

Methods: Using 11 constructs and sub-constructs of the consolidated framework for implementation research (CFIR) combined with interpretivism methods, we performed a qualitative study to understand the main barriers and facilitators of job satisfaction from the perspective of health workers in five districts of Manica province (Mozambique). Seventy semi-structured interviews were conducted through seven focus group discussions and 63 individual questionaries. Data analysis followed a case-oriented approach with a two-cycle coding strategy. The final identification of barriers and facilitators was based on code repetition.

Results: Among FGD participants, 37 (62.7%) were female, 32 (54.2%) were married, and the mean age was 32.9 years. Among IDI participants, 36 (57.1%) were female, and the mean age was 34.1 years. Overall, the main barriers were the difficulty in implementing health workers' promotions (***Interventions Characteristics***), poor implementation of the new salary reform and patient care-seeking delays (***Outer Setting***), poor working conditions, lack of mechanisms to ensure effective selection of candidates for short-term training and removal of incentives (***Inner Setting***). The main facilitators included wider implementation of career promotion and progression, public system robustness and stability (**Outer Setting**), engagement of frontline health workers in the decision-making process, and motivator leadership (**Inner Setting**).

Conclusion: CFIR was applicable and helped map the most relevant determinants of job satisfaction. The results suggest that the levels of dissatisfaction within the health system in Mozambique are concerning, and effective and timely implementation of policies and strategies to address motivation and satisfaction are needed.

Keywords:

Job satisfaction, motivation, health sector, Manica, Mozambique

INTRODUCTION

Globally, access to equitable and quality health services remains challenging, particularly in low- and middle-income countries (LMIC).[10,11,13] Achieving Universal Health Coverage (UHC) by 2030 will require governments to make significant investments to strengthen health systems, particularly in addressing challenges at the core of every health system – human resources for health (HRH).[7–9,11,12,110] The availability of trained human resources directly affects the availability and quality of health service delivery and will determine the extent to which countries will meet UHC goals by 2030 and sustain these achievements after 2030.[12,89,91,111,112] Although HRH shortages exist and are well-documented in many countries, other challenges – such as inefficiencies in their distribution and lack of motivation and satisfaction – persist.[90,108,109,113] Health workforce distribution is skewed in LMIC countries, with over-representation in urban areas due to challenges to allocate and retain qualified health workers in rural settings.[91] Health worker motivation and job satisfaction are important determinants of retention and productivity; therefore, understanding determinants of motivation and satisfaction is important for improving service availability and quality, thereby contributing to UHC goals.

Job satisfaction refers to the pleasure, comfort, contentment, or positive emotional feeling resulting from accomplishing one's job expectation based on one's assessment of daily experiences,[114] and reflects the extent to which an individual feels satisfied with their work.[115] Job satisfaction can vary substantially over time depending on several factors, including individual characteristics and expectations, organizational structure and climate, external context, and policies in place to improve motivation and satisfaction.[116,117] Furthermore, the role of leadership in staff accountability and quality performance is widely recognized, where leadership and management practices contribute to an amiable organizational climate that affects frontline staff's motivation

and satisfaction.[36–40] Other factors include levels of trust, wages, individual expectations, promotion policies, and housing policies.[116–120] Many of these factors are context-specific and interrelated, and understanding how these factors interplay and how they differ across individuals and levels of the health system is critical to establishing human-centered and context-adjusted policies.

Studying determinants of health worker satisfaction is important and may lead to policy changes that target improved coverage and quality of health service delivery. However, measuring satisfaction is challenging as available methods do not apply to all contexts, resulting in ambiguity when comparisons between settings are the main goal.[114,121,122] Several studies have quantified the level of health workforce satisfaction; however, comparison across studies is challenged by high variability in satisfaction as an outcome.[114] In Africa, for example, it is estimated that half of doctors and nurses are satisfied, while in Vietnam, satisfaction ranged from 69% to 91% and from 2.4% to 18.9% in Thailand. The Job Satisfaction Survey, a tool developed to measure job satisfaction in public and private organizations, has produced consistent results in several settings, while substantial adjustments have been needed in other settings.[114] Contemporary implementation science frameworks and tools have been used to generate evidence across multiple disciplines and settings and, therefore, provide a great opportunity to study job satisfaction within healthcare settings. The Consolidated Framework for Implementation Research (CFIR) – a commonly used determinants framework – provides a practical guide to designing and assessing public health interventions.[123,124] The five CFIR domains (intervention characteristic, outer setting, inner setting, individual characteristics, and processes) provide an approach to structure data collection and analysis to assess determinants of health worker satisfaction. However, it has been applied in a few studies for this purpose globally.[125,126]

In Mozambique, HRH shortages and distribution inefficiencies are well documented in previous studies.[127] And while dissatisfaction among health workers has been reported in this setting, solid evidence on causes or determinants of documented satisfaction is limited. Several factors have been associated with poor satisfaction among health workers in Mozambique, including the availability of housing, education opportunities, and availability of essential equipment and medicines at the health facility level.[128] Furthermore, motivation and satisfaction are dynamic and may change abruptly due to new scenarios or recurrent external shocks. Exogenous shocks such as the COVID-19 pandemic, infrastructure destruction due to cyclones and floods, and acts of terrorism – all of which occur regularly in Mozambique – impose uncertainty, increase fear, and reduce health workers' satisfaction and motivation, particularly if not addressed timely and appropriately.[129–131] Given that the range of potential determinants of health worker satisfaction in Mozambique is diverse and may vary by health worker cadre, qualitative studies are needed to document and categorize the most relevant determinants of health workforce satisfaction.

Brain drain and high turnover have been reported in Mozambique. To minimize these issues, Mozambique drafted a national strategy to attract and retain health workers (NSARHW) in 2018 that includes specific actions and innovations to improve motivation and satisfaction as a strategy to increase health worker retention. Even though the final document has not been formally approved, since other government reforms were also ongoing, including the salary reform, some innovations of the NSARHW have been put in place. Furthermore, the State General Statute for Public Employees and Agents (SGEPEA) provides the rights for every public sector worker, which should be the bases for implementing initiatives to improve motivation and satisfaction. Thus,

Mozambique represents a great opportunity to explore the determinants of health worker satisfaction and apply implementation science tools to evaluate the effects of existing policies.

This study aimed to answer two questions from the health workers' perspective. First, what individual and institutional factors were perceived as important drivers of health workers' satisfaction? Second, whether leadership and management characteristics were perceived as essential determinants of satisfaction? Furthermore, this study assessed the extent to which health workers were informed of the government strategy to improve retention and satisfaction levels. The conceptual framework used to guide this study combines elements developed by Krueger (2002) and the CFIR (figure 1).[123,132,133] It assumes that determinants of individual satisfaction can be summarized within the CFIR domains, and when health worker satisfaction is achieved, that improved satisfaction will positively impact service availability and quality.

METHODS

Study design

We used a case-oriented design to describe district-specific findings. We combined elements of traditional qualitative research (interpretivism) with contemporary implementation research tools (CFIR) to address the study questions.[134,135] Motivation and satisfaction are subjective since, under the same circumstances, individuals may have different judgments or perceptions based on their past experiences, feelings, emotional status, beliefs, or any other intrinsic or extrinsic factor socially constructed. The interpretivism approach allowed for the generation of new concepts without constraining previous knowledge on this topic. Therefore, it allowed us to shape our own perceptions based on the subjective interpretation of what has been said and experienced in the field during the data collection. CFIR domains and constructs were used to develop the interview

guide, conduct the analysis, and summarize research findings. CFIR was preferred to other frameworks for its flexibility in combining predefined and emerging constructs, a typical characteristic of interpretivism.

Study setting

This study was conducted in Manica province, located in central Mozambique. Manica has 12 districts and five municipalities. The projected population for 2023 is 2,298,753, of which 48% (1,111,192) are male, and 63% (1,454,281) live in rural areas. Overall, there are 120 health facilities, of which 115 (95.8%) area primary health care centers (primary level), 4 (3.3%) are district and rural hospitals (secondary level), and one is the province hospital (tertiary level).[97] The health system is hierarchal structured, which ensures a comprehensive continuum of care.

Data collection

Health facility sampling: Interviews with key informants were performed in five selected sites, including the provincial capital city (Chimoio) and four other districts (Manica, Sussundenga, Gondola, and Macate) (Table 10). Districts were chosen based on the access and safety conditions (the province had insecurity issues when the protocol was designed), number of populations, representativeness of urban and rural characteristics, and our knowledge from working in this setting. Within each district, we interviewed representatives from the district health services (health administration), the main hospital, and a primary health care facility with high utilization (defined as number of outpatients visits and first antenatal care). The purposeful sampling approach was used to optimize the use of study time and increase the chance of including relevant informants working within the health system.

Participants sampling: In-Depth Interview (IDI) and Focus Group Discussion (FGD) participants from each district were selected using homogeneous sampling (to reduce variation, simplify analysis and facilitate group interviewing), and extreme or deviant cases sampling (to detect unusual and atypical cases).[136] This included the selection of the same leadership positions across districts (e.g, district and hospital directors), the same programmatic role (e.g, head of hospital services and district health program supervisors), and similar cadres. Participants were selected from those working at the health facility on the interview date. In the district health services, we conducted IDIs with the district director (or their representative) and one district supervisor. At the health facility level, we interviewed the facility director (or their representative), one service head (suggested by the facility director), and three additional health workers representing distinct health worker cadres who had no management role. FGD participants were selected to include representatives from across health worker cadres and categories (e.g, physicians, nurses, maternal and child health nurses, lab technicians, pharmacists, administrative staff, and attendants, among others); however, none of the FGD included participants with leadership positions (e.g, district and hospital directors, district medical officer, and supervisors).

Data collection process: Two experienced researchers fluent in Portuguese tested and validated the interview guides (semi-structured, open-ended questions) and conducted the IDIs and FGDs. We used IDI and FGD as complementary techniques to best probe hesitant and fearful participants, assuming that they could engage and speak freely among their peers, particularly if sharing the same concerns. No sequence between IDI and FGD was not pre-defined; however, most of the FGD were held by the end of the working day to reduce conflicts with the health facility routine.

Data collection was performed over two consecutive weeks in February 2023. One team member conducted the interviews, while the second documented field notes and audio-recorded the

sessions. Interviews were conducted in Portuguese during working hours (8 am – 4 pm). The interview time, on average, was 38 minutes for the IDI and 84 minutes for FGD. Essential demographic characteristics of respondents were documented, including age, gender, marital status, living area, education level, category, and availability of house and school for the kids. Before each interview, written informed consent was sought from participants, and they were informed that they could skip questions, stop at any time, and request to be excluded from the study without further clarification. Furthermore, participants were informed that the study intent was exclusively to inform health sector policies and contribute to the scientific literature, and no individual identifiers would be shared with health authorities. At the end of each working day, the interviewers met to review the materials and correct or enhance daily notes.

Analysis

Data analysis followed a case-oriented approach[137]. Interview transcription and coding were conducted immediately after data collection was completed. Five people, including the two interviewers, transcribed the 70 interviews; however, only the two interviewers with relevant research expertise conducted the coding using a two-cycle coding strategy. Primary codes (deductive codes) were predefined based on the CFIR constructs (organized into domains), and secondary codes (inductive codes) emerged from the FGD and IDI analysis to cover salient areas outside of the CFIR constructs. The eleven deductive codes were selected based on i) the literature review about the determinants of job satisfaction in the healthcare setting,[114,115,138,139] ii) our experience from working in the study setting, and iii) the results from group discussions to agree on which constructs could better capture and summarize the determinants of job satisfaction (Table 11). Details about the codes (codes and definitions) were stored in a codebook validated by the study principal investigator. To ensure intercoder agreement, each researcher coded the

interviews separately, and at the end, codes were compared and discrepancies resolved based on consensus and the PI guidance.[140] We developed matrixes with the codes and quotations, and based on code repetition, we identified the main barriers and facilitators.[141]

RESULTS

Participants description

Of the 122 key informants, 59 (48.4%) provided their perspectives through FGD, and other 63 (51.6%) responded to an individual interview. Among FGD participants, 37 (62.7%) were female, 32 (54.2%) were married, 40 (67.8) completed high school, 34 (57.6) had been promoted, and only 5.1% lived in housing provided by the health system. The mean age among participants from FGD was 32.9 (SD: 7.4). Among IDI participants, 36 (57.1%) were female, and the mean age was 34.1 (SD6.7). The majority (69.8%) of IDI respondents were married or living with their partners, 61.9% completed high school, and 23.8 % lived in a health system house (Table 12).

A. CFIR-related Barriers

Intervention Characteristics

Overall, few study participants knew or had heard about the draft of NSARHW or other similar strategies. Participants noted their knowledge of the terms "attraction and retention" to infer what the draft strategy would be or was about; indeed, respondents did not know the specific strategies or innovations proposed in the document itself.

> *"It seems like it's a new thing; I may probably have seen it written somewhere, but I never had the information directly, not yet." (Chimoio_Manager)*

Nevertheless, participants indicated a set of factors that contribute to the attraction, retention, motivation, and satisfaction of health workers, including opportunities for career progression,

training (short- and long-term), working conditions, housing availability (particularly for health workers beginning their career), salary maintenance when absences were justified, participation in public health campaigns or other activities that include per diem payment, comfortable working schedules, among others.

> *"Some of the measures include career promotions and progressions, which motivate the health worker to perform well; [regular] working hours, having a normal shift … we know that when someone is permanently overloaded he/she may even age prematurely."(Chimoio_Provider)*

Furthermore, participants, particularly managers, recognized that resource constraints and decisions above the district level limit the possibility of consistently addressing these determinants of satisfaction at the district level. However, health workers with no management role expressed that measures to improve motivation could be implemented easily as long as the HRH managers were organized.

> *"It is not easy to implement promotions. It requires funds. Each year we have less State budget. So, it is difficult to implement these policies due to limited resources." (Chimoio_Manager)*

> *"When we have organized human resource managers, then it is easy to implement promotions. However, if they are not, it can be difficult. When you are organized, it is easier to classify health workers and promote those who deserve." (Sussundenga_FGD)*

Overall, participants agreed that incentives such as opportunities for career progression and promotions (as defined by law) and continuing to study are being widely implemented; however, weaknesses persist, and there is still little participation of health workers in the prioritization plans. For other incentives, such as housing and short-term courses, participants said the process is still restrictive and not transparent enough, and the criteria used to select health workers for housing are not always shared.

> *"... These incentives are not inclusive enough– we lack infrastructure – the employees end up having to rent a house in the community. [Sometimes] the employee still does not have the salary but must start renting an apartment, leading to debts. It's a dilemma." (Manica_Manager)*

Inner Setting

Clear organizational mechanisms that allow the active participation of health workers in decision-making processes, including the definition of training priorities and internal communication strategies, are important to establish a harmonious working environment. Regarding short courses and workshop attendance, participants identified inadequate practices that negatively affect the organization's cordial environment. These practices fall into two main categories: i) Training opportunity differences between health programs (where some health programs have a large number of training activities, which leads to increased training opportunities for health workers working in these priority sectors); and ii) acts of favoritism or nepotism (characterized by the repeated selection of the same employees for training or selection of employees not meeting minimum requirements for the training). These practices lead to organizational inefficiency, staff dissatisfaction, and, ultimately, a negative working environment.

> *"I don't know what selection criteria is being used (...) for example, in a sector of three to four nurses, only one and the same nurse goes for training; that is frustrating." (Manica_Provider)*

Furthermore, working conditions were mentioned as an important barrier to motivation, satisfaction, and quality of work. Unanimously, employees, regardless of their position in the institution's hierarchy, identified poor working conditions and tense relationships between health worker cadres as important determinants of dissatisfaction. Working conditions were found to affect satisfaction in three ways, namely: i) By creating a feeling of frustration and demotivation because health workers cannot fully utilize their capabilities and best serve their users; ii) by creating a feeling of anxiety and concern since they recognize that patient dissatisfaction can lead to the labelling of health facility staff as incompetent or providing services of poor quality; and iii) by creating an environment of tension and resentment between health worker categories.

> *"Actually, what worries me the most is that in the health center, we don't have enough resources to meet the demand. For example, we don't receive enough medicines for one month. In the middle of the month, we may have stockouts. It is challenging because sometimes we receive patients who have certain diseases that, if we had the means, for example, laboratory tests, we could treat them right here, but we don't have it; and sometimes we have to refer them to the provincial capital." (Macate_Manager)*

Institutional incentives are essential to raise employee motivation and satisfaction levels; however, their allocation is perceived to differ between employees with and without management positions. Among health workers not in leadership positions, there is a perception of a lack or reduction of institutional incentives to stimulate satisfaction, from financial incentives to working conditions. Health workers referred to practices, such as the so-called "lunch allowance" and recognition for the length of service, which existed in the past but were stopped without clear justification. Likewise, delays in processing administrative tasks, such as career shifts, promotion, and progression, raise employee concerns. All these aspects are leading to health workers' dissatisfaction.

> *"Years ago, we had a 'lunch allowance'. That was a great incentive, but suddenly it stopped. It really makes us sad. With the lunch subsidy, we could keep some cash and pay for a snack, a soft drink, and a sandwich. We are crying about that lunch subsidy, we miss it." (Chimoio_Provider)*

Outer Setting

Several extra-institutional factors were consistently reported as related to health workers' satisfaction, including government policies, wage differences between and within institutions, and some users' attitudes. Regarding institutional policies, the new salary reform was highlighted, which establishes a single salary table for all employees throughout the entire public sector. The implementation of this reform did not meet the initial expectations of those who were interviewed. In general, participants from all cadres expressed dissatisfaction directly related to two situations, including: i) Salary increases below what was initially expected by health workers; and ii) salary reductions in direct contrast to the spirit of the reform. The testimonies of doctors were the most

worrying, as they mentioned that in addition to not having met their expectations of a salary increase, the reform resulted in a wage reduction, which contrasts with the principle of salary irreducibility that was foreseen in the reform (by law, in public sector, no individual monthly wage should be lower than the period before the new reform; it could be equal or higher). Furthermore, the lack of wage differences between peripheral (rural) areas and urban areas was cited as a reason for dissatisfaction.

> *"…. It has been said that there would be no salary reduction, but what happened is that for all doctors, there was a reduction. This is really sad. When you are faced with a [salary] reduction, there is dissatisfaction …" (Gondola_Manager)*

> *"For example, I'm in a rural area, and my colleague is in the city, and the job is the same. I earn five thousand meticais, and my colleague in the city also earns five thousand meticais. The demotivation comes from there. I even prefer to go back to the city because it doesn't make a difference, the salary is the same. This demotivates me." (Manica_Provider)*

Though not a point of consensus, there was a recognition that non-governmental organizations have their own salary policies and pay higher salaries. Study participants noted that having professionals of the same category perform similar jobs with large salary differentials depending on the organization they work for is a cause of dissatisfaction. This aspect is particularly relevant for employees of organizations who work closely with the public sector. On the other hand, a considerable number of participants mentioned that this is a normal situation that reflects different institutional policies and individual choices.

> *"Yes, it really bothers us. Look, [when] you see a colleague of the same category receiving high wages, and with better conditions in life and in the workplace, this really bothers us." (Macate_Manager)*

The late arrival of patients to health facilities also generates frustration and dissatisfaction among health workers. Although interviewees recognize that long distances and the quality of the roads explain late arrivals, they mentioned that this causes them dissatisfaction and affects the quality of their work (whereby patients who arrive in a serious condition have a greater risk of dying being

referred to a superior health facility). Furthermore, participants noted that they feared that delayed care seeking reflects clients' lack of confidence or dissatisfaction with health services, leading to them seeking services as the last alternative (after seeking alternative care, such as traditional medicine). This phenomenon was noted as a source of dissatisfaction among public sector health workers.

> *"Well, other [patients] go to the healer first, others go to the prophet; there are many things involved. It affects me a lot. Let's say there are some diseases that, if they seek services early, it is possible to diagnose and have successful treatment, but when they arrive late, for example, uterine cancer, there is no way." (Gondola_Provider)*

Characteristics of Individuals

Overall, employees have mixed perceptions about their role in establishing a more participatory work environment that contributes to greater harmony and satisfaction. In general, interviewees recognized their potential to contribute to improving organizational processes but noted their lack of proactivity to do so (an individual barrier), instead waiting for opportunities to be created by managers. This scenario was noted as a source of frustration and a feeling of undervaluation of individuals' potential in determining the course of institutional processes.

> *"Due to the time I have worked, I don't say that I know everything, but with the little that I know, I could [make] positive contributions. If I am invited, I will embrace it with two hands and be very grateful." (Gondola_Manager)*

CFIR-related Facilitators

Inner Setting

Informal communication and the use of mobile technologies, such as "WhatsApp" groups, were identified by participants as effective mechanisms for sharing relevant information in a timely manner, facilitating participation in institutional processes and dynamics. Although these forms of

communication are becoming routine at the health facility level, participants did not refer to clear control mechanisms, and no procedures to harmonize the constitution and functioning of these groups. Even so, participants recognized their usefulness for timely access to information, which contributes to their satisfaction.

> *"We have WhatsApp group platforms at the health center for the technical team. There, we only share confidential information with technicians. We have a second group, a football WhatsApp group; we [also] have a WhatsApp group where we include activists …."(Sussundenga_Manager)*

Managers mentioned several ways to encourage employees to participate, from local initiatives to the implementation of administrative acts outlined in the SGEPEA. It should be noted that managers also recognize continuous training as a determinant of job satisfaction.

> *"There are some activities, for example, supervision, and at the end of the activity after writing the report, the administrative sector pays per diem. This is one of the ways of motivating colleagues. Even that colleague who receives supervision, sometimes he's invited to participate in the final debriefing meeting, and in these meetings, per diems are paid to motivate the colleague." (Manica_Manager)*

Many of the reported issues are somehow related to leadership characteristics. Commitment, engagement, and accountability are essential characteristics of leaders and managers to ensure an adequate working climate and inspire collaboration. Some participants have raised concerns about their leaders across different levels of the system, either directly or pointing to issues they expect from their leaders' timely solutions. However, other several have recognized their leaders as good enough to motivate and guide them to achieve their goals.

> *"My boss…I think she is a gift from God (...) she is a mother and father at the same time. She gives time herself to follow and check those doing the right and wrong things, then she calls you and gives advice as she was advising her sister or daughter." (Gondolal_Provider)*

Outer Setting

Government policies, which provide greater career stability and predictability for public sector employees, have an impact on employee satisfaction and, consequently, their maintenance in the public system. Several employees mentioned that they continue to work in the public sector, despite the low wages, because of the stability it provides in their careers and the care provided in situations of illness.

> *"Being a public sector employee, I am already aware that those in NGOs earn more; the public sector pays what is stipulated by law. Of course, the temptation exists; and [sometimes] I think, why don't leave? But at the same time, I stop, think, and balance the advantages and disadvantages of being in the NGO and the public sector. Despite the money, I think about the future. Suddenly I could get sick, the government is there to support me, but NGOs are not." (Gondola_Manager)*

1. Characteristics of Individuals

Some participants felt motivated by having the opportunity to contribute to the discussion of the institution's problems and the ability to propose valid and feasible solutions, which their leaders accommodate. This dynamic contributes to their greater engagement and contribution to the health facility's management processes and individual satisfaction.

> *"For example, when we were assigned to work in the community, sometimes we had to go to places far away; we used to get back and do the night shift at the hospital. So, we suggested to the director that if a person was assigned to work in the community, he shouldn't be assigned to hospital shifts." (Gondola_Provider)*

Additionally, several health workers demonstrated strong values and virtues by clearly stating their commitment to stay in the public sector regardless of salary. Indeed, many of them explained that being a nurse or a health technician was a dream, and they would never risk replacing their profession with others or changing the public with the private sector.

> *"I would never change nursing profession even if I had the opportunity to change. Suppose they say to go to work in the bank to be (.....) ahh!! I would never change my profession, I do it with love, so there is no way I would change it." ((Sussundenga_Provider).*

Table 13 summarizes the domains and constructs used and respective barriers and facilitators of health workers' satisfaction.

DISCUSSION

This qualitative study identified leading determinants (barriers and facilitators) of health workers' satisfaction at the district level in Mozambique. The primary barriers and facilitators that surfaced through IDIs and FGDs were common across sampled districts and health workers, with and without leadership roles, and across different cadres. The barriers that were consistently identified across the study included: i) poor working conditions; ii) non-observance of clear criteria to select participants to attend short courses and workshops; iii) unmet expectations with the new salary reform; iv) lack of housing; and v) delayed patient care-seeking. Other studies performed in different settings have reported similar findings.[115,118–120,132,142] This study also identified important facilitators of satisfaction, including the use of technologies to fill in the information gap, existence of motivator leaderships, and recognition of the robustness and stability of the public system. Even though levels of satisfaction were not assessed quantitatively (which was outside of the scope of this study), it can be inferred by the type, number, and consistency of identified barriers and facilitators that satisfaction among public sector health workers is low, and modifiable barriers should be addressed to enhance the work experience of human resources for health in Mozambique. Clear signals are the recurrent strikes of doctors, one in 2013 and the other in December 2022.

One important document, the State General Statute for Public Employees and Agents (SGEPEA), defines the rights and duties of every public sector worker. The draft NSARHW brings new interventions and innovations for improving attraction, retention, motivation, and satisfaction for

health workers in Mozambique. The finding that some innovations of the NSARHW are still unknown should be an incentive to develop a dissemination strategy to ensure wider dissemination of the strategy when it translates to national policy. Indeed, a considerable number of evidence-based interventions fail to be implemented because they lack a dissemination strategy or, when it exists, it is not implemented consistently due to a lack of knowledge among critical stakeholders responsible for their implementation.[143,144] Closing this Know-Do-Gap is critical to translating policies into effective implementation; however, it requires addressing determinants of their implementation, including giving it appropriate value and allocating adequate resources to develop and implement effective dissemination strategies.[145,145,146]

This study presents relevant findings to inform decision-making across all levels of the health system in Mozambique. Even though results are context-specific, study findings can inform other countries with similar health system characteristics. The following five points summarize key study findings.

First: It is evident that poor working conditions are among the most relevant determinants of job satisfaction, as has been described in other studies. Poor working conditions limit individual performance, reduce efficiency and quality of services, and, importantly, expose front-line workers to a negative popular judgment as they are the "face of the health system" to clients.[116,120,132] The fact that health workers, with and without management positions, consistently reported this barrier highlights its relevance as a driver of work satisfaction among district-level health workers. The main issues that embody poor working conditions include frequent stockouts of medicines and other consumables and the lack of transport to support an efficient referral system. These findings represent a warning for decision-makers at higher levels of the health system who have the primary responsibility for managing the centralized procurement and logistics systems.

Second: This study's results demonstrate that attending short courses and workshops is a great incentive, and it improves health workers' satisfaction. However, it is unclear if continuing education is a motivator due to learning new technical material that enhances workers' capabilities, or if it is due to the payment of *per diems* or other extrinsic motivators associated with trainings. Distinguishing which of these two is most relevant for enhancing motivation can lead to corrective actions that are more likely to address dissatisfaction. Here we provide the authors' interpretation. First, in this analysis, salary did not directly emerge as a critical driver of satisfaction. Implementation of the new salary reform policy was a commonly cited barrier since it went contrary to the expectations of a significant salary increase for most health workers and led to salary reductions in some categories. Second, several participants recognized the government's inability to pay higher salaries; however, they also recognized the stability and robustness of the public system compared to the private sector (including NGOs). Combining these two findings, due to constraints on the health system to increase salaries, health workers have begun to institutionalize *per diem* payments as a practical alternative to compensate for low salaries. This impression is reinforced because activities that result in payment of *per diems*, such as participation in outreach campaigns and supervision visits, were mentioned as facilitators for satisfaction. Addressing this driver of dissatisfaction and an unpleasant work environment will require establishing and implementing effective institutional criteria and practices to regulate attendance at short courses and workshops. Because this issue is likely not specific to the study setting, nor to the health sector, perhaps, it may require high-level reforms, multisectoral approaches, and strengthening of code of conduct implementation since implementing partners (local and international organizations) also have a role with *per diems* payments.

Third: A considerable number of employees voiced concern regarding the implementation of the new salary reform. The implementation process was challenging and faced several constraints, including salary reductions for specific health worker cadres. However, recognizing this differential effect, the government established a multisectoral commission to study and resolve cases of inequity. Considering that at the time of data collection, this process was ongoing, as, by law, salary reductions are not allowed, it can be assumed that cases of salary reduction would be solved. Therefore, this barrier indeed reflects weaknesses in effective institutional communication mechanisms. This study highlighted the increasing role of informal communications, which is noteworthy as this form of communication is increasingly influential (and formal, one-to-one meetings are becoming less relevant), which will likely lead to an increase in miscommunication and misunderstandings. Therefore, it is critical to invest in building communication skills among those with leadership and management positions across the health system to ensure effective institutional communication.

Fourth: Despite weaknesses identified in the public system, participants still considered it the most stable, robust, and reliable system to work in. This finding is relevant as it provides an opportunity to implement reforms with the active involvement of health workers who trust in the system that they are a part of. Even so, it will be necessary to strengthen mechanisms for employees to participate in governance processes, including the removal of barriers to engagement (both between leadership and health workers, as well as between different health worker cadres). Several participants mentioned being unable to find the space and opportunity to contribute to shared governance and make their voices heard, even though they recognized its potential. Improving organizational climate and creating a learning system is essential to engaging health workers, which will only be addressed through strong health system leadership.[120]

Fifth: The barriers identified in this study are modifiable; however, they require strategic and coordinated action at different levels of the system (including skilled and committed local leadership) to effectively implement reforms, some of those outlined in the draft NSARHW. They also require the capacity to mobilize additional resources to close identified gaps in the national health system, including budgeting to ensure greater availability of medicines and supplies (in addition to strengthening the remaining pillars of the health system).

Limitations: There are a few notable methodological limitations to this study. First, data collection was carried out in the work environment, which may have influenced the responses of some of the professionals. Measures were taken to prevent this potential bias, such as conducting interviews in safe and interference-free locations and guaranteeing confidentiality for participants, which we believe minimized this potential limitation. Second, some interviewees (particularly those responsible for specific health service sectors), were identified by district and facility directors, which may have contributed to reducing variability in responses. We believe that the large number of interviews and consistency in findings demonstrate that this concern is not likely to have affected our results. Third, data collection took place after the introduction of a major salary reform that resulted in a physician's strike. Although the situation had abated by the time data collection started, the reform process may have shaped some responses. Fourth, this study was conducted in one province, Manica, reducing the generalizability since other styles of leadership in other provinces might have substantially different impacts on health workers' satisfaction. Despite these limitations, our findings were consistent across health system levels and cadres, supporting the validity of our results.

To the best of our knowledge, this is the first study on determinants of health worker satisfaction that used the CFIR to design, collect, analyze, and report in a LMIC setting. CFIR proved useful,

flexible, and applicable to identify determinants of job satisfaction, and provides a suitable tool that can be used to guide assessments across health system building blocks and inform policies to improve service delivery.

CONCLUSION

This study identified essential determinants of job satisfaction in the public sector health system in Manica Province, Mozambique. Even though the study did not quantify levels of satisfaction, the identified determinants of satisfaction highlight the importance of this issue for the health system. Previous strikes in the health sector, including the most recent physician's strike related to implementing the new salary reform (at the end of 2022), suggest that the level of dissatisfaction within the health system in Mozambique is a "*ticking time bomb*" which can explode at any time. Effective and timely implementation of policies and strategies to address motivation and satisfaction could address many determinants of satisfaction among public sector health workers; however, some health system bottlenecks will require broader action including expanding the number of health workers, allocating funding to support health system logistics, and ensuring consistent availability of essential medicines and supplies. Further research, including studies to quantify the level of satisfaction across the health sector, to understand the impact of different types of incentives, and to assess the effect of austerity measures and international donors support should be considered to complement this study on determinants of health worker satisfaction.

Table 10: Study participants

Districts	Interview sites	Number of FGD participants	Number of IDI participants
Manica	District health services	-	2
	Manica district hospital	9	4
	4º Congresso health center	8	5
Macate	District health services	-	2
	Macate health center	7	7
	Marera health center	-	5
Sussundenga	District health services	-	2
	Sussundenga health center	7	6
	Dombe health center	-	6
Gondola	District health services	-	2
	Gondola district hospital	9	4
	Josina Machel health center	-	5
Chimoio	District health services	-	3
	1º de Maio health center	9	5
	7 de Abril health center	10	5
Total		**59**	**63**

Table 11: Initial domains and constructs (Deductive codes)

Domains	Constructs & Sub-constructs
Interventions Characteristics	Relative advantage
	Complexity
Outer Setting	Patient needs and resources
	Peer pressure
	External policies and incentives
Inner Setting	Structural characteristics
	Networks and communications
	Implementation climate (Organization Incentives and rewards)
	Implementation climate (Leadership engagement)
	Culture
Characteristics of Individuals	Self-efficacy

Table 12: Participants demographic characteristics

Characteristics (N=122)	**FGD**	**IDI**	**Total**
Gender (N, %)			
Female	37 (62.7)	36 (57.1)	73 (59.8)
Male	22 (37.3)	27 (42.9)	49 (40.2)
Mean Age (Standard deviation)	32.9 (7.4)	34.1 (6.7)	33.53 (7.1)
Age Categories (N, %)			
< 30	26 ((44.1)	21 (33.3)	47 (38.5)
31 – 40	24 (40.6)	29 (46.1)	53 (43.4)
40 +	9 (15.3)	13 (20.6)	22 (18.1)
Marital status (N, %)			
Married or living with partner	32 (54.2)	44 (69.8)	76 (62.3)
Single	26 (44.1)	18 (28.6)	44 (36.1)
Widow	1 (1.7)	1 (1.6)	2 (1.6)
Level of education (N, %)			
Degree (university)	6 (10.2)	17 (27.0)	23 (18.9)
Middle (high school)	40 (67.8)	39 (61.9)	79 (64.7)
Basic (secondary school)	13 (22.0)	7 (11.1)	20 (16.4)
Leadership Position (N, %)			
Yes	4 (6.8)	24 (38.1)	28 (23.0)
No	55 (93.2)	39 (61.9)	94 (77.0)
Ever been Promoted (N, %)			
Yes	34 (57.6)	32 (50.8)	66 (54.1)
No	15 (25.4)	15 (23.8))	30 (24.6)
Not Applicable	10 (17.0)	16 (25.4)	26 (21.3)
Service housing (N, %)			
Yes	3 (5.1)	15 (23.8)	18 (14.8)
No	56 (94.9)	48 (76.2)	104 (85.2)
School for kids (N, %)			
No	0 (0.0)	1 (1.6)	1 (0.8)
Yes	44 (74.6)	42 (66.7)	86 (70.5)
Not Applicable	15 (25.4)	20 (31.7)	35 (28.7)

Table 13: Summary of the domains and constructs used and respective barriers and facilitators of health workers' satisfaction.

Domains	Constructs & Sub-constructs	Barriers	Illustrative Quotes
Interventions Characteristics	Complexity	- Perceived difficulty to effectively implement interventions to improve motivation and satisfaction (promotions and progressions)	*"It is not easy to implement promotions. It requires funds. Each year we have less State budget. So, it is difficult to implement these policies due to limited resources." (Chimoio_Manager)* *"Promotion measures are easy to implement, it is about following the plan. You know that each employee was promoted in the year X. So, it's about planning the next promotion on a calendar. If you postpone promotions, then [yes], it will be difficult." (Sussundenga_Provider)* *"When we have organized human resource managers, then it is easy to implement promotions. However, if they are not, it can be difficult. When you are organized, it is easier to classify health workers and promote those who deserve." (Sussundenga_FGD)* *"... These incentives are not inclusive enough– we lack infrastructure – the employees end up having to rent a house in the community. [Sometimes] the employee still does not have the salary but must start renting an apartment, leading to debts. It's a dilemma." (Manica_Manager)*
Outer Setting	Patient needs and resources	- Patients care-seeking delays	*"Well, other [patients] go to the healer first, others go to the prophet; there are many things involved. It affects me a lot. Let's say there are some diseases that, if they seek services early, it is possible to diagnose and have successful treatment, but when they arrive late, for example, uterine cancer, there is no way." (Gondola_Provider)* *"I currently work with patients who are on antiretroviral treatment; so, one of the things that frustrates me is that patients are missing appointments or abandon treatment." (Gondola_Provider)*

	Peer pressure	- Payment of better wages by NGO's compared to Public Sector.	*"In my [point of] view, it does not interfere because I know that in terms of local and international NGO's, some have remuneration policies that are different from the public sector." (Gondola_Manager)* *"Yes, it really bothers us. Look, [when] you see a colleague of the same category receiving high wages, and with better conditions in life and in the workplace, this really bothers us." (Macate_Manager)*
	External policies and incentives	- Poor implementation of the new salary reform	*"…. It has been said that there would be no salary reduction, but what happened is that for all doctors, there was a reduction. This is really sad. When you are faced with a [salary] reduction, there is dissatisfaction …" (Gondola_Manager)* *"For example, I'm in a rural area, and my colleague is in the city, and the job is the same. I earn five thousand meticais, and my colleague in the city also earns five thousand meticais. The demotivation comes from there. I even prefer to go back to the city because it doesn't make a difference, the salary is the same. This demotivates me." (Manica_Provider)*
Inner Setting	Structural characteristics	- Poor working conditions. - Lack of mechanisms to ensure effective selection of candidates to short term training.	*"Let's pretend we're in a sector and we're all colleagues, and she's the one who does the activity, but the person who goes to the training on the same subject is someone else (...) it ends up demotivating the people who do the job." (Manica_Provider)* *"I don't know what selection criteria is being used (...) for example in a sector of three to four nurses, only one and the same nurse goes for training; that is frustrating." (Manica_Provider)* *"I'll give you an example. Listen, for that introduction of new registries, who went to that training is the colleague who was already on the study continuation list; however, who stayed to implement it was the one who didn't go there [for training], who didn't know how to start and how to do the job (...) the person who was trained has gone; [he/she]was trained and then left to study." (Manica_Provider)*

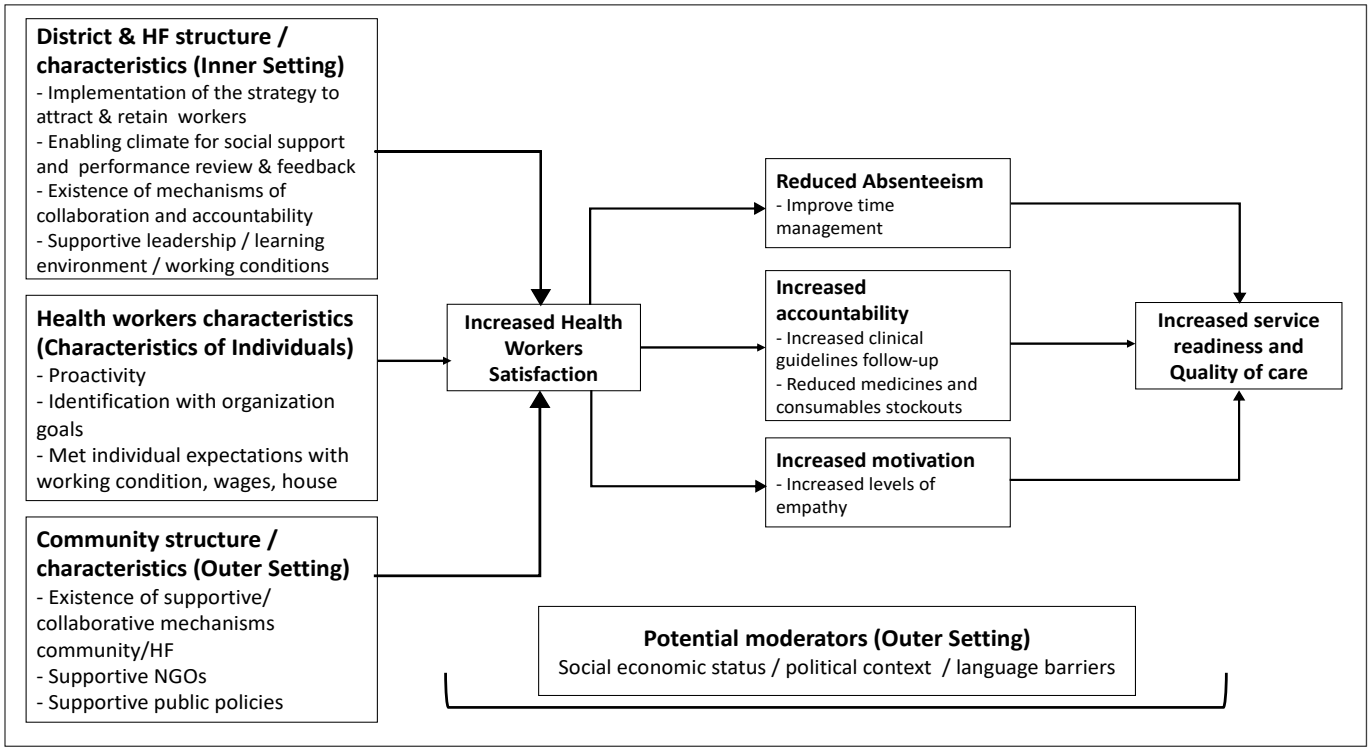
			"I am sure if this was a paid [per diem] session, none of us would have been invited. We are here because it is not a paid session, it is just a conversation (…) Look, I started my career in 2016 and attended training only in 2017. Since then, I never participated in a training session."(Sussundenga_Provider) *"Actually, what worries me the most is that in the health center, we don't have enough resources to meet the demand. For example, we don't receive enough medicines for one month. In the middle of the month, we may have stockouts. It is challenging because sometimes we receive patients who have certain diseases that, if we had the means, for example, laboratory tests, we could treat them right here, but we don't have it; and sometimes we have to refer them to the provincial capital." (Macate_Manager)*
	Implementation climate (Organization Incentives and rewards)	- Removal of incentives including of the "lunch allowance." - Delays to operationalize career progressions	*"In the past, we use to have [incentives], but not now. I remember that in 2008 I had a diploma awarded by Dr. IG since I had more than 25 years of service. I was decorated, and I was given a diploma and a silver medal. It motivated me." (Manica_FGD)* *"Yah… there is something that demotivates me (...) I completed my degree in 2020, and since then, I still haven't changed my career; but it is not just my situation, there are many of us. We have been told that there would be a green light. [However], since 2020 until today, I still haven't changed my career. This is concerning." (Gondola_Manager)* *"Years ago, we had a 'lunch allowance'. That was a great incentive, but suddenly it stopped. It really makes us sad. With the lunch subsidy we could keep some cash, pay for a snack, a soft drink, and a sandwich. We are crying about that lunch subsidy, we miss it." (Chimoio_Provider)*
	Culture	- Tension between health workers categories	*"To be an attendant is not an easy job; you are ignored. When you arrive in your blue coat, colleagues don't respect you as if you were a colleague, you*

			look like anyone else (…). That's what I see; it's not easy to be an attendant; there's total disrespect." (Gondola_FGD)
Characteristics of Individuals	Self-efficacy	- Insufficient proactivity	*"Due to the time I have worked, I don't say that I know everything, but with the little that I know, I could [make] positive contributions. If I am invited, I will embrace it with two hands and be very grateful." (Gondolal_Manager)*
Domains	**Constructs & Sub-constructs**	**Facilitators**	**Illustrative Quotes**
Interventions Characteristics	Complexity	- Wider implementation of career promotion and progression, including study continuation	*"In our district, in collaboration with our leadership, when it comes to studying, there are no problems. All we must do is to request and choose a course that meets the Ministry of Health guidelines." (Manica_Manager)*
Outer Setting	Peer pressure	- Recognition of public system's robustness and stability	*"I am firm where I am. There are colleagues who left for projects and stayed for two years, and then the project closed. They lost their job. Sometimes they ask to come back. For me, I'm fine where I am." (Manica_Manager)* *"Being a public sector employee, I am already aware that those in NGOs earn more; the public sector pays what is stipulated by law. Of course, the temptation exists; and [sometimes] I think, why don't leave? But at the same time, I stop, think, and balance the advantages and disadvantages of being in the NGO and the public sector. Despite the money, I think about the future. Suddenly I could get sick, the government is there to support me, but NGOs are not." (Gondola_Manager)*
Inner Setting	Networks and communications	- Establishment of informal mechanisms to update health workers (institutional communication)	*"We have WhatsApp group platforms at the health center for the technical team. There, we only share confidential information with technicians. We have a second group, a football WhatsApp group; we [also] have a WhatsApp group where we include activists …."(Sussundenga_Manager)* *"Here at the health center, communication is oral, but there are also administrative acts that need to be written down, such as a request for dismissal, vacations, justification for absences." (Macate_Manager)*

	Implementation climate (Organization Incentives and rewards)	- Payment of *per diems*	*"There are some activities, for example, supervision, and at the end of the activity after writing the report, the administrative sector pays per diem. This is one of the ways of motivating colleagues. Even that colleague who receives supervision, sometimes he's invited to participate in the final debriefing meeting, and in these meetings, per diems are paid to motivate the colleague." (Manica_Manager)*
	Implementation climate (Leadership engagement)	- Motivator leadership - Engagement of frontline health workers in the decision-making process	*"My boss…I think she is a gift from God (...) she is a mother and father at the same time. She gives time herself to follow and check those doing the right and wrong things, then she calls you and gives advice as she was advising her sister or daughter." (Gondola_CS_Josina Machel_Provider)* *"Demotivation No! Motivation Yes! They don't work with us as bosses. They never say they are bosses. They don't say don't talk to us. When you do something wrong, they talk to you in a good manner, they are not bosses, they are leaders." (MANICA_Provider)*
Characteristics of Individuals	Self-efficacy	- Existence of active contributors	*"Yes, they called me. They asked what was missing in the sector, how the sector was doing, and what should have been done to improve the job; each person explained or suggested what should have been done in terms of additional materials and human resources." (Gondola_Provider).* *"For example, when we were assigned to work in the community, sometimes we had to go to places far away; we used to get back and do the night shift at the hospital. So, we suggested to the director that if a person was assigned to work in the community, he shouldn't be assigned to hospital shifts." (Gondola_Provider)*
	Individual identification with organization	- Self-identification with the institution	*"Look, I have 18 years of experience. During this period, I had several opportunities [to leave]; however, I decided to stay in the public health system because I feel good here, I feel appreciated. I am staying here. (Manica_Manager)*

	Other Personal attributes	- Individual virtues	*"I would never change nursing profession even if I had the opportunity to change. Suppose they say to go to work in the bank to be (.....) ahh!! I would never change my profession, I do it with love, so there is no way I would change it." ((Sussundenga_Provider).*

Figure 8: Conceptual model for providers satisfaction



CHAPTER 5: Overall Conclusions

UHC is both a global priority and is achievable; however, it demands committed and research-oriented leaders to make the right decisions in a timely fashion. This dissertation focuses on Mozambique's health systems challenges, and together, the results provide important guidance on health system bottlenecks that hamper progress towards UHC. The following conclusions are the most relevant and, if not accounted for, will undoubtedly negatively influence achievement of SDG 3.2:

1) Unless Mozambique implements audacious measures to address the negative impacts of the recurrent external shocks (cyclones and floods) on the health system, these threats will impose setbacks on the country's gains and impede progress towards UHC.

2) Although Mozambique has made improvements in expanding the overall workforce density, the shortage of health workers is still high, and requires extraordinary measures to accelerate the hiring of new health workers (including community health workers), and deploying and retaining health workers in the most underserved areas. If the current workforce density trends persist, achieving UHC will be compromised.

3) Inequitable distribution of health workforce is an important and persistent issue in Mozambique, and efforts to address inequities will require improved leadership and management, particularly at the subnational level. If robust measures to improve distribution are immediately implemented, important gains on workforce availability and equity could be achieved, enhancing efforts to achieve UHC.

4) Although qualitative study exploring health worker satisfaction was conducted in one province, the results suggest that important organizational structures, including leaders' characteristics and practices, shape frontline health workers' satisfaction, which then influences their performance. If sound measures to improve satisfaction and motivation are not taken (such as implementation of effective hiring and retention strategies), negative impacts can be anticipated on service readiness and quality, impeding achievement of UHC.

5) The first two studies demonstrated the importance of routine data to understand health system performance and bottlenecks. Currently, routine data is under-utilized in favor of survey data, which have limitations in terms of representativeness, timeliness and cost. Routine data systems (and robust methods used to analyze these data) merit attention as they can inform decision-making and guide efforts to achieve UHC.

This dissertation provides a replicable approach to maximize routine data systems, combined with survey data, to address important health system challenges. It can be a model for other settings facing similar health system challenges and the imperative of reaching UHC. Furthermore, this dissertation leads to other research questions that should be addressed in future studies, including extending the granularity of the analysis to assess health worker distribution within hospital setting, studying patterns of health worker movement and turnover between health facilities, and understanding the extent to which staff availability correlates to services utilization. These topics, together with a deeper understanding of the other health system building blocks, provide critical evidence to support Mozambique's plans to achieve UHC by 2030.

References

[1] Kruk ME, Myers M, Varpilah ST, Dahn BT. What is a resilient health system? Lessons from Ebola. Lancet 2015;385:1910–2.

[2] Wagenaar BH, Augusto O, Beste J, Toomay SJ, Wickett E, Dunbar N, et al. The 2014–2015 Ebola virus disease outbreak and primary healthcare delivery in Liberia: Time-series analyses for 2010–2016. PLoS Med 2018;15:e1002508.

[3] Lassi ZS, Naseem R, Salam RA, Siddiqui F, Das JK. The Impact of the COVID-19 Pandemic on Immunization Campaigns and Programs: A Systematic Review. Int J Environ Res Public Health 2021;18:988.

[4] Hogan AB, Jewell BL, Sherrard-Smith E, Vesga JF, Watson OJ, Whittaker C, et al. Potential impact of the COVID-19 pandemic on HIV, tuberculosis, and malaria in low-income and middle-income countries: a modelling study. Lancet Glob Heal 2020;8:e1132-e1141. Correction appears in Lancet Glob Hea. https://doi.org/https://doi.org/10.1016/S2214-109X(20)30288-6.

[5] Jewell BL, Mudimu E, Stover J, Ten Brink D, Phillips AN, Smith JA, et al. Potential effects of disruption to HIV programmes in sub-Saharan Africa caused by COVID-19: results from multiple mathematical models. Lancet HIV 2020;7(9):e629–40.

[6] Dorward J, Khubone T, Gate K, Ngobese H, Sookrajh Y, Mkhize S, et al. The impact of the COVID-19 lockdown on HIV care in 65 South African primary care clinics: an interrupted time series analysis. Lancet HIV 2021;8(3):e158–65.

[7] McDonnell A, Urrutia A, Samman E. Reaching universal health coverage: a political economy review of trends across 49 countries 2019.

[8] Boerma T, Eozenou P, Evans D, Evans T, Kieny M-P, Wagstaff A. Monitoring progress towards universal health coverage at country and global levels. PLoS Med 2014;11:e1001731.

[9] Reich MR, Harris J, Ikegami N, Maeda A, Cashin C, Araujo EC, et al. Moving towards universal health coverage: lessons from 11 country studies. Lancet 2016;387:811–6.

[10] Dieleman JL, Sadat N, Chang AY, Fullman N, Abbafati C, Acharya P, et al. Trends in future health financing and coverage: future health spending and universal health coverage in 188 countries, 2016–40. Lancet 2018;391:1783–98.

[11] Tangcharoensathien V, Mills A, Palu T. Accelerating health equity: the key role of universal health coverage in the Sustainable Development Goals. BMC Med 2015;13:101.

[12] Campbell J, Buchan J, Cometto G, David B, Dussault G, Fogstad H, et al. Human resources for health and universal health coverage: fostering equity and effective coverage. Bull World Health Organ 2013;91:853–63.

[13] Organization WH. Primary health care on the road to universal health coverage: 2019 global monitoring report 2021.

[14] Koon AD, Rao KD, Tran NT, Ghaffar A. Embedding health policy and systems research into decision-making processes in low-and middle-income countries. Heal Res Policy Syst 2013;11:30.

[15] Remme JHF, Adam T, Becerra-Posada F, D'Arcangues C, Devlin M, Gardner C, et al. Defining research to improve health systems. PLoS Med 2010;7.

[16] Sherr K, Cuembelo F, Michel C, Gimbel S, Micek M, Kariaganis M, et al. Strengthening integrated primary health care in Sofala, Mozambique. BMC Health Serv Res 2013;13:S4.

[17] Organization WH. Pillars of strength: how embedded research supports resilient health systems in Mozambique: story of change 2020.

[18] Bitton A, Ratcliffe HL, Veillard JH, Kress DH, Barkley S, Kimball M, et al. Primary health care as a foundation for strengthening health systems in low-and middle-income countries. J Gen Intern Med 2017;32:566–71.

[19] Muldoon LK, Hogg WE, Levitt M. Primary care (PC) and primary health care (PHC). Can J Public Heal 2006;97:409–11.

[20] De Maeseneer J, Willems S, De Sutter A, Van de Geuchte I, Billings M. Primary health care as a strategy for achieving equitable care: a literature review commissioned by the Health Systems Knowledge Network 2007.

[21] You D, Hug L, Ejdemyr S, Beise J, Idele P, Gerland P, et al. Levels and trends in child mortality. Report 2015. Estimates developed by the UN Inter-agency Group for Child Mortality Estimation 2015.

[22] Alkema L, Chou D, Hogan D, Zhang S, Moller A-B, Gemmill A, et al. Global, regional, and national levels and trends in maternal mortality between 1990 and 2015, with scenario-based projections to 2030: a systematic analysis by the UN Maternal Mortality Estimation Inter-Agency Group. Lancet 2016;387:462–74.

[23] You D, Hug L, Ejdemyr S, Idele P, Hogan D, Mathers C, et al. Global, regional, and national levels and trends in under-5 mortality between 1990 and 2015, with scenario-based projections to 2030: a systematic analysis by the UN Inter-agency Group for Child Mortality Estimation. Lancet 2015;386:2275–86.

[24] Liu L, Johnson HL, Cousens S, Perin J, Scott S, Lawn JE, et al. Global, regional, and

national causes of child mortality: An updated systematic analysis for 2010 with time trends since 2000. Lancet 2012;379:2151–61. https://doi.org/10.1016/S0140-6736(12)60560-1.

[25] Bongaarts J. WHO, UNICEF, UNFPA, World Bank Group, and United Nations Population Division Trends in Maternal Mortality: 1990 to 2015 Geneva: World Health Organization, 2015. Popul Dev Rev 2016;42:726.

[26] Hug L, Alexander M, You D, Alkema L, for Child UNIG. National, regional, and global levels and trends in neonatal mortality between 1990 and 2017, with scenario-based projections to 2030: a systematic analysis. Lancet Glob Heal 2019;7:e710–20.

[27] UN-IGME. Levels and Trends in Child Mortality: Report 2018, Estimates developed by the UN Inter-agency Group for Child Mortality Estimation. 2018.

[28] Organization WH. Trends in maternal mortality 2000 to 2017: estimates by WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division 2019.

[29] Ministerio da Saude. MOÇAMBIQUE Estudo nacional sobre a mortalidade infantil 2009:1–18.

[30] Devi S. Cyclone Idai: 1 month later, devastation persists. Lancet 2019;393:1585.

[31] Lequechane JD, Mahumane A, Chale F, Nhabomba C, Salomão C, Lameira C, et al. Mozambique's response to cyclone Idai: how collaboration and surveillance with water, sanitation and hygiene (WASH) interventions were used to control a cholera epidemic. Infect Dis Poverty 2020;9:1–4.

[32] World Health Organization (WHO). World health statistics 2019: monitoring health for the SDGs, sustainable development goals. 2019.

[33] Haggerty J, Burge F, Lévesque J-F, Gass D, Pineault R, Beaulieu M-D, et al. Operational definitions of attributes of primary health care: consensus among Canadian experts. Ann Fam Med 2007;5:336–44.

[34] Veillard J, Cowling K, Bitton A, Ratcliffe H, Kimball M, Barkley S, et al. Better Measurement for Performance Improvement in Low-and Middle-Income Countries: The Primary Health Care Performance Initiative (PHCPI) Experience of Conceptual Framework Development and Indicator Selection. Milbank Q 2017;95:836–83.

[35] Ministério da Saúde (MISAU). Plano Nacional de Desenvolvimento de Recursos Humanos para Saúde 2016-2025. Maputo: 2016.

[36] Mathole T, Lembani M, Jackson D, Zarowsky C, Bijlmakers L, Sanders D. Leadership and the functioning of maternal health services in two rural district hospitals in South Africa. Health Policy Plan 2018;33:ii5–15.

[37] Gilson L, Agyepong IA. Strengthening health system leadership for better governance: what does it take? 2018.

[38] Gilson L, Elloker S, Olckers P, Lehmann U. Advancing the application of systems thinking in health: South African examples of a leadership of sensemaking for primary health care. Heal Res Policy Syst 2014;12:30.

[39] Gilson L, Daire J. Leadership and governance within the South African health system. South African Heal Rev 2011;2011:69–80.

[40] Mutale W, Vardoy-Mutale A-T, Kachemba A, Mukendi R, Clarke K, Mulenga D. Leadership and management training as a catalyst to health system strengthening in low-income settings: Evidence from implementation of the Zambia Management and Leadership course for district health managers in Zambia. PLoS One 2017;12:e0174536.

[41] Anand S, Bärnighausen T. Human resources and health outcomes: cross-country econometric study. Lancet 2004;364:1603–9.

[42] Hongoro C, McPake B. How to bridge the gap in human resources for health. Lancet 2004;364:1451–6.

[43] Parkhurst JO, Penn-Kekana L, Blaauw D, Balabanova D, Danishevski K, Rahman SA, et al. Health systems factors influencing maternal health services: a four-country comparison. Health Policy (New York) 2005;73:127–38.

[44] CDRED. Human Cost of Disasters: An overview of the last 20 years 2000-2019 2020. https://www.emdat.be/index.php.

[45] Alderman K, Turner LR, Tong S. Floods and human health: a systematic review. Environ Int 2012;47:37–47.

[46] Callaghan WM, Rasmussen SA, Jamieson DJ, Ventura SJ, Farr SL, Sutton PD, et al. Health concerns of women and infants in times of natural disasters: lessons learned from Hurricane Katrina. Matern Child Health J 2007;11:307–11.

[47] Watts N, Adger WN, Agnolucci P, Blackstock J, Byass P, Cai W, et al. Health and climate change: policy responses to protect public health. Lancet 2015;386:1861–914.

[48] Brunson J. Maternal, newborn, and child health after the 2015 Nepal earthquakes: an investigation of the long-term gendered impacts of disasters. Matern Child Health J 2017;21:2267–73.

[49] Tees MT, Harville EW, Xiong X, Buekens P, Pridjian G, Elkind-Hirsch K. Hurricane Katrina-related maternal stress, maternal mental health, and early infant temperament. Matern Child Health J 2010;14:511–8.

[50] Man RX-G, Lack DA, Wyatt CE, Murray V. The effect of natural disasters on cancer care: a systematic review. Lancet Oncol 2018;19:e482–99.

[51] Watson JT, Gayer M, Connolly MA. Epidemics after natural disasters. Emerg Infect Dis 2007;13:1.

[52] Fundter DQP, Jonkman B, Beerman S, Goemans CLPM, Briggs R, Coumans F, et al. Health impacts of large-scale floods: governmental decision-making and resilience of the citizens. Prehosp Disaster Med 2008;23:s70–3.

[53] Assanangkornchai S, Tangboonngam S, Edwards JG. The flooding of Hat Yai: predictors of adverse emotional responses to a natural disaster. Stress Heal J Int Soc Investig Stress 2004;20:81–9.

[54] Stephens KU, Grew D, Chin K, Kadetz P, Greenough PG, Burkle FM, et al. Excess mortality in the aftermath of Hurricane Katrina: a preliminary report. Disaster Med Public Health Prep 2007;1:15–20.

[55] Parker G, Lie D, Siskind DJ, Martin-Khan M, Raphael B, Crompton D, et al. Mental health implications for older adults after natural disasters–a systematic review and meta-analysis. Int Psychogeriatrics 2016;28:11–20.

[56] Tong VT, Zotti ME, Hsia J. Impact of the Red River catastrophic flood on women giving birth in North Dakota, 1994–2000. Matern Child Health J 2011;15:281–8.

[57] Glynn LM, Wadhwa PD, Dunkel-Schetter C, Chicz-DeMet A, Sandman CA. When stress happens matters: effects of earthquake timing on stress responsivity in pregnancy. Am J Obstet Gynecol 2001;184:637–42.

[58] Datar A, Liu J, Linnemayr S, Stecher C. The impact of natural disasters on child health and investments in rural India. Soc Sci Med 2013;76:83–91.

[59] Baten A, Wallemacq P, van Loenhout JAF, Guha-Sapir D. Impact of recurrent floods on the utilization of maternal and newborn healthcare in Bangladesh. Matern Child Health J 2020.

[60] Klinger C, Owen Landeg VM. Power outages, extreme events and health: a systematic review of the literature from 2011-2012. PLoS Curr 2014;6.

[61] Fridell M, Edwin S, Von Schreeb J, Saulnier DD. Health system resilience: what are we talking about? A scoping review mapping characteristics and keywords. Int J Heal Policy Manag 2020;9:6.

[62] Grimm PY, Merten S, Wyss K. Evidence of health system resilience in Myanmar during Cyclone Nargis: a qualitative analysis. BMJ Open 2021;11:e050700.

[63] Koeva S, Rohova M. Health system resilience: Concept development. J IMAB-Annual Proceeding (Scientific Pap 2020;26:3251–8.

[64] Ministerio da Saude - MISAU/Moçambique, Instituto Nacional de Estatística - INE/Moçambique, ICF International. Moçambique Inquérito Demográfico e de Saúde 2011. Calverton, Maryland, USA: MISA/Moçambique, INE/Moçambique and ICF International; 2013.

[65] Instituto Nacional de Estatística (INE). Relatório final do Inquérito ao Orçamento Familiar – IOF2014/15. Maputo: 2015.

[66] Xiao H, Augusto O, Wagenaar BH. Reflection on modern methods: a common error in the segmented regression parameterization of interrupted time-series analyses. Int J Epidemiol 2021;50:1011–5.

[67] Bernal JL, Soumerai S, Gasparrini A. A methodological framework for model selection in interrupted time series studies. J Clin Epidemiol 2018;103:82–91.

[68] Bernal JL, Cummins S, Gasparrini A. Interrupted time series regression for the evaluation of public health interventions: a tutorial. Int J Epidemiol 2017;46:348–55.

[69] Araujo S, Dade A, Zacarias MF, Chipembe CS, Maunze XH, Singano CC. Multiple indicators cluster survey 2008. 2009.

[70] Mozambique National Institute for Disaster Management (INGC). Mozambique — Baseline Assessment - Cyclone Idai - Round 6. Maputo: 2019.

[71] Demidenko E. Mixed models: theory and applications with R. John Wiley & Sons; 2013.

[72] Congdon PD. Bayesian hierarchical models: with applications using R. Chapman and Hall/CRC; 2019.

[73] R Core Team. R: A Language and Environment for Statistical Computing 2018.

[74] Bürkner PC. brms: An R package for Bayesian multilevel models using Stan. J Stat Softw 2017;80. https://doi.org/10.18637/jss.v080.i01.

[75] Instituto Nacional de Estatística (INE). IV Recenseamento Geral da População e Habitação de 2017. Maputo: 2017.

[76] Lederman SA, Rauh V, Weiss L, Stein JL, Hoepner LA, Becker M, et al. The effects of the World Trade Center event on birth outcomes among term deliveries at three lower Manhattan hospitals. Environ Health Perspect 2004;112:1772–8.

[77] Goodman A. In the aftermath of disasters: the impact on women's health. Crit Care Obstet Gynecol 2016;2:29.

[78] UNICEF-Mozambique. Mozambique: Children living in storm affected areas face worsening food insecurity and nutrition crisis six months after Cyclone Idai 2019. https://www.unicef.org/mozambique/en/press-releases/mozambique-children-living-storm-affected-areas-face-worsening-food-insecurity-and (accessed July 14, 2020).

[79] Rodriguez-Llanes JM, Ranjan-Dash S, Degomme O, Mukhopadhyay A, Guha-Sapir D. Child malnutrition and recurrent flooding in rural eastern India: a community-based survey. BMJ Open 2011;1:e000109.

[80] Béné C, Wood RG, Newsham A, Davies M. Resilience: new utopia or new tyranny? Reflection about the potentials and limits of the concept of resilience in relation to vulnerability reduction programmes. IDS Work Pap 2012;2012:1–61.

[81] Barasa EW, Cloete K, Gilson L. From bouncing back, to nurturing emergence: reframing the concept of resilience in health systems strengthening. Health Policy Plan 2017;32:iii91–4.

[82] Folke C, Carpenter SR, Walker B, Scheffer M, Chapin T, Rockström J. Resilience thinking: integrating resilience, adaptability and transformability. Ecol Soc 2010;15.

[83] Biddle L, Wahedi K, Bozorgmehr K. Health system resilience: a literature review of empirical research. Health Policy Plan 2020.

[84] Willcox ML, Peersman W, Daou P, Diakité C, Bajunirwe F, Mubangizi V, et al. Human resources for primary health care in sub-Saharan Africa: progress or stagnation? Hum Resour Health 2015;13:76.

[85] Dayrit MM, Dolea C, Dreesch N. Addressing the human resources for health HRH crisis in countries: how far have we gone? What can we expect to achieve by 2015? Rev Peru Med Exp Salud Publica 2011;28:327–36.

[86] Pozo-Martin F, Nove A, Lopes SC, Campbell J, Buchan J, Dussault G, et al. Health workforce metrics pre-and post-2015: a stimulus to public policy and planning. Hum Resour Health 2017;15:14.

[87] World Health Organization (WHO). World health statistics 2018: monitoring health for the SDGs, sustainable development goals, World Health Organization. Geneva: 2018.

[88] Scheffler RM, Liu JX, Kinfu Y, Dal Poz MR. Forecasting the global shortage of physicians: an economic-and needs-based approach. Bull World Health Organ 2008;86:516-523B.

[89] Gupta N, Maliqi B, França A, Nyonator F, Pate MA, Sanders D, et al. Human resources for maternal, newborn and child health: from measurement and planning to performance for improved health outcomes. Hum Resour Health 2011;9:16.

[90] Kanchanachitra C, Lindelow M, Johnston T, Hanvoravongchai P, Lorenzo FM, Huong NL, et al. Human resources for health in southeast Asia: shortages, distributional challenges, and international trade in health services. Lancet 2011;377:769–81.

[91] World Health Organization (WHO). Global strategy on human resources for health: workforce 2030. 2016.

[92] Hung YW, Hoxha K, Irwin BR, Law MR, Grépin KA. Using Routine Health Information Data for Research in Low-and Middle-Income Countries: A Systematic Review 2020.

[93] Wagenaar BH, Sherr K, Fernandes Q, Wagenaar AC. Using routine health information systems for well-designed health evaluations in low-and middle-income countries. Health Policy Plan 2016;31:129–35.

[94] Morrato EH, Elias M, Gericke CA. Using population-based routine data for evidence-based health policy decisions: lessons from three examples of setting and evaluating national health policy in Australia, the UK and the USA. J Public Health (Bangkok) 2007;29:463–71.

[95] Van Panhuis WG, Paul P, Emerson C, Grefenstette J, Wilder R, Herbst AJ, et al. A systematic review of barriers to data sharing in public health. BMC Public Health 2014;14:1–9.

[96] World Health Organization (WHO). Classifying health workers: Mapping occupations to the international standard classification. 2019.

[97] Instituto Nacional de Saúde (INS). Service Availability and Readiness Assessment Report (SARA) 2020. https://www.misau.gov.mz/index.php/inqueritos-de-saude (accessed September 10, 2021).

[98] World Health Organization (WHO). Global reference list of 100 core health indicators. 2015.

[99] Hilbe JM, Hardin JW (James W. Generalized estimating equations. 2nd ed. Boca Raton: Boca Raton : CRC Press; 2013.

[100] Gardiner JC, Luo Z, Roman LA. Fixed effects, random effects and GEE: what are the differences? Stat Med 2009;28:221–39.

[101] Hubbard AE, Ahern J, Fleischer NL, Van der Laan M, Satariano SA, Jewell N, et al. To GEE or not to GEE: comparing population average and mixed models for estimating the associations between neighborhood risk factors and health. Epidemiology 2010:467–74.

[102] Boniol M, McIsaac M, Xu L, Wuliji T, Diallo K, Campbell J. Gender equity in the health workforce: analysis of 104 countries. World Health Organization; 2019.

[103] Sherr K, Mussa A, Chilundo B, Gimbel S, Pfeiffer J, Hagopian A, et al. Brain drain and health workforce distortions in Mozambique. PLoS One 2012;7. https://doi.org/10.1371/journal.pone.0035840.

[104] Anand S, Fan VY, Zhang J, Zhang L, Ke Y, Dong Z, et al. China's human resources for health: quantity, quality, and distribution. Lancet 2008;372:1774–81.

[105] Chen L, Evans T, Anand S, Boufford JI, Brown H, Chowdhury M, et al. Human resources for health: overcoming the crisis. Lancet 2004;364:1984–90.

[106] Dussault G, Dubois C-A. Human resources for health policies: a critical component in health policies. Hum Resour Health 2003;1:1–16.

[107] Salami B, Dada FO, Adelakun FE. Human resources for health challenges in Nigeria and nurse migration. Policy, Polit Nurs Pract 2016;17:76–84.

[108] Manzi F, Schellenberg JA, Hutton G, Wyss K, Mbuya C, Shirima K, et al. Human resources for health care delivery in Tanzania: a multifaceted problem. Hum Resour Health 2012;10:1–10.

[109] Ferrinho P, Siziya S, Goma F, Dussault G. The human resource for health situation in Zambia: deficit and maldistribution. Hum Resour Health 2011;9:1–11.

[110] Rahman MS, Rahman MM, Gilmour S, Swe KT, Abe SK, Shibuya K. Trends in, and projections of, indicators of universal health coverage in Bangladesh, 1995–2030: a Bayesian analysis of population-based household data. Lancet Glob Heal 2018;6:e84–94.

[111] Kruk ME, Prescott MR, de Pinho H, Galea S. Are doctors and nurses associated with coverage of essential health services in developing countries? A cross-sectional study. Hum Resour Health 2009;7:27.

[112] Nguyen MP, Mirzoev T, Le TM. Contribution of health workforce to health outcomes: empirical evidence from Vietnam. Hum Resour Health 2016;14:68.

[113] Castillo-Laborde C. Human resources for health and burden of disease: an econometric approach. Hum Resour Health 2011;9:4.

[114] Batura N, Skordis-Worrall J, Thapa R, Basnyat R, Morrison J. Is the Job Satisfaction Survey a good tool to measure job satisfaction amongst health workers in Nepal? Results of a validation analysis. BMC Health Serv Res 2016;16:308.

[115] Nguyen H Van, Duong HT, Vu TT. Factors associated with job satisfaction among district hospital health workers in Northern Vietnam: a cross-sectional study. Int J Health Plann Manage 2017;32:163–79.

[116] Asegid A, Belachew T, Yimam E. Factors influencing job satisfaction and anticipated

turnover among nurses in Sidama zone public health facilities, South Ethiopia. Nurs Res Pract 2014;2014.

[117] Alrawashdeh HM, Al-Tammemi AB, Alzawahreh MK, Al-Tamimi A, Elkholy M, Al Sarireh F, et al. Occupational burnout and job satisfaction among physicians in times of COVID-19 crisis: a convergent parallel mixed-method study. BMC Public Health 2021;21:1–18.

[118] Fogarty L, Kim YM, Juon H-S, Tappis H, Noh JW, Zainullah P, et al. Job satisfaction and retention of health-care providers in Afghanistan and Malawi. Hum Resour Health 2014;12:11.

[119] Jang Y, Lee AA, Zadrozny M, Bae S-H, Kim MT, Marti NC. Determinants of job satisfaction and turnover intent in home health workers: The role of job demands and resources. J Appl Gerontol 2017;36:56–70.

[120] Kumar R, Ahmed J, Shaikh BT, Hafeez R, Hafeez A. Job satisfaction among public health professionals working in public sector: a cross sectional study from Pakistan. Hum Resour Health 2013;11:1–5.

[121] Spector PE. Measurement of human service staff satisfaction: Development of the job satisfaction survey. Am J Community Psychol 1985;13:693.

[122] Stamps PL, Piedmont EB, Slavitt DB, Haase AM. Measurement of work satisfaction among health professionals. Med Care 1978;16:337–52.

[123] Birken SA, Powell BJ, Presseau J, Kirk MA, Lorencatto F, Gould NJ, et al. Combined use of the Consolidated Framework for Implementation Research (CFIR) and the Theoretical Domains Framework (TDF): a systematic review. Implement Sci 2017;12:2.

[124] Means AR, Kemp CG, Gwayi-Chore M-C, Gimbel S, Soi C, Sherr K, et al. Evaluating and optimizing the consolidated framework for implementation research (CFIR) for use in low-and middle-income countries: a systematic review. Implement Sci 2020;15:1–19.

[125] Ho M, Livingston P, Bould MD, Nyandwi JD, Nizeyimana F, Uwineza JB, et al. Barriers and facilitators to implementing a regional anesthesia service in a low-income country: a qualitative study. Pan Afr Med J 2019;32.

[126] Eakin MN, Ugbah L, Arnautovic T, Parker AM, Needham DM. Implementing and sustaining an early rehabilitation program in a medical intensive care unit: a qualitative analysis. J Crit Care 2015;30:698–704.

[127] Fernandes Q, Augusto O, Machai H, Pfeiffer J, Carone M, Pinto N, et al. Scrutinizing human resources for health availability and distribution in Mozambique between 2016 and 2020: a subnational descriptive longitudinal study. Hum Resour Health 2023;21:1–13.

[128] Honda A, Vio F. Incentives for non-physician health professionals to work in the rural and remote areas of Mozambique—a discrete choice experiment for eliciting job preferences. Hum Resour Health 2015;13:23.

[129] Fernandes Q, Augusto O, Chicumbe S, Anselmi L, Wagenaar BH, Marlene R, et al. Maternal and child health care service disruptions and recovery in Mozambique after Cyclone Idai: an uncontrolled interrupted time series analysis. Glob Heal Sci Pract 2022;10.

[130] Augusto O, Roberton T, Fernandes Q, Chicumbe S, Manhiça I, Tembe S, et al. Early effects of COVID-19 on maternal and child health service disruption in Mozambique. Front Public Heal 2023;11.

[131] Manhiça I, Augusto O, Sherr K, Cowan J, Cuco RM, Agostinho S, et al. COVID-19-related healthcare impacts: an uncontrolled, segmented time-series analysis of tuberculosis diagnosis services in Mozambique, 2017–2020. BMJ Glob Heal 2022;7:e007878.

[132] Krueger P, Brazil K, Lohfeld L, Edward HG, Lewis D, Tjam E. Organization specific predictors of job satisfaction: findings from a Canadian multi-site quality of work life cross-sectional survey. BMC Health Serv Res 2002;2:1–8.

[133] Dormann C, Zapf D. Job satisfaction: A meta-analysis of stabilities. J Organ Behav Int J Ind Occup Organ Psychol Behav 2001;22:483–504.

[134] Damschroder LJ, Aron DC, Keith RE, Kirsh SR, Alexander JA, Lowery JC. Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. Implement Sci 2009;4:50.

[135] Alharahsheh HH, Pius A. A review of key paradigms: Positivism VS interpretivism. Glob Acad J Humanit Soc Sci 2020;2:39–43.

[136] Palinkas LA, Horwitz SM, Green CA, Wisdom JP, Duan N, Hoagwood K. Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. Adm Policy Ment Heal Ment Heal Serv Res 2015;42:533–44.

[137] Strauss A, Corbin J. Basics of qualitative research techniques. Sage publications Thousand Oaks, CA; 1998.

[138] Rockers PC, Jaskiewicz W, Wurts L, Kruk ME, Mgomella GS, Ntalazi F, et al. Preferences for working in rural clinics among trainee health professionals in Uganda: a discrete choice experiment. BMC Health Serv Res 2012;12:1–13.

[139] Mussa AH, Pfeiffer J, Gloyd SS, Sherr K. Vertical funding, non-governmental organizations, and health system strengthening: perspectives of public sector health workers in Mozambique. Hum Resour Health 2013;11:1–9.

[140] MacQueen KM, McLellan E, Kay K, Milstein B. Codebook development for team-based qualitative analysis. Cam J 1998;10:31–6.

[141] Hsieh H-F, Shannon SE. Three approaches to qualitative content analysis. Qual Health Res 2005;15:1277–88.

[142] Chiok Foong Loke J. Leadership behaviours: effects on job satisfaction, productivity and organizational commitment. J Nurs Manag 2001;9:191–204.

[143] Atujuna M, Tucker J, Crooks N, Zanoni B, Donenberg GR. Disseminating Evidence-Based Interventions for Adolescent HIV Treatment and Prevention in Sub-Saharan Africa. AIDS Behav 2022:1–9.

[144] Brown CH, Curran G, Palinkas LA, Aarons GA, Wells KB, Jones L, et al. An overview of research and evaluation designs for dissemination and implementation. Annu Rev Public Health 2017;38:1–22.

[145] Ghaffar A, Swaminathan S, Sheikh K, Al-Mandhari A, Jhalani M, Sambo B, et al. Implementation research is crucial to countries' efforts to strengthen learning health systems. Health Policy Plan 2020;35:ii4–6.

[146] Tran N, Langlois E V, Reveiz L, Varallyay I, Elias V, Mancuso A, et al. Embedding research to improve program implementation in Latin America and the Caribbean. Rev Panam Salud Pública 2017;41:e75.