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ReKAP of the COVID-19 Pandemic: Knowledge, Attitudes, and Practices among Healthcare Workers with Varying Ebola History in the Democratic Republic of the Congo, August 2020 to August 2021

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ReKAP of the COVID-19 Pandemic: Knowledge, Attitudes, and Practices among Healthcare Workers with Varying Ebola History in the Democratic Republic of the Congo, August 2020 to August 2021

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Epidemiology

by

Angelica Lynne Barrall

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ABSTRACT OF THE DISSERTATION

ReKAP of the COVID-19 Pandemic: Knowledge, Attitudes, and Practices among Healthcare Workers with Varying Ebola History in the Democratic Republic of the Congo, August 2020 to August 2021

by

Angelica Lynne Barrall

Doctor of Philosophy in Epidemiology

University of California, Los Angeles, 2023

Professor Anne W. Rimoin, Chair

Mounting an effective response to an emergent pathogen, such as SARS-CoV-2, can be particularly challenging for public health systems that are overburdened and under resourced, like that in the Democratic Republic of the Congo (DRC). Conversely, the DRC has an extensive history combatting infectious diseases, and perhaps, one of the most practiced health workforces, globally, in the prevention and control of emergent diseases, such as Ebola virus disease (EVD). However, the extent of knowledge, attitudes, and practice (KAP) among HCWs in DRC during the COVID-19 pandemic is not well understood. This dissertation utilizes repeated measures of KAP collected via 25 phone interviews among four cohorts of Congolese HCWs (N=545) from communities with varied EVD history throughout a year of the pandemic (August 2020 to August 2021) to enhance awareness of fluctuations in KAP over time and between cohorts in this population. Chapter 1 summarizes the epidemiology and prevention and control strategies for

COVID-19 and EVD, both generally and in the context of DRC. Chapter 2 assesses potential and perceived COVID-19 risk reported by the sample; the probability of providing care to a patient with COVID-19 symptoms increased modestly in each cohort throughout the study, while perceptions of risk remained comparatively stable over time but differed by cohort. Chapter 3 assesses perceptions of efficacy of six COVID-19 prevention behaviors and compliance with those same behaviors; most of the sample consistently reported the efficacy of each behavior throughout the study, but fluctuations in compliance with mask wearing, avoiding gathering, and socially distancing were observed over time as well as differences between cohorts. Chapter 4 assesses workplace safety measures specifically during periods of concurrent EVD outbreaks in Mbandaka and Beni. Perceptions of workplace safety remained relatively stable during the study regardless of EVD outbreaks, but cohort differences were observed. Fluctuations in access to cloth and surgical face masks over time and consistently low access to N95 face masks were also found. This dissertation establishes a reference for KAP among a sample of HCWs in DRC during a major infectious disease event and indicates that longitudinal and subnational analyses are warranted to adequately identify potential barriers to future outbreak response.

The dissertation of Angelica Lynne Barrall is approved.

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2023

DEDICATION

To the Congolese healthcare workers who entrusted us with their thoughts and experiences and to my colleagues in DRC who made countless phone calls to record those thoughts and experiences for an entire pandemic year, thank you. Without you all, this research would not have been possible.

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CHAPTER 1. Introduction

1.1 Coronavirus disease

The emergence of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in late 2019 led to the most consequential public health emergency of the last century. The World Health Organization (WHO) declared the novel coronavirus disease (COVID-19) outbreak in Wuhan, China a global emergency on January 30, 2020[1] and declared COVID-19 a global pandemic on March 11, 2020.[2] As of February 13, 2023, there have been 755.1 million cumulative, confirmed cases of COVID-19, including 6.8 million deaths worldwide.[3] During this pandemic, the world experienced dramatic loss of life, economic and social disruption, and unprecedented challenges to medical and public health systems. Mitigating the spread of COVID-19 proved to be difficult on a global scale; but this collective experience provided crucial opportunities for lessons learned particularly for public health authorities faced with organizing response efforts for the next novel infectious disease threat. Outbreak response poses a distinct challenge to regions with already overburdened healthcare systems and under-resourced public health infrastructures such as those in low-and middle-income countries (LMICs).[4]

Epidemiology

COVID-19 is caused by SARS-CoV-2, an RNA virus of the Coronaviridae family.[5] Coronaviruses are known to primarily reside in animal reservoirs (e.g., bats, mice, rats, dogs, cat, camels) and cause respiratory infection in mammals. Spatial, environmental, and genomic studies[6,7] support the theory that SARS-CoV-2 crossed the animal–human species barrier in a zoonotic event associated with live wildlife trade at the Huanan market in Wuhan, China in November 2019. SARS-CoV-2 was a previously unknown pathogen to the human population prior to this event.

Human-to-human transmission of SARS-CoV-2 predominately occurs via exposure to infectious respiratory fluids. According to the U.S. Centers for Disease Control and Prevention (CDC),[8] exposure to SARS-CoV-2 can occur through 1) the inhalation of fine respiratory droplets or aerosol particles containing virus, 2) deposition of virus from fine droplets or aerosols onto exposed mucous membranes (e.g., mouth, nose, eye), and 3) touching mucous membranes with hands contaminated by respiratory fluids containing virus or by touching surfaces containing virus. Following exhalation, concentration of infectious droplets and particles in the air decreases and the viability of the virus wanes over time. Therefore, the risk of SARS-CoV-2 infection is greatest when one is in immediate proximity to the source of exhaled infectious droplets or particles. Further, research has shown that while not impossible, transmission of SARS-CoV-2 through contaminated surfaces is comparatively low compared to direct contact or airborne transmission.[9]

Certain population groups are at higher risk of severe COVID-19 progression and associated mortality. The most consistently cited risk factor for COVID-19 disease severity and mortality is higher age.[10-12] Men have also been shown to be at higher risk of severe disease and death from COVID-19 compared to women.[11-13] Further, comorbidities or underlying medical conditions such as hypertension, diabetes, cardiovascular disease, chronic lung disease, tuberculosis, and obesity place a person at higher risk of severe illness from COVID-19.[12,14,15] Lifestyle risk factors related to more severe COVID-19 include physical inactivity and current or former smoking.[10-12,15] Immunocompromised people are also more at risk for serious disease and related outcomes. Of note, the majority of studies examining associations between lifestyle, demographic, and medical factors with COVID-19 outcomes have been conducted in upper-middle and high income countries.[10]

Healthcare workers (HCWs), particularly those on the frontline of the pandemic response, have a greater risk of infection with SARS-CoV-2 than the general population. Clinical responsibilities and patient care put HCWs at risk for high viral load exposure and prolonged exposure time.[11,16] HCWs were particularly vulnerable early in the pandemic when necessary personal protective equipment (PPE) was scarce.[17] Given the transmission route of SARS-CoV-2 via respiratory fluids, some clinical activities that produce respiratory droplets and aerosols, such as clinical lung function tests, intubation, and use of nebulizers, further increase exposure risk among HCWs.[11,18]

Global Distribution

The COVID-19 outbreak began in the Hubei province of China in late 2019; by March 1, 2020, there were 88,402 cumulative confirmed cases of COVID-19 globally.[19] Five months later (August 1, 2020), 17.8 million COVID-19 cases had been confirmed in the world; of these, 43.0% were in high income countries (HICs), 37.0% in upper-middle income countries, 19.3% in lower-middle income countries, and 0.7% of confirmed cases were in low income countries. As of February 13, 2021, high income countries accounted for 63.8% of cumulative cases of COVID-19 while lower-middle and low-income countries account for 14.8% (as of February 13, 2023). Further, 41.7% of cumulative COVID-19 deaths occurred in HICs compared to 20.3% in lower-middle and low-income countries. By contrast, HICs accounted for just 15.7% of the global population while lower-middle and low income countries accounted for more than half (51.5%) in 2020.[20]

Throughout the pandemic so far (as of the writing of this dissertation), COVID-19 transmission has been defined by region-specific waves. Transmission waves are related to several factors: seasonality, effectiveness of vaccines over time, human behavior, policies, and mutation in the virus itself.[21] The WHO classifies a new variant of SARS-CoV-2 as a variant of concern (VOC) if it has been demonstrated to be associated with an increase in transmissibility, increase in virulence, or decrease in the effectiveness of public health measures or available diagnostics, vaccines, or therapeutics.[22] The WHO classified the Alpha and Beta variants of SARS-CoV-2 as VOCs on December 18, 2020 and the Gamma variant as a VOC on January 11, 2021. All three variants were downgraded to a “previous VOC” on March 9, 2022. The Delta variant was designated as a VOC on May 11, 2021, and as a previous VOC on June 7, 2022. On November 26, 2021, the WHO declared the Omicron variant to be a variant of concern and as of February 13, 2023, Omicron remains the only currently circulating VOC.[23]

Clinical Disease

The clinical spectrum of COVID-19 ranges from asymptomatic or pre-symptomatic infection to mild, moderate, severe, and critical illness.[24] The WHO reports that most infected people develop mild to moderate illness with symptoms including: fever, cough, tiredness, loss of taste or smell sore throat, headache, myalgias, gastrointestinal symptoms, skin rash, and irritated eyes.[25] The most serious symptoms of COVID-19 infection include difficulty breathing or shortness of breath, confusion, chest pain, respiratory failure, multiple organ dysfunction and sometimes, death.[24] Although the proportion of infected individuals who remain truly asymptomatic is poorly defined,[24] one metanalysis of 95 eligible studies estimated that 40.5% of confirmed COVID-19 cases are asymptomatic.[26]

Prevention and Control

Throughout the COVID-19 pandemic, infection prevention and control (IPC) best practices have evolved. According to the WHO,[27] recommended public health and social measures in the community to reduce SARS-CoV-2 transmission include personal protective measures (mask-wearing, hand hygiene); environmental measures (disinfection, ventilation); surveillance and response measures (testing, isolation, and quarantine); and physical distancing measures (maintaining distance in public, avoiding crowded areas). Additionally, vaccines against COVID-19 began development only months into the pandemic in 2020 and were rolled out on a global-scale in 2021. As of April 8, 2022, WHO has found that 10 vaccines met necessary criteria for safety and efficacy.[28] Vaccination is strongly recommended to provide protection against COVID-19-related serious illness and death, although it is still possible to develop COVID-19 and infect others following vaccination.

Proper IPC in healthcare settings is vital to the COVID-19 response as both patients and HCWs are vulnerable to infection. Particularly at the beginning of the pandemic, incidence of healthcare-associated COVID-19 infections was a threat to the safety of patients and providers.[29,30] To protect both patients and HCWs in healthcare settings, the WHO recommends that IPC plans include: universal mask wearing in areas of known or suspected SARS-CoV-2 transmission, respirators and other PPE (gown, gloves, eye protection) worn by HCWs performing aerosol-generating procedures, frequent and correct hand hygiene, strong surveillance and testing among HCWs, and adequately ventilated patient rooms or areas.[27,31,32] Acknowledging that some countries have limited capacity for IPC, the WHO has also established minimum requirements for IPC to provide minimum protection to patients, HCWs, and visitors based on its core components.[33]

Early recognition of infected persons and eliminating routes of transmission are key to COVID-19 IPC strategies. However, the asymptomatic transmission of SARS-CoV-2 meant that the traditional methods of early detection of disease (symptom-based case recognition and testing) that had been successful in controlling the SARS-CoV-1 outbreak, were not effective.[34,35] Studies throughout the pandemic have varied widely on the estimated proportion of asymptomatic COVID-19 cases from 15% up to 70%.[36-39] Regardless, the ability of asymptomatic and presymptomatic individuals to successfully transmit SARS-CoV-2 is among the greatest challenges to the public health response to COVID-19.[18,40-42] During the pandemic, effective control of COVID-19 has depended partly on reducing the risk of transmission by promoting mitigation measures such as wearing masks, hand hygiene, physical distancing, and deliberate testing of people who are not ill.[34,43-45]

1.2 Ebola virus disease

Ebola was first documented in 1976 when nearly simultaneous outbreaks of what was discovered to be *Sudan ebolavirus* occurred in southern Sudan and *Zaire ebolavirus* occurred near the Ebola River in what is now the Democratic Republic of the Congo (DRC).[46,47] Ebola virus disease (EVD) refers to disease caused by one species of Ebolavirus: *Zaire ebolavirus*.[48] EVD is largely been considered a malady of Central and Western African countries[49] with exceptions, namely the West African Ebola outbreak from 2014 to 2016 in which disease spread from a rural area of Guinea to five nearby countries (i.e., Sierra Leone, Liberia, Mali, Nigeria, Senegal) and on to four countries outside of the region (i.e., Italy, Spain, United Kingdom, United States) within months.[50] Ebola outbreaks in Africa are becoming more frequent, which is potentially due to increased human-animal contact related to deforestation, hunting, and mining, increased mobility among previously remote populations, and climate change.[47,49,51-54]

Epidemiology

EVD is caused by infection with *Zaire ebolavirus*, within the virus family *Filoviridae*.[48] There are five other ebolaviruses (i.e., *Bombali*, *Bundibugyo*, *Reston*, *Sudan*, *Taï Forest*), three of which are associated with human disease. Though unknown, there is speculation that fruit bats are natural Ebola virus hosts.[55,56] Animal-to-human transmission of Ebola virus occurs through direct contact with infected animals (e.g., bats, gorillas, chimpanzees, monkeys, antelope, porcupines), typically via the handling of infected animal carcasses.[47,55,57] After this initial zoonotic event, human-to-human transmission (commonly to family members or HCWs) leads to EVD outbreak.

Ebola virus is highly transmissible between humans by direct contact with infected blood, secretions, tissues, organs, and other bodily fluids from a deceased or living infected person.[55,57] Transmission is also possible via fomites, inanimate objects contaminated with infected bodily fluids (blood, feces, vomit) from a EVD case or from the body of a person who died from EVD. Further, pregnant women who still carry Ebola virus in their breastmilk pose a risk of transmitting the virus to their baby via breastfeeding.[55] An infected person cannot spread EVD until they develop symptoms and remain infectious until their blood no longer contains Ebola virus.[55]

Given the direct route of transmission of EVD, people who encounter infected animals, are close contacts of EVD patients, or are HCWs caring for EVD patients are at an elevated risk of infection. In the community, infection has been linked to the administration of funeral rites which involves cleansing the cadaver and removal of hair, fingernails, toe nails, and clothing before burial.[47] Visiting or taking care of an infected person either in the home or hospital setting also increases risk of EVD.

As a high risk population for infection, HCWs are commonly cited as drivers of EVD outbreaks.[47,52,57,58] In fact, the first outbreak of *Sudan ebolavirus* began at a hospital at which the index case was treated and the first outbreak of *Zaire ebolavirus* was caused by the reuse of contaminated needles in a healthcare facility.[47,56] Historically, nosocomial outbreak of EVD, or transmission within medical or healthcare facilities, is characterized by epidemic amplification and relatively high case fatality among HCWs as opposed to community-based outbreaks that tend to end spontaneously with limited chain of transmission.[47,58]

Global Distribution

Since the Ebola viruses' discovery, there have been 51 documented Ebola outbreaks worldwide.[59] DRC leads the world in EVD burden having experienced 15 outbreaks since 1976. Uganda has had seven documented EVD outbreaks while Gabon and the Republic of Congo have each experienced four. Since 2017, seven EVD outbreaks have occurred in DRC, two EVD outbreaks occurred in Uganda, and one outbreak occurred in Guinea in 2021. *Zaire ebolavirus* is the most common Ebolavirus to be detected, particularly in recent outbreaks,[60] with the recent exception of the *Sudan ebolavirus* outbreak in Uganda in 2022.[61]

Clinical Disease

The clinical features of EVD are commonly divided into four phases.[47,57] Phase 1 is characterized by influenza-like syndrome or sudden onset of high fever, headache, arthralgia, myalgia, sore throat, or malaise with nausea. Phase 2 is acute persistent fever that does not respond to antimalarials or antibiotics, headache, intense fatigue, followed by diarrhea, abdominal pain, anorexia, and vomiting. This stage has been described as the point of the illness when "dry" symptoms (e.g., fever, aches, fatigue) progress to "wet" symptoms (e.g., diarrhea, vomiting).[62] Phase 3, or pseudo-remission, occurs about a week after symptom onset when the patient feels better and seeks food. Some patients might recover during Phase 3 and survive their disease. Phase 4 is described as aggravation in which the patient's health status worsens, and the following might be observed: respiratory disorder, symptoms of hemorrhagic diathesis, skin manifestations, cardiovascular distress, and death. Due to non-specific symptoms early in the clinical progress of EVD, it is often mistaken for more common diseases, such as influenza or malaria, often delaying recognition, treatment, and containment of the disease.[47,62]

Prevention and Control

Effective EVD outbreak control consists of a package of interventions, such as case management, surveillance and contact tracing, laboratory response, safe burials, and social mobilization. The WHO emphasizes the need for community engagement in reducing the risk of human Ebola virus transmission.[55] First, risk of spillover from Ebola virus infected animals to humans should be reduced by wearing gloves and other protective clothing when handling animals and thoroughly cooking animal products, such as blood and meat, before consumption. Human-to-human transmission of Ebola virus should be prevented by reducing direct or close contact with individuals with EVD symptoms. Containment measures, such as safely burying the dead, promptly identifying contacts of EVD cases and monitoring their health, isolating sick individuals, and maintaining good hygiene and a clean environment, should also be a focus of EVD control efforts. Risk of sexual transmission of EVD can be reduced by following the WHO guidance that male survivors practice safe sex and hygiene for twelve months from onset of symptoms or until their semen tests negative for Ebola virus twice. Further, pregnant women who are EVD survivors should have their sexual and reproductive care and delivery conducted in a safe manner to reduce the risk of transmission from pregnancy related fluids and tissue.

Proper IPC activities should be maintained in healthcare settings as they are a particularly high-risk environment for Ebola virus transmission. In addition to standard precautions during patient care (basic hand hygiene, respiratory hygiene, use of PPE, safe injection practices, safe burial practices), HCWs caring for confirmed or suspected EVD patients should abide by more stringent IPC measures to prevent contact with the patients' blood and bodily fluids or with contaminated surfaces or medical supplies. Specifically, HCWs should wear face protection (face shield or medical mask and goggles), a clean non-sterile long-sleeved gown, and gloves when within one meter of an EVD patient. Respiratory protection is also recommended, such as an N95 respirator, because of the risk posed by aerosol-generating clinical procedures.[63]

In addition to HCWs with direct patient care responsibilities, laboratory staff are also at increased risk of EVD due to handling of biological specimens. Therefore, samples taken from both humans and animals for Ebola virus infection investigation should be processed by trained staff in suitably equipped laboratories. When performing Ebola virus laboratory testing, the CDC recommends proper PPE utilization: disposable gloves, gowns, surgical mask, and eye protection with a full-face shield or goggles with side shield.[64] Specimen transport should also only be performed with proper PPE.

1.3 Democratic Republic of the Congo

A former Belgian colony, DRC gained independence in 1960 and, between 1971 and 1997, was known as Zaire. DRC is the second largest country geographically in Africa,[65] following Algeria, and has the fourth largest population, an estimated 97 million in 2022.[66] The capital of DRC, Kinshasa, is one of the most populous cities in Africa with a population of approximately 15.6 million.[66] The country is bordered by the Central African Republic and South Sudan to the north, by Uganda, Rwanda, Burundi, and Tanzania to the east, by Zambia to the southeast, by Republic of Congo to the west, and by Angola to the southwest.[67] The country has a narrow coastline to the west on the Atlantic Ocean. The geography of DRC is diverse including the Congo basin, a major valley, high plateaus, three mountain ranges, rainforest, and a low coastal plain. The Congo River runs throughout the country and is the world's deepest river and Africa’s second longest river, after the Nile.[68] About half of the population of DRC (46.0%) lives in an urban setting compared to a rural setting.

Despite being one of the world’s richest countries in natural resources, such as cobalt, gold, and copper, DRC is categorized as a low-income economy by the World Bank and among the five poorest nations in the world.[20,65] The country has experienced conflict for nearly three decades, primarily in eastern DRC. As a result of sustained internal conflict and economic hardship, approximately 5.5 million people are internally displaced in the country, more than anywhere else in Africa.[69] Life expectancy at birth in DRC is 61 years and the median age is 17 years old with 46.0% of the total population being younger than 15 years old.[66] In 2016, 89.0% of adult men in DRC were literate compared to 66.0% of adult women.[20] Only 16.8% of Congolese women have completed secondary school while 47.5% of the labor force is female, most of whom work in agriculture. DRC has the third highest fertility rate in sub-Saharan Africa (SSA) with nearly 6 children born per woman in 2020. The mortality rate of children under five in DRC was 81 per 1000 live births in 2020, and the prevalence of low height-for-age and of being underweight are both high among children under five for the SSA region (41.8% and 23.0%, respectively, in 2017).[70] These indicators of poor population health indicate, among other factors, a dysfunctional health system in DRC.

Health System

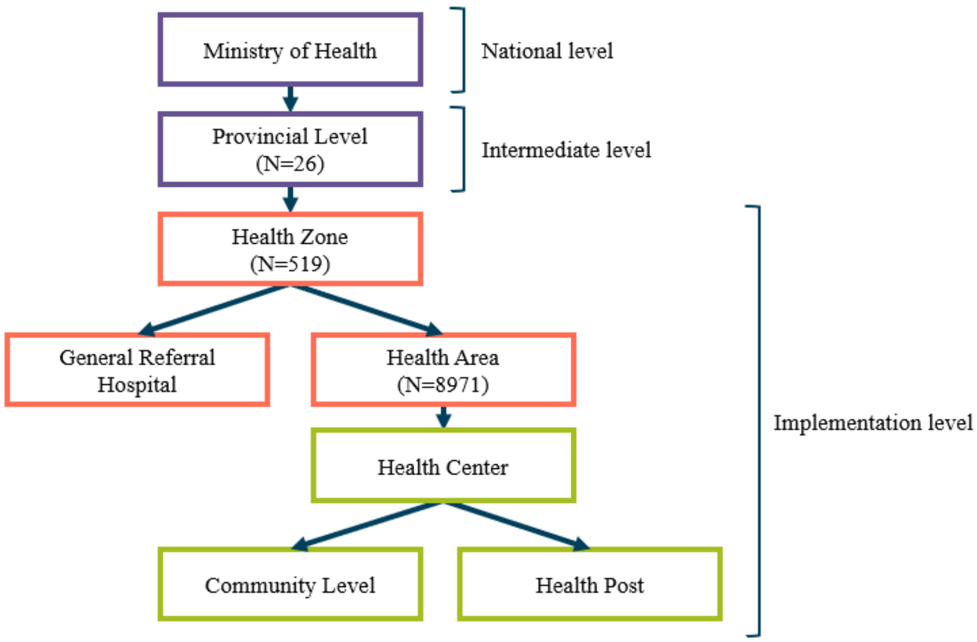
The health system in DRC has three tiers (Figure 1.1). At the national level, the Ministry of Health sets national standards for the delivery of healthcare and coordinates activities across donors and non-governmental organizations (NGOs). The intermediate level, managed by each of the 26 provincial health departments in DRC, is responsible for technical and logistic support. Each health department collects, analyzes, and interprets health data within its province and sends these findings back to the national level. The implementation level is comprised of health zones across the country, within each of which there is one district referral hospital (Hôpital Général de Référence), one central office (Bureau Central de Zone), and a network of health facilities that altogether service at least 100,000 people.[71] Health zones are considered the operational unit of the health system and are responsible for planning and implementing health activities and ensuring service delivery. There is typically one health center in each health area, a further subdivision within a health zone, and each health area contains roughly a dozen villages in rural settings or streets in urban settings.[71] Health areas focus on managing and mobilizing resources, overseeing health service delivery, and ensuring systems for community engagement. HCWs at the implementation level can also work as community health volunteers or at a health post associated with a health center.

Health expenditures in DRC are relatively low. In 2019, DRC spent just 3.5% of its national gross domestic product on health or $21USD per capita, which is a quarter of the SSA region average.[20] In 2021, 11.4% of the national budget in DRC was allocated to health, below the country goal of 15%.[72] Households remained the largest contributor to health expenditures (42%) followed by multilateral aid (25%) and the central government (16%) in 2019. The majority (75%) of the national health budget was allocated to the operational tier (implementation level) of the health system in 2019. Overall, poor health financing, decades of armed conflict, geographically remote areas, and several endemic tropical diseases contribute to the challenge of timely response to disease emergencies in DRC.

COVID-19 Epidemic

SARS-CoV-2 transmission is driven by characteristics of the virus, biological and behavioral factors of the host, and the environment. Variation in these factors led to vastly different

Figure 1.1. Organization of the health system in Democratic Republic of the Congo



Note. Figure adapted from Hoff, N. A. (2014). Utilization assessment of infectious disease surveillance data to enhance methods for better understanding disease occurrence, trends and gaps in disease reporting in a resource limited setting: Monkeypox in the Democratic Republic of Congo. *UCLA*. Retrieved from https://escholarship.org/uc/item/51v3n3hx

pandemic trajectories between LMICs and HICs. In the early months of the pandemic, LMICs, particularly those in Africa, experienced considerably fewer confirmed cases and deaths compared to HICs and generally, COVID-19 burden among LMICs never reached that of HICs.[73-75] Specifically, a cumulative total of 845.9 confirmed cases of COVID-19 per 100,000 population have occurred in Africa compared to 18,537.5, 10,211.6, and 29,196.5 per 100,000 population in the Americas, Western Pacific, and Europe regions, respectively, as of February 13, 2023.[3]

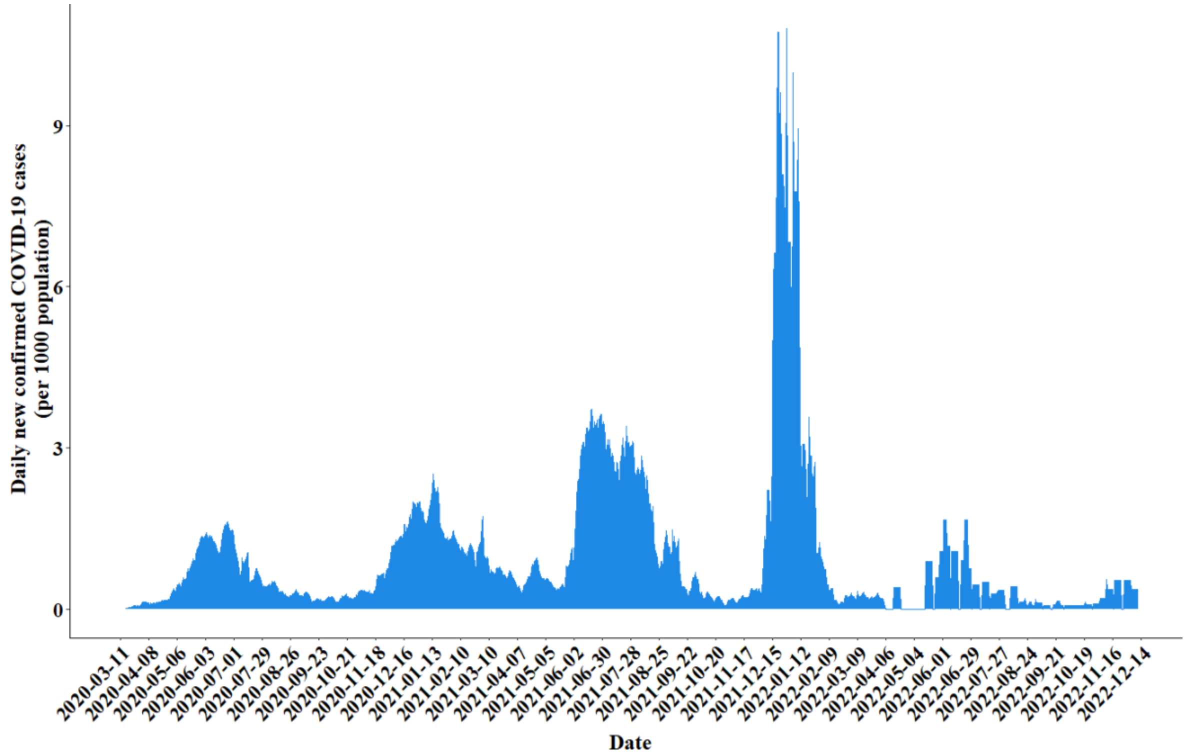
A total of 95,645 cumulative confirmed COVID-19 cases (106.8 cases per 100,000 population) and 1,464 confirmed deaths have occurred in DRC since the beginning of the COVID-19 pandemic.[3] Otshudiema et al. [76] described four waves of COVID-19 transmission in

DRC throughout the pandemic: 1) mid-April to late-August 2020, 2) mid-November 2020 to early-April 2021, 3) mid-May to mid-August 2021, and 4) early-November to early-January 2022. Another moderate uptick in COVID-19 cases occurred between early-May and early-July 2022 in DRC as well (Figure 1.2).[3] As of December 1, 2021, the provinces with the largest share of confirmed COVID-19 cases in DRC were Kinshasa, North Kivu, and Haut-Katanga (with 58.8%, 10.6%, and 7.4% of cumulative cases, respectively).

Explanations for lower morbidity and mortality from the COVID-19 pandemic in LMICs compared to HICs include: a smaller proportion of the population who are above 65 years old and consequently, at increased risk for mortality; [75,77-80] a smaller burden of high risk comorbidities such as diabetes and obesity;[80] early and strong political commitment to interventions such as nationwide lockdowns and travel restrictions;[75,81] warmer and wetter climates which reduce SARS-CoV-2 transmission;[82,83] higher levels of genetic variation or cross-immunity from other circulating diseases,[84] particularly within Africa, which may increase resistance to COVID-19;[74,81] and less international air traffic.[75,83] On the other hand, suggestions for why the pandemic would be more severe in lower resourced countries include: greater household size;[77] higher contact rates among elderly individuals increasing transmission risk to this vulnerable group;[77] and a greater proportion of individuals with comorbidities such as HIV/AIDS, malnutrition, and tuberculosis.[77]

However, heterogeneity in testing and reporting practices between as well as within LMICs, particularly those in the SSA region,[73-75,85,86] exacerbated by a lack of research exploring the dynamics of the pandemic[86-90] make the true burden and trajectory of the pandemic in these countries uncertain. For example, an analysis by the WHO estimates that the true number of SARS-CoV-2 infections in Africa is seven times the reported 8.4 million infections by October

Figure 1.2. Daily confirmed cases of COVID-19 (per 1000 population) in Democratic Republic of the Congo, March 11, 2020 to December 14, 2022



10, 2021 and that two in three deaths from COVID-19 go unrecorded in the region.[80] Further, a robust modelling study utilizing techniques such as adjustment for seroprevalence surveys estimated that from the start of the pandemic (mid-March 2020) to mid-November 2021, SSA had the highest cumulative infection rate among all global regions (79.3 per 100 population compared to 49.1 globally and 22.1 in HICs).[91] Specifically in DRC, SARS-CoV-2 seroprevalence in general population samples in mid-2021 was estimated as 83.2-84.0%, well above estimates from confirmed case data.[92,93]LMICs have limited capacity for public health activities such as surveillance and screening. Surveillance of a disease with considerable asymptomatic cases, such as COVID-19, is challenging universally, but especially in a generally younger African population where it is estimated that 65-85% of cases are asymptomatic[80] compared to 35% worldwide.[94]

Standard outbreak response activities, such as testing and diagnosis, has been limited in Africa due to infrastructure needs, global supply chain issues, workforce training and supervision, and health seeking behavior among the public.[95] By October 2021, more than a year and a half into the pandemic, only about 70 million COVID-19 tests had been administered in African countries compared to 550 million tests in the United States, a nation with a third of the population of the African continent.[96] Many African nations, such as DRC, had a limited number of laboratories capable of conducting COVID-19 testing particularly early in the pandemic.[90] In practice, SARS-CoV-2 testing has typically been limited to symptomatic individuals or those attempting travel. During the early days of the pandemic in many countries in Africa, including DRC, surveillance was focused on identifying imported COVID-19 cases from incoming travelers or local residents returning from international travel.[86] For example, DRC required a negative PCR test from travelers with proof of full vaccination to enter or exit the country until October 1, 2022.[97] In DRC, the test positivity rate for COVID-19 is high, ranging from 5-45% between August 2020 and August 2021 indicating that cases in the country have likely gone unreported.[19] Despite the underreporting and under detection of COVID-19 cases that occurred in Africa,[86,98] including in DRC, the pandemic did not overwhelm the health system as it did in many HICs.[99,100]

Ebola History

DRC has experienced 15 EVD outbreaks resulting in a total of more than 4,000 confirmed cases and about 3,000 deaths (Table 1.1).[59,101-105] Although EVD is considered rare, it is an often fatal disease with case fatalities in the Congolese EVD outbreaks ranging from about 40% to 90%. Since a large outbreak in Kikwit in 1995 caused about 250 deaths, EVD outbreaks have become more frequent in DRC. For example, eight outbreaks have occurred between 2017 and

Table 1.1. History of Ebola outbreaks in Democratic Republic of the Congo

#	**Province (City or Health Zone)**	**Approximate Dates**	**Cases**	**Case Fatality Ratio**
1	Équateur (Yambuku); Kinshasa	Sep 1976 - Oct 1976	318	88%
2	Sud-Ubangi (Tandala)	Jun 1997	1	100%
3	Kwilu (Kikwit)	Jan 1995 - Jul 1995	315	81%
4	Kasai Occidental (Luebo & Mweke)	Sept 2007 - Nov 2007	264	71%
5	Kasai Occidental (Luebo & Mweke)	Dec 2008 - Feb 2009	32	47%
6	Orientale (Isiro)	Aug 2012	52	42%
7	Équateur (Boende)	Aug 2014 - Nov 2014	69	71%
8	Bas Uélé (Likati)	May 2017 - Jul 2017	8	50%
9	Équateur (Bikoro)	May 2018 - Jul 2018	54	61%
10	North Kivu (Beni); Ituri; South Kivu	Aug 2018 - Jun 2020	3470	66%
11	Équateur (Mbandaka)	Jun 2020 - Nov 2020	130	42%
12	North Kivu (Butsili)	Feb 2021 - May 2021	12	50%
13	North Kivu (Beni)	Oct 2021 - Dec 2021	11	82%
14	Équateur (Mbandaka)	Apr 2022 - July 2022	5	100%
15	North Kivu (Beni)	Aug 2022 - Sep 2022	1	100%

2022: four outbreaks occurred in North Kivu province in eastern DRC, three occurred in the west along the Congo River in Équateur province, and one occurred in Bas-Uélé province along the country's northern border.

The first EVD vaccine, rVSVΔG-ZEBOV-GP, was fully licensed by the U.S. Food and Drug Administration and the European Medicines Agency as Ervebo® in 2019.[106,107] However, compassionate use of this single-dose vaccine to help mitigate on-going EVD outbreaks in DRC began in May 2018 in Équateur province and the vaccine continued to be deployed in subsequent outbreaks.[108] The 13th EVD outbreak in North Kivu province in 2021 was the first time the vaccine was used in the country post licensure.[109] At present, immediate launch of vaccination activity is a standard control measure used within DRC to control EVD outbreaks. In DRC, vaccination for EVD control utilizes the "ring vaccination" strategy in which contacts of confirmed cases, contacts of contacts of confirmed cases, and healthcare and other workers on the frontline of the outbreak are eligible for vaccination.

Despite the challenges of working within a weak health infrastructure and in areas of insecurity, the HCWs of DRC have proven to be a major strength of EVD responses in recent years. During the 10th EVD outbreak in eastern DRC from August 2018 to June 2020, more than 16,000 local frontline responders worked to control the outbreak.[110] Congolese HCWs were persistent in tracking and tracing EVD contacts even while response efforts were restricted due to violence in the region. In fact, a considerable number of health workers aiding in the EVD outbreak response experienced violence, specifically more than 450 attacks were recorded including 27 deaths among HCWs.[111] In areas where fraud, corruption, and conflict were already common, widespread community resentment and resistance to the EVD effort contributed to the public distrust and violence towards HCWs. An evaluation of the response to the 10th EVD outbreak found that local HCWs were a unique strength to control efforts and called to address the lack of local HCWs trained to manage health emergencies in the affected areas.[112] Specifically, increased capacity among properly trained HCWs from the community in an infectious disease emergency lessens the need to recruit international HCWs whose presence can lead to community resistance.

Healthcare Workers and Outbreak Response

The WHO has identified availability, accessibility, and quality of the health workforce as a key solution to improving health outcomes worldwide.[113] Mere availability of HCWs does not lead to impactful health service coverage, rather it is essential to public health that HCWs are competent, motivated, and empowered to deliver quality care. Effective public health emergency response is dependent on robust health workforce capability.

Infectious disease outbreaks can put enormous strain on health systems, particularly those that are already poorly functioning, such as that in DRC. Prior to the COVID-19 pandemic, the DRC health system faced many challenges such as low coverage of essential health service, low quality of care, and low health expenditure. DRC further has a scarce health workforce with a ratio of 1.2 HCWs per 1,000 population,[20] well below the WHO recommendation of 4.45 HCWs per 1,000 population. HCWs are essential to a functioning health system and are the frontline responders to public health emergencies, yet they are particularly vulnerable in low resource settings. Effective resource distribution is vital to minimizing the threat of infectious disease outbreaks on the health workforce in an already strained health system environment.

In terms of outbreak response among HCWs in DRC, EVD is an apt comparison to COVID-19 in several ways. Although the two diseases have differing routes of transmission and levels of disease severity, both share strategies for outbreak response and are high priority outbreaks for control, especially in healthcare settings. The discovery of the Ebola virus and investigations of its zoonotic origins are still in the memory of many in DRC, mirroring the more recent emergence of COVID-19. Further, infection prevention and control measures among the health workforce has been a major focus of both outbreak responses. Therefore, some prevention, control, and treatment activities employed by the health system might differ between the two diseases, but the attention and framework given to the outbreak response of each is comparable.

The health workforce in DRC has dealt with more EVD outbreaks in recent years than any other national health workforce in the world. In addition to EVD, Congolese HCWs routinely work to contain other serious and highly contagious infectious diseases, such as measles, polio, and cholera. It has been posited that LMICs, such as DRC, with decades of experience managing national and international infectious disease outbreaks have an advantage when facing the task of controlling a novel disease.[16,74,114-116] For example, Kabwama et al.[115] argue that the response model, developed in DRC during previous Ebola outbreaks, to empower national and subnational officials to boost the health system capacity during public heath emergencies[112] could be implemented during the COVID-19 pandemic. However, these discussions typically focus on national government actions rather than the impact of previous outbreak experience on individual HCWs' response to a novel pathogen. In fact, at the beginning of the pandemic, the national leadership of EVD response in DRC was tasked with supervising COVID-19 response thereby redirecting existing infrastructure from one response effort to the other.[117,118]

Assessing behaviors and attitudes towards COVID-19 prevention and control during the pandemic offers a critical opportunity to better understand the response among Congolese HCWs to an outbreak of a novel pathogen of global concern. Subnational analysis of knowledge, attitudes, and practices across time can further enhance the identification of behaviors and beliefs among subpopulations of HCWs in DRCs that might pose challenges to prevention and control efforts. Targeted allocation of IPC training and resources would both strengthen future response efforts and create opportunities to redirect resources that are unlikely to have an impact on KAP. Unfortunately, the extent to which KAP varies between HCWs in different regions of DRC and throughout an outbreak are not well studied.

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CHAPTER 2. Potential and perceived COVID-19 risk among four cohorts of healthcare workers from regions with varying Ebola outbreak experience in the Democratic Republic of the Congo, August 2021 to August 2022

2.1 Abstract

Healthcare workers (HCWs) in the Democratic Republic of the Congo (DRC) are the frontline defense against emergent infectious disease and an effective national outbreak response is vital to adequately protect the health workforce. However, the extent to which HCWs were potentially exposed to COVID-19 in their clinical work and perceived risk of infection across DRC over time is poorly understood. A longitudinal study of active HCWs (N=545) from four cohorts in DRC (Kinshasa, Kikwit, Mbandaka, and Beni) was conducted between August 2020 and August 2021 with 24 total data collection time points. Seven outcomes were analyzed descriptively and by mixed effect models to assess the average level of each outcome over time. Then, pairwise comparisons were made between cohorts. Most baseline characteristics differed between the cohorts. The Kinshasa cohort had the fewest HCWs with previous EVD response experience (4% compared to 51% in Kikwit, 42% in Beni, and 36% in Mbandaka). Overall, probability of recently performing a risky clinical procedure for COVID-19 exposure in the sample was low throughout the study (range: 16.6-23.1%). Over time, slight increases in probability of providing care to an individual with COVID-19 symptoms occurred in each cohort. Perceived risk of infection among the cohorts was typically reported by more than half of the respondents in each cohort throughout the study but differences between cohorts were evident. The probability of believing that COVID-19 infection was likely or that oneself is susceptible to infection was consistently highest and slightly increasing over time among the Kinshasa and Mbandaka cohorts. The probability of reporting likelihood of and susceptibility to COVID-19 infection

decreased slightly over time among the Beni cohort, but the probability of believing an infection would be severe was highest overall and increased over time among this cohort. The differences observed between the cohorts support the need for subnational analyses and, possibly, more tailored dissemination of resources. Future research should continue to explore aspects of the HCW experience during COVID-19 as a lesson learned opportunity to better inform future outbreak response efforts.

2.2 Background

The Democratic Republic of the Congo (DRC) has a long history of combatting infectious disease of great consequence including Ebola virus disease (EVD), measles, plague, and vaccine-derived poliovirus.[1] The COVID-19 outbreak, which began on March 10, 2020 in DRC,[2] only added further strain to the country's overburdened health system. Healthcare workers (HCWs) are the nation's frontline defense against the frequent outbreaks in DRC and are one of the highest risk populations for morbidity and mortality from infectious disease.[3] Surveillance estimates of COVID-19 cases and related deaths in DRC are flawed, largely due to limited testing,[4] which complicates assessments of risk among HCWs during the pandemic. Therefore, insights into the heterogeneity of experiences and perceptions among HCWs during the COVID-19 pandemic across DRC are invaluable.

A total of 95,645 COVID-19 cases (106.8 cases per 100,000 population) and 1,464 deaths have been confirmed in DRC as of February 13, 2023.[5] Otshudiema et al. [6] describes four waves of COVID-19 transmission in DRC throughout the pandemic: 1) mid-April to late-August 2020, 2) mid-November 2020 to early-April 2021, 3) mid-May to mid-August 2021, and 4) early-November to early-January 2022. Another moderate uptick in COVID-19 cases occurred between early-May and early-July 2022 in DRC as well.[5] In each of the four waves, Kinshasa

Province, the national capital and the region with the most access to COVID-19 testing, appeared to be the most affected province contributing 79.5%, 68.9%, 51.6%, and 52.2% of confirmed cases in each wave, respectively.[6] Other provinces that were particularly impacted during the waves were North Kivu, Kongo Central, and Haut Katanga. The later waves of transmission generally subsided more quickly, consisted of more confirmed cases, and had lower test positivity compared to the earlier waves, likely due to better access to testing throughout the country over time. A larger proportion of cases were frontline HCWs in the first two waves compared to the second two (i.e., 5.2%, 1.1%, 0.8%, and 0.9%, respectively).[6] A serology study assessing presence of SARS-CoV-2 antibodies among HCWs in Kinshasa found that up to 17.3% of the sample had COVID-19 infection between July 2020 and January 2021.[7]

HCWs, particularly those on the frontline of outbreak response, have a greater risk than the general population for infection due to clinical responsibilities.[8,9] Given the transmission route of SARS-CoV-2 via respiratory fluids, clinical activities that produce respiratory droplets and aerosols (clinical lung function tests, intubation, use of nebulizers) contribute to HCW exposure risk.[8,10] Further, contact with individuals with general flu-like symptoms pose considerable risk to HCWs who, particularly early in the pandemic, might not have suspected COVID-19 infection in these patients and failed to adopt protective measures.[11] Failure to recognize COVID-19 infection is particularly likely in a setting such as DRC where febrile illness, often related to vector-borne and other infections, is commonplace. However, the extent to which these risk factors for disease exposure (caring for an infectious patient, performing high risk procedures) are experienced by HCWs in DRC during a novel pathogen outbreak is unknown.

Of studies that investigated knowledge, attitudes, and practices among HCWs in DRC during the pandemic, none assessed risk perceptions related to COVID-19 infection itself.[12-14] It is well-understood that risk perception is positively related to protective health behaviors.[15-17] During an outbreak, widespread engagement in infection prevention and control (IPC) behavior, especially among HCWs, is critical to public safety; in the context of a disease outbreak, research has shown that greater perceived risk of infection is related to better prevention compliance.[18-21] Therefore, monitoring risk perceptions within HCWs during an outbreak can provide valuable insight. Studies conducted in other sub-Saharan countries found fear and perceived risk of COVID-19 to be higher in HCWs compared to the general population.[22-27] The majority of these studies used convenience samples for cross-sectional analysis in the early months of the pandemic, typically between March and June 2020. For example, Migisha et al.,[24] found that 81% of HCWs surveyed in five Ugandan referral hospitals between April and May 2020 felt they were at risk of COVID-19 infection. A multi-country study concluded that risk perceptions for COVID-19 varied across and within countries due to factors such as: direct personal experience with the virus, having received information from family or friends, and trust in medical professionals and/or science.[21] Therefore, within a health workforce with varied culture, access to resources, and clinical experience, such as that found in DRC, risk perceptions are likely heterogeneous.

While combatting infectious diseases such as malaria, intestinal parasites, and tuberculosis is commonplace to HCWs throughout DRC, it is rarer to work on the frontlines of a high-profile outbreak of an emergent pathogen, such as SARS-CoV-2. The most pertinent comparison to some HCWs in DRC is likely EVD outbreak response. Since 2018, seven EVD outbreaks have occurred in 2 of 26 provinces in DRC: North Kivu and Équateur.[28] Further, frontline HCWs in EVD affected areas can receive additional training in IPC, field epidemiology, and surveillance to enhance their capacity to control the outbreak.[29] As a result, this relative containment of EVD response has likely imparted some provincial health workforces with knowledge and skill in the rapid mobilization of IPC activities while HCWs in other areas of DRC remain comparatively naïve. Among HCWs in Hong Kong, Chua et al.[30] found that those who had responded to the SARS outbreak about 20 years prior perceived less risk of COVID-19 infection for themselves and family members compared to HCWs who did not have this experience. Therefore, HCWs with previous EVD outbreak experience in DRC might have different attitudes and behaviors in response to a novel pathogen compared to HCWs with no EVD experience.

Exposure risk and perceptions of risk among Congolese HCWs during the COVID-19 pandemic are not well understood. Further, heterogeneity in the experiences and attitudes among the frontline workforce within DRC and over time is likely and would indicate that tailored allocation of training, resources, or messaging could contribute to a more effective outbreak response to the next emerging pathogen. Therefore, this study aims to assess potential COVID-19 exposure and risk perceptions among HCWs in four location-based cohorts in DRC from August 2020 to August 2021. Due to the heavier burden of COVID-19 cases in Kinshasa and North Kivu during study follow-up, HCWs from these areas are expected to report more potential exposures to COVID-19 infection compared to HCWs in other locations. Further, given EVD outbreak history and the findings of Chua et al.[30], HCWs from North Kivu and Équateur Provinces, where more prior EVD response experience is expected, are hypothesized to perceive less risk of COVID-19 compared to HCWs in the other cohorts. Finally, HCWs in the Kinshasa cohort are expected to have the greatest perceived risk of COVID-19 infection compared to other locations due to possible perceptions of higher viral transmission within Kinshasa.

2.3 Methods

Study design and sample

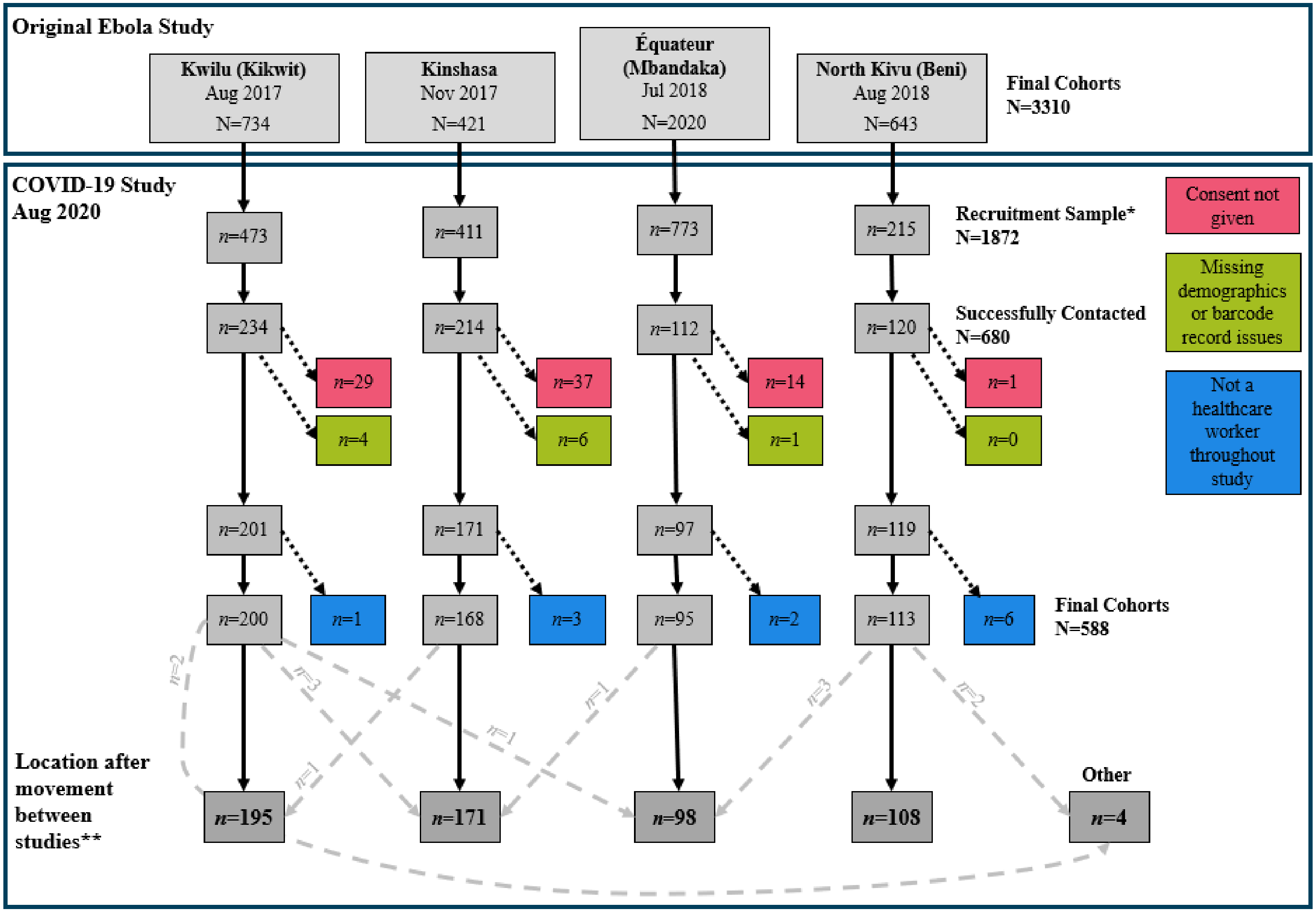
A sample of HCWs in DRC within four existing research cohorts were contacted in August 2020 for enrollment in a longitudinal study of COVID-19-related measures. The original cohorts were created for an ongoing study, "Epidemiology, Immunopathology Immunogenetics and Sequelae of Ebola Virus and other Viral Hemorrhagic Fever Infections," in which participants were recruited in 1) Kinshasa Province, 2) the city of Kikwit in Kwilu Province, 3) the city of Mbandaka in Équateur Province, and 4) the city of Beni in North Kivu Province.

For the Kinshasa and Kikwit cohorts, the target populations were currently active HCWs. In August 2017, health facilities in the two health zones in the city of Kikwit, North Kikwit and South Kikwit, were selected as recruitment units. The referral hospitals, or hôpitaux généraux de référence, in each health zone were selected followed by smaller health facilities which were selected based on accessibility. All healthy adults (18 years of age or older) in the health workforce at one of the selected health facilities were eligible to participate. The same recruitment procedures were repeated in the selected health facilities in three health zones within Kinshasa province (Kinshasa, Lingwala, and Nsele) in November 2017.

The target population of the Mbandaka cohort consisted of two groups: 1) individuals who received the rVSVΔG-ZEBOV-GP vaccine, which was being used under a compassionate use protocol, and 2) HCWs actively working near Mbandaka city (health zones: Mbandaka, Wangata, and Bolenge). The former included contacts of confirmed cases, contacts of contacts of confirmed cases, and healthcare and other workers on the frontline of the outbreak because these groups were eligible for EVD vaccination per the "ring vaccination" strategy utilized. In June and July 2018, study staff joined EVD vaccinators organized by the national Expanded Program for Immunization (EPI) and the World Health Organization (WHO) to offer study enrollment to any healthy individuals who were not pregnant and who received vaccination with rVSVΔG-ZEBOV-GP. For the HCW population, health facilities in the three select health zones within Mbandaka city were selected as recruitment units. As with the Kikwit and Kinshasa cohorts, the referral hospitals were selected in addition to the accessible health facilities in each chosen health zone. All adults in the health workforce at one of the selected health facilities were eligible to participate. The Beni cohort consisted only of individuals who received the rVSVΔG-ZEBOV-GP vaccine. The recruitment procedures utilized in Beni in August 2018 were like those used in Mbandaka: any healthy individuals who were not pregnant and received vaccination (i.e., contacts of confirmed cases, contacts of contacts of confirmed cases, and healthcare and other workers on the frontline of the outbreak) were eligible to enroll.

Among the 3,310 participants in the four Ebola-related research cohorts, 56.6% were selected for possible recruitment for the current study as they were a HCW and consented to future contact for additional studies (Figure 2.1). Based on available labor and funding within the study team at the time of study recruitment activities, those eligible for recruitment were randomly contacted in August 2020 using phone numbers collected during their initial study visit. After confirming the individual's name and HCW status on the initial call, the study interviewer invited the individual to participate in a repeated measures study related to COVID-19. Upon oral consent to study participation, the baseline interview was completed over the phone. Study recruitment continued until 680 total individuals were successfully contacted by phone. Among successful contacts, 81 individuals did not consent to study participation and 11 individuals were dropped from the study due to failure to complete a baseline questionnaire or errors in recordkeeping of the unique study identifier.

Figure 2.1. Study participant flow chart



*restricted to healthcare workers only who consented to future contact

**13 participants moved locations between the original Ebola Study and COVID-19 Study; "Other Provinces" included Ituri, Kwango, Sud Ubangi, and Tshopo

Data collection for this study was conducted in two phases: baseline and follow-up. During baseline data collection, individuals were contacted from August 11 to September 7, 2020 for study enrollment and part one of baseline questionnaire completion. Participants were called again roughly two weeks after their enrollment to complete a second questionnaire with additional baseline measures. During the first few weeks of data collection (8/11/20-8/29/20) study procedures were piloted, and interviewers completed their training. Baseline part-two responses were collected from August 30 to October 12, 2020 with the majority of responses collected in early-September. Follow-up data collection began on September 14, 2020 for all participants and continued until late-August 2021. Follow-up data collection typically occurred from a Monday to the following Tuesday of the next week. Baseline phone calls took between one and one and a half hours to complete and follow-up calls took between 10 and 20 minutes to complete.

Prior to study enrollment activities, interviewers were trained in study procedures and in conducting phone-based interviews including obtaining verbal informed consent. Consent forms, study scripts, and questionnaires were written in English, translated into French and local languages (i.e., Lingala, Kikongo, Swahili), and translated back into English to ensure quality of translation. Interviewers administered questionnaires over the phone using electronic questionnaires in Open Data Kit (ODK) Collect.[31] Subjects retained their unique identifiers from their original cohorts and were assigned new unique codes to link to their repeated measures throughout this study.

Outcomes

Exposure opportunities to COVID-19. Potential exposure to COVID-19 infection was collected in four repeated measures in this study. First, having performed a high- or medium-risk clinical activity in terms of COVID-19 exposure in the past two weeks was assessed at baseline and at each follow-up of the study (24 possible measures per participant). Of the 13 procedures participants were asked if they had performed, 11 were considered to present higher risk of potential COVID-19 exposure to the HCW as they required direct patient contact (collecting nasopharyngeal swabs, intubation/airway procedures, cleaning high touch surfaces in hospital) compared to conducting COVID-19 research and performing laboratory testing. This measure was dichotomized to indicate that the HCW had performed any one of these procedures in the past two weeks. Second, participants were asked if they had cared for anyone exhibiting COVID-19 symptoms (cough, fever, chills, muscle aches, runny nose, shortness of breath) in the past two weeks at their workplace, in their household, or in the community. Each of the three measures was dichotomized (*yes, no/don't know).* Caring for a COVID-19 symptomatic individual in the home or community was asked at every follow-up (23 measures), while caring for a COVID-19 symptomatic patient at work was asked at a subset of follow-ups (18 measures).

Risk perceptions of COVID-19 infection. Three items related to COVID-19 infection risk perceptions were collected in each questionnaire (24 measures). First, each respondent was asked about their current probability of getting infected with COVID-19 with answer options: *extremely likely, likely, somewhat likely, neutral, somewhat unlikely, unlikely,* and *extremely unlikely*. Second, participants were asked to assess how severe contracting COVID-19 would be for them with response options: v*ery severe, severe, somewhat more severe, neutral, somewhat severe, a little severe,* and *not severe at all*. Finally, participants reported how susceptible they considered themselves to be to a COVID-19 infection with responses: v*ery susceptible, susceptible, somewhat more susceptible, neutral, somewhat susceptible, a little susceptible,* and *not susceptible at all*. These measures and response options were based on the WHO standard protocol for COVID-19 Snapshot MOnitoring (COSMO).[32] Each measure's responses were dichotomized to compare the three affirmative statements to the neutral and three dissenting statements.

Predictors

Location. This study employs an outcome-wide approach in which the associations of a single exposure, location, with multiple outcomes are assessed.[33] Location is defined as the city area in which the HCW lived and worked (Kinshasa, Kikwit, Mbandaka, Beni). Participants were asked in what province and city they lived in at study baseline, the midway point of follow-up, and study end.

Time. In this analysis, time was operationalized as the two-week intervals of data collection per study protocol. Time was centered midway through data collection (at data collection interval 2/28/2022 to 3/13/2022). There was no data collection between December 19, 2020 and January 17, 2021 due to the winter holidays.

Demographics

Gender. Participants reported their gender (*male* or *female*) in the baseline questionnaire.

Age. Age in years was self-reported at baseline and treated as a continuous variable.

Education level. Each participant's highest level of education was collected at study baseline. Response options included: *no education*, *less than high school graduate*, *graduated high school*, *some college (including vocational training or associate degree)*, *Bachelor's degree,* and *advanced degree*. Since most of the sample (65.1%) reported *some college*, responses were categorized into *high school education or less, some college,* and *Bachelor's or advanced degree*.

Chronic disease. Participants self-identified as having a chronic disease (e.g., chronic lung disease, diabetes cardiovascular disease, chronic renal or liver disease) or otherwise being immunocompromised at study baseline.

Environment setting. Participants reported whether they considered their current living setting as *urban* or *rural* in the baseline questionnaire.

Employment status. Participants reported their employment status (i.e., full-time, part-time, contracted, unemployed) at study baseline, midway point, and end.

Direct patient care responsibilities. Participants were asked at study baseline if they have direct patient care responsibilities in their job (*yes*/*no*).

Health facility type. The health facility at which each participant reported they worked at study baseline was assigned a type (general hospital, health post, health center, hospital center, clinic/medical center/private hospital, coordinating office, and other) by study staff familiar with the local areas. Each health facility type category represents a unique healthcare setting in terms of resources, structure, and management. Facility types that only one to two participants reported (health post, church, home) were collapsed into the *other* category to reduce sparse data issues.

EVD Outbreak Experience. Direct EVD outbreak experience among the participants in this study was measured previously as a part of their participation in the original Ebola-related study cohorts. Therefore, these measures were collected in August 2017 for participants in the original Kikwit cohort, November 2017 for Kinshasa, June or July 2018 for Mbandaka, and August 2018 for Beni. During these original studies, participants were asked at baseline 1) if they had ever been involved in an EVD outbreak and 2) if they had ever received the EVD vaccine (rVSVΔG-ZEBOV-GP). Recent EVD vaccination was a study eligibility requirement for some participants in the original Mbandaka cohort and for all participants in the original Beni cohort.

Statistical analysis

Sample. Among the 588 study participants who completed at least one interview, those who did not live within Kinshasa, Kikwit, Mbandaka, or Beni at baseline (*n*=4) or who did not work in healthcare throughout the study (*n*=12) were excluded retrospectively due to ineligibility. Participants who moved away from the four areas of interest during follow-up (*n*=10) were also excluded from the analytic dataset since they would no longer have a time-fixed exposure of interest. Outcome responses collected during the study pilot were excluded from analysis (*n*=394 responses) to retain consistency in measurement across the study. Participants who no longer contributed any outcome measures to statistical analysis after dropping data collected during the study pilot period were also excluded (*n*=17). A sensitivity analysis was performed to determine if retaining the group of participants who moved during the study and utilizing their baseline location in analysis would impact study findings.

Cross-sectional analysis. Descriptive statistics on study population characteristics and demographics were calculated for the analytic sample as well as for those excluded from analysis to assess potential selection bias. Chi-square tests were used to determine if there was a difference in the distribution of responses to categorical demographics variables (i.e., gender, education level, chronic disease, environment setting, direct patient care responsibilities, ever involved in EVD outbreak, and received EVD vaccine) among the location groups. At least one cell count in the expected frequency in each of the response categories of two categorical variables (i.e., employment status and health facility type) by location group was below five; therefore, Fisher's exact test was more appropriate to assess the association with location. For continuous age, ANOVA was used to determine the equality of the four cohort mean ages.

Longitudinal analysis. Each of the seven outcomes of interest in this analysis were assessed visually and computationally. First, the count and percentages of responses were calculated for each outcome across the study as well as within each interval of data collection. Second, for each outcome, average response over time per respondent was plotted in histograms, and the proportion who consistently responded in the affirmative to each outcome throughout the study was calculated to inform model parameterization. Third, the proportion of participants in each data collection interval responding in the affirmative by location group for each outcome was plotted. Finally, mixed effect logistic models were used to determine the relationship between location, time, and each outcome accounting for repeated measure clustering within the data.

Mixed effects modeling procedures are appropriate for this analysis as there is an a priori belief that the relationship between location and the outcomes of interest could vary by individual, health zone, or health facility effects. Four model types were constructed for each outcome utilizing a different set of random effects: 1) individual only, 2) individual and health zone, 3) individual and health facility, and 4) individual, health zone, and health facility. Based on model performance, the individual only set of random effects was used in all final models. Models were run using the PROC GLIMMIX procedure in SAS[34] with Cholesky parameterization of the covariance structure and a pseudo-likelihood estimation technique based on maximum likelihood (METHOD=MMPL). An interaction term between time and location was included in each model as a fixed effect to assess change in the relationship between location and each outcome over time. Gender and continuous age were added into final models as covariates. Fitted values were calculated on the logit scale for each final model (for a 42 year old male). Then, each estimate was offset by a random normal variate scaled by the standard deviation (SD) of the subject random effect in each model and transformed to probabilities and averaged for each combination of location and time. Finally, to account for 42 models assessing exposure-outcome associations for seven outcomes, including pairwise comparisons between locations, a Bonferroni corrected level of significance was calculated as α/K, where $K = 42$ and $\alpha=0.05$, or 0.001.

Ethical

Institutional review board approval was obtained from the University of California, Los Angeles (IRB#20–001321) as well as the Kinshasa School of Public Health at the University of Kinshasa (ESP/CE/118/2020), which served as the local ethics committee. During phone calls, participants provided an oral consent to participate. The original cohorts were enrolled under ethics approvals: UCLA: IRB#16–001346/KSPH IRB: ESP/CE/022/2017.

2.4 Results

Sample

The study sample consisted of 545 HCWs who contributed a total of 8,877 responses throughout the study. A third (35.4%) of the sample lived and worked in the Kikwit city area during the study period, 31.4% in Kinshasa, 19.8% in the Beni city area, and 16.5% in the Mbandaka city area (Table 2.1). Overall and within each cohort, the average number of repeated measures contributed to the study was about 15 among 25 total questionnaires throughout the study period. (Figure 2.2). A comparison of demographic variables between the analytic sample and several groups of excluded participants is provided in Supplemental Table 2.1.

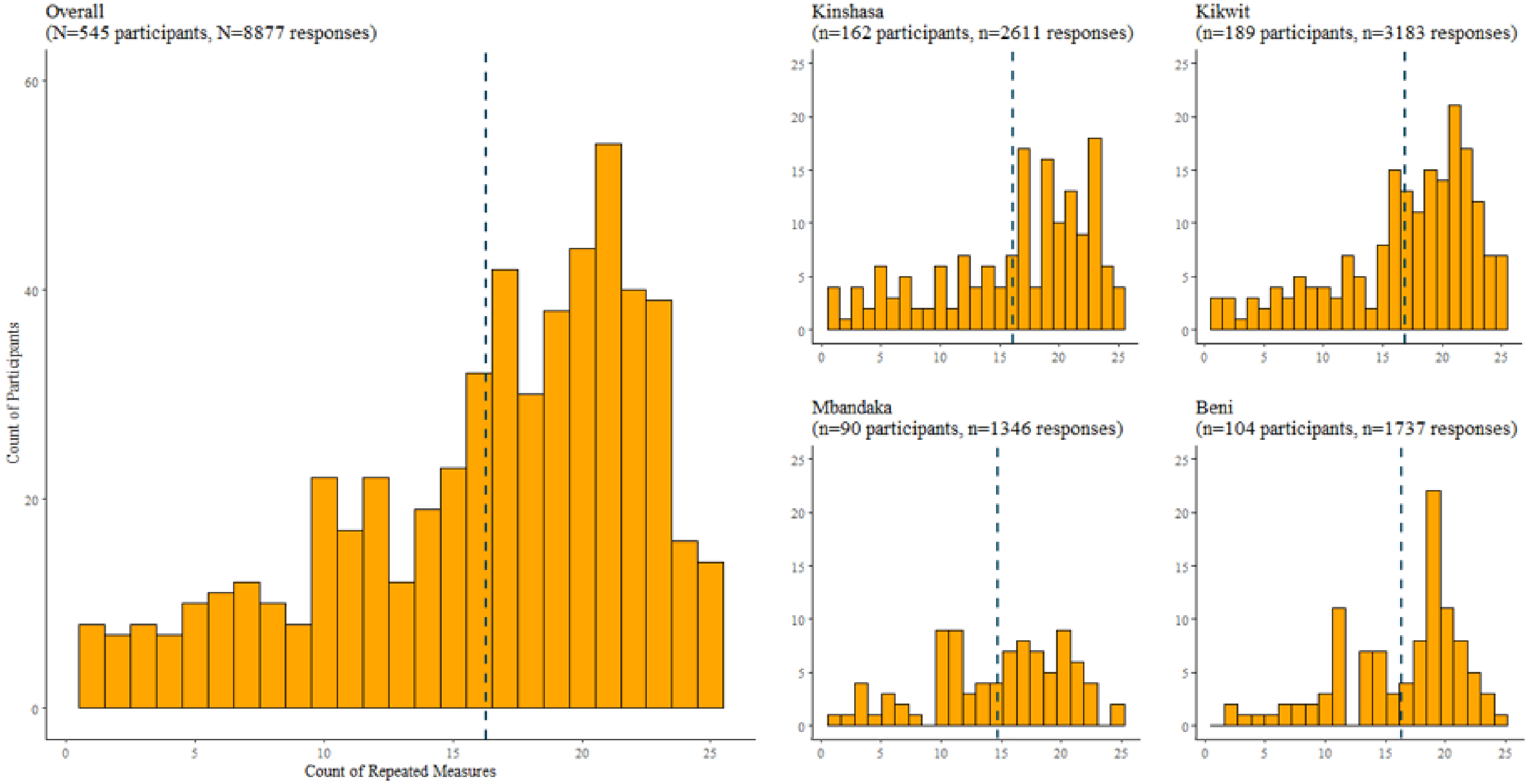
Cross-sectional

All demographic factors differed between the cohorts apart from chronic disease status and direct patient care responsibilities (Table 2.1). A greater proportion of the Kinshasa cohort was female (54.9%) compared to Kikwit, Mbandaka, and Beni (48.1%, 31.1%, and 30.8%, respectively). Participants from Beni were younger on average (37.5 years old) and a greater proportion lived rurally (64.4%) compared to the other cohorts. The distribution of participants living in an urban versus rural setting varied significantly between locations with 5.6% in Kinshasa, 25.6% in Mbandaka, and 45.5% in Kikwit living rurally at study baseline. More than three-quarters of participants in each location (range: 77.9-90.0%) had at least some college education and more than half (range: 56.2-83.6%) held a full-time job at baseline. However, a greater proportion of participants from the Kikwit and Beni areas worked full-time compared to those from Kinshasa and Mbandaka. Most participants in each location worked at either a health center, general referral hospital, or hospital center (range: 73.1-92.7%). Consistent with EVD outbreak history in DRC, all but 7 HCWs from Kinshasa reported no involvement in an EVD outbreak response while about half of the respondents in the Kikwit and Beni cohorts (51.3% and 42.3%, respectively) and a third of respondents in the Mbandaka cohort (35.6%) reported EVD outbreak response experience. Per study protocol, all participants from Beni and a proportion of those from Mbandaka (44.4%) previously received the EVD vaccine.

Longitudinal

Overall, about a third of the sample consistently responded throughout the study that they had not performed a risky clinical procedure in terms of COVID-19 exposure nor cared for someone with COVID-19 symptoms in the clinic, household, and community (Supplemental Figure 2.1, Supplemental Table 2.2). Comparatively, about a quarter of the sample consistently responded that they felt a COVID-19 infection was likely, a COVID-19 infection would be severe, and they were susceptible to a COVID-19 infection. However, average response varied

Figure 2.2. Repeated measure count throughout study among all participants and by cohort



Repeated Measure Statistic	Overall	Kinshasa	Kikwit	Mbandaka	Beni
Mean	16.3	16.1	16.8	15.0	16.7
Median	18	17	18	16	18
Mode	21	23	21	21	20

Note. Dotted vertical lines represents mean repeated measure count in each group.

Table 2.1. Baseline sample characteristics by cohort (N=545)

	Kinshasa (*n*=162) *n* (%)	Kikwit (*n*=189) *n* (%)	Mbandaka (*n*=90) *n* (%)	Beni (*n*=104) *n* (%)	p-value
Gender					<0.0001^
Male	73 (45.1%)	98 (51.9%)	62 (68.9%)	72 (69.2%)	
Female	89 (54.9%)	91 (48.1%)	28 (31.1%)	32 (30.8%)	
Age, continuous					<0.0001$^+$
Mean (SD)	44.9 (12.2)	44.4 (12.6)	45.2 (10.6)	37.5 (10.4)	
Median [Min, Max]	43.0 [23.0, 79.0]	43.0 [20.0, 81.0]	45.0 [25.0, 78.0]	35.0 [21.0, 67.0]	
Education					0.01^
H.S. or less	25 (15.4%)	27 (14.3%)	9 (10.0%)	23 (22.1%)	
Some college/Assoc.	108 (66.7%)	136 (72.0%)	54 (60.0%)	59 (56.7%)	
Bach./Advanced deg.	29 (17.9%)	26 (13.8%)	27 (30.0%)	22 (21.2%)	
Chronic disease	19 (11.7%)	16 (8.5%)	7 (7.8%)	3 (2.9%)	0.09^
Environment setting					<0.0001^
Urban	153 (94.4%)	103 (54.5%)	67 (74.4%)	37 (35.6%)	
Rural	9 (5.6%)	86 (45.5%)	23 (25.6%)	67 (64.4%)	
Employment status					<0.0001~
Full-time	91 (56.2%)	158 (83.6%)	59 (65.6%)	80 (76.9%)	
Part-time	70 (43.2%)	28 (14.8%)	28 (31.1%)	23 (22.1%)	
Contracted	1 (0.6%)	3 (1.6%)	3 (3.3%)	1 (1.0%)	
Direct patient care	114 (70.4%)	130 (68.8%)	63 (70.0%)	82 (78.8%)	0.09^
Health facility type					0.0005~
Health center	16 (9.9%)	84 (44.4%)	45 (50.0%)	43 (41.3%)	
General hospital	44 (27.2%)	70 (37.0%)	27 (30.0%)	32 (30.8%)	
Hospital center	90 (55.6%)	13 (6.9%)	2 (2.2%)	1 (1.0%)	
Clinic/medical center/private hospital	3 (1.9%)	18 (9.5%)	7 (7.8%)	18 (17.3%)	
Coordinating office	7 (4.3%)	1 (0.5%)	4 (4.4%)	10 (9.6%)	
Other*	2 (1.2%)	3 (1.6%)	3 (3.3%)	0 (0%)	
Unknown	0 (0%)	0 (0%)	2 (2.2%)	0 (0%)	
Ever involved in EVD outbreak					<0.0001^
Yes	7 (4.3%)	97 (51.3%)	32 (35.6%)	44 (42.3%)	
No	155 (95.7%)	92 (48.7%)	54 (60.0%)	51 (49.0%)	
Missing	0 (0%)	0 (0%)	4 (4.4%)	9 (8.7%)	
Ever received EVD vaccine	1 (0.6%)	0 (0%)	40 (44.4%)	104 (100%)	<0.0001^

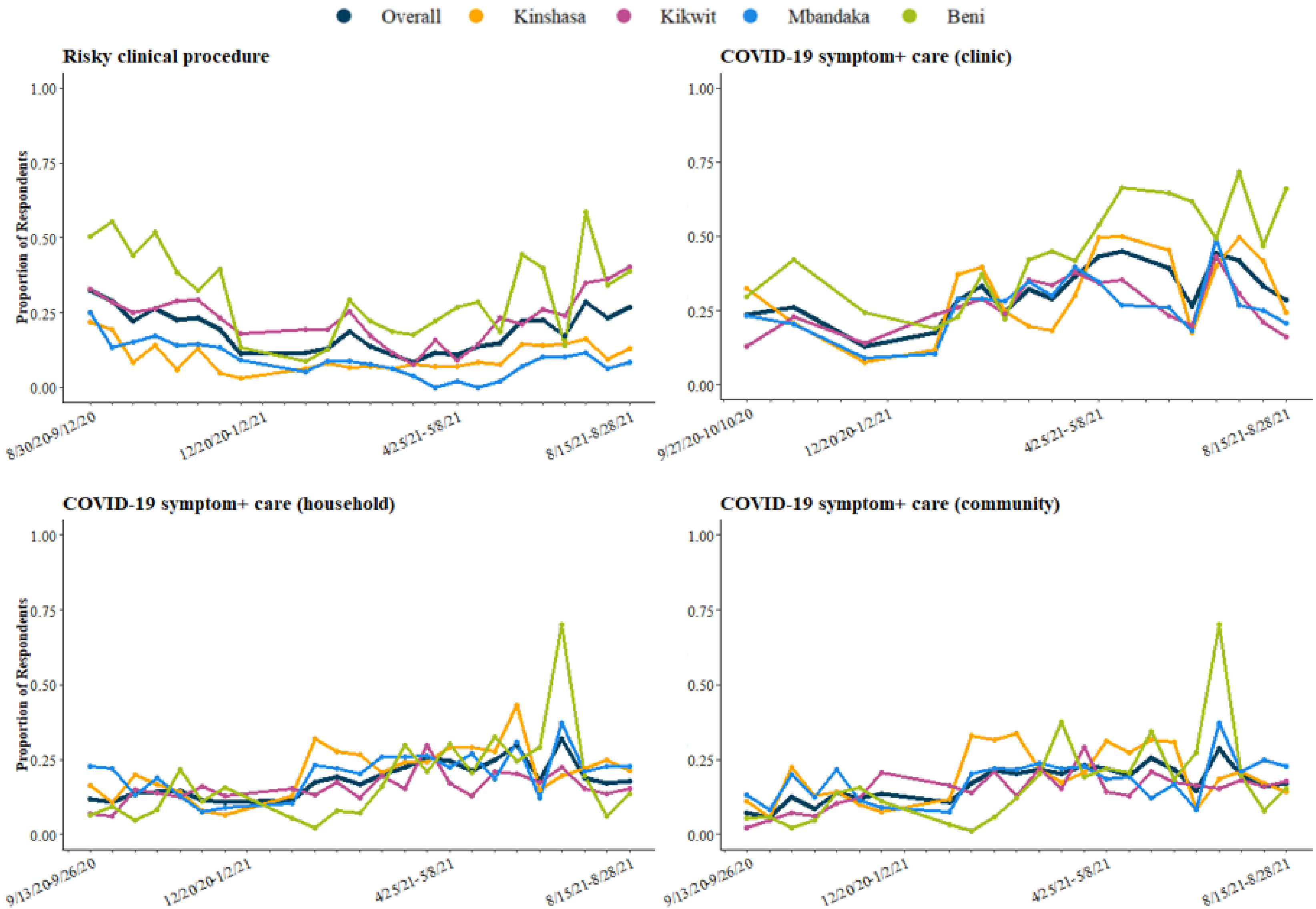
Note: *'Other' health facility types include health post, church, home, etc. Inferential tests of the equality of counts or means between the four groups are noted by: ^ Chi-square test, $^+$ ANOVA, ~ Fisher's exact test.

over time and the time trends varied by location. For example, nearly all (91.3%) of participants from Beni changed their response to having recently performed a risky clinical procedure during the study compared to other three cohorts (range: 53.1-75.1%). Further, 85.6% of the Beni cohort changed their response during the study regarding clinical care for a patient with COVID-19 symptoms compared to 65.6% in Mbandaka, 67.9% in Kinshasa, and 70.4% in Kikwit.

Fewer than a third of respondents reported having performed a risky clinical procedure in terms of COVID-19 infection in the past two weeks in each data collection interval throughout the study (Figure 2.3, Supplemental Table 2.3). A greater proportion of Kikwit respondents reported performing risky clinical procedures compared to the Mbandaka or Kinshasa cohorts throughout the study, but an even larger proportion of the Beni HCWs reported this experience in the beginning and at the end of the study. The proportion of HCWs in each cohort reporting having cared for a COVID-19 symptomatic individual in the last 2 weeks in the clinic, household, and community appeared to increase throughout the study. However, the proportion of overall respondents who cared for COVID-19 symptomatic patients in any settings remained below 45.0 % throughout the study. The proportion of HCWs in the overall sample reporting the belief that a COVID-19 infection is likely, a COVID-19 infection would be severe, or that they were susceptible to a COVID-19 infection never fell below 61.5% (Figure 2.4, Supplemental Table 2.4). The proportion of HCWs in the study reporting all three perceptions remained relatively stable over time with some exceptions particularly among the Beni cohort. Time trend differences between cohorts are particularly distinct in response over time to whether a COVID-19 infection was likely; the proportion of HCWs reporting this outcome in the Kinshasa cohort was greater than the proportion in any other cohort in nearly every data collection interval.

In final fitted model results, the odds of performing a risky clinical procedure for COVID-19 exposure declined significantly among HCWs in Beni and Mbandaka over time but remained stable among HCWs in Kinshasa or Kikwit (Figure 2.5, Supplemental Table 2.5). The slope among the Mbandaka cohort was more negative than those of the Kinshasa and Kikwit cohorts and the slope among the Beni cohort was more negative than that of the Kikwit cohort

Figure 2.3. Observed proportion of respondents over time reporting each experience in the past two weeks, by cohort

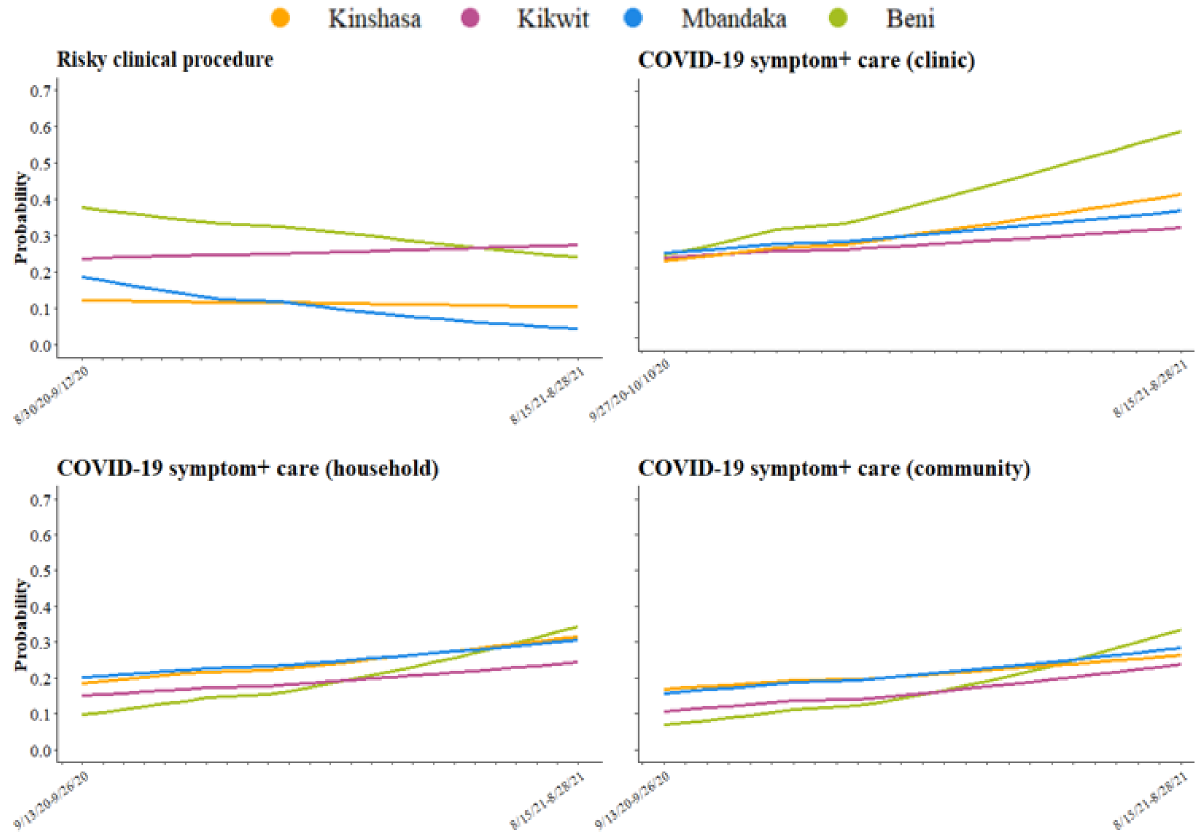


(Supplemental Table 2.6). The fitted probability in the overall sample of having recently performed a risky procedure fell from 23.0% in early-October 2020 to 16.6% in mid-August 2021 (Supplemental Table 2.7). For the three outcomes about caring for a COVID-19 symptomatic patient, the odds of reporting in the affirmative slightly increased among HCWs in each cohort. The positive slopes observed for all three measures were statistically significance among the Kinshasa and Beni cohorts. Comparatively, modest positive slopes in the odds of treating a COVID-19 symptomatic patient in a community setting were significant in the Kikwit and Mbandaka cohorts. The positive slope in odds of treating a COVID-19 symptomatic patient in a household setting was also significant among the Kikwit cohort. Several pairwise comparisons found significant slope differences between the cohorts. By the end of data collection, the fitted probability among the overall sample for caring for a COVID-19 symptomatic patient in a clinic was 41.6% compared to 30.2% and 28.1% in a household and community setting, respectively.

Consistent with the plotted observed proportions, odds of perceiving that a COVID-19 infection is likely were stable across time among each cohort except for a slight increase in odds observed among the Kinshasa cohort (Supplemental Table 2.5). Throughout the study, the Kinshasa cohort consistently had the greatest probability of perceiving that an infection was likely followed by the Mbandaka, Beni, and Kikwit cohorts (Figure 2.6). A slightly positive change in odds of perceiving a COVID-19 infection to be severe over time among the Beni cohort was significantly different from the stable time trend observed among the Mbandaka and Kikwit HCWs. The strongest estimates of change in odds over time were found in reports of susceptibility to COVID-19; a significantly positive slope over time was found among the Kinshasa, Kikwit and Mbandaka HCWs. Odds of reporting susceptibility to COVID-19 infection

Figure 2.4. Observed proportion of respondents over time reporting in the affirmative to each perception, by cohort

Figure 2.5. Fitted predicted probability of reporting each experience in the past two weeks over time, by cohort



	Slope				Pairwise Slope Difference
	Kinshasa	Kikwit	Mbandaka	Beni	
Risky clinical procedure			*	*	Mbandaka vs. Kinshasa Mbandaka vs. Kikwit Beni vs. Kikwit
COVID-19 symptom+ care (clinic)	*			*	Beni vs. Kikwit
COVID-19 symptom+ care (household)	*	*		*	Beni vs. Kinshasa Mbandaka vs. Beni Beni vs. Kikwit
COVID-19 symptom+ care (community)	*	*	*	*	Beni vs. Kinshasa Mbandaka vs. Beni Beni vs. Kikwit

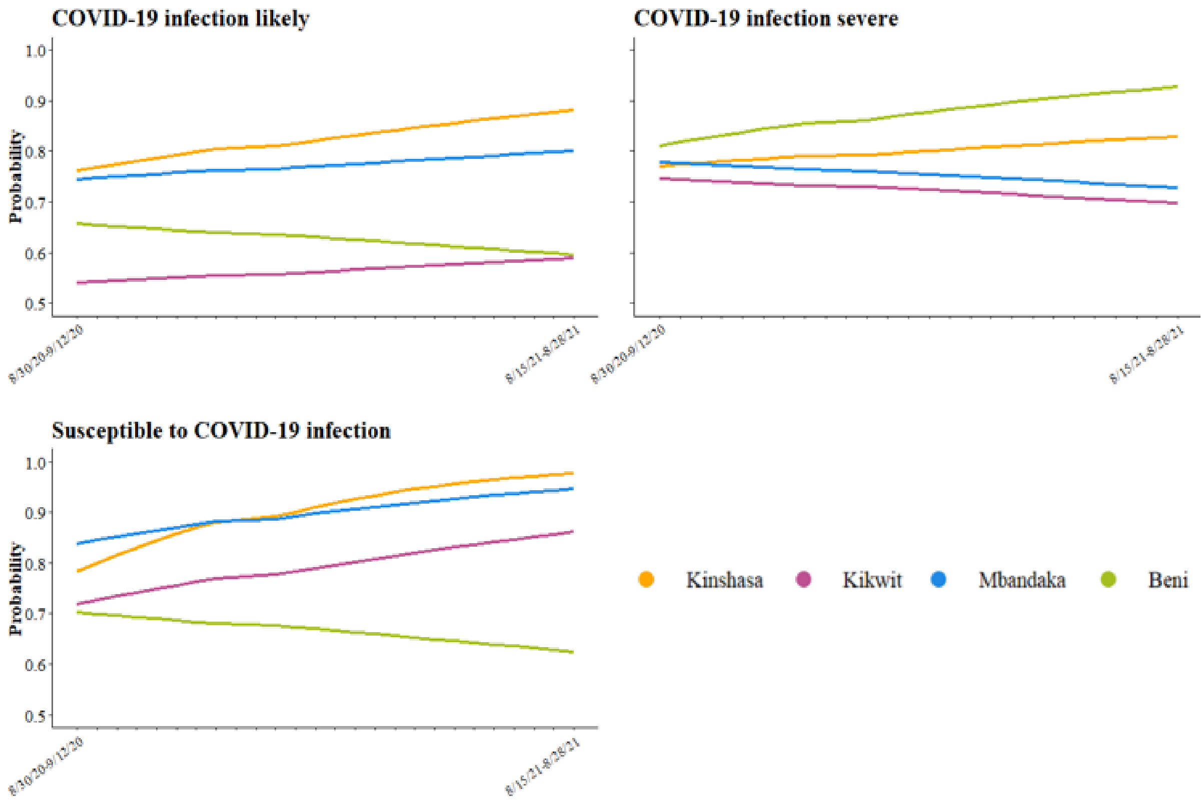
Note. Probabilities presented for a 42 year old male. Asterisk in table indicates statistically significant estimate of change in odds of reporting each experience in the past two weeks and statistically significant difference in this slope between cohorts after adjustment for gender and age. Statistical significance is defined as $p < 0.001$.

among the Beni cohort decreased over time which was a significantly different slope from the three other cohorts.

Sensitivity

Demographic factors did not differ appreciably between the participants included in

Figure 2.6. Fitted predicted probability of reporting in the affirmative to each perception over time, by cohort



	Slope				Pairwise Slope Difference
	Kinshasa	Kikwit	Mbandaka	Beni	
COVID-19 infection likely	*				Beni vs. Kinshasa
COVID-19 infection severe				*	Mbandaka vs. Beni Beni vs. Kikwit
Susceptible to COVID-19 infection	*	*	*		Beni vs. Kinshasa Kikwit vs. Kinshasa Mbandaka vs. Beni Beni vs. Kikwit

Note. Probabilities presented for a 42 year old male. Asterisk in table indicates statistically significant estimate of change in odds of reporting in the affirmative to each and statistically significant difference in this slope between cohorts after adjustment for gender and age. Statistical significance is defined as $p < 0.001$.

analysis and those excluded due to having moved locations during the study (Supplemental Table 2.1). Excluded participants who were ineligible or moved during the study tended to be younger and a greater proportion had a Bachelor or advanced degree compared to the analytic sample. About two-thirds of the ineligible population and those who did not contribute to the longitudinal analysis were female compared to 44.0% within the analytic sample. The included and excluded groups were generally comparable on environment setting, employment status, and the type of health facility at which they worked. Conclusions from final models did not differ when individuals who had moved during the study were included in the analysis as a member of their baseline cohort.

2.5 Discussion

Overall, this study found that the four cohorts of HCWs had distinct demographic profiles. Throughout analysis, the Beni cohort emerged as the most divergent among the four groups. This cohort was younger, more likely to live rurally, and had the largest proportion of HCWs with high school education or less compared to the other cohorts. Predictably, the Kinshasa cohort, who lived and worked in the capital city region, had a greater share of HCWs living in an urban setting and working at either a general referral hospital or a hospital center compared to the other cohorts. The Mbandaka cohort had the greatest proportion of HCWs who had received a Bachelor or advanced degree and the Kikwit cohort had the greatest proportion of full-time workers.

As expected, the Mbandaka and Beni cohorts reported more EVD outbreak involvement compared to Kinshasa. It is notable that over half (51.3%) of the Kikwit participants reported EVD outbreak experience despite the most recent (and only) outbreak in the area having occurred nearly thirty years prior; a possible explanation is the relatively stationary nature of HCWs in DRC as evidenced by only four HCWs moving outside of the study locations between the original enrollment studies and the current study. The HCWs in Kikwit who reported EVD outbreak experience were older on average than those who did not (38.6 compared to 49.9 years old), so it is possible that some of these HCWs were involved in the 1995 EVD outbreak in Kikwit. Given that an EVD outbreak has never taken place in Kinshasa, the seven HCWs in this cohort with EVD outbreak experience likely traveled to another region of DRC as a part of previous EVD response efforts.

Nearly half (17 out of 42; 40.5%) of the pairwise comparisons between cohorts of change over time in reporting each outcome were statistically significant. Given the disproportionate share of COVID-19 cases in Kinshasa and North Kivu provinces compared to Équateur and Kwilu provinces during the study period,[6] it was hypothesized that the HCWs in Kinshasa and Beni (in North Kivu province) would be more likely to report potential exposures to COVID-19. This pattern was not reliably observed in this study, however, particularly among the Kinshasa cohort. Consistent with the hypothesis, the Beni cohort had the greatest probability of performing a risky clinical procedure throughout most of the study. However, this measure could be impacted by differences between the cohorts including access to COVID-19 testing,[4] since several of the reported procedures involved interaction with a COVID-19 positive patient. Since the Beni cohort was recruited based on their involvement in a recent EVD outbreak, it is also possible that this group of HCWs typically performs more intensive clinical procedures during periods of outbreak compared to the other cohorts.

The slight increases over time in probability of treating a patient with COVID-19 symptoms observed in each of the cohorts could be related to more widespread transmission of COVID-19 as the pandemic continued; however, this measure likely also captured care for cases of other diseases that produce similar symptoms to COVID-19 (e.g., malaria, influenza) leading to a poor measure of potential COVID-19 exposure. Further, asymptomatic COVID-19 transmission which is thought to be particularly pervasive in African countries (up to 67% of cases)[35] renders symptom-dependent measures of COVID-19 exposure deeply flawed. It is likely that the HCWs in this study underreported their care of COVID-19 cases because they were unaware of the patient's infection status. This is consistent with the relatively low probability within the overall sample of reporting having cared for a patient with COVID-19 symptoms throughout the study (range: 12.6-41.6%).

As hypothesized, the Kinshasa cohort had the highest probability of believing that a COVID-19 infection was likely throughout the study compared to the other cohorts. The HCWs in Kinshasa were likely more exposed to public health messaging warning of the dangers of COVID-19 and more stringent restrictions during this time of the pandemic compared to the HCWs in other areas of the country. For example, during the period of study follow-up, strict lockdowns and curfews were in place in parts of Kinshasa that did not exist in other areas of the country.[36] The living and working atmosphere in Kinshasa during this period of pandemic was unique among the cohorts and likely contributed to an increase in perceived risk to infection. Interestingly, the probability of believing that a COVID-19 infection would be severe was greatest among the Beni cohort, and the probability of believing oneself to be susceptible to infection was similar within the Kinshasa and Mbandaka cohorts. Perceptions of risk among the Beni cohort tended to be distinct from the other cohorts: overall, HCWs in Beni reported that COVID-19 infection was not particularly likely and that they were not particularly susceptible to infection, but if infected, they thought the health consequences would be severe. HCWs in the other cohorts increasing believed in the likelihood and susceptibility of infection while the probability of believing that an infection would be severe was stable over time. This pattern might be related to differences between the four settings in terms of exposure to public health information or resources available to COVID-19 positive patients.

Not only had the communities of Mbandaka and Beni recently experienced EVD outbreaks prior to this study, both areas also experienced EVD outbreaks concurrent with data collection: an EVD outbreak in Mbandaka began on June 1, 2020 (prior to the beginning of baseline data collection) and ended November 18, 2020 (data collection interval: 11/8/2020-11/21/2020) and an EVD outbreak near Beni began February 7, 2021 (data collection interval: 1/31/2021-2/13/2021) and ended May 3, 2021 (data collection interval: 4/25/2021-5/8/2021). However, contrary to expectations, HCWs from these two EVD-affected areas did not consistently have less perception of risk regarding COVID-19 infection and in fact, had differing trends in reporting these perceptions over time. This suggests that the relationship between risk perception and previous outbreak experience is likely complex requiring more specific measurement of outbreak experience and methods to account for confounding or mediating factors.

The findings of this study should be interpreted considering its limitations. First, the cohorts in this study are not representative of HCWs in the areas of DRC from which they were recruited. All the HCWs from Beni and a portion from Mbandaka were originally recruited based on their EVD response experience; therefore, the HCWs in these cohorts might be more likely to be exposed to symptomatic patients during a subsequent outbreak due to clinical expertise or more likely to perceive less risk of a novel pathogen. Second, data collection for this study began towards the end of the first wave of COVID-19 infection in DRC; therefore, the study baseline is not a true representation of the beginning of the participants' experience with COVID-19. It is likely that unmeasured factors occurring in the first months of the pandemic impacted the cohorts' possible exposures to COVID-19 infection and their risk perceptions. Third, the regression models used in this study only control for confounding contributed by gender and age measures. This decision was made for two reasons: 1) as the predictor of interest is location, it is unlikely that most factors considered for confounding would have an effect on the location a

HCW lives, and 2) there is little a priori knowledge of associations between the predictor and outcomes of interest and other factors among this population. Given that location is likely to impact many covariate measures and there is little existing understanding of these relationships in this population, it is possible that these factors mediate the pathway between location and the outcomes rather than confound. Fourth, outcome responses were collapsed into dichotomous categories possibly obscuring important variation in outcome response. However, affirmative and negative responses to outcome variables were generally concentrated in a single category of the Likert scale response options. Therefore, response detail was likely not lost by combining categories together for analysis and practical interpretation. Finally, temporally dependent factors, such as waves of COVID-19 transmission, outbreaks of other infectious disease, infection control policies, and holidays in each community, likely impacted the HCWs' likelihood of caring for COVID-19 patients and perceptions of risk. However, either these events were not measured by this study or case data at the province or health zone level was unavailable.

This is the only longitudinal study (to the authors' knowledge) to collect a robust set of measures from HCWs in DRC throughout a year of the COVID-19 pandemic. Frequent data collection throughout the year of follow-up allowed for more precise examination of longitudinal patterns in measures of interest. Therefore, the associations explored among these populations are novel contributions to the literature. Recruitment from four city areas in four different provinces further allowed for the comparison of the HCW cohorts at the subnational level. Retention in the study was relatively high and there was minimal missing data among successful follow-up data collection. Using an outcome-wide analytic method provides several advantages as well: 1) more information is presented, including null results, that will inform subsequent theorizing compared to a single exposure-outcome analysis, 2) as modeling choices were made across models there is less opportunity for bias by investigator choice, and 3) clear and direct comparison of effect sizes among this population is possible.[37]

As this is likely one of the only studies, if not the first, to examine these specific outcomes longitudinally among HCWs from different areas of DRC, this study provides an opportunity to guide further hypothesis generation. First, fluctuation in potential exposures to COVID-19 and perceived risk of infection over time, albeit relatively moderate, indicates that these measures among HCWs were not static throughout the pandemic. Further, differences observed between cohorts support the conclusion that knowledge, attitudes, and practices related to outbreak response in DRC are not consistent across the country. Future research should focus on more accurate measurement of infection risk during outbreaks experienced by HCWs in DRC; this insight would have important implications for more effective resource allocation, training, and IPC policies contributing to a safer health workforce. Likewise, monitoring differences in perceived risk to an emerging pathogen, especially among HCWs, might indicate which subpopulations are more likely to comply with recommended IPC behaviors. The heterogeneity in the experiences and attitudes reported in this study indicate that needs among the health workforce in DRC are likely community-specific during an outbreak. It is vital to use the COVID-19 pandemic as an opportunity to better understand the patterns and nuances of these needs to mount a more robust and equitable response to the next emerging pathogen.

2.6 Appendix

Supplemental Table 2.1. Comparison of sample characteristics at study baseline between participants included in analysis (N=545) and three groups of participants excluded from analysis

	Included	**Excluded**		
	(N=545) *n* (%)	Ineligible for participation* (N=16) *n* (%)	Moved during follow-up (N=10) *n* (%)	No contribution to outcome measures (N=17) *n* (%)
Location				
Kinshasa	162 (29.7%)	2 (12.5%)	0 (0%)	9 (52.9%)
Kikwit	189 (34.7%)	1 (6.3%)	2 (20.0%)	4 (23.5%)
Mbandaka	90 (16.5%)	2 (12.5%)	8 (80.0%)	0 (0%)
Beni	104 (19.1%)	6 (37.5%)	0 (0%)	4 (23.5%)
Other	0 (0%)	5 (31.3%)	0 (0%)	0 (0%)
Gender				
Male	305 (56.0%)	6 (37.5%)	7 (70.0%)	6 (35.3%)
Female	240 (44.0%)	10 (62.5%)	3 (30.0%)	11 (64.7%)
Age, continuous				
Mean (SD)	43.4 (12.1)	32.1 (8.81)	38.7 (6.52)	43.9 (10.7)
Median [Min, Max]	42.0 [20.0, 81.0]	30.0 [22.0, 60.0]	39.0 [27.0, 49.0]	43.0 [25.0, 65.0]
Education				
H.S. or less	84 (15.4%)	3 (18.8%)	2 (20.0%)	5 (29.4%)
Some college/Assoc.	357 (65.5%)	5 (31.3%)	3 (30.0%)	9 (52.9%)
Bach./Advanced deg.	104 (19.1%)	8 (50.0%)	5 (50.0%)	3 (17.6%)
Chronic disease	45 (8.3%)	0 (0%)	0 (0%)	1 (5.9%)
Environment setting				
Urban	360 (66.1%)	10 (62.5%)	7 (70.0%)	13 (76.5%)
Rural	185 (33.9%)	6 (37.5%)	3 (30.0%)	4 (23.5%)
Employment status				
Full-time	388 (71.2%)	4 (25.0%)	7 (70.0%)	14 (82.4%)
Part-time	149 (27.3%)	4 (25.0%)	2 (20.0%)	3 (17.6%)
Contracted	8 (1.5%)	0 (0%)	1 (10.0%)	0 (0%)
Unemployed	0 (0%)	8 (50.0%)	0 (0%)	0 (0%)
Direct patient care	389 (71.4%)	11 (68.8%)	7 (70.0%)	10 (58.8%)
Health facility type				
Health center	188 (34.5%)	5 (31.3%)	3 (30.0%)	5 (29.4%)
General hospital	173 (31.7%)	1 (6.3%)	3 (30.0%)	2 (11.8%)
Hospital center	106 (19.4%)	0 (0%)	1 (10.0%)	8 (47.1%)
Clinic/medical center/private hospital	46 (8.4%)	1 (6.3%)	2 (20.0%)	2 (11.8%)
Coordinating office	22 (4.0%)	1 (6.3%)	0 (0%)	0 (0%)
Other	8 (1.5%)	0 (0%)	1 (10.0%)	0 (0%)
Unknown	2 (0.4%)	0 (0%)	0 (0%)	0 (0%)
Unemployed	0 (0%)	8 (50.0%)	0 (0%)	0 (0%)
Ever involved in EVD outbreak				
Yes	180 (33.0%)	2 (12.5%)	2 (20.0%)	6 (35.3%)
No	352 (64.6%)	12 (75.0%)	8 (80.0%)	11 (64.7%)
Missing	13 (2.4%)	2 (12.5%)	0 (0%)	0 (0%)
Ever received EVD vaccine	145 (26.6%)	10 (62.5%)	5 (50.0%)	4 (23.5%)

Note. * Individuals who did not live within Kinshasa, Kikwit, Mbandaka, or Beni at baseline or who did not work in healthcare throughout the study.

Supplemental Table 2.2. Proportion of participants in each cohort who consistently responded 'yes', 'no', or changed response for each outcome across all responses in the study

	Kinshasa			**Kikwit**			**Mbandaka**			**Beni**			**Overall**		
	Yes	*No*	*Changed*	*Yes*	*No*	*Changed*	*Yes*	*No*	*Changed*	*Yes*	*No*	*Changed*	*Yes*	*No*	*Changed*
Risky clinical procedure performed, last 2wks	0.0	46.9	53.1	1.6	23.3	75.1	1.1	43.3	55.6	1.0	7.7	91.3	0.9	30.6	68.4
COVID-19 symptom+ care (clinic), last 2wks	1.2	30.9	67.9	2.6	27.0	70.4	1.1	33.3	65.6	1.0	13.5	85.6	1.7	26.6	71.7
COVID-19 symptom+ care (household), last 2wks	0.0	33.3	66.7	0.0	26.5	73.5	0.0	33.3	66.7	0.0	27.9	72.1	0.0	29.9	70.1
COVID-19 symptom+ care (community), last 2wks	0.0	37.0	63.0	0.0	27.5	72.5	0.0	30.0	70.0	0.0	34.6	65.4	0.0	32.1	67.9
COVID-19 infection likely	28.4	1.2	70.4	9.5	0.5	89.9	24.4	0.0	75.6	11.5	1.9	86.5	18.0	0.9	81.1
COVID-19 infection severe	28.4	0.0	71.6	15.3	0.0	84.7	25.6	1.1	73.3	32.7	0.0	67.3	24.2	0.2	75.6
Susceptible to COVID-19 infection	35.2	0.6	64.2	24.3	0.0	75.7	35.6	1.1	63.3	12.5	1.0	86.5	27.2	0.6	72.3

Supplemental Table 2.3. Observed proportion of respondents reporting that they performed each behavior in the past two weeks over time

Data collection interval	Num. of respondents	Risky clinical procedure	COVID-19 symptom+ care (clinic)	COVID-19 symptom+ care (household)	COVID-19 symptom+ care (community)
8/30/20-9/12/20	n=473	153 (32.3%)	-	-	-
9/13/20-9/26/20	n=468	135 (28.8%)	-	56 (12.0%)	34 (7.3%)
9/27/20-10/10/20	n=424	95 (22.4%)	100 (23.6%)	46 (10.8%)	25 (5.9%)
10/11/20-10/24/20	n=436	115 (26.4%)	-	61 (14.0%)	55 (12.6%)
10/25/20-11/7/20	n=397	90 (22.7%)	103 (25.9%)	57 (14.4%)	34 (8.6%)
11/8/20-11/21/20	n=355	83 (23.4%)	-	52 (14.6%)	49 (13.8%)
11/22/20-12/5/20	n=338	66 (19.5%)	-	39 (11.5%)	41 (12.1%)
12/6/20-12/19/20	n=288	33 (11.5%)	37 (12.8%)	31 (10.8%)	39 (13.5%)
1/17/21-1/30/21	n=345	40 (11.6%)	61 (17.7%)	40 (11.6%)	37 (10.7%)
1/31/21-2/13/21	n=391	51 (13.0%)	112 (28.6%)	68 (17.4%)	67 (17.1%)
2/14/21-2/27/21	n=286	53 (18.5%)	95 (33.2%)	55 (19.2%)	61 (21.3%)
2/28/21-3/13/21	n=396	55 (13.9%)	97 (24.5%)	66 (16.7%)	80 (20.2%)
3/14/21-3/27/21	n=320	35 (10.9%)	103 (32.2%)	64 (20.0%)	70 (21.9%)
3/28/21-4/10/21	n=286	24 (8.4%)	83 (29.0%)	64 (22.4%)	58 (20.3%)
4/11/21-4/24/21	n=336	39 (11.6%)	122 (36.3%)	86 (25.6%)	78 (23.2%)
4/25/21-5/8/21	n=310	34 (11.0%)	134 (43.2%)	76 (24.5%)	68 (21.9%)
5/9/21-5/22/21	n=360	49 (13.6%)	162 (45.0%)	77 (21.4%)	71 (19.7%)
5/23/21-6/5/21	n=342	51 (14.9%)	-	85 (24.9%)	87 (25.4%)
6/6/21-6/19/21	n=308	68 (22.1%)	121 (39.3%)	92 (29.9%)	67 (21.8%)
6/20/21-7/3/21	n=305	69 (22.6%)	81 (26.6%)	55 (18.0%)	45 (14.8%)
7/4/21-7/17/21	n=349	60 (17.2%)	154 (44.1%)	111 (31.8%)	101 (28.9%)
7/18/21-7/31/21	n=334	96 (28.7%)	139 (41.6%)	63 (18.9%)	66 (19.8%)
8/1/21-8/14/21	n=335	78 (23.3%)	111 (33.1%)	57 (17.0%)	54 (16.1%)
8/15/21-8/28/21	n=318	85 (26.7%)	91 (28.6%)	57 (17.9%)	54 (17.0%)
Total respondents		545	526	535	535
Total responses		8500	6029	8027	8027

Supplemental Table 2.4. Observed proportion of respondents reporting in the affirmative to each perception over time

Data collection interval	Num. of respondents	COVID-19 infection likely	COVID-19 infection severe	Susceptible to COVID-19 infection
8/30/20-9/12/20	n=473	309 (65.3%)	363 (76.7%)	378 (79.9%)
9/13/20-9/26/20	n=468	305 (65.2%)	371 (79.3%)	379 (81.0%)
9/27/20-10/10/20	n=424	298 (70.3%)	356 (84.0%)	346 (81.6%)
10/11/20-10/24/20	n=436	317 (72.7%)	369 (84.6%)	369 (84.6%)
10/25/20-11/7/20	n=397	286 (72.0%)	356 (89.7%)	347 (87.4%)
11/8/20-11/21/20	n=355	238 (67.0%)	282 (79.4%)	265 (74.6%)
11/22/20-12/5/20	n=338	212 (62.7%)	261 (77.2%)	260 (76.9%)
12/6/20-12/19/20	n=288	196 (68.1%)	240 (83.3%)	210 (72.9%)
1/17/21-1/30/21	n=345	234 (67.8%)	309 (89.6%)	267 (77.4%)
1/31/21-2/13/21	n=391	268 (68.5%)	334 (85.4%)	303 (77.5%)
2/14/21-2/27/21	n=286	202 (70.6%)	213 (74.5%)	176 (61.5%)
2/28/21-3/13/21	n=396	271 (68.4%)	317 (80.1%)	294 (74.2%)
3/14/21-3/27/21	n=320	230 (71.9%)	274 (85.6%)	264 (82.5%)
3/28/21-4/10/21	n=286	219 (76.6%)	254 (88.8%)	274 (95.8%)
4/11/21-4/24/21	n=336	241 (71.7%)	286 (85.1%)	310 (92.3%)
4/25/21-5/8/21	n=310	223 (71.9%)	249 (80.3%)	277 (89.4%)
5/9/21-5/22/21	n=360	232 (64.4%)	311 (86.4%)	325 (90.3%)
5/23/21-6/5/21	n=342	223 (65.2%)	282 (82.5%)	293 (85.7%)
6/6/21-6/19/21	n=308	226 (73.4%)	269 (87.3%)	264 (85.7%)
6/20/21-7/3/21	n=305	210 (68.9%)	252 (82.6%)	261 (85.6%)
7/4/21-7/17/21	n=349	278 (79.7%)	315 (90.3%)	334 (95.7%)
7/18/21-7/31/21	n=334	248 (74.3%)	267 (79.9%)	302 (90.4%)
8/1/21-8/14/21	n=335	258 (77.0%)	276 (82.4%)	283 (84.5%)
8/15/21-8/28/21	n=318	216 (67.9%)	252 (79.2%)	268 (84.3%)
Total respondents		545	545	545
Total responses		8477	8477	8477

Supplemental Table 2.5. Estimated change in odds of reporting each outcome over time, by cohort

	Kinshasa			Kikwit			Mbandaka			Beni		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Risky clinical procedure performed, last 2wks	0.99	(0.97, 1.01)	0.39	1.01	(1.00, 1.02)	0.14	0.93	(0.91, 0.96)	<.0001	0.97	(0.96, 0.99)	0.0001
COVID-19 symptom+ care (clinic), last 2wks	1.05	(1.03, 1.07)	<.0001	1.02	(1.01, 1.04)	0.01	1.03	(1.01, 1.06)	0.01	1.08	(1.06, 1.11)	<.0001
COVID-19 symptom+ care (household), last 2wks	1.04	(1.02, 1.05)	<.0001	1.03	(1.02, 1.05)	<.0001	1.03	(1.01, 1.05)	0.01	1.08	(1.06, 1.11)	<.0001
COVID-19 symptom+ care (community), last 2wks	1.03	(1.01, 1.05)	0.0002	1.05	(1.03, 1.07)	<.0001	1.04	(1.02, 1.06)	0.0004	1.10	(1.08, 1.13)	<.0001
COVID-19 infection likely	1.04	(1.02, 1.06)	<.0001	1.01	(1.00, 1.02)	0.07	1.02	(1.00, 1.03)	0.12	0.99	(0.97, 1.00)	0.09
COVID-19 infection severe	1.02	(1.00, 1.04)	0.02	0.99	(0.98, 1.00)	0.04	0.99	(0.97, 1.01)	0.16	1.05	(1.03, 1.08)	<.0001
Susceptible to COVID-19 infection	1.11	(1.09, 1.14)	<.0001	1.04	(1.03, 1.06)	<.0001	1.05	(1.03, 1.08)	0.0002	0.98	(0.97, 1.00)	0.03

Note. All models are adjusted for gender and age and account for clustering at the individual level.

Supplemental Table 2.6. Pairwise comparisons between cohorts of estimated change in odds of reporting each outcome over time

	Beni vs. Kinshasa			Kikwit vs. Kinshasa			Mbandaka vs. Kinshasa		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Risky clinical procedure performed, last 2wks	0.98	(0.96, 1.00)	0.07	1.02	(1.00, 1.04)	0.13	0.94	(0.91, 0.97)	0.0004
COVID-19 symptom+ care (clinic), last 2wks	1.03	(1.01, 1.06)	0.01	0.98	(0.95, 1.00)	0.04	0.98	(0.95, 1.01)	0.25
COVID-19 symptom+ care (household), last 2wks	1.05	(1.02, 1.07)	0.0009	0.99	(0.97, 1.02)	0.59	0.99	(0.97, 1.02)	0.57
COVID-19 symptom+ care (community), last 2wks	1.07	(1.04, 1.10)	<.0001	1.02	(1.00, 1.04)	0.08	1.01	(0.98, 1.04)	0.47
COVID-19 infection likely	0.95	(0.93, 0.97)	<.0001	0.97	(0.95, 0.99)	0.003	0.98	(0.95, 1.00)	0.06
COVID-19 infection severe	1.04	(1.00, 1.07)	0.03	0.97	(0.95, 0.99)	0.003	0.97	(0.94, 0.99)	0.01
Susceptible to COVID-19 infection	0.88	(0.86, 0.91)	<.0001	0.94	(0.91, 0.96)	<.0001	0.95	(0.91, 0.98)	0.01
	Beni vs. Kikwit			**Mbandaka vs. Beni**			**Mbandaka vs. Kikwit**		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Risky clinical procedure performed, last 2wks	0.98	(0.94, 0.98)	<.0001	0.96	(0.93, 0.99)	0.02	0.93	(0.90, 0.95)	<.0001
COVID-19 symptom+ care (clinic), last 2wks	1.06	(1.03, 1.09)	<.0001	0.95	(0.92, 0.98)	0.002	0.95	(0.92, 0.98)	0.002
COVID-19 symptom+ care (household), last 2wks	1.05	(1.02, 1.08)	0.0002	0.95	(0.92, 0.98)	0.0006	1.00	(0.97, 1.02)	0.91
COVID-19 symptom+ care (community), last 2wks	1.05	(1.02, 1.08)	0.0006	0.94	(0.91, 0.97)	0.0002	0.99	(0.96, 1.02)	0.47
COVID-19 infection likely	0.98	(0.96, 1.00)	0.01	1.03	(1.00, 1.05)	0.02	1.01	(0.98, 1.03)	0.62
COVID-19 infection severe	1.07	(1.04, 1.10)	<.0001	0.93	(0.91, 0.97)	<.0001	1.00	(0.98, 1.02)	0.93
Susceptible to COVID-19 infection	0.94	(0.93, 0.96)	<.0001	1.07	(1.04, 1.11)	<.0001	1.01	(0.98, 1.05)	0.43

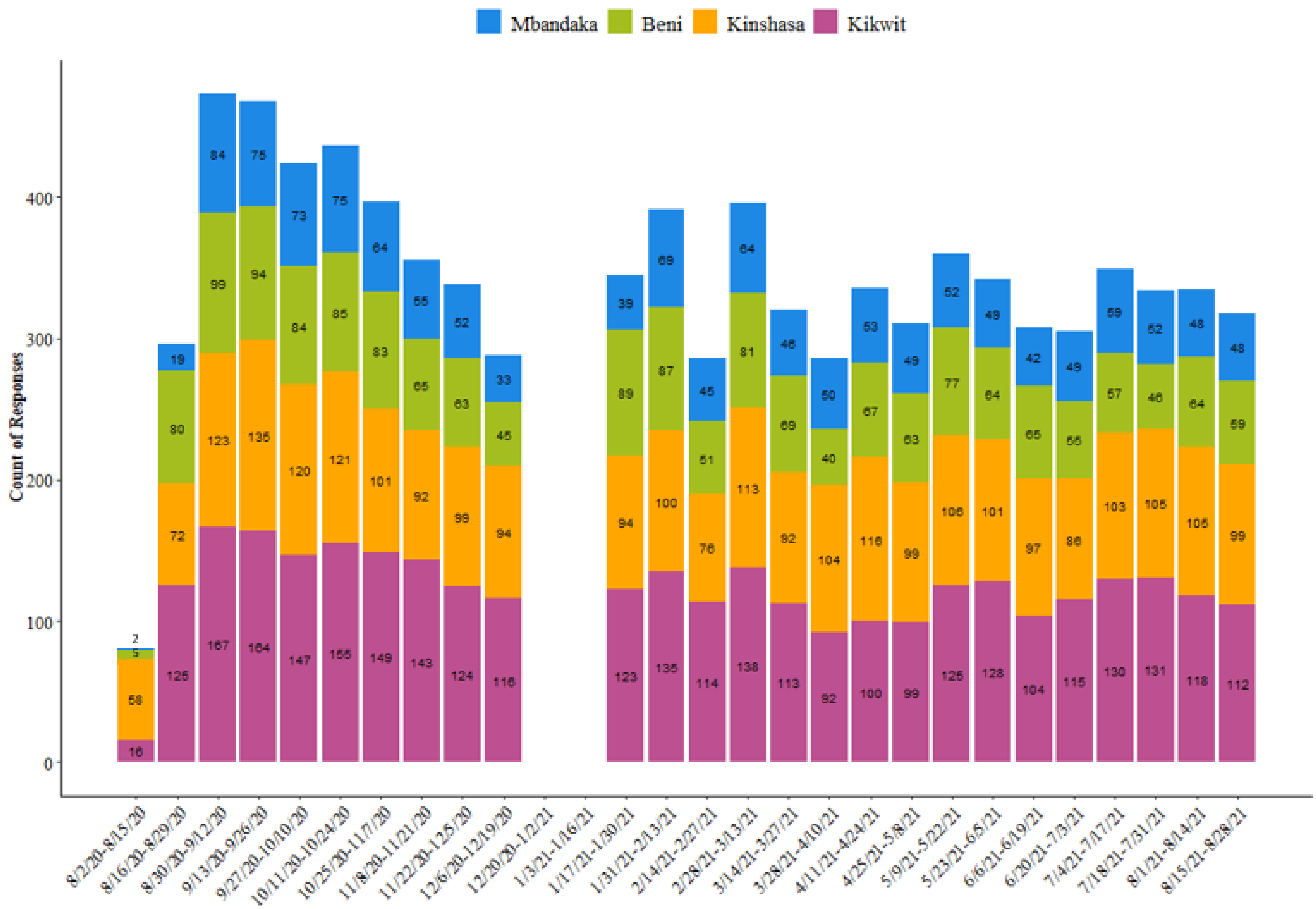
Note. All models are adjusted for gender and age and account for clustering at the individual level.

Supplemental Table 2.7. Fitted predicted probabilities overall in each data collection interval of reporting each COVID-19 prevention behavior

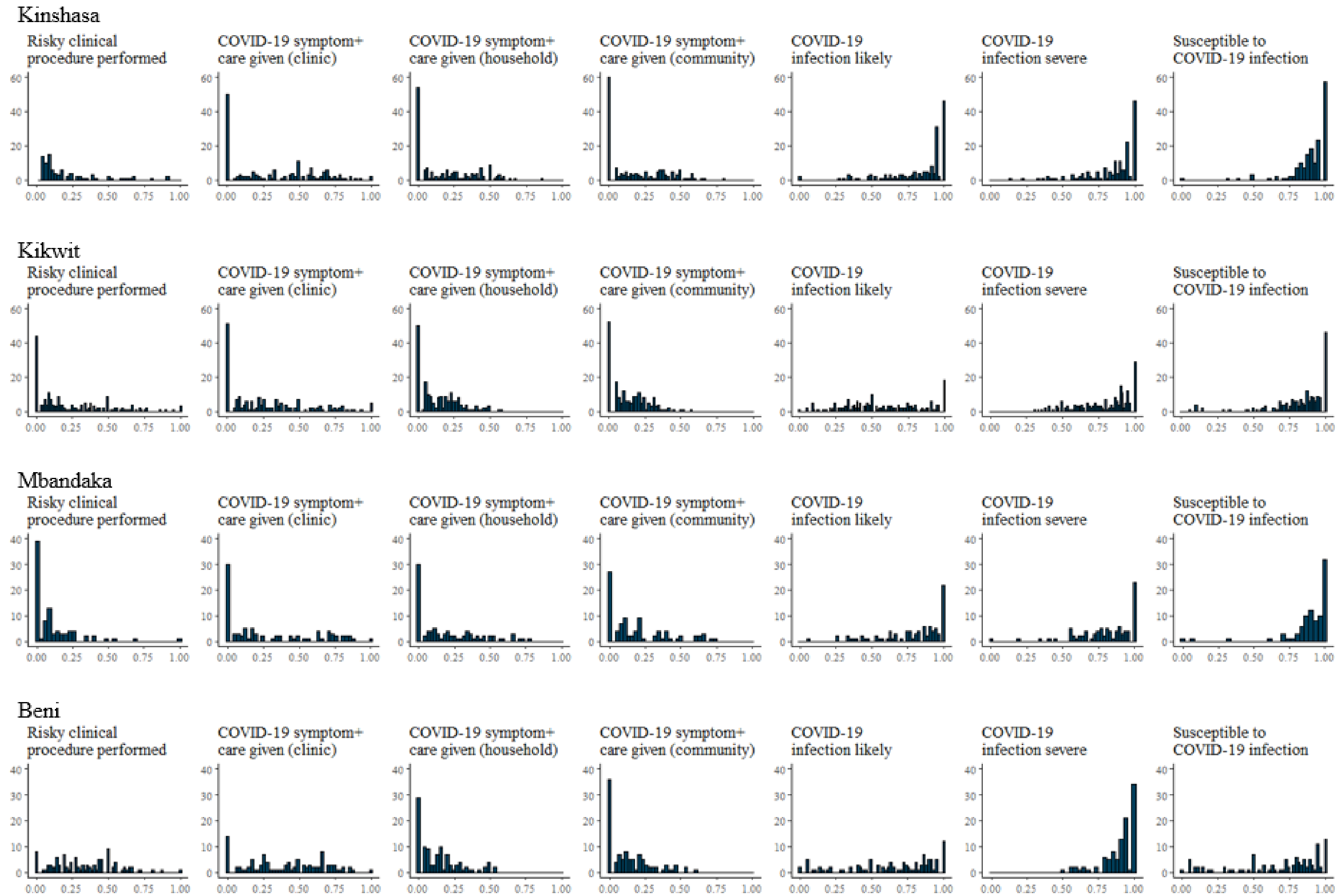
Data collection interval	Risky clinical procedure performed	COVID-19 symptom+ care (clinic)	COVID-19 symptom+ care (household)	COVID-19 symptom+ care (community)	COVID-19 infection likely	COVID-19 infection severe	Susceptible to COVID-19 infection
8/30/20-9/12/20	23.1	-	-	-	67.6	77.7	76.1
9/13/20-9/26/20	22.8	-	15.9	12.6	67.8	77.8	76.8
9/27/20-10/10/20	22.4	23.0	16.4	13.1	68.0	78.0	77.4
10/11/20-10/24/20	22.0	-	16.9	13.6	68.2	78.1	78.1
10/25/20-11/7/20	21.6	24.5	17.4	14.1	68.4	78.2	78.7
11/8/20-11/21/20	21.3	-	18.0	14.6	68.6	78.3	79.3
11/22/20-12/5/20	20.9	-	18.5	15.2	68.8	78.4	79.8
12/6/20-12/19/20	20.6	27.0	19.1	15.7	69.0	78.5	80.3
1/17/21-1/30/21	20.3	27.8	19.7	16.3	69.2	78.6	80.8
1/31/21-2/13/21	20.0	28.6	20.3	17.0	69.4	78.7	81.2
2/14/21-2/27/21	19.7	29.5	20.9	17.6	69.6	78.8	81.7
2/28/21-3/13/21	19.4	30.4	21.5	18.3	69.8	78.9	82.1
3/14/21-3/27/21	19.1	31.3	22.1	19.0	69.9	79.0	82.5
3/28/21-4/10/21	18.8	32.2	22.8	19.7	70.1	79.1	82.8
4/11/21-4/24/21	18.6	33.1	23.5	20.4	70.3	79.1	83.1
4/25/21-5/8/21	18.3	34.0	24.2	21.2	70.4	79.2	83.4
5/9/21-5/22/21	18.1	35.0	24.9	22.0	70.6	79.3	83.7
5/23/21-6/5/21	17.9		25.6	22.8	70.8	79.3	84.0
6/6/21-6/19/21	17.6	36.9	26.3	23.6	70.9	79.4	84.2
6/20/21-7/3/21	17.4	37.8	27.1	24.5	71.1	79.4	84.5
7/4/21-7/17/21	17.2	38.8	27.8	25.3	71.2	79.5	84.7
7/18/21-7/31/21	17.0	39.7	28.6	26.2	71.4	79.5	84.9
8/1/21-8/14/21	16.8	40.7	29.4	27.2	71.5	79.5	85.1
8/15/21-8/28/21	16.6	41.6	30.2	28.1	71.6	79.6	85.2

Note. Fitted predicted probabilities presented for a 42 year old male.

Supplemental Figure 2.1. Response count in each data collection interval by cohort



Supplemental Figure 2.2. Within-person average values of each repeated measure across data collection – performed each behavior in the past two weeks or reported in the affirmative to each perception



Note. If a participant has an average value of 1.0 across the repeated measures contributed to the study, this indicates that the participant responded in the affirmative to the measure at each time point of response. Likewise, a participant with an average value of 0.0 dissented at each response point. An average value between 0.0 and 1.0 indicates the individual changed their response at least once throughout the study.

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Chapter 3. Perceived efficacy of COVID-19 prevention behavior and adherence to prevention measures in four cohorts of healthcare workers during the COVID-19 pandemic in the Democratic Republic of the Congo

3.1 Abstract

Monitoring perceptions of recommended COVID-19 prevention measures and adherence to these measures among healthcare workers (HCWs) is critical to a successful national outbreak response. However, in the Democratic Republic of the Congo (DRC), assessments of these measures are limited to cross-sectional data collected at the beginning of the COVID-19 pandemic. Perceptions of efficacy of and compliance with six standard COVID-19 prevention measures were collected longitudinally among four cohorts of HCWs in DRC between August 2020 and August 2021 (N=545, with 23 possible data collection points). Each outcome was assessed descriptively while mask wearing, avoiding gatherings, and socially distancing in the past two weeks were further analyzed with mixed effect models to assess association with direct patient care responsibility and location. Perceptions of efficacy of each of the six prevention measures as well as handwashing, avoiding touching the face, and using disinfectants were reported by most of the sample consistently throughout the study (range: 84.2%-100.0%). Fluctuations in compliance with mask wearing, avoiding gatherings, and socially distancing were observed; in particular, a significant decrease in probability of mask wearing from late-January to mid-August 2021 (81.9% to 48.0%). No outcome assessed longitudinally was related to direct patient care duties, but the change in odds of mask wearing, avoiding gatherings, and socially distancing over time did differ by location. HCWs in DRC likely have high perceptions of efficacy of standard infection prevention and control measures, and therefore, additional resources need not be allocated to impact these attitudes. Instead, additional research should be

done to determine what community-level factors influence consistent HCW compliance with infection prevention measures, such as mask wearing, at a subnational level in DRC to inform future outbreak response efforts.

3.2 Background

The health workforce, including personnel working in health facilities regardless of whether they provide clinical services, serve in supportive functions, or are in training, is one of the most precious resources a country has in combatting an outbreak. Thus, a healthy workforce is an essential prerequisite for any well-performing health system. However, in lower-resourced countries such as the Democratic Republic of the Congo (DRC), frequent infectious disease outbreaks, underdeveloped infrastructure, and even instability and conflict are considerable challenges to the safety of healthcare workers (HCWs). Especially during outbreaks, frontline workers are a high-risk population for morbidity and mortality due to direct contact with patients and can be powerful amplifiers of pathogen transmission.[1-3] It is imperative that HCWs adhere to infection prevention and control (IPC) recommendations for their own safety as well as the safety of their patients and the community at large.

COVID-19 IPC guidelines published by various public health agencies are consistent in certain behavioral recommendations to prevent the spread of COVID-19. From early in the pandemic, enhanced hygiene behaviors (e.g., washing hands frequently, disinfection), wearing face masks, postponing travel, and physical distancing and limiting contacts (e.g., keeping a safe distance from others and avoiding crowded areas) were recommended particularly for essential workers and individuals in close contact with COVID-19 cases such as frontline HCWs.[4-7] Adoption of prevention behaviors during infectious disease outbreaks varies and is related to a network of factors, such as perceptions of risk, efficacy of the particular prevention behavior, and ability to perform the behavior.[8,9] A study conducted in the United Kingdom and the Netherlands in 2020,[5] found that in a complex psychological system, the perception that a behavior was effective at COVID-19 prevention had one of the strongest positive relationships with adoption of that behavior. Further, this relationship differed in strength between the two samples. It is, therefore, vital to outbreak response to monitor infection prevention behavior adoption, promote the efficacy of prevention measures, and acknowledge that these measures and their relationship likely differ by country and community. However, the extent of perceived efficacy regarding recommended COVID-19 prevention behaviors among HCWs in DRC as well as their compliance with these recommendations throughout the pandemic is poorly understood.

Investigations of knowledge, attitudes, and practices (KAP) related to COVID-19 prevention measures among the Congolese population are limited to cross-sectional studies completed early in the pandemic. Akilimali et al.[10] conducted random household interviews in three health zones within Kinshasa province in June 2020. Awareness of current COVID-19 prevention measures varied within the sample from 33.0% reporting that avoiding touching the face with unclean hands was a prevention measure to 88.5% for frequent hand cleaning. Most participants knew that wearing a face mask (86.9%), physical distancing (80.3%), and avoiding unnecessary travel outside the home (53.0%) were COVID-19 prevention measures. The proportion of this study population reporting awareness did differ by community for several measures (e.g., avoiding touching face, frequent hand cleaning, physical distancing, avoiding travel). Overall, 77.5% of the participants believed that the prevention measures could stop COVID-19 transmission. Michel-Kabamba et al.[11] assessed KAP related to COVID-19 in DRC in HCWs at 23 general referral hospitals in three town areas in different provinces of DRC from March to April 2020. Most HCWs in the study knew that medical masks and avoiding crowded places and public transportation can prevent infection with COVID-19 (78.5% and 92.3%, respectively). In both cases, correct knowledge did not significantly differ between doctors and other HCWs (e.g., nurses, midwives, laboratory technicians). This study did not compare HCW knowledge of effective COVID-19 prevention measures between the three localities or control for location in analysis.

More studies in DRC have measured COVID-19 prevention behavior than perceived efficacy of those behaviors but they are similarly constrained by cross-sectional data collection. Akilimali et al.[10] found that reported COVID-19 prevention behavior among their sample in Kinshasa in June 2020 varied widely by behavior: wore a face mask (86.0%), regularly washed hands (85.7%), physically distanced (72.0%), avoided public gatherings (64.3%), reduced their exposure to closed spaces (53.3%), and avoided touching their face with unclean hands (35.1%). Comparatively, Michel-Kabamba et al.[11] found lower levels of compliance among their HCW sample from other areas of DRC: about half (54.9%) consistently used PPE in the clinical setting, half (49.4%) consistently wore masks, and 39.8% avoided crowded places. A slightly greater proportion of doctors reported each behavior compared to other HCWs. Ditekemena et al.[12] conducted an online-based cross-sectional study among a general population sample from five provinces from April to June 2020 and these data were utilized in a multi-country study[13] in which DRC was compared to five other countries in sub-Saharan Africa (SSA). Adherence to COVID-19 prevention measures varied greatly by province: most participants from Kinshasa and North Kivu (79.2% and 92.0%, respectively) reported wearing a mask compared to 16.7% in Haut-Katanga, 14.1% in Kasi-Oriental and 4.5% in Kasai-Central. Generally, Kinshasa, the capital city of DRC and the area with the most resources, and North Kivu, the location of an extensive Ebola virus disease (EVD) outbreak that ended just before the start of the COVID-19 pandemic, had greater compliance compared to the other areas. Non-HCWs in this study had nearly twice the odds of poor adherence to COVID-19 prevention measures compared to HCWs (aOR: 1.85, 95% CI: 1.52, 2.27). Overall, participants from DRC were found to have the lowest adherence to prevention measures compared to the five other SSA countries. Another study among women in Kinshasa completed in June 2020 found high compliance with COVID-19 prevention measures: more than 90% reported washing hands, using sanitizer, socially distancing, and mask wearing.[14] However, in a study in which women at antenatal appointments in Kinshasa between August 2020 and January 2021 were observed by interviewers rather than asked to self-report, 33.1% wore a face mask, among whom only 10.7% wore the mask correctly.[15] Among other factors, differences in measurement of behavior likely contributed to the discrepancies observed in the compliance estimated by these studies.

Outbreak response efforts for emerging diseases in a large low-resource country, such as DRC, might be optimized by targeting specific populations of HCWs for training and additional resources. Patterns observed during the COVID-19 pandemic offer a valuable opportunity to determine if specific subpopulations of HCWs should be prioritized for additional IPC training in the face of a novel outbreak. For example, HCWs with direct patient care responsibilities (e.g., nurses, physicians) have been shown to be more knowledgeable and compliant with IPC measures compared to health facility workers who interact less directly with patients (e.g., administrators, hygienic staff).[16,17] Further, in DRC where high-profile outbreaks are relatively frequent, frontline responders to outbreaks often receive additional training opportunities. Specifically, Congolese HCWs in EVD outbreak affected areas can receive surveillance, field epidemiology, and IPC training to bolster their response efforts.[18] However, studies previously conducted in DRC provide only a snapshot of perceptions of efficacy related to COVID-19 prevention behaviors and adherence to these behaviors during the first months of the pandemic. Further, only one previous study[11] examined these measures among HCWs and no studies have evaluated the impact of direct patient care on COVID-19 prevention behavior.

Utilizing an outcome-wide approach,[19] this study aims to assess the impact of direct patient care responsibilities on perceptions of efficacy of COVID-19 prevention measures and prevention measures taken during the pandemic among four cohorts of HCWs living in different areas of DRC. Further, given likely differences between the cohorts, the relationship between these measures and location will be assessed. It is hypothesized that HCWs with direct patient care responsibilities will be more likely to report efficacy of COVID-19 prevention measures and performing those measures throughout the pandemic. Perceived efficacy is expected to increase over time regardless of location, but prevention behaviors will be reported more among HCWs from Kinshasa throughout the study compared to the other cohorts due to potentially more exposure to COVID-19 prevention messaging and to policies requiring IPC compliance.

3.3 Methods

Study design and sample

Between August 2020 and August 2021, four cohorts of HCWs from DRC participated in a study collecting repeated measures on knowledge, attitudes, and practices related to COVID-19. The four cohorts were sampled from participants of an ongoing study since 2016, "Epidemiology, Immunopathology Immunogenetics and Sequelae of Ebola Virus and other Viral Hemorrhagic Fever Infections," in which participants were recruited in Kinshasa, the city of Kikwit in Kwilu Province, the city of Mbandaka in Équateur Province, and the city of Beni in North Kivu Province. Only individuals in the original study who consented to future contact for research and who still actively worked in healthcare in August 2020 were recruited for the current study. A detailed description of the study design, sampling methods, and participant flow between studies is provided elsewhere.[20]

The four original study cohorts were recruited based on their EVD outbreak response experience. The Kikwit cohort consisted of active HCWs at health facilities in the two health zones in the city of Kikwit, North Kikwit and South Kikwit, as of August 2017. In November 2017, the Kinshasa cohort was similarly recruited and consisted of active HCWs in health facilities in three health zones of Kinshasa city (Kinshasa, Lingwala, and Nsele). The Mbandaka cohort consisted of two groups: 1) individuals who received the rVSVΔG-ZEBOV-GP vaccine being used under a compassionate use protocol for EVD outbreak response, and 2) HCWs actively working in health facilities in three health zones of the Mbandaka city area, Mbandaka, Wangata, and Bolenge. Per the "ring vaccination" strategy used in June and July 2018, when recruitment for the original cohort took place in Mbandaka, individuals eligible for the rVSVΔG-ZEBOV-GP vaccine included contacts of confirmed cases, contacts of contacts of confirmed cases, and healthcare and other workers on the frontline of the outbreak. Any individuals who received rVSVΔG-ZEBOV-GP vaccination in the Beni city area in August 2018 were eligible for study enrollment.

In August 2020, study staff successfully contacted 680 individuals from the recruitment sample (N=1,872) by phone with telephone numbers collected during the participants' initial study recruitment. Participants were asked to confirm their name and their status as a HCW and then invited to participate in a longitudinal study collecting COVID-19 related measures over the course of a year. Individuals who did not consent to participation (N=81) were not contacted again. Study enrollment and baseline questionnaire collection took place from August 11 to September 7, 2020, and phone calls lasted between one and one and a half hours to complete.

Follow-up data collection began in mid-September 2020 and continued until late-August 2021. Follow-up data collection typically occurred from a Monday to the following Tuesday and questionnaires took between 10 and 20 minutes to complete over the phone. Open Data Kit (ODK) Collect[21] was used by study interviewers to administer questionnaires. Interviewers were able to discuss study protocols, obtain verbal informed consent, and administer surveys in both French and local languages (i.e., Lingala, Kikongo, Swahili).

Outcomes

Perceptions of efficacy of COVID-19 prevention behaviors. Participants were presented with a list of 23 behaviors and asked if each measure was effective at preventing the spread of COVID-19 infection (*yes/no*). The behaviors listed in the questionnaire ranged in effectiveness for COVID-19 prevention (e.g., staying home when you are sick, using algae, drinking ginger tea). Six specific measures were chosen for analysis to assess the HCW's knowledge of objectively effective COVID-19 prevention behaviors: 1) hand wash for 20 seconds, 2) avoid touching face with unwashed hands, 3) use disinfectants when soap and water are not available to wash hands, 4) wear face mask, 5) avoid places where many people gather, and 6) social distance. Measures from 18 data collection points throughout the study were analyzed in this study.

Performing effective COVID-19 prevention behaviors. Following the knowledge measure, the participant was presented with the same list of 23 behaviors and asked if they had taken each of the measures to prevent infection from COVID-19 in the past two weeks (*yes/no*). The same six measures were selected to assess the HCW's compliance with objectively effective COVID-19 prevention behaviors. Measures from 23 data collection points throughout the study were analyzed in this study.

Predictors

Direct patient care responsibilities. The primary predictor of interest in this analysis was a participant's exposure to patients. This exposure was assessed in two ways: 1) participants were asked at study baseline if they have direct patient care responsibilities in their job (*yes*/*no*), and 2) level of patient contact (*direct*, *indirect*, *likely none*) was assigned based on the participant's reported job title at baseline based on a previous publication on another subset of these participants.[22] The first definition was preferred as it was self-reported by participants rather than assigned by the investigator, but the strength and significance of the association between the two measures was tested using Cramer's V[23] and Chi-square tests.

Location. The secondary predictor of interest was location as outcomes among this sample have been shown to differ by location.[20] The city area in which the HCW lived and worked (i.e., Kinshasa, Kikwit, Mbandaka, Beni) was self-reported at study baseline, midway point, and end.

Time. Time was measured as two-week intervals corresponding to data collection. No data collection took place from December 20, 2020 to January 16, 2021 due to holidays.

Demographics

Gender. Participants reported their gender in the baseline questionnaire. As is standard in this setting, only *male* and *female* were response options.

Age. Participants self-reported their age in years at study baseline. Age is presented as a continuous variable.

Education level. Participants reported their highest level of education at study baseline. Response options were as follows: *no education, less than high school graduate*, *graduated high* *school, some college (including vocational training or associate degree)*, *Bachelor's degree*, and *advanced degree*. Most of the sample (65.1%) reported some college; therefore, responses were categorized into *high school education or less*, *some college*, and *Bachelor's or advanced degree*.

Chronic disease. At baseline, participants self-reported if they had a chronic disease (e.g., chronic lung disease, diabetes cardiovascular disease, chronic renal or liver disease) or if they were otherwise immunocompromised.

Environment setting. Participants reported if they considered where they currently lived *urban* or *rural* at baseline.

Employment status. Participants were asked to report their employment status (*full-time*, *part-time*, *contracted*, *unemployed*) at study baseline, midway point, and end.

Health facility type. Participants reported the name of their health facility at study baseline. Study staff familiar with the local areas then assigned the type of health facility to each unique facility reported. Health facility type categories (general hospital, health post, health center, hospital center, clinic/medical center/private hospital, coordinating office, and other) were chosen such that each category represented a unique healthcare setting in terms of resources, structure, and management. Only one participant reported working at a health post so this category was collapsed into "other".

Job title. Participants reported their job titles at study baseline. Any position category with less than 20 participants was collapsed into an "other" category to highlight the most common jobs within the cohorts.

EVD Outbreak Experience. Two measures of direct EVD outbreak experience were reported by participants at baseline of the original EVD-related studies: 1) ever been involved in an EVD outbreak and 2) ever received the EVD vaccine (rVSVΔG-ZEBOV-GP).

Statistical analysis

Sample. The analytic sample was restricted to participants who lived and worked within one the four main city areas of interest (Kinshasa, Kikwit, Mbandaka, Beni) throughout follow up and to participants who contributed outcomes measures to analysis. Study participants (N=588) were excluded if they moved from one of the four cities before baseline (*n*=4) or moved or became unemployed during follow up (*n*=22). Further, outcome responses collected during the pilot weeks of the study (8/11/20-8/29/20) were not included in analysis (*n*=394 responses). Participants who no longer contributed any outcome measures to statistical analysis after these two data collection intervals were dropped were also excluded (*n*=17).

Cross-sectional analysis. Descriptive statistics for demographics and EVD response measures collected at study baseline were calculated for the analytic sample. Count and sample proportions were calculated for categorical variables. For age in years, the only continuous baseline variable, mean, standard deviation, median, and range were calculated. The associations between direct patient care responsibilities and each categorical baseline characteristics were assessed with Chi-square tests apart from employment status and health facility type. For these three variables, at least one expected cell count was below five; therefore, Fisher’s exact test was more appropriate to assess the association with direct patient care responsibility. For continuous age, a two-sample t-test was used to determine the equality of the two population mean ages.

Longitudinal analysis. The count and proportion of affirmative responses for each of the 12 outcomes were calculated across the study and within each data collection interval. Average response over time to each outcome per respondent was plotted in histograms and the proportion of participants who consistently responded in the affirmative to each outcome was calculated. Line plots of the proportion of participants in each data collection interval responding in the affirmative by patient care responsibilities and location group for each outcome were created. Outcome measures with 1) little within-participant response change over time, 2) no distinct population change over time, and 3) no apparent meaningful difference by direct patient care or location were analyzed descriptively only.

Spline functions within mixed effect logistic regression models were used to explore possible nonlinearity in the association between the two predictors and three outcomes of interest between specified time periods. Given that study collection was paused for a four-week period (from 12/20/2020 to 1/16/2021), the last data collection interval prior to the break (12/6/20-12/19/20) and first collection interval following the break (1/17/21 to 1/30/21) were selected as knots creating two analytic periods: before and after the winter break. As an estimated 95.8% of DRC population is Christian,[24] the winter holidays are a major occasion for celebration, worship, and gathering in the country, which could possibly lead to shifts in attitudes and behaviors. Simple linear spline functions were appropriate because it was assumed that the exposure effect in each time period followed a linear shape but might be non-linear across periods.[25]

Mixed effect models were used in this analysis to account for potential clustering at the individual, health zone, or health facility level. Four model types were initially constructed for each outcome of interest utilizing a different set of random effects: 1) individual only, 2) individual and health zone, 3) individual and health facility, and 4) individual, health zone, and health facility (Supplemental Table 3.1). Two additional model structures with 2-knot spline functions as fixed effects were tested with individual only and individual and health zone random. Models were run using the PROC GLIMMIX procedure in SAS[26] with both Cholesky and unstructured parameterization of the covariance structure and a pseudo-likelihood estimation technique based on maximum likelihood (i.e., METHOD=MMPL). Only models that achieved convergence and rational estimates were selected as final models and rerun with additional covariates (i.e., gender and age) to control for potential confounding. Finally, fitted values were calculated on the logit scale for each final model (for a 42 year old male). Then, each estimate was offset by a random normal variate scaled by the standard deviation (SD) of the subject random effect in each model and transformed to probabilities and averaged for each combination of location and time. To account for 36 models assessing exposure-outcome associations for three behavioral outcomes, including pairwise comparisons between locations, a Bonferroni corrected level of significance was calculated as α/K, where $K = 36$ and $\alpha=0.05$, or 0.001.

Ethical

Institutional review board approval was obtained from the University of California, Los Angeles (IRB#20–001321) as well as the Kinshasa School of Public Health at the University of Kinshasa (ESP/CE/118/2020), which served as the local ethics committee. During phone calls, participants provided an oral consent to participate. The original cohorts were enrolled under ethics approvals: UCLA: IRB#16–001346/KSPH IRB: ESP/CE/022/2017.

3.4 Results

Sample

A third of the 545 participants in the analytic sample lived and worked in the Kikwit city area (34.7%), followed by 29.7% in Kinshasa, 19.1% in the Beni city area, and 16.5% in the Mbandaka area. Over half (56.0%) of participants were male and the median age was 42.0 years old. Nearly two-thirds (65.5%) of the sample reported having some college education and most reported no chronic disease or otherwise being immunocompromised (91.7%). Two-thirds of the

HCWs lived in an urban setting at study baseline and most (71.2%) were employed full-time. At baseline, most of the sample (85.7%) either worked at a health center (34.5%), a general hospital (31.7%), or a hospital center (19.4%). More than half (54.5%) of the participants were nurses at baseline while 9.6% were laboratory technicians and 9.0% were physicians. One-third of the participants (33.0%) had previous direct EVD outbreak experience and 26.6% had previously received the EVD vaccine in Beni or Mbandaka.

Cross-sectional

The two definitions of direct patient exposure considered in this study were strongly dependent (chi-square p-value < 0.0001, Cramer's V = 0.64; Supplemental Table 3.2). Therefore, the self-reported measure of direct patient care responsibility was used to assess the relationship between patient exposure and baseline characteristics. The majority of HCWs (71.4%) reported direct patient care responsibilities. The proportion of HCWs reporting direct patient care duties did not significantly differ across the four location cohorts. Further, chronic disease status, environment setting, employment status, health facility type, direct EVD outbreak experience, and receipt of the EVD vaccine were not significantly related to direct patient care responsibility (Table 3.1). A larger proportion of HCWs with direct patient care duties were female and worked as nurses compared to those without patient care duties. Alternatively, those who did not directly care for patients were significantly older and a larger proportion had high school education or less compared to those who did care for patients.

Longitudinal

For most of the longitudinally measured outcomes (all six perceptions of efficacy of COVID-19 prevention behaviors as well as reporting washing hands for 20 seconds, avoiding touching the face, and using disinfectants in the past two weeks), within-participant response did

Table 3.1. Sample characteristics by direct patient care responsibility (N=545).

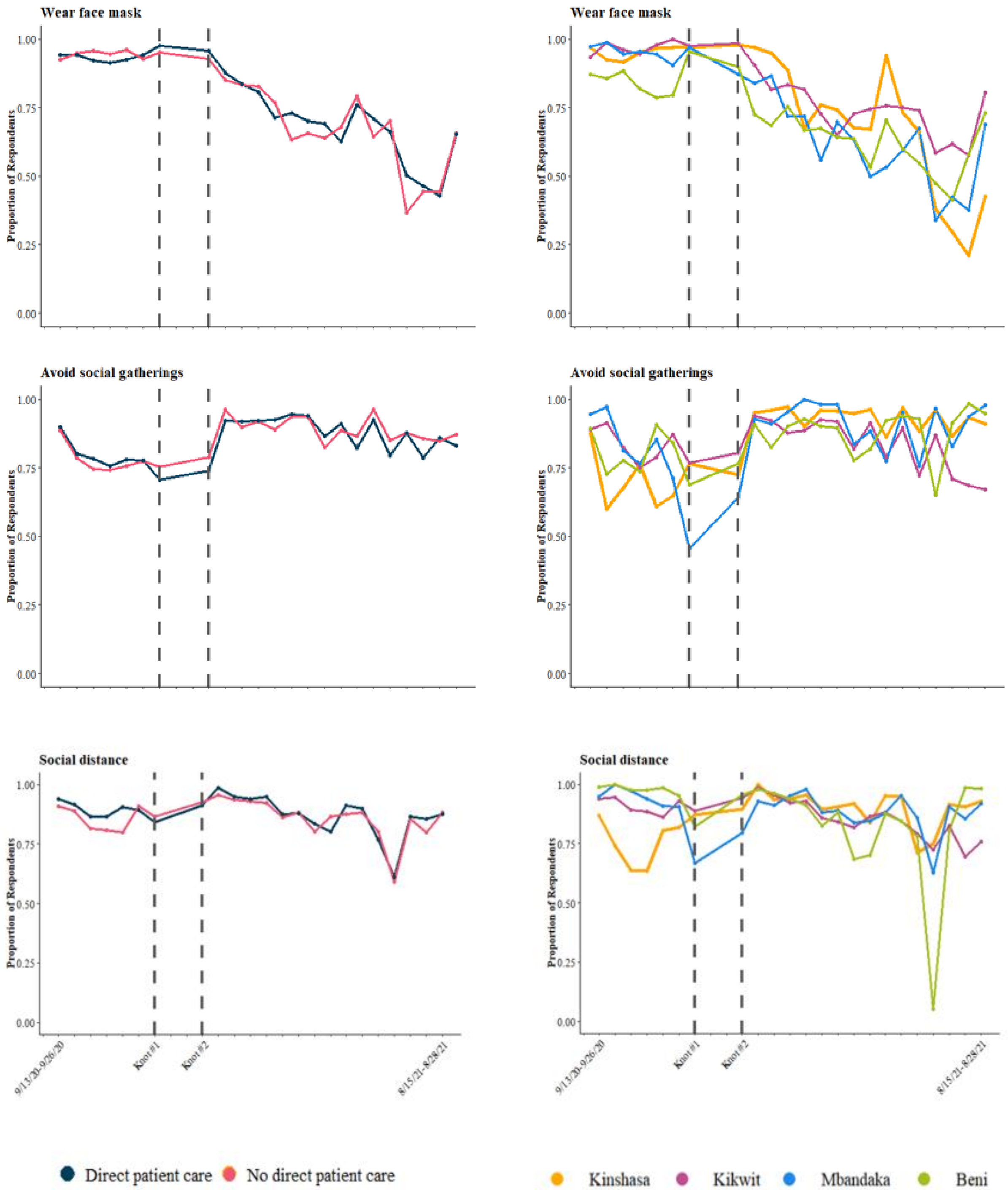
	Direct Patient Care Responsibility		
	Yes (*n*=389)	No (*n*=156)	
	n (%)	*n* (%)	p-value
Location			0.30^
Kinshasa	114 (29.3%)	48 (30.8%)	
Kikwit	130 (33.4%)	59 (37.8%)	
Mbandaka	63 (16.2%)	27 (17.3%)	
Beni	82 (21.1%)	22 (14.1%)	
Gender			0.0002^
Male	198 (50.9%)	107 (68.6%)	
Female	191 (49.1%)	49 (31.4%)	
Age, continuous			<0.0001⁺
Mean (SD)	41.6 (11.1)	47.9 (13.3)	
Median [Min, Max]	40.0 [20.0, 78.0]	47.0 [23.0, 81.0]	
Education level			<0.0001^
H.S. or less	40 (10.3%)	44 (28.2%)	
Some college/Assoc.	275 (70.7%)	82 (52.6%)	
Bach./Advanced deg.	74 (19.0%)	30 (19.2%)	
Chronic disease	33 (8.5%)	12 (7.7%)	0.76^
Environment setting			0.07^
Urban	248 (63.8%)	112 (71.8%)	
Rural	141 (36.2%)	44 (28.2%)	
Employment status			1.00~
Full-time	277 (71.2%)	111 (71.2%)	
Part-time	106 (27.2%)	43 (27.6%)	
Contracted	6 (1.5%)	2 (1.3%)	
Health facility type			0.05~
Health center	145 (37.3%)	43 (27.6%)	
General hospital	122 (31.4%)	51 (32.7%)	
Hospital center	76 (19.5%)	30 (19.2%)	
Clinic/medical center/private hospital	28 (7.2%)	18 (11.5%)	
Coordinating office	13 (3.3%)	9 (5.8%)	
Other*	5 (1.3%)	3 (1.9%)	
Unknown	0 (0%)	2 (1.3%)	
Job title			<0.0001^
Nurse	267 (68.6%)	30 (19.2%)	
Laboratory technician	27 (6.9%)	26 (16.7%)	
Physician	47 (12.1%)	2 (1.3%)	
Healthcare administration	8 (2.1%)	30 (19.2%)	
Community volunteer	3 (0.8%)	22 (14.1%)	
Other**	37 (9.5%)	46 (29.5%)	
Ever involved in EVD outbreak			0.58^
Yes	131 (33.7%)	49 (31.4%)	
No	248 (63.8%)	104 (66.7%)	
Missing	10 (2.6%)	3 (1.9%)	
Ever received EVD vaccine	106 (27.2%)	39 (25.0%)	0.59^

Note. * ‘Other’ category: health post, church, home, etc.; ** ‘Other’ category: midwife, room attendant, housekeeping, trainee, guard, maintenance, traditional healer, pastor, pharmacy, surveillance, Red Cross, and ordinary worker. Inferential tests of the equality of counts or means between the four groups are noted by: ^ = Chi-square test, ⁺ = T-test, ~ = Fisher’s exact test.

not fluctuate appreciably throughout the study (Supplemental Figure 3.1, Supplemental Table 3.3). Most participants (75.0%-94.1% among overall) responded that they felt that each of the six preventative measures were effective consistently throughout the study and reported hand washing, avoiding touching the face, and using disinfectants in the past two weeks consistently throughout the study (78.5%, 66.6%, and 78.2% among overall, respectively). This lack of change in response over time was observed within the main predictor subgroups of interest (i.e., those with and without direct patient care responsibility), as well as within the location cohorts (Supplemental Figure 3.2, Supplemental Table 3.3). The plots of the observed proportion reporting these nine outcomes over time by both predictor subgroupings (direct patient care responsibility and location) did not reveal any clear group difference or population changes over time. In the data collecting intervals in which these items were measured, the proportion of overall respondents agreeing that any of the six COVID-19 prevention measures was effective never fell below 90.9% and never below 84.2% for the three behaviors (Supplemental Table 3.4 and 3.5). These nine outcomes were analyzed descriptively only.

Within-person fluctuation was observed, however, among three COVID-19 prevention behavior measures: wearing a face mask, avoiding crowds, and socially distancing (Supplemental Figure 3.2, Supplemental Figure 3.4, and Supplemental Table 3.2). About three-quarters of participants (63.8%-78.9%) in either the direct patient care or no direct patient care groups changed their response to these three behavioral items throughout the study. However, within-participant behavioral changes differed more between the four cohorts (Supplemental Table 3.2). Further, plots of the observed proportion of respondents within various exposure subgroups of interest reporting wearing a face mask, avoiding crowds, and socially distancing indicated a possible nonlinearity in the overall trend (Figure 3.1).

Figure 3.1. Observed proportion of respondents over time reporting that they performed each COVID-19 prevention behavior in the past two weeks, by direct patient care responsibility and by cohort

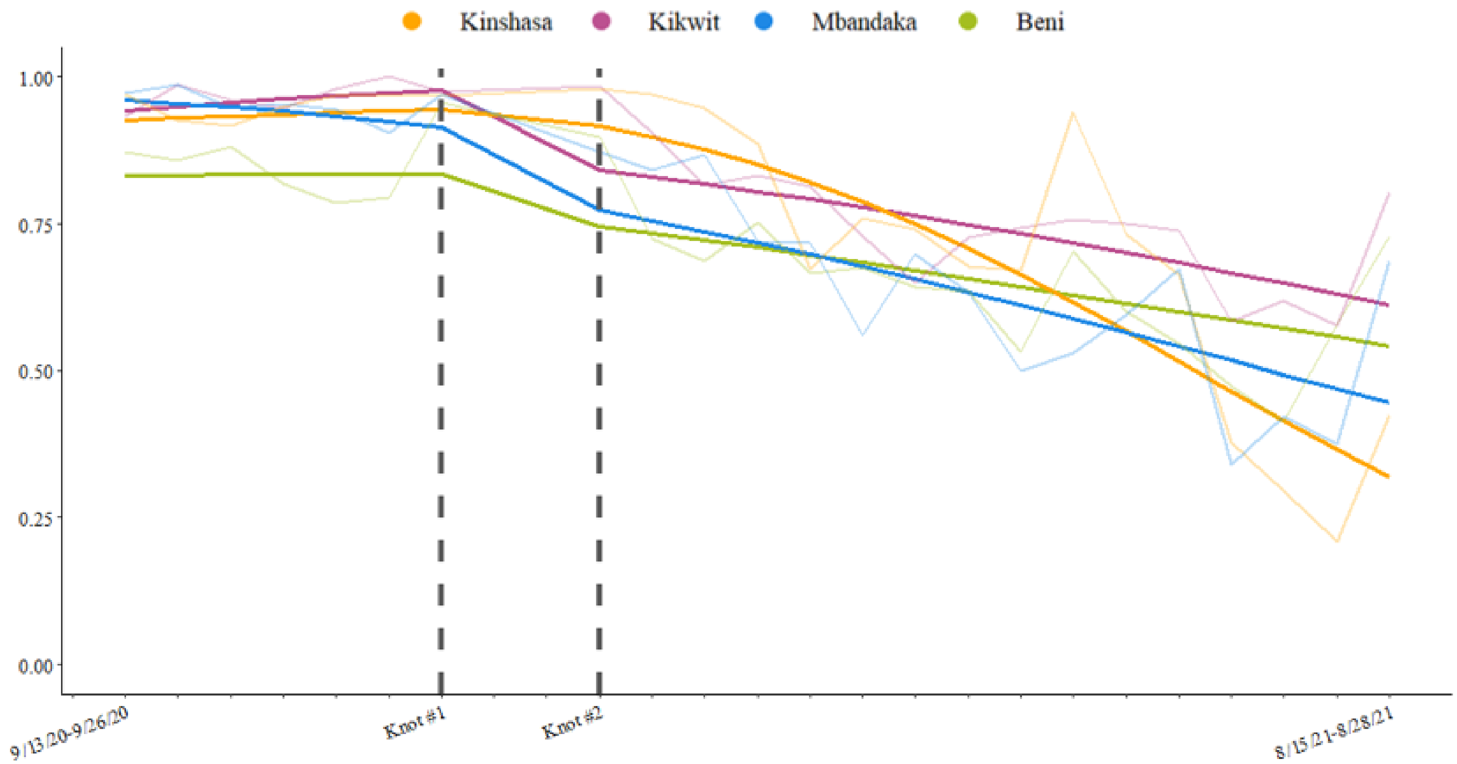


Note. Vertical dashed lines on study timeline indicate the knots in final models

Final mixed effect models for 1) wearing a face mask, 2) avoiding crowds, and 3) socially distancing included location only as the main predictor of interest due to descriptive observations of no meaningful differences in these three behaviors throughout the study by direct patient care responsibility. Further, based on most consistent model performance between several parameterizations, final models included a 2-knot spline function and accounted for clustering in the repeated measures at the individual level (Supplemental Table 3.1). Figures 3.2, 3.3, and 3.4 present the fitted probability of reporting each of the three COVID-19 prevention behaviors plotted over time by cohort as well as indicators for statistically significant slopes in the period prior to and following the winter break in data collection. Statistically significant differences in slopes between the four cohorts are also indicated.

Between study baseline and the beginning of the winter break in data collection (late 2020), the predicted probability of wearing a face mask remained stable around 90% among the Kinshasa, Kikwit, and Mbandaka cohorts and about 83% among the Beni cohort (Figure 3.2). Following the winter break (early- to mid- 2021), the probability of wearing a face mask significantly decreased in all four cohorts (Supplemental Table 3.6) but the greatest decline was among the Kinshasa cohort. The decline in odds of wearing a face mask in the past two weeks during this period was significantly greater (more negative) among HCWs in Kinshasa compared to the other cohorts (Supplemental Table 3.7). Declines in predicted probability of avoiding gatherings for COVID-19 prevention were observed between baseline and the winter break but was significant only among the Kikwit and Mbandaka HCWs. The decrease in odds of avoiding gatherings during this period was significantly greater in Mbandaka than Beni and Kikwit. Following the winter break, the probability of avoiding gathering in the past two weeks became more stable around 80% except within the Kikwit cohort in which a significant decrease in

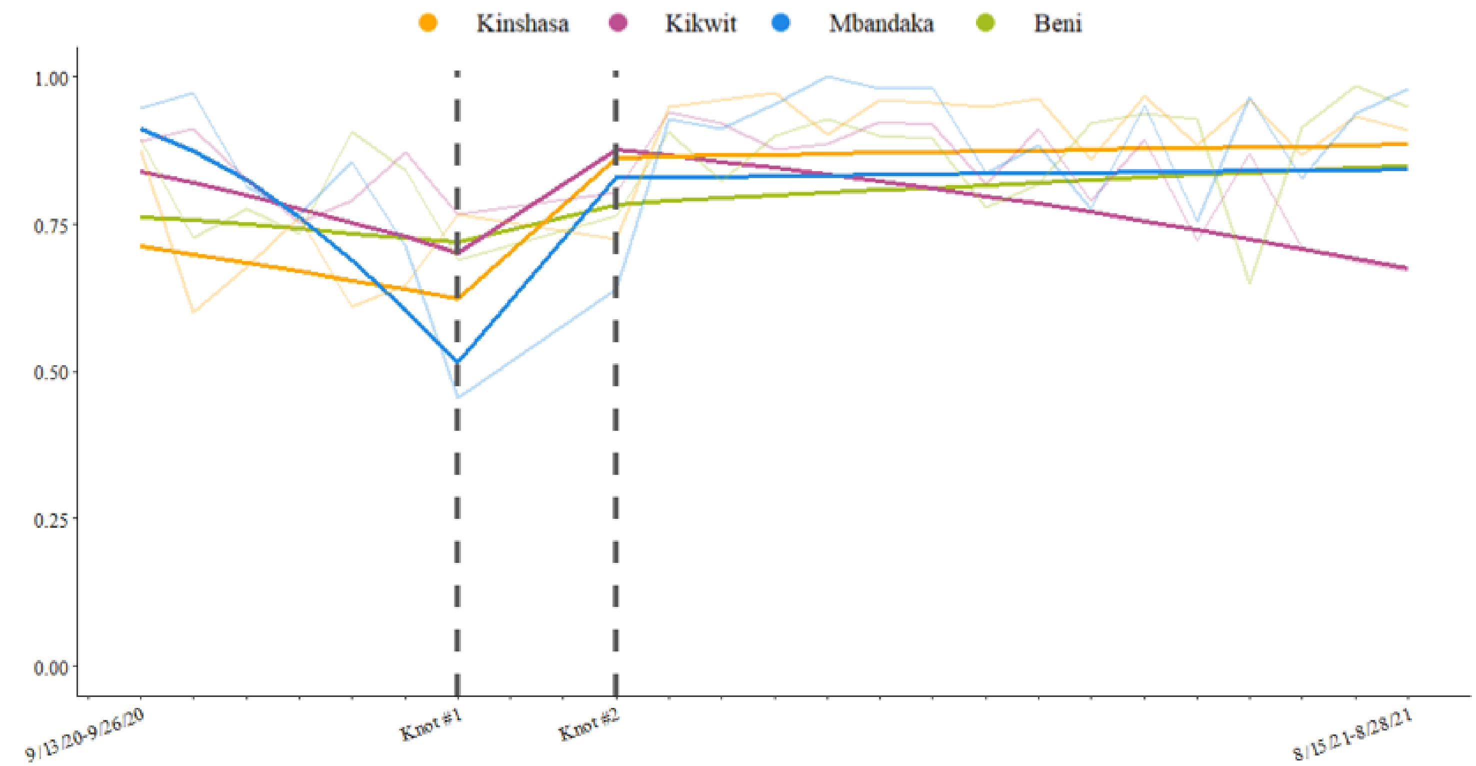
Figure 3.2. Fitted predicted probability of reporting wearing a face mask for COVID-19 prevention in the past two weeks over time by cohort



	Before Knot #1					After Knot #2				
	Slope	*Comparison Group*				Slope	*Comparison Group*			
		Kinshasa	*Kikwit*	*Mbandaka*	*Beni*		*Kinshasa*	*Kikwit*	*Mbandaka*	*Beni*
Kinshasa		-	-	-	-	*	-	-	-	-
Kikwit			-	-	-	*	*	-	-	-
Mbandaka				-	-	*	*		-	-
Beni					-	*	*			-

Note. Observed proportions for each cohort displayed in lines with greater transparency. Probabilities presented for a 42 year old male. Asterisk in table indicates statistically significant estimate of change in odds of performing the behavior in the past two weeks in each period and statistically significant difference in this slope between cohorts after adjustment for gender and age. Statistical significance is defined as $p < 0.001$.

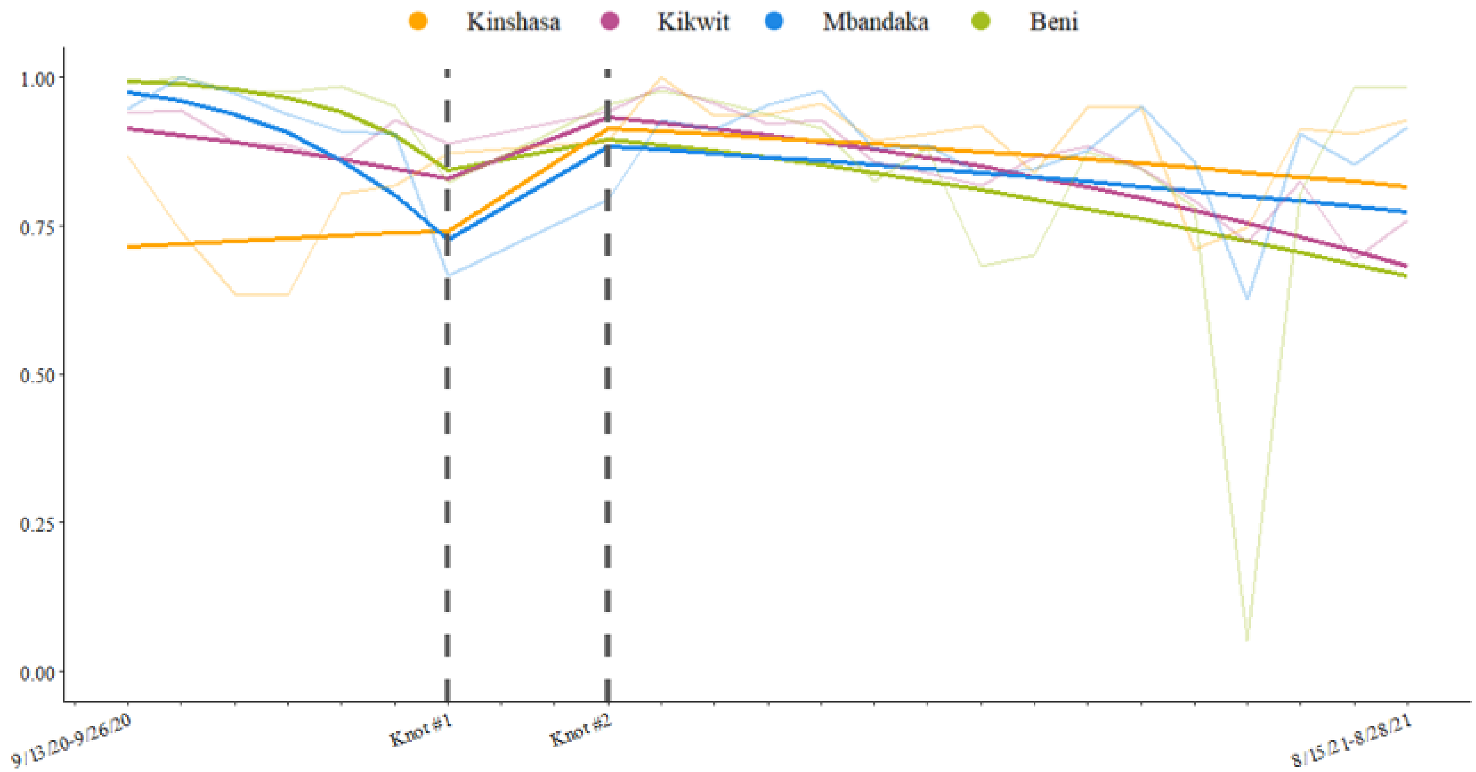
Figure 3.3. Fitted predicted probability of reporting avoiding gatherings for COVID-19 prevention in the past two weeks over time by cohort



	Before Knot #1					After Knot #2				
	Slope	*Comparison Group*				Slope	*Comparison Group*			
		Kinshasa	*Kikwit*	*Mbandaka*	*Beni*		*Kinshasa*	*Kikwit*	*Mbandaka*	*Beni*
Kinshasa		-	-	-	-		-	-	-	-
Kikwit	*		-	-	-	*	*	-	-	-
Mbandaka	*		*	-	-		*	*	-	-
Beni				*	-			*		-

Note. Observed proportions for each cohort displayed in lines with greater transparency. Probabilities presented for a 42 year old male. Asterisk in table indicates statistically significant estimate of change in odds of performing the behavior in the past two weeks in each period and statistically significant difference in this slope between cohorts after adjustment for gender and age. Statistical significance is defined as $p < 0.001$.

Figure 3.4. Fitted predicted probability of reporting social distancing for COVID-19 prevention in the past two weeks over time by cohort



	Before Knot #1					After Knot #2				
	Slope	*Comparison Group*				Slope	*Comparison Group*			
		Kinshasa	*Kikwit*	*Mbandaka*	*Beni*		*Kinshasa*	*Kikwit*	*Mbandaka*	*Beni*
Kinshasa		-	-	-	-	*	-	-	-	-
Kikwit			-	-	-	*		-	-	-
Mbandaka	*	*		-	-				-	-
Beni	*	*		*	-	*				-

Note. Observed proportions for each cohort displayed in lines with greater transparency. Probabilities presented for a 42 year old male. Asterisk in table indicates statistically significant estimate of change in odds of performing the behavior in the past two weeks in each period and statistically significant difference in this slope between cohorts after adjustment for gender and age. Statistical significance is defined as $p < 0.001$.

probability was observed (87.6% to 67.5%, Supplemental Table 3.8). Thus, the change in odds of avoiding gatherings among Kikwit HCWs was significantly more negative compared to the other three cohorts following the winter break. The probability of social distancing prior to the winter break in data collection declined in Mbandaka, Beni, and Kikwit but remained stable in Kinshasa; only the negative slopes observed among the Mbandaka and Beni HCWs were statistically significant, and both were significantly different from each other and from the slope observed among the Kinshasa HCWs. In the period between the winter break and the end of the study, the predicted probability of social distancing gradually declined from about 90% to around 75%. The downward trends were all statistically significant except for that observed among the Mbandaka cohort.

3.5 Discussion

This study produced several encouraging findings regarding the prevention beliefs and behaviors reported by a sample of Congolese HCWs throughout a year of the COVID-19 pandemic. First, HCWs in this study were consistent in their beliefs in the efficacy of the six COVID-19 prevention behaviors. It follows that the high proportions observed in this study are even greater than the observations of Michel-Kabamba et al.[11] among another HCW sample as that study was conducted three to four months before the current study began. As time passed, HCWs in DRC were likely exposed to more health messaging as more research was conducted and the pandemic response strengthened. Unexpectedly, perceptions of efficacy among HCWs in this sample were not dependent on patient care responsibility or location and in fact were nearly universally high across the year. This might indicate that the general health workforce in DRC, not just the portion working directly with patients, maintains strong belief in the efficacy of typical IPC measures such as hand hygiene, mask wearing, and limiting physical contact.

Second, three of the COVID-19 prevention behaviors assessed (washing hands for 20 seconds, avoiding touching the face, and using disinfectants in the past two weeks) were similarly consistently reported by the cohorts across the study. Again, these behaviors were reported by most of the participants regardless of patient care responsibilities and location. However, it is likely that the method in which these behaviors were collected in this study did not adequately measure proper IPC behavior. HCWs in this study were asked if they had performed each behavior in the past two weeks; active HCWs following proper IPC measures during the COVID-19 pandemic would likely perform these behaviors several times a day. For example, Michel-Kabamba et al.[11] utilized a more specific measure and found that only about half of HCWs surveyed consistently used of face masks and avoided crowded areas. Behaviors such as washing hands, avoiding touching the face, and using disinfectant are likely standard IPC behaviors practiced by the majority of individuals working in healthcare at all times and are therefore not specific enough to assess behavior adoption in the response to an emerging pathogen.

Third, the probability of avoiding gatherings and social distancing to prevent COVID-19 remained relatively high (typically above 75%) among all participants throughout the study. The probability of wearing a face mask, avoiding gatherings, and socially distancing did differ over time and between the cohorts, however. Again, reporting these prevention behaviors was not related to direct patient care responsibilities. In the first half of 2021 (between Knot #2 and the end of the study), the probability of avoiding social gatherings remained stable in all cohorts except Kikwit indicating relatively consistent compliance among HCWs in Kinshasa, Mbandaka, and Beni. Despite slight decreases observed during this same period in social distancing among the cohorts, the probability of reporting social distancing in the past two weeks remained above

73.4% in the overall sample.

There was a dramatic decline among participants in the probability of wearing a face mask from early- to mid-2021 (81.9% in late-January 2021 to 48.0% in mid-August 2021). Better masking compliance was expected among the Kinshasa cohort due to more exposure to public health communication. This was also previously observed by Ditekemena et al.[12] who posited that the higher morbidity and mortality from COVID-19 in Kinshasa might motivate the population to wear masks. However, following the winter break the decline in mask use among Kinshasa HCWs was significantly greater than in any other cohort. A notable decline in respondents reporting several prevention behaviors (e.g., social distancing, avoiding gatherings) was observed in the 7/4/2021 to 7/17/2021 data collection period especially among the Beni cohort. This period of data collection directly follows the June 30th Congo Independence Day holiday in DRC. Therefore, it is likely that the decline in limiting social contact reflects celebrations and gatherings that took place in the days before data collection. This study did not measure or account for changes in PPE supply and distribution throughout the country which would have impacted accessibility to individual study participants.

Among HCWs from Mbandaka, a significant decrease in the probability of avoiding social gatherings and social distancing was observed from late-September to mid-December 2021. This might be related to an EVD outbreak in the area subsiding during this time (ending officially on November 18, 2020) and social contact behaviors returning to higher levels. Similarly, the probability of avoiding social gatherings following the holiday break slightly increased among the Beni cohort, which was also combatting another EVD outbreak (from February 7, 2021 to May 3, 2021). This might indicate an impact of concurrent EVD outbreaks specifically on IPC behaviors perceived to be effective for both EVD and COVID-19, such as avoiding crowds, rather than wearing a face mask or socially distancing which might be perceived to be specific to COVID-19 prevention. Among a general population sample, Ditekemena et al.[12] observed higher adherence to physical distancing and hand hygiene in North Kivu where a recent EVD outbreak had occurred. This finding in light of the current study's findings strengthens the arguments that 1) the occurrence of a concurrent outbreak might impact ongoing IPC compliance and 2) IPC compliance likely differs between HCWs and the general population.

Further, the lack of a relationship between direct patient care and any of the perceptions of or compliance with COVID-19 prevention measures indicates that resources to support compliance with IPC measures should be distributed evenly to the health workforce to ensure its health and safety during future outbreaks. Unexpectedly, HCWs in certain roles requiring direct patient contact (e.g., nurses, physicians) might not be more likely to report IPC compliance compared to HCWs who do not care for patients (e.g., administrators). The contribution of HCWs in less traditional patient-care roles to infection control in health facilities and the community at-large should not be underestimated. These members of the health workforce should be exposed to training, health communications, and other resources aimed at improving IPC compliance. Interestingly, having direct patient care responsibilities was also not related to having EVD outbreak response experience or having received the EVD vaccine indicating that EVD response likely involves the entire health workforce of a community rather than just those who care directly for patients. Finally, a similar proportion of HCWs with direct patient care responsibility was found in each of the four study cohorts in DRC suggesting that patient exposure would not confound the relationships observed between location and the outcomes explored in this sample.

This study has several limitations. First, this sample cannot be considered representative of HCWs in the areas of enrollment in DRC. In fact, all participants originally recruited to the Beni cohort and a portion of the Mbandaka cohort were enrolled because of recent receipt of the EVD vaccine. These HCWs might have been more likely to perceive the efficacy of standard IPC measures and comply with these measures, especially those that are common to both EVD and COVID-19 prevention. Second, COVID-19 transmission levels were not accounted for in this analysis because province-level data was not available. Participants might have been more likely to comply with COVID-19 prevention measures during times of elevated COVID-19 case rates and likewise less likely to comply when COVID-19 cases in the area waned. Relatedly, the study does not account for COVID-19 policies in different areas of DRC during follow up. For example, a strict lockdown was in place in parts of Kinshasa that did not exist in other areas of the country, likely impacting compliance with COVID-19 prevention measures such as avoiding gathering and socially distancing.[27] Lastly, the survey items used in this study were not specific enough to measure a more appropriate outcome of interest: level of compliance with COVID-19 prevention measures over time. It would be more informative to measure frequency of performing each measure in the past two weeks to better distinguish levels of compliance within the HCWs. However, questionnaire length and acceptability to participants necessitated that some measures be simplified to promote retention in the study.

This study has several strengths as well. This is the first study to collect perceptions of COVID-19 prevention measures as well as compliance with these measures over time among HCWs in DRC. Given good study retention, the findings add insight into the fluctuations of these measures over time among four cohorts of HCWs in DRC to an existing body of literature that was conducted cross-sectionally in the beginning months of the pandemic.[10-12] Further, the outcome-wide approach[28] allows six COVID-19 prevention measures to be investigated both in terms of perceived efficacy and adherence over time and the relationship of each with direct patient care responsibility and location to be reported altogether. This paper adds considerable findings, including null results, that can inform future research. Spline functions, which are typically underutilized in epidemiologic analyses,[25] were also included in final models of several outcomes in this study. This method allowed for the accommodation of specific study procedures (i.e., a pause in data collection during the winter holidays) in model parameterization.

This study provides insight into changes, or lack thereof, in perceptions of efficacy and compliance with COVID-19 prevention among HCWs in DRC throughout the pandemic. Based on behavior differences observed between the HCW cohorts in this study and similar findings of Ditekemena et al.,[12] IPC behavior should be evaluated at a subnational level in DRC in the future. Differences in response behavior to future outbreaks will likely differ between HCWs in different areas of the country. Further, the Congolese public health authorities need not focus on additional resources to increase the awareness of the efficacy of basic IPC measures among HCWs in DRC. Instead, resources should be directed towards investigating the relationship between both behavior adoption and proper compliance in the context of outbreak response and potential community-level influences, such as frequency of other infectious disease outbreaks locally, social norms, and quality of IPC training.[8,9,16,29] Finally, it is necessary to examine why HCWs in DRC might strongly believe in the efficacy of IPC behaviors but not consistently practice those behaviors. Improved understanding of the factors related to IPC compliance among HCWs will contribute to a robust outbreak response not only to the next high-profile, emergent pathogen but also to the endemic diseases that are a constant burden to the fraught health system in DRC.

3.6 Appendix

Supplemental Table 3.1. Matrix of mixed effect model performance for six model parameterizations using both Cholesky and unstructured covariance structures per outcome of interest

					2-knot Spline Models	
	Type 1	***Type 2***	***Type 3***	***Type 4***	***Type 5***	***Type 6***
Random effect:	*Person*	*Person & HZ*	*Person & HF*	*Person, HZ, & HF*	*Person*	*Person & HF*
Predictor: Direct patient care responsibility						
Wear face mask	CH: did not converge UN: did not converge	CH: converged UN: converged	CH: converged UN: converged	CH: converged UN: converged	CH: converged UN: did not converge	CH: converged UN: converged
Avoid social gatherings	CH: converged UN: converged	CH: converged UN: converged	CH: converged UN: converged	CH: converged UN: converged	CH: converged UN: converged	CH: converged UN: converged
Social distance	CH: converged UN: converged	CH: G NPD UN: G NPD	CH: G NPD UN: did not converge	CH: G NPD UN: G NPD	CH: converged UN: converged	CH: G NPD UN: G NPD
Predictor: Location						
Wear face mask	CH: converged UN: did not converge	CH: zero estimate UN: converged	CH: zero estimate UN: G NPD	CH: zero estimate UN: G NPD	**CH: converged** UN: did not converge	CH: zero estimate UN: G NPD
Avoid social gatherings	CH: converged UN: converged	CH: converged UN: converged	CH: converged UN: converged	CH: G NPD UN: did not converge	**CH: converged** UN: converged	CH: converged UN: converged
Social distance	CH: converged UN: converged	CH: G NPD UN: G NPD	CH: G NPD UN: G NPD	CH: G NPD UN: G NPD	**CH: converged** UN: did not converge	CH: G NPD UN: G NPD

Note. HZ = health zone; HF = health facility; CH = Cholesky; UN = unstructured; G NPD = G-matrix non-positive definite; zero estimate = at least one covariance parameter estimate calculated as 0; each model also included a time interaction with the main predictor.

Supplemental Table 3.2. Contingency table of two measurements of direct patient contact responsibility among study participants (N=545)

		Self-reported		
		Yes	No	Total
Assignment based on job title	Direct	342	38	380
	Indirect	38	75	113
	Unlikely	9	43	52
	Total	389	156	

Supplemental Table 3.3. Proportion of participants in each group who consistently responded 'yes' to each measure across all responses in the study

	Direct patient care responsibility (*n*=389)	**No direct patient care responsibility** (*n*=156)	**Kinshasa** (*n*=162)	**Kikwit** (*n*=189)	**Mbandaka** (*n*=90)	**Beni** (*n*=104)	**Overall** (N=545)
Belief that behavior is effective COVID-19 prevention measure							
Wash hands for 20sec	85.9	89.1	93.8	87.8	86.7	74.0	86.8
Avoid touching face	92.3	91.0	93.8	87.8	96.7	92.3	91.9
Use disinfectant	94.6	92.9	96.3	93.7	92.2	93.3	94.1
Wear face mask	81.7	80.1	84.6	83.6	82.2	71.2	81.3
Avoid social gatherings	74.6	76.3	80.2	72.0	72.2	75.0	75.0
Social distance	85.1	82.1	84.6	83.1	86.7	83.7	84.2
Reported behavior, past 2wks							
Wash hands for 20sec	79.2	76.9	82.1	86.8	85.6	51.9	78.5
Avoid touching face	66.8	65.4	59.9	56.6	71.1	90.4	66.4
Use disinfectant	78.9	76.3	84.0	73.0	75.6	80.8	78.2
Wear face mask	21.1	23.1	15.4	28.0	22.2	19.2	21.7
Avoid social gatherings	24.9	26.9	25.9	30.7	28.9	12.5	25.5
Social distance	36.2	30.8	30.9	39.7	42.2	25.0	34.7

Supplemental Table 3.4. The observed proportion of respondents reporting that each COVID-19 prevention behavior is effective over time

Data collection interval	Num. of respondents	Wash hands for 20sec	Avoid touching face	Use disinfectant	Wear face mask	Avoid social gatherings	Social distance
8/30/20-9/12/20	n=473	430 (90.9%)	453 (95.8%)	456 (96.4%)	449 (94.9%)	446 (94.3%)	451 (95.3%)
9/13/20-9/26/20	n=468	-	-	-	-	-	-
9/27/20-10/10/20	n=424	408 (96.2%)	419 (98.8%)	417 (98.3%)	414 (97.6%)	410 (96.7%)	416 (98.1%)
10/11/20-10/24/20	n=436						
10/25/20-11/7/20	n=397	393 (99.0%)	396 (99.7%)	397 (100%)	393 (99.0%)	386 (97.2%)	387 (97.5%)
11/8/20-11/21/20	n=355	-	-	-	-	-	-
11/22/20-12/5/20	n=338	-	-	-	-	-	-
12/6/20-12/19/20	n=288	287 (99.7%)	287 (99.7%)	287 (99.7%)	287 (99.7%)	270 (93.8%)	288 (100%)
1/17/21-1/30/21	n=345	345 (100%)	345 (100%)	344 (99.7%)	341 (98.8%)	330 (95.7%)	343 (99.4%)
1/31/21-2/13/21	n=391	386 (98.7%)	383 (98.0%)	391 (100%)	389 (99.5%)	381 (97.4%)	387 (99.0%)
2/14/21-2/27/21	n=286	282 (98.6%)	281 (98.3%)	281 (98.3%)	282 (98.6%)	281 (98.3%)	285 (99.7%)
2/28/21-3/13/21	n=396	394 (99.5%)	395 (99.7%)	395 (99.7%)	394 (99.5%)	384 (97.0%)	385 (97.2%)
3/14/21-3/27/21	n=320	319 (99.7%)	315 (98.4%)	315 (98.4%)	311 (97.2%)	310 (96.9%)	313 (97.8%)
3/28/21-4/10/21	n=286	286 (100%)	280 (97.9%)	286 (100%)	280 (97.9%)	283 (99.0%)	279 (97.6%)
4/11/21-4/24/21	n=336	334 (99.4%)	334 (99.4%)	334 (99.4%)	325 (96.7%)	333 (99.1%)	330 (98.2%)
4/25/21-5/8/21	n=310	309 (99.7%)	308 (99.4%)	306 (98.7%)	303 (97.7%)	308 (99.4%)	307 (99.0%)
5/9/21-5/22/21	n=360	360 (100%)	357 (99.2%)	357 (99.2%)	347 (96.4%)	349 (96.9%)	350 (97.2%)
5/23/21-6/5/21	n=342	-	-	-	-	-	-
6/6/21-6/19/21	n=308	307 (99.7%)	306 (99.4%)	307 (99.7%)	297 (96.4%)	306 (99.4%)	303 (98.4%)
6/20/21-7/3/21	n=305	304 (99.7%)	302 (99.0%)	305 (100%)	298 (97.7%)	305 (100%)	302 (99.0%)
7/4/21-7/17/21	n=349	341 (97.7%)	346 (99.1%)	347 (99.4%)	342 (98.0%)	343 (98.3%)	346 (99.1%)
7/18/21-7/31/21	n=334	334 (100%)	334 (100%)	334 (100%)	328 (98.2%)	332 (99.4%)	330 (98.8%)
8/1/21-8/14/21	n=335	335 (100%)	335 (100%)	335 (100%)	327 (97.6%)	331 (98.8%)	332 (99.1%)
8/15/21-8/28/21	n=318	-	-	-	-	-	-
Total respondents		535	535	535	535	535	535
Total responses		6223	6223	6223	6223	6223	6223

Supplemental Table 3.5. The observed proportion of respondents reporting that they performed each COVID-19 prevention behavior in the past two weeks over time

Data collection interval	Num. of respondents	Wash hands for 20sec	Avoid touching face	Use disinfectant	Wear face mask	Avoid social gatherings	Social distance
8/30/20-9/12/20	n=473	-	-	-	-	-	-
9/13/20-9/26/20	n=468	445 (95.1%)	452 (96.6%)	460 (98.3%)	439 (93.8%)	419 (89.5%)	435 (92.9%)
9/27/20-10/10/20	n=424	422 (99.5%)	390 (92.0%)	418 (98.6%)	400 (94.3%)	338 (79.7%)	385 (90.8%)
10/11/20-10/24/20	n=436	426 (97.7%)	411 (94.3%)	428 (98.2%)	406 (93.1%)	337 (77.3%)	371 (85.1%)
10/25/20-11/7/20	n=397	394 (99.2%)	385 (97.0%)	391 (98.5%)	366 (92.2%)	299 (75.3%)	337 (84.9%)
11/8/20-11/21/20	n=355	355 (100%)	351 (98.9%)	351 (98.9%)	332 (93.5%)	275 (77.5%)	311 (87.6%)
11/22/20-12/5/20	n=338	337 (99.7%)	330 (97.6%)	334 (98.8%)	317 (93.8%)	262 (77.5%)	303 (89.6%)
12/6/20-12/19/20	n=288	288 (100%)	281 (97.6%)	288 (100%)	279 (96.9%)	207 (71.9%)	244 (84.7%)
1/17/21-1/30/21	n=345	345 (100%)	336 (97.4%)	343 (99.4%)	327 (94.8%)	260 (75.4%)	316 (91.6%)
1/31/21-2/13/21	n=391	381 (97.4%)	381 (97.4%)	384 (98.2%)	340 (87.0%)	365 (93.4%)	382 (97.7%)
2/14/21-2/27/21	n=286	286 (100%)	275 (96.2%)	276 (96.5%)	239 (83.6%)	261 (91.3%)	270 (94.4%)
2/28/21-3/13/21	n=396	395 (99.7%)	382 (96.5%)	390 (98.5%)	322 (81.3%)	365 (92.2%)	370 (93.4%)
3/14/21-3/27/21	n=320	320 (100%)	299 (93.4%)	316 (98.8%)	233 (72.8%)	293 (91.6%)	301 (94.1%)
3/28/21-4/10/21	n=286	286 (100%)	270 (94.4%)	284 (99.3%)	201 (70.3%)	270 (94.4%)	249 (87.1%)
4/11/21-4/24/21	n=336	334 (99.4%)	311 (92.6%)	330 (98.2%)	231 (68.8%)	315 (93.8%)	295 (87.8%)
4/25/21-5/8/21	n=310	304 (98.1%)	279 (90.0%)	298 (96.1%)	210 (67.7%)	265 (85.5%)	256 (82.6%)
5/9/21-5/22/21	n=360	360 (100%)	338 (93.9%)	344 (95.6%)	231 (64.2%)	325 (90.3%)	295 (81.9%)
5/23/21-6/5/21	n=342	342 (100%)	320 (93.6%)	331 (96.8%)	263 (76.9%)	285 (83.3%)	308 (90.1%)
6/6/21-6/19/21	n=308	306 (99.4%)	295 (95.8%)	305 (99.0%)	213 (69.2%)	288 (93.5%)	275 (89.3%)
6/20/21-7/3/21	n=305	305 (100%)	284 (93.1%)	300 (98.4%)	205 (67.2%)	247 (81.0%)	237 (77.7%)
7/4/21-7/17/21	n=349	294 (84.2%)	320 (91.7%)	339 (97.1%)	162 (46.4%)	306 (87.7%)	211 (60.5%)
7/18/21-7/31/21	n=334	332 (99.4%)	303 (90.7%)	315 (94.3%)	153 (45.8%)	269 (80.5%)	288 (86.2%)
8/1/21-8/14/21	n=335	332 (99.1%)	290 (86.6%)	322 (96.1%)	145 (43.3%)	287 (85.7%)	281 (83.9%)
8/15/21-8/28/21	n=318	317 (99.7%)	276 (86.8%)	312 (98.1%)	208 (65.4%)	268 (84.3%)	279 (87.7%)
Total respondents		542	542	542	542	542	542
Total responses		8021	8021	8021	8021	8021	8021

Note. F value and corresponding p-value are based on final models for selected outcomes.

Supplemental Table 3.6. Estimated change in odds of reporting each COVID-19 prevention behavior across time in the two periods of study

	Kinshasa			Kikwit			Mbandaka			Beni		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Wear face mask												
Before Knot #1	1.06	(0.89, 1.26)	0.50	1.17	(0.96, 1.43)	0.11	0.87	(0.67, 1.12)	0.27	1.00	(0.88, 1.14)	0.96
After Knot #2	0.79	(0.76, 0.81)	<.0001	0.91	(0.89, 0.94)	<.0001	0.89	(0.86, 0.92)	<.0001	0.93	(0.91, 0.96)	<.0001
Avoid social gatherings												
Before Knot #1	0.91	(0.84, 0.99)	0.02	0.84	(0.77, 0.92)	0.0001	0.61	(0.53, 0.71)	<.0001	0.95	(0.85, 1.07)	0.39
After Knot #2	1.02	(0.98, 1.06)	0.43	0.90	(0.87, 0.93)	<.0001	1.01	(0.96, 1.06)	0.72	1.04	(1.00, 1.08)	0.07
Social distance												
Before Knot #1	1.03	(0.94, 1.12)	0.53	0.87	(0.78, 0.97)	0.01	0.61	(0.49, 0.76)	<.0001	0.55	(0.40, 0.76)	0.0003
After Knot #2	0.94	(0.90, 0.97)	0.0006	0.87	(0.84, 0.90)	<.0001	0.94	(0.90, 0.99)	0.01	0.89	(0.86, 0.93)	<.0001

Note. 2-knot simple linear spline model used with Knot #1 at 12/20/2020 to 1/16/2021 and Knot #2 at data collection interval 1/17/21 to 1/30/21. All models are adjusted for gender and age and account for clustering at the individual level.

Supplemental Table 3.7. Pairwise comparisons between cohorts of estimated change in odds of reporting each COVID-19 prevention behavior across time in the two periods of study

	Beni vs. Kinshasa			Kikwit vs. Kinshasa			Mbandaka vs. Kinshasa		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Wear face mask									
Before Knot #1	0.95	(0.76, 1.17)	0.62	1.11	(0.85, 1.44)	0.44	0.82	(0.60, 1.11)	0.19
After Knot #2	1.18	(1.14, 1.23)	<.0001	1.16	(1.12, 1.20)	<.0001	1.14	(1.09, 1.19)	<.0001
Avoid gatherings									
Before Knot #1	1.04	(0.91, 1.20)	0.56	0.92	(0.82, 1.04)	0.17	0.92	(0.82, 1.04)	0.17
After Knot #2	1.02	(0.97, 1.08)	0.46	0.89	(0.84, 0.93)	<.0001	0.89	(0.84, 0.93)	<.0001
Social distance									
Before Knot #1	0.54	(0.38, 0.75)	0.0003	0.84	(0.73, 0.97)	0.02	0.6	(0.47, 0.75)	<.0001
After Knot #2	0.95	(0.90, 1.01)	0.08	0.93	(0.88, 0.97)	0.003	1.00	(0.95, 1.07)	0.87
	Kikwit vs. Beni			**Mbandaka vs. Beni**			**Mbandaka vs. Kikwit**		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Wear face mask									
Before Knot #1	1.17	(0.92, 1.48)	0.19	0.86	(0.65, 1.15)	0.31	0.74	(0.54, 1.02)	0.06
After Knot #2	0.98	(0.94, 1.02)	0.27	0.96	(0.92, 1.00)	0.07	0.98	(0.94, 1.02)	0.34
Avoid gatherings									
Before Knot #1	0.89	(0.77, 1.02)	0.09	0.64	(0.53, 0.77)	<.0001	0.72	(0.61, 0.86)	0.0003
After Knot #2	0.87	(0.83, 0.91)	<.0001	0.97	(0.91, 1.03)	0.37	1.12	(1.06, 1.19)	<.0001
Social distance									
Before Knot #1	1.57	(1.12, 2.22)	0.01	0.64	(0.53, 0.77)	<.0001	0.71	(0.55, 0.90)	0.01
After Knot #2	0.97	(0.93, 1.02)	0.28	0.97	(0.91, 1.03)	0.37	1.08	(1.02, 1.14)	0.01

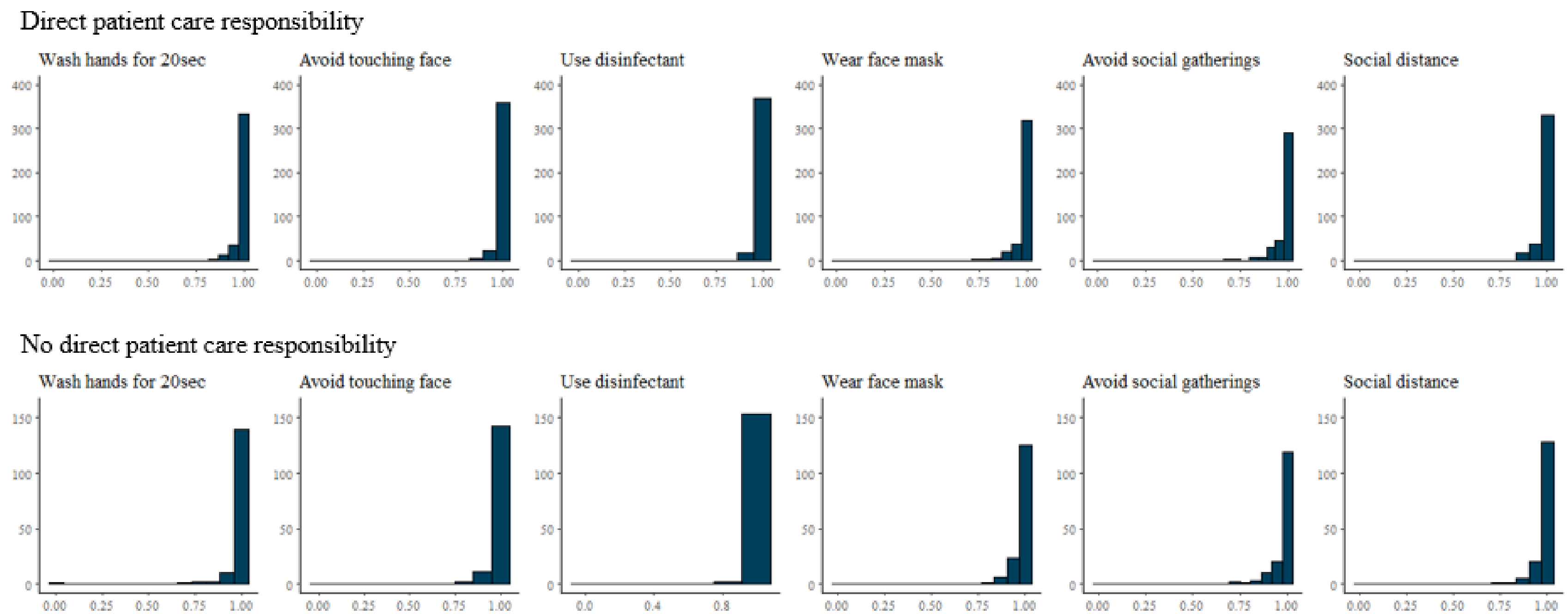
Note. 2-knot simple linear spline model used with Knot #1 at 12/20/2020 to 1/16/2021 and Knot #2 at data collection interval 1/17/21 to 1/30/21. All models are adjusted for gender and age and account for clustering at the individual level.

Supplemental Table 3.8. Fitted predicted probabilities overall in each data collection interval of reporting each COVID-19 prevention behavior

Data collection interval	Wear face mask	Avoid gatherings	Social distance
9/13/20-9/26/20	91.5	80.7	89.9
9/27/20-10/10/20	91.7	78.7	89.3
10/11/20-10/24/20	91.8	76.4	88.3
10/25/20-11/7/20	91.9	73.8	86.9
11/8/20-11/21/20	91.9	70.8	85.0
11/22/20-12/5/20	91.9	67.5	82.2
12/6/20-12/19/20	91.8	64.0	78.6
1/17/21-1/30/21	81.9	83.8	90.7
1/31/21-2/13/21	80.4	83.8	89.9
2/14/21-2/27/21	78.8	83.7	89.2
2/28/21-3/13/21	77.1	83.6	88.3
3/14/21-3/27/21	75.2	83.5	87.4
3/28/21-4/10/21	73.1	83.4	86.5
4/11/21-4/24/21	71.0	83.3	85.5
4/25/21-5/8/21	68.7	83.1	84.4
5/9/21-5/22/21	66.3	82.9	83.2
5/23/21-6/5/21	63.8	82.7	82.0
6/6/21-6/19/21	61.2	82.5	80.8
6/20/21-7/3/21	58.6	82.3	79.4
7/4/21-7/17/21	55.9	82.1	78.0
7/18/21-7/31/21	53.2	81.8	76.5
8/1/21-8/14/21	50.6	81.6	75.0
8/15/21-8/28/21	48.0	81.3	73.4

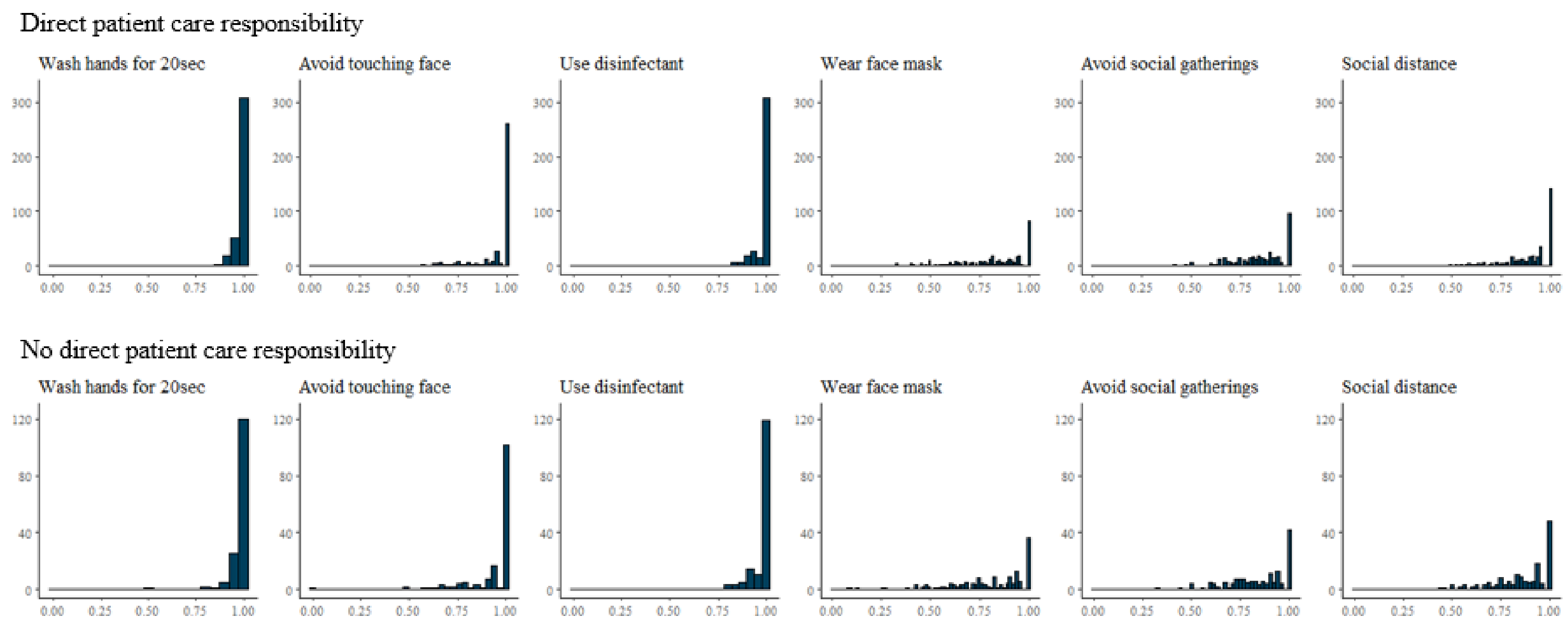
Note. Fitted predicted probabilities presented for a 42 year old male.

Supplemental Figure 3.1. Within-person average values of repeated measures across data collection - whether each COVID-19 prevention behavior is effective



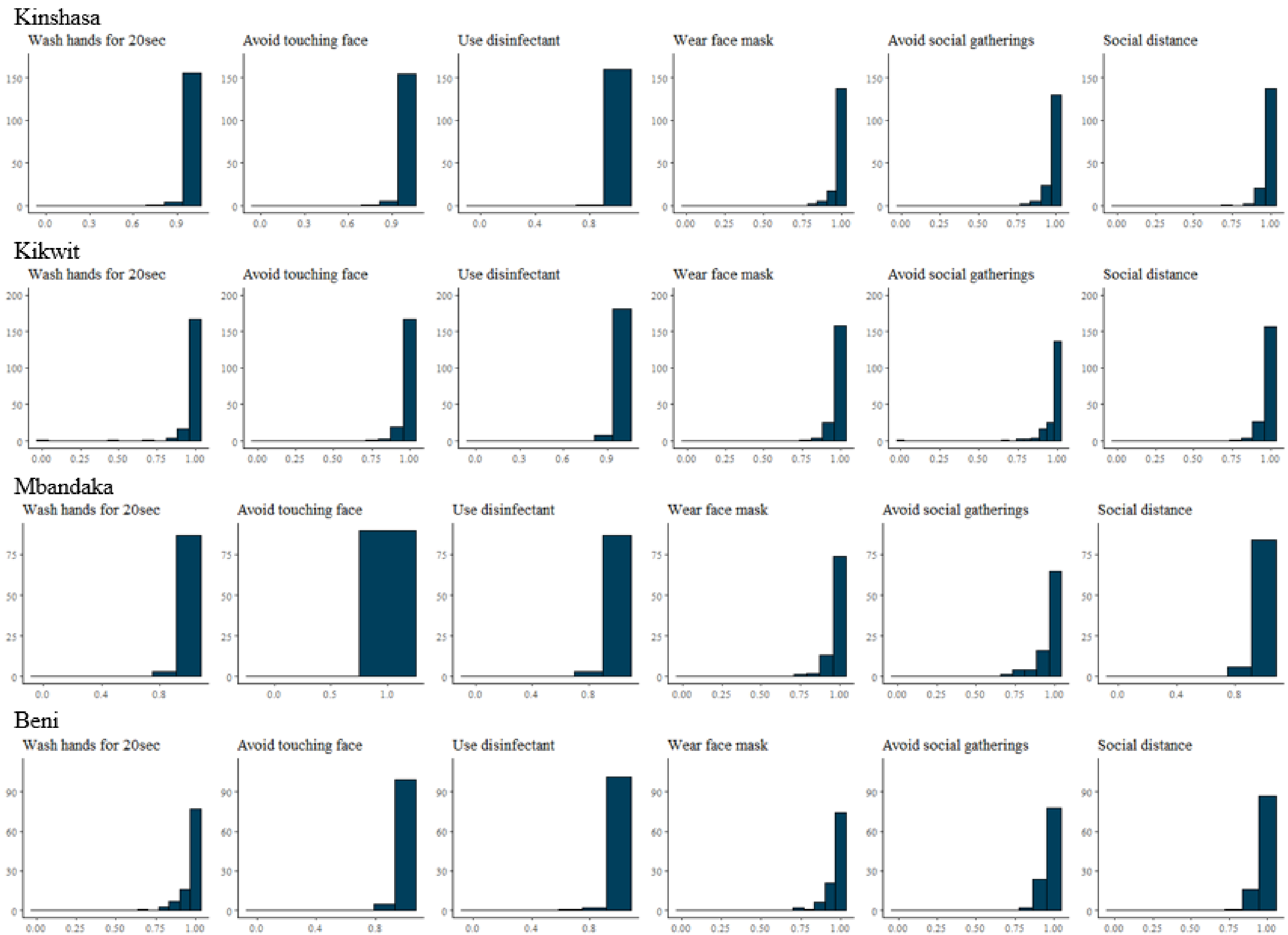
Note. If a participant has an average value of 1.0 across the repeated measures contributed to the study, this indicates that the participant responded in the affirmative to the measure at each time point of response. Likewise, a participant with an average value of 0.0 dissented at each response point. An average value between 0.0 and 1.0 indicates the individual changed their response at least once throughout the study.

Supplemental Figure 3.2. Within-person average values of repeated measures across data collection - whether each COVID-19 prevention behavior was performed in the past two weeks



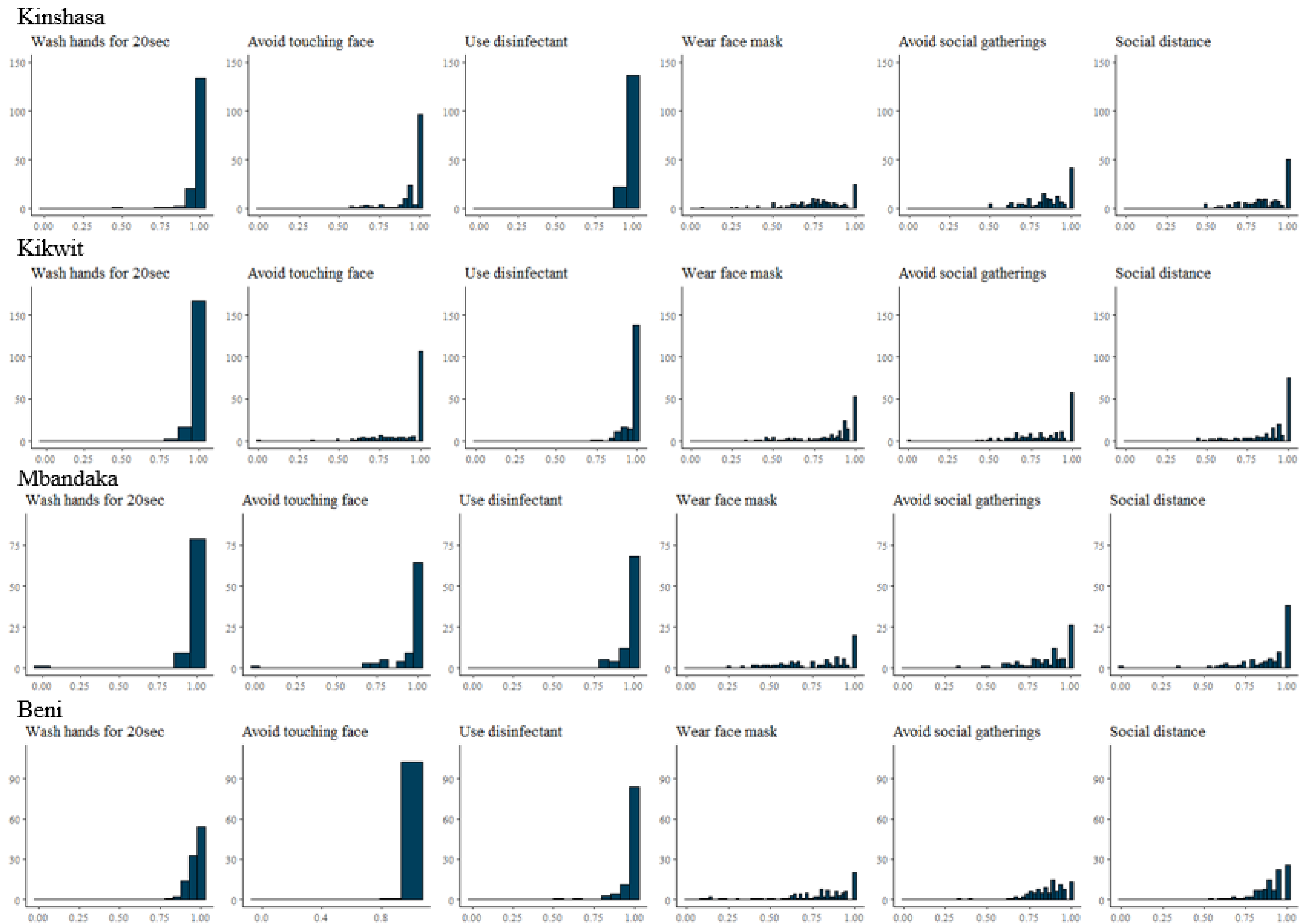
Note. If a participant has an average value of 1.0 across the repeated measures contributed to the study, this indicates that the participant responded in the affirmative to the measure at each time point of response. Likewise, a participant with an average value of 0.0 dissented at each response point. An average value between 0.0 and 1.0 indicates the individual changed their response at least once throughout the study.

Supplemental Figure 3.3. Within-person average values of repeated measures across data collection - whether each COVID-19 prevention behavior is effective by cohort



Note. If a participant has an average value of 1.0 across the repeated measures contributed to the study, this indicates that the participant responded in the affirmative to the measure at each time point of response. Likewise, a participant with an average value of 0.0 dissented at each response point. An average value between 0.0 and 1.0 indicates the individual changed their response at least once throughout the study.

Supplemental Figure 3.4. Within-person average values of repeated measures across data collection - whether each COVID-19 prevention behavior was performed in the past two weeks by cohort



Note. If a participant has an average value of 1.0 across the repeated measures contributed to the study, this indicates that the participant responded in the affirmative to the measure at each time point of response. Likewise, a participant with an average value of 0.0 dissented at each response point. An average value between 0.0 and 1.0 indicates the individual changed their response at least once throughout the study.

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Chapter 4. A tale of two outbreaks: Ebola virus disease outbreak and workplace safety among healthcare workers during the COVID-19 pandemic in the Democratic Republic of the Congo

4.1 Abstract

Five Ebola Virus Disease (EVD) outbreaks have occurred in the Democratic Republic of the Congo (DRC) since the beginning of the COVID-19 pandemic. However, the impact of these concurrent outbreaks on health facility factors such as perceptions of safety and available resources among frontline healthcare workers (HCWs) is poorly understood. This study measured infection control norms, face mask access, and safety perceptions at the workplace among four cohorts of HCWs in DRC (Kinshasa, Kikwit, Mbandaka, Beni) between August 2020 and August 2021 (N=545, 23 possible data collection points). Observed proportions of each outcome and fitted probabilities of two outcomes, assessed by mixed effects models, within five periods defined by the start and end dates of the 11th and 12th EVD outbreaks in DRC in Mbandaka and near Beni, respectively, were examined. Infection prevention norms remained stable among participants apart from those from Beni, among whom the proportion reporting each norm typically decreased over time. The probability of access to cloth face masks significantly decreased; and probability of surgical face mask access significantly increased among the Mbandaka cohort during the study period coinciding with an EVD outbreak in the region. In comparison, cloth mask access remained stable and surgical face mask access significantly increased among the Beni cohort during the nearby EVD outbreak. Reporting positive workplace safety perceptions did not change over time considerably within any cohort but did differ by cohort. The observed fluctuations, especially in access to face masks, indicate lapses in the proper protection of frontline HCWs in the workplace throughout an emerging

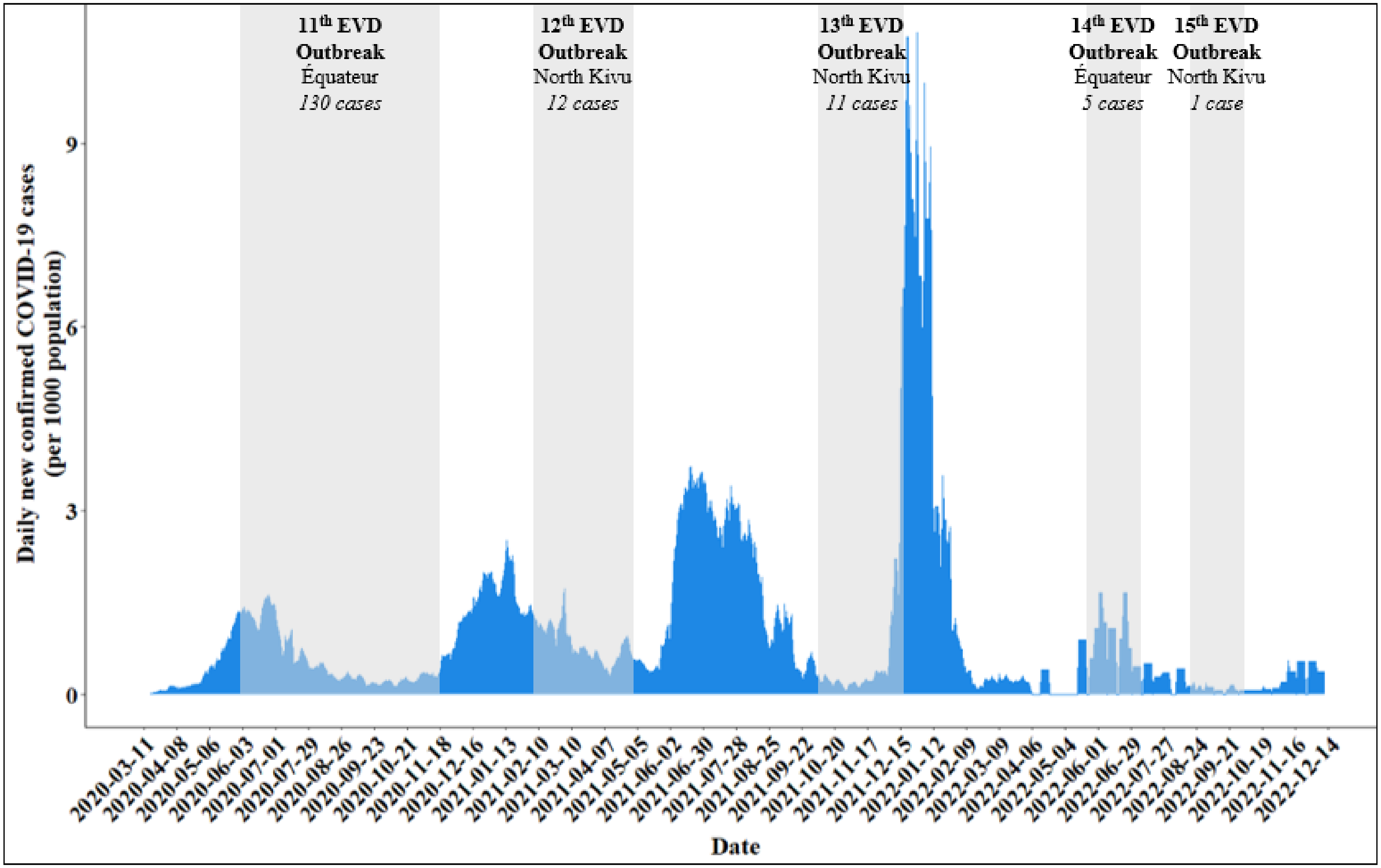
infectious disease outbreak, and for some participants, during concurrent high-risk outbreaks. Future outbreak response activities in DRC should focus on acquisition and sustained distribution of vital personal protective equipment throughout the country to ensure a healthy and safe health workforce. This study supports the feasibility of a longitudinal phone-based survey to measure attitudes and experiences among HCWs in DRC, but future research should explore the complexities of measuring the impact of dual outbreaks on the health system.

4.2 Background

Throughout the COVID-19 pandemic, the Democratic Republic of the Congo (DRC) has battled outbreaks caused by another high-profile, emergent pathogen of concern: the Ebola virus. In fact, there have been five Ebola virus Disease (EVD) outbreaks in DRC since the COVID-19 global pandemic was declared by the World Health Organization in March 2020 (Figure 4.1).[1] The coexistence of these two outbreaks puts additional strain on an already overburdened and under-resourced national health system.[2-4] However, at a programmatic level, lessons learned and systems put in place for EVD response can be leveraged to help develop a COVID-19 national response in DRC.[5,6] For example, national leadership of EVD response in DRC was tasked with supervising COVID-19 response at the beginning of the pandemic, redirecting workforces from one response effort to the other.[3,7] The impact of dual outbreaks on the working conditions and perceived safety among frontline workers of these efforts is not well studied but essential to a more complete understanding of the functioning of DRC's health system under the stress of dual outbreaks.

Beyond morbidity and mortality caused directly by EVD, the impact of an EVD outbreak on the health system in DRC is considerable and the impact on frontline HCWs, specifically, can be complex. For example, disruptions in routine healthcare and utilization, poor surveillance and

Figure 4.1. Daily confirmed cases of COVID-19 (per 1000 population) and Ebola virus disease outbreaks in the Democratic Republic of the Congo, March 11, 2020 to December 14, 2022



Note. Dates of each EVD outbreak shown above are as follows: 1) 11th EVD outbreak: from June 1, 2020 to November 18, 2020 in Mbandaka, Équateur province, 2) 12th EVD outbreak: from February 7, 2021 to May 3, 2021 in Biena health zone, North Kivu province, 3) 13th EVD outbreak: from October 8, 2021 to December 16, 2021 in Beni health zone, North Kivu province, 4) 14th EVD outbreak: from April 23, 2022 to July 4, 2022 in Mbandaka, Équateur province, and 5) 15th EVD outbreak: from August 21, 2022 to September 27, 2022 in Beni health zone, North Kivu province.

health data management, and weak leadership among public health authorities are commonly observed during EVD outbreaks.[8] On one hand, HCWs on the frontlines of EVD outbreaks face increased workloads, stress, health risk, and, at times, stigma and blame from the community.[9-11] On the other hand, HCWs working in the EVD response in DRC can receive more money, training, and capacity-building opportunities.[8] Specifically, those working at the frontlines of an EVD outbreak can receive more surveillance, field epidemiology, and infection prevention and control (IPC) training. During a qualitative study conducted in the South Kivu province of DRC from April to September 2021, HCWs interviewed discussed how a recent EVD response exacerbated issues of limited resources, but others cited the ability to leverage existing infrastructure (e.g., handwashing stations, community mobilization) from the EVD response for COVID-19.[12] This study also reported that HCW training shifted focus from EVD to COVID-19, and the increased knowledge among frontline workers of effective IPC measures for EVD, such as physical distancing and hand hygiene, enhanced prevention behavior for COVID-19.

Facility preparedness has emerged as a major influence on HCW health and wellbeing during EVD outbreaks as well as the COVID-19 pandemic. A systematic review investigating exposure risk among HCWs working on the frontlines of EVD and Marburg virus disease outbreaks found that inadequate access to appropriate personal protective equipment (PPE) and exposure at the point of care (e.g., unrecognized cases, inadequate hand hygiene) were some of the most commonly reported risks factors for exposure among HCWs.[11] Similar themes related to the impact of the COVID-19 pandemic were found among HCWs interviewed in South Kivu.[12] Lack of necessary PPE and hygiene materials, particularly early in the pandemic, not only put frontline HCWs at increased risk of infection because they were unable to practice basic infection control activities, but also reduced morale and perceptions of safety. Lacking PPE, performing higher risk procedures (e.g., intubation, contact with bodily secretions), and working in a high-risk healthcare department, such as an inpatient setting, have been linked to increased risk of COVID-19 exposure among HCWs[13,14] which can contribute to poorer mental health outcomes.[15,16]

Correct and consistent IPC behavior among HCWs is essential to their health and wellbeing during an infectious disease outbreak. Several behavioral theories suggest that factors that could influence HCWs' compliance with proper IPC measures include perceived risk, perceived barriers and benefits, self-efficacy, and norms (e.g., is the behavior adopted by others, do others approve or disapprove of this behavior).[17-19] Indeed, several studies have found that favorable norms or social expectations are associated with compliance with prevention measures (e.g., hand hygiene, vaccination) among groups of HCWs.[20-24] Further, in a low-resourced setting such as DRC, facility infrastructure and access to the necessary resources to properly comply with IPC guidelines, such as PPE, soap and water, or disinfectants, are factors related to IPC measure adherence that cannot be disregarded.[24] Additional studies suggest there is a connection between an employee's perceptions of workplace safety and events of employee injury.[25,26] Given the influence of facility factors on HCW safety during infectious disease outbreaks, understanding the fluctuations in the organizational culture, climate of safety, and available resources at health facilities throughout dual outbreaks can provide better insight on the wellbeing of HCWs in DRC.

While several qualitative studies have explored how EVD outbreaks indirectly impact the health workforce even during the COVID-19 pandemic,[8,10,13] no studies have quantitatively and longitudinally assessed the impact of dual high-profile outbreaks on health facility factors as reported by HCWs in DRC. This study aims to assess the impact of two EVD outbreaks (DRC's

11th and 12th EVD outbreaks) that coincided with longitudinal data collection on the norms, PPE access, and perceptions related to workplace safety among HCWs during a year of the COVID-19 pandemic. It is hypothesized that expectations from employers and health authorities to comply with COVID-19 prevention behavior as well as reports of peer compliance will increase during EVD outbreaks in the affected communities as these are IPC strategies common to both diseases. Periods of active EVD outbreak are expected to be associated with an increase in PPE access among HCWs in the affected areas as more resources are directed to these areas for EVD response. Finally, HCWs working during active EVD outbreaks in their communities will be less likely to report perceptions of workplace safety compared to periods of no EVD outbreak and to communities with no EVD outbreak.

4.3 Methods

Study design and sample

In August 2020, four cohorts of HCWs from DRC (N=588) were enrolled in a longitudinal study measuring knowledge, attitudes, and practices related to COVID-19. The study sample was selected from the participant pool of another ongoing longitudinal study, "Epidemiology, Immunopathology Immunogenetics and Sequelae of Ebola Virus and other Viral Hemorrhagic Fever Infections." Only individuals in the original study who consented to future contact for research and who still actively worked in healthcare were recruited in 2020 (N=1,872). Study staff successfully contacted 680 individuals by phone and invited each to participate in a yearlong study collecting COVID-19 related measures.

Participants were recruited in 1) the city of Kinshasa in Kinshasa Province, 2) the city of Kikwit in Kwilu Province, 3) the city of Mbandaka in Équateur Province, and 4) the city of Beni in North Kivu Province. The Kinshasa, Kikwit, Mbandaka, and Beni cohorts were initially recruited in November 2017, August 2017, June/July 2018, and August 2018, respectively. The Kinshasa and Kikwit cohorts consisted of active HCWs in select health zones in both city areas. The Mbandaka cohort was recruited as either a recipient of the rVSVΔG-ZEBOV-GP vaccine during an EVD outbreak in Équateur Province or as an active HCW in select health zones in the city area. The Beni cohort consisted only of recipients of the rVSVΔG-ZEBOV-GP vaccine in the city area. At the time of enrollment in Mbandaka and Beni, the rVSVΔG-ZEBOV-GP vaccine was used under a compassionate use protocol for EVD outbreak response and those eligible for the vaccine included contacts of confirmed cases, contacts of contacts of confirmed cases, and healthcare and other workers on the frontline of the outbreak. A detailed description of the study design, sampling methods, and participant flow between studies is provided in a previous paper.[27]

Study enrollment and baseline questionnaire completion took place from August 11 to September 7, 2020. Participants were then called about every two weeks from mid-September 2020 to late-August 2021 to complete additional questionnaires. Data collection typically occurred from a Monday to the following Tuesday, and questionnaires took between 10 and 20 minutes to complete over the phone. Open Data Kit (ODK) Collect[28] was used by study interviewers to administer questionnaires. The interviewer team was able to discuss study protocols, obtain verbal informed consent, and administer surveys in French, Lingala, Kikongo, or Swahili.

Outcomes

COVID-19 prevention norms. Study interviewers asked four questions related to peer prevention behaviors and expectations in the workplace: 1) “I see my work colleagues at the health facility washing their hands frequently,” 2) “Health authorities urge me to wash my hands frequently,” 3) “Health authorities urge me to avoid crowded areas,” and 4) “My employer urges me to avoid crowded areas at work.” Response options for each item were *strongly agree, agree, neutral*, *disagree,* and *strongly disagree*. These measures were dichotomized for analysis as *strongly agree* compared to the other options because in a clinical setting, HCWs are expected to be practicing hand hygiene and authorities should encourage prevention behaviors among HCWs to a high degree. Measures collected at 16 time points throughout the study are analyzed in this study.

PPE access. At each data collection point analyzed in this study (n=23), participants were asked, “Currently (last 14 days), while performing your work duties, how often do you have access to the following PPE?” and provided a list of 11 pieces of PPE. Response options were *always*, *sometimes*, *rarely*, and *never*. This study focuses on always having access to cloth masks, surgical masks, and N95 masks to measure an ideal workplace characteristic for appropriate use of PPE during the COVID-19 pandemic.

Perceived workplace safety. Participants’ perceptions of workplace safety were also measured at 16 time points with the question, “In regard to the current COVID-19 outbreak, to what extent do you agree or disagree with the following statements?” and items: “I feel safe at work,” “I feel confident in my employer's ability to protect my wellbeing,” and “I feel that my employer is doing everything in their power to protect me.” For analysis, these outcomes were dichotomized as *strongly agree* compared to *agree*, *neutral*, *disagree,* and *strongly disagree* to measure an ideal workplace characteristic for HCWs during the COVID-19 pandemic.

Predictors

Time. Time was measured as two-week intervals corresponding to data collection. No data collection took place from December 20, 2020 to January 16, 2021 due to holidays. EVD outbreaks were defined by the data collection intervals corresponding to the official start and end dates as announced by the World Health Organization (WHO) and DRC government. The EVD outbreak of interest in Mbandaka began on June 1, 2020 (prior to the beginning of baseline data collection) and ended November 18, 2020 (data collection interval: 11/8/2020-11/21/2020). The EVD outbreak near Beni during the study began February 7, 2021 (data collection interval: 1/31/2021-2/13/2021) and ended May 3, 2021 (data collection interval: 4/25/2021-5/8/2021).

Location. At study baseline, midway through the study, and at the end of the study, HCWs reported in which city area they lived and worked (Kinshasa, Kikwit, Mbandaka, Beni).

Demographics

Gender. Participants reported their gender ("male" or "female") at study baseline.

Age. At baseline, participants self-reported their age in years.

Education level. Highest level of education at study baseline was collected as: *no education*, *less than high school graduate*, *graduated high school*, *some college (including vocational training or associate degree)*, *Bachelor's degree*, and *advanced degree*. Nearly two-thirds of participants (65.1%) reported having some college education. Less education than *some college* was categorized together as was more education than *some college*.

Chronic disease. Participants self-reported if they had a chronic disease (e.g., chronic lung disease, diabetes cardiovascular disease, chronic renal or liver disease) or if they were otherwise immunocompromised at baseline.

Environment setting. Participants reported if they lived in a rural or urban setting at baseline.

Employment status. Participants reported their employment status (*full-time*, *part-time*, *contracted*, *unemployed*) at study baseline, midway point, and end.

Health facility type. The name of the health facility at which each participant worked was collected at study baseline. Study staff familiar with the local areas then assigned the type of health facility to each unique facility reported. Only one participant reported working at a health post, so this category was collapsed into "other".

Job title. Participant's provided their job title at baseline. Positions reported by less than 20 individuals were collapsed into an "other" category to highlight the most common jobs within the sample.

EVD Outbreak Experience. Two measures of direct EVD outbreak experience were collected during the original Ebola-related studies: 1) ever been involved in an EVD outbreak and 2) ever received the EVD vaccine (rVSVΔG-ZEBOV-GP).

Statistical analysis

Sample. Of 588 study participants who gave consent and were successfully enrolled in the study,[27] those who had moved away from the four main city areas of interest (Kinshasa, Kikwit, Mbandaka, Beni) by study baseline (*n*=4) or whose exposures of interest changed during follow-up (i.e., became unemployed or moved provinces; *n*=22) were excluded from analysis. Descriptive statistics for sociodemographic and occupational measures were calculated: count and sample proportions were calculated for categorical variables and mean, standard deviation, median, and range were calculated for age.

A single data collection interval (7/4/21 to 7/17/21; *n*=349 responses) was excluded from analysis due to widespread misclassification of the outcome measures. An aberrant number of extreme responses to outcome measures (e.g., *strongly agree*, *strongly disagree*) were observed during this follow-up interval compared to preceding and following intervals, warranting further investigation. The responses were closely linked to a single interviewer who likely presented or recorded response options incorrectly. This pattern was not observed in any other intervals of data collection and therefore this interval of outcome collection was excluded to maintain consistency in measurement across the study. Outcome responses collected in the first two intervals of data collection (8/11/20-8/29/20) were also excluded (*n*=394 responses) as these were pilot weeks for the study. Participants who no longer contributed any outcome measures to statistical analysis after these three data collection intervals were dropped were excluded from the study (*n*=17).

Longitudinal analysis. The count and percentage of respondents reporting each of the 10 outcomes of interest across the study and within each period of data collection were calculated. Histograms of average response to each outcome over time within participant were created in addition to the count and proportion of participants who did or did not change their response throughout the study. Line plots to visually present the observed proportion of respondents, overall and by cohort, reporting each outcome of interest throughout the study were also created.

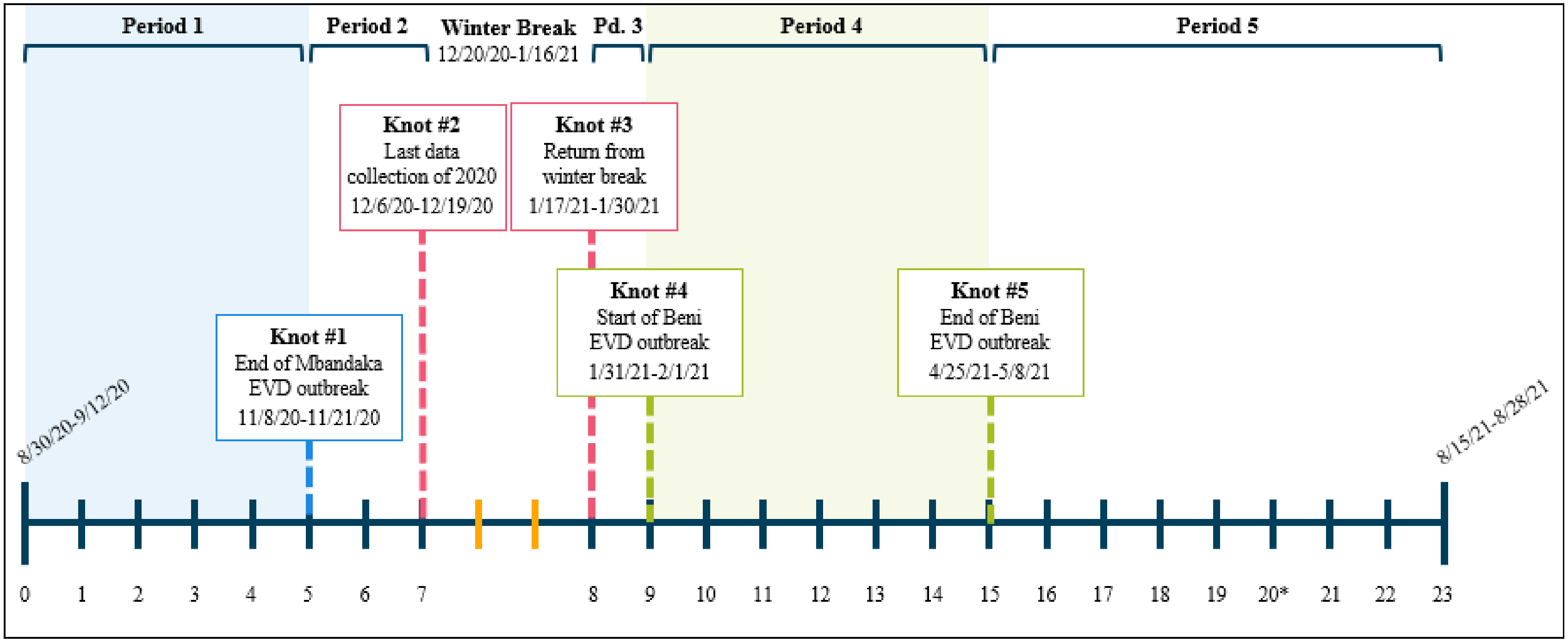
Mixed effect models were used to assess the association between each of the 10 outcomes of interest, location, and time, accounting for clustering in the data. Simplified models with four sets of random effects (individual only, individual and health zone, individual and health facility, and individual, health zone, and health facility) and both Cholesky and unstructured covariance structures were run for each outcome (Supplemental Table 4.1). Based on model performance with the simplified model structure and conclusions from plots, final models were run for two outcomes (i.e., access to cloth masks at work, access to surgical masks at work) while other outcomes are discussed descriptively.

Final models included spline functions to assess the association between location and each outcome in specific time periods of interest. Five knots across the study timeline were selected: 1) the end of the EVD outbreak in Mbandaka, 2) the last data collection interval prior to a winter break in data collection, 3) return from the break in data collection (as was done previously[29]), 4) the start of the EVD outbreak near Beni, and 5) the end of the EVD outbreak near Beni (Figure 4.2). Simple linear spline functions were used due to an a priori belief that the exposure effect in each of the five time periods of interest would be linear but might be non-linear across periods.[30] Based on consistency in performance of the simplified models, final mixed effect models accounted for clustering at the individual level across the repeated measures and had an unstructured covariance structure. Final models included the five knots of interest as well as gender and age as additional covariates. Models were run using the PROC GLIMMIX procedure in SAS.[31] Finally, fitted values were calculated on the logit scale for each final model (for a 42 year old male). Then, each estimate was offset by a random normal variate scaled by the standard deviation (SD) of the subject random effect in each model and transformed to probabilities and averaged for each combination of location and time. To account for 10 exposure-outcome associations, a Bonferroni corrected level of significance was calculated as α/K, where $K = 10$ and $\alpha=0.05$, or 0.005. Note that despite the Bonferroni significance threshold of 0.005, tables present 95% confidence intervals.

Ethical

Institutional review board approval was obtained from the University of California, Los Angeles (IRB#20–001321) as well as the Kinshasa School of Public Health at the University of

Figure 4.2. Overview of study timeline with spline function knots in final models



Note. Each tick on the timeline represents a two-week interval of data collection. There was no data collection between 12/20/20 and 1/16/21 due to the winter holidays. The first two data collection intervals of the study (8/11/20-8/29/20) are not shown as they were removed from longitudinal analysis. Shading indicates an active EVD outbreak in DRC. *Responses collected in this interval were excluded from analysis due to inverviewer data collection inconsistencies.

Kinshasa (ESP/CE/118/2020), which served as the local ethics committee. During phone calls, participants provided an oral consent to participate. The original cohorts were enrolled under ethics approvals: UCLA: IRB#16–001346/KSPH IRB: ESP/CE/022/2017.

4.4 Results

Sample

Table 4.1. presents the sample characteristics collected at baseline for the analytic sample in this study (N=545). Statistical testing assessing differences between the four cohort groups (Kinshasa: 29.7%, Kikwit: 34.7%, Mbandaka: 16.5%, Beni: 19.1%) are described elsewhere.[27] Briefly, the Kinshasa and Kikwit cohorts had larger proportions of females compared to the Mbandaka and Beni cohorts while the Beni cohort was younger on average than the others. The Kinshasa cohort had the largest proportion of HCWs living in an urban setting followed by Mbandaka, Kikwit, then Beni. The Kinshasa cohort also had the largest proportion of part-time workers and HCWs who worked at hospital centers as opposed to health centers or general referral hospitals. About half of the Kikwit and Beni cohorts and a third of the Mbandaka cohort reported direct EVD outbreak response experience.

Longitudinal

Supplemental Figure 4.1 shows within-participant average response across data collection for the ten dichotomized longitudinal outcomes of interest. The proportion of respondents who and surgical masks (94.3% and 90.8%, respectively), but about half (46.4%) consistently replied that they did not always have access to N95 masks. Three-quarters of the study sample (71.4-75.2%) changed their level of agreement throughout the study with feeling safe at work, being confident in their employer's ability to protect their wellbeing, and their employer doing everything in its power to protect them.

Table 4.1. Baseline sample characteristics by cohort (N=545).

	Overall (N=545) *n* (%)	**Kinshasa (*n*=162)** *n* (%)	**Kikwit (*n*=189)** *n* (%)	**Mbandaka (*n*=90)** *n* (%)	**Beni (*n*=104)** *n* (%)
Gender					
Male	305 (56.0%)	73 (45.1%)	98 (51.9%)	62 (68.9%)	72 (69.2%)
Female	240 (44.0%)	89 (54.9%)	91 (48.1%)	28 (31.1%)	32 (30.8%)
Age, continuous					
Mean (SD)	43.4 (12.1)	44.9 (12.2)	44.4 (12.6)	45.2 (10.6)	37.5 (10.4)
Median [Min, Max]	42.0 [20.0, 81.0]	43.0 [23.0, 79.0]	43.0 [20.0, 81.0]	45.0 [25.0, 78.0]	35.0 [21.0, 67.0]
Education					
H.S. or less	84 (15.4%)	25 (15.4%)	27 (14.3%)	9 (10.0%)	23 (22.1%)
Some college/Assoc.	357 (65.5%)	108 (66.7%)	136 (72.0%)	54 (60.0%)	59 (56.7%)
Bach./Advanced deg.	104 (19.1%)	29 (17.9%)	26 (13.8%)	27 (30.0%)	22 (21.2%)
Chronic disease	45 (8.3%)	19 (11.7%)	16 (8.5%)	7 (7.8%)	3 (2.9%)
Environment setting					
Urban	360 (66.1%)	153 (94.4%)	103 (54.5%)	67 (74.4%)	37 (35.6%)
Rural	185 (33.9%)	9 (5.6%)	86 (45.5%)	23 (25.6%)	67 (64.4%)
Employment status					
Full-time	388 (71.2%)	91 (56.2%)	158 (83.6%)	59 (65.6%)	80 (76.9%)
Part-time	149 (27.3%)	70 (43.2%)	28 (14.8%)	28 (31.1%)	23 (22.1%)
Contracted	8 (1.5%)	1 (0.6%)	3 (1.6%)	3 (3.3%)	1 (1.0%)
Health facility type					
Health center	188 (34.5%)	16 (9.9%)	84 (44.4%)	45 (50.0%)	43 (41.3%)
General hospital	173 (31.7%)	44 (27.2%)	70 (37.0%)	27 (30.0%)	32 (30.8%)
Hospital center	106 (19.4%)	90 (55.6%)	13 (6.9%)	2 (2.2%)	1 (1.0%)
Clinic/medical center/private hospital	46 (8.4%)	3 (1.9%)	18 (9.5%)	7 (7.8%)	18 (17.3%)
Coordinating office	22 (4.0%)	7 (4.3%)	1 (0.5%)	4 (4.4%)	10 (9.6%)
Other*	8 (1.5%)	2 (1.2%)	3 (1.6%)	3 (3.3%)	0 (0%)
Unknown	2 (0.4%)	0 (0%)	0 (0%)	2 (2.2%)	0 (0%)
Ever involved in Ebola outbreak					
Yes	180 (33.0%)	7 (4.3%)	97 (51.3%)	32 (35.6%)	44 (42.3%)
No	352 (64.6%)	155 (95.7%)	92 (48.7%)	54 (60.0%)	51 (49.0%)
Missing	13 (2.4%)	0 (0%)	0 (0%)	4 (4.4%)	9 (8.7%)
Ever received Ebola vaccine	145 (26.6%)	1 (0.6%)	0 (0%)	40 (44.4%)	104 (100%)

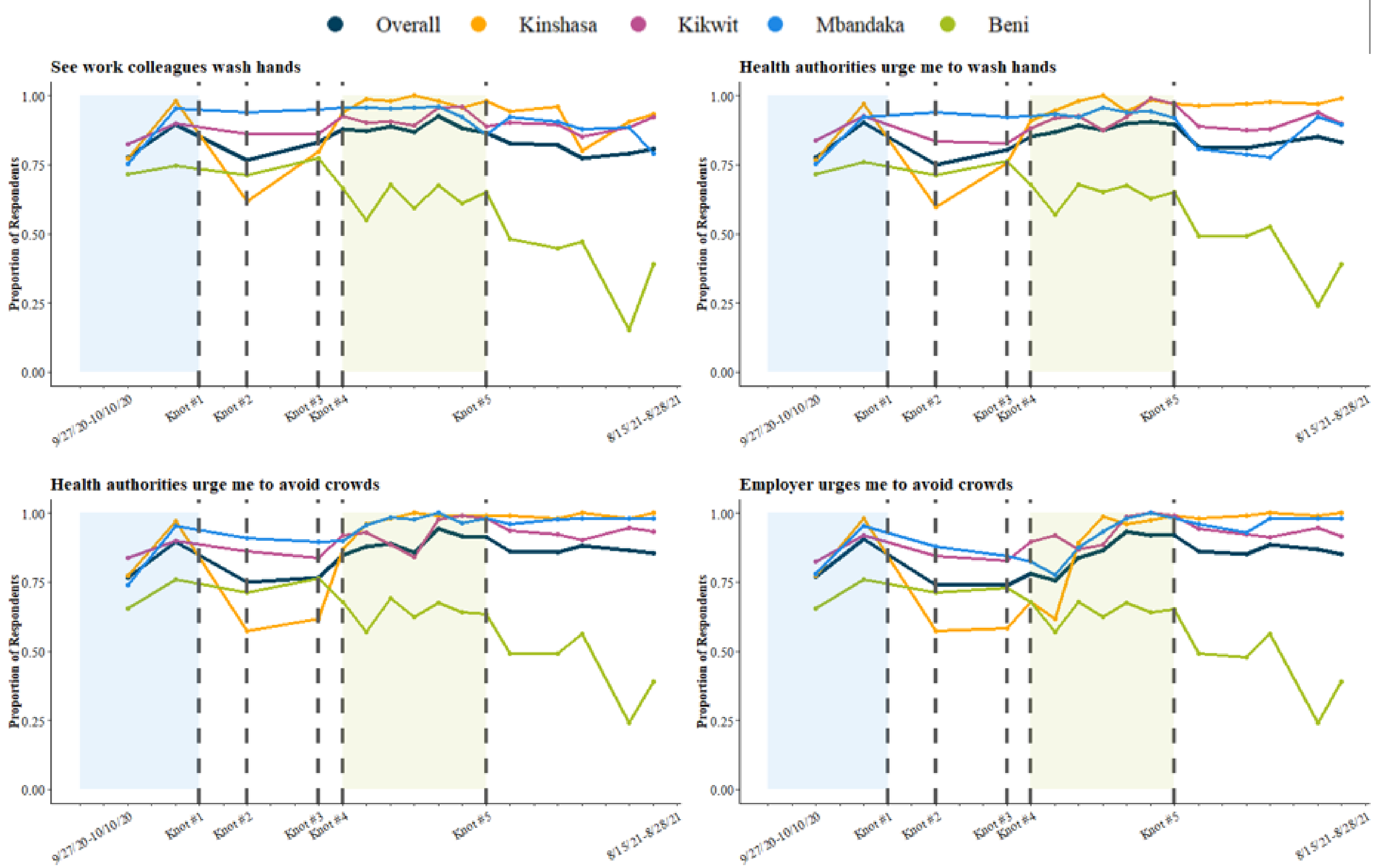
Note. * ‘Other’ category: health post, church, home, etc.

Among COVID-19 prevention norms outcomes, responses from the Kinshasa, Kikwit, and Mbandaka cohorts remained stable across the study (Figure 4.3 and Supplemental Table 4.3). Most respondents in each data collection interval overall strongly agreed with: seeing work colleagues wash hands frequently, health authorities urging them to wash hands, health authorities urging them to avoid crowds, and their employer urging them to avoid crowds (76.7-92.7%, 75.0-90.8%, 75.0-94.4%, and 73.9-93.4%, respectively). The Beni cohort stood out as having an overall decline in the proportion of participants agreeing with these items throughout the study.

Always having access to cloth and surgical masks was dynamic over time in all cohorts (Figure 4.4). Among all respondents, always having access to cloth masks was reported by the smallest proportion of respondents (29.8%) in the May 23, 2021 to June 5, 2021 data collection interval and the largest proportion (76.5%) in the September 13, 2020 to September 26, 2020 interval (Supplemental Table 4.4). In comparison, the proportion reporting always having access to surgical masks at work did not fluctuate as widely throughout the study and was never reported by less than half of all respondents (from 52.9% at 8/30/20-9/12/20 to 77.4% at 12/6/20-12/19/20). Generally, access to N95 masks was much lower across the study in all cohorts compared to cloth and surgical masks. In the overall sample, the proportion of respondents reporting always having access to N95 masks was never reported by more than one in five HCWs and was typically lower.

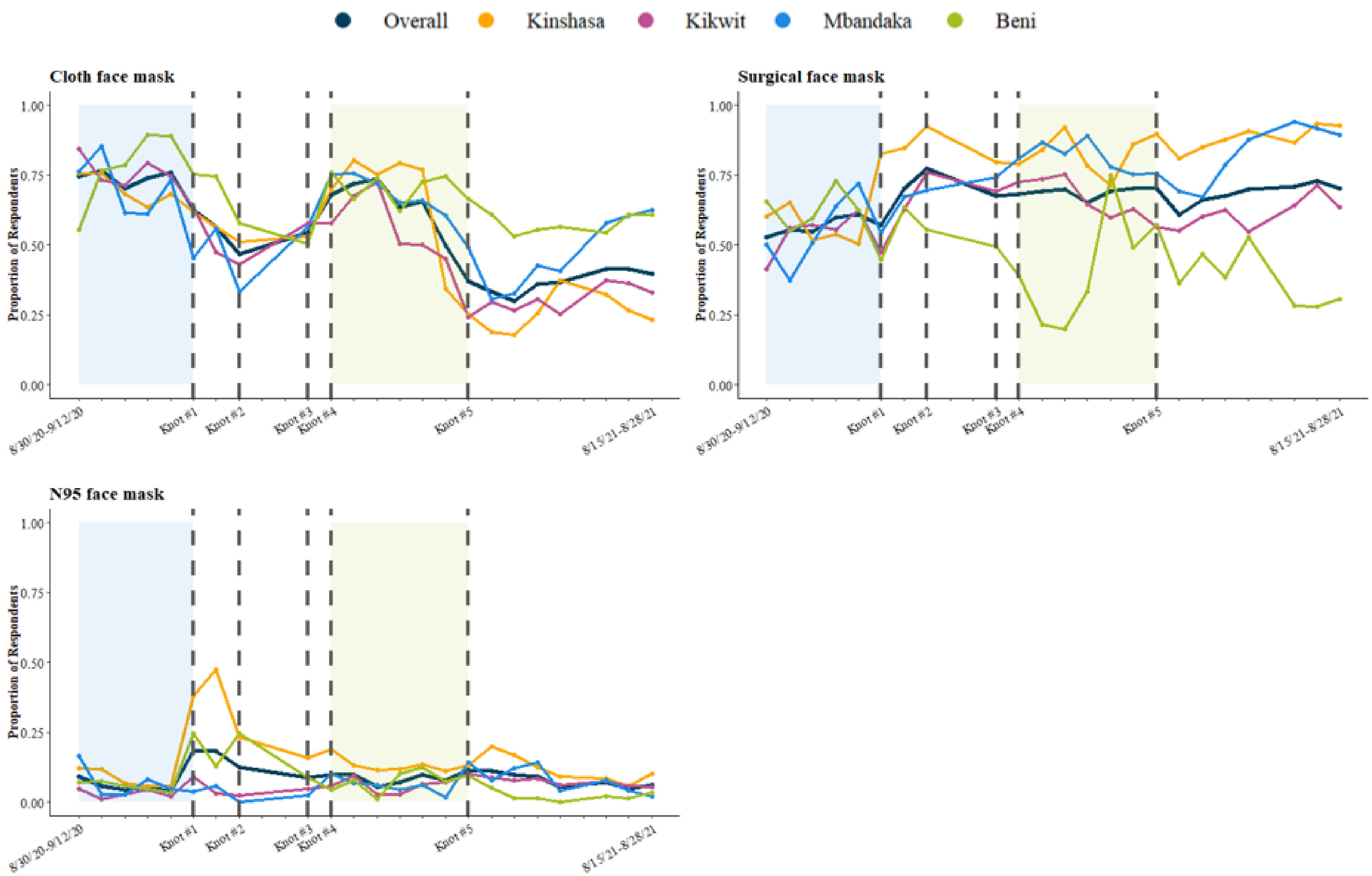
Perceptions of workplace safety were relatively stable over time but appeared to differ between cohorts. Throughout the study, the Kikwit and Mbandaka cohorts consistently had the largest proportions of HCWs reporting positive perceptions of workplace safety followed by Kinshasa and Beni (Figure 4.5). Strongly agreeing with feeling safe at work, being confident in their employer's ability to protect them, and their employer doing everything in its power to protect them was reported by more than half of respondents overall throughout the study (50.9-72.3%, 53.9-76.3%, and 55.2-74.4%, respectively).

Figure 4.3. Observed proportion of respondents over time reporting that they strongly agree to each norm, by cohort



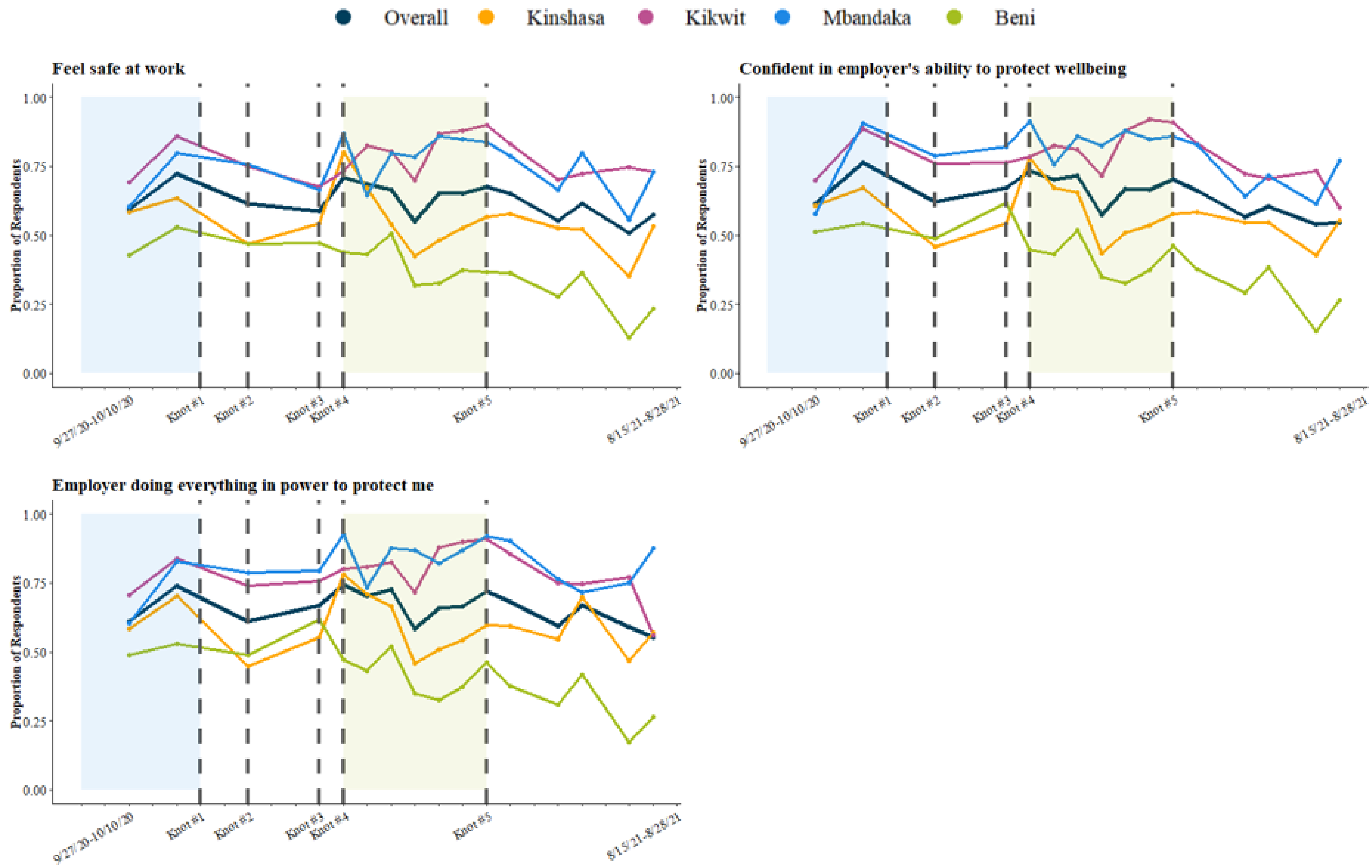
Note. Blue shaded area indicates the Mbandaka EVD outbreak during Period 1. Green shaded area indicates the Beni EVD outbreak during Period 4.

Figure 4.4. Observed proportion of respondents over time reporting that they always had access to each item at work, by cohort



Note. Blue shaded area indicates the Mbandaka EVD outbreak during Period 1. Green shaded area indicates the Beni EVD outbreak during Period 4.

Figure 4.5. Observed proportion of respondents over time reporting that they strongly agree to each perception, by cohort

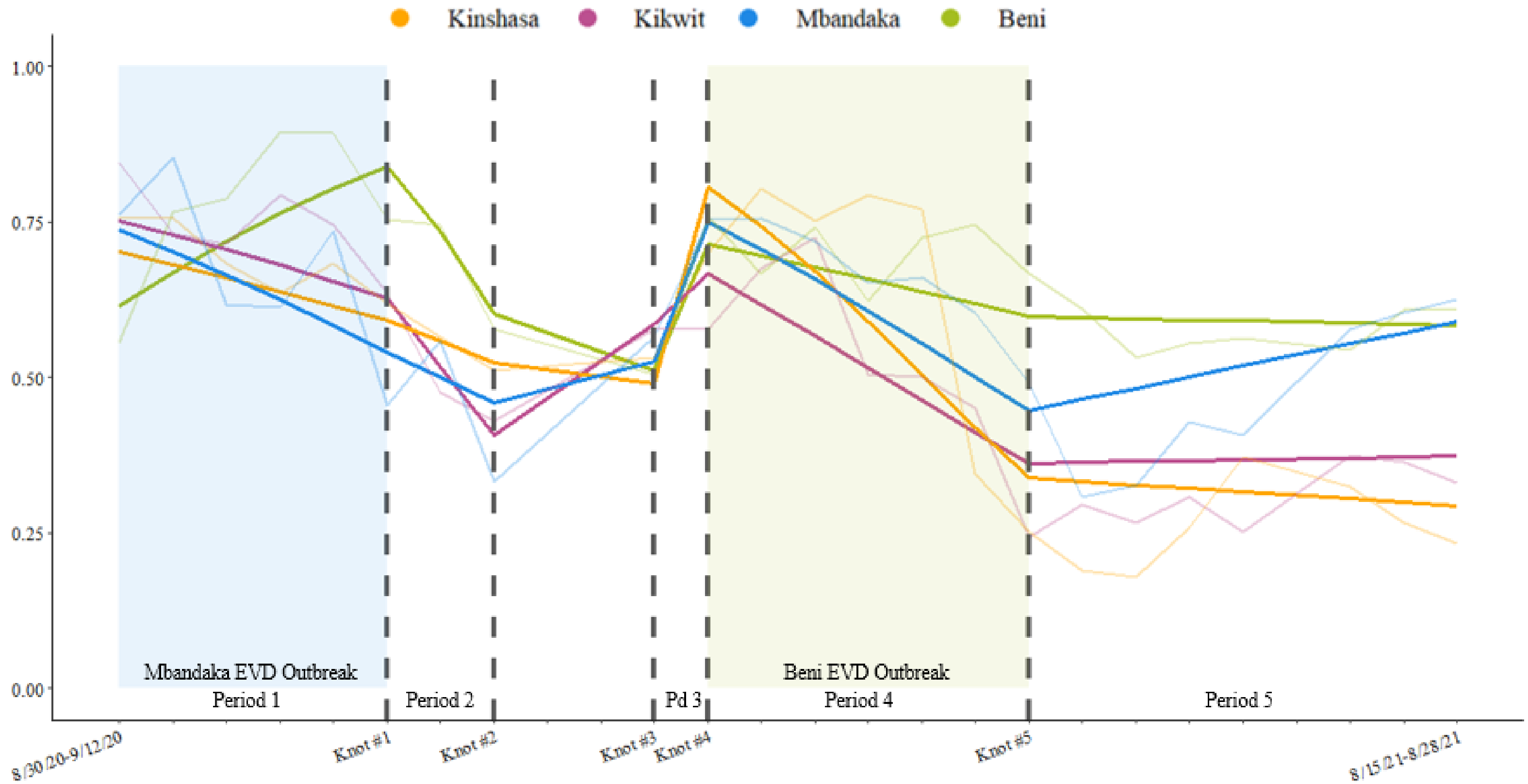


Note. Blue shaded area indicates the Mbandaka EVD outbreak during Period 1. Green shaded area indicates the Beni EVD outbreak during Period 4.

Fitted predicted probabilities of always having access to cloth face masks and to surgical face masks at work during the study are plotted by cohort in Figures 4.6 and 4.7, respectively. These figures indicate when the estimated change in odds of access to each item across time (slope) in each period of interest and when the difference in slope from one period to the next at each knot reaches statistical significance as defined by $\alpha<0.005$. The corresponding effect measure, 95% CI, and p-value for each period and knot can be found in Supplemental Tables 4.5 and 4.6. Fitted predicted probabilities for access to cloth and surgical face masks at work during each data collection point in the overall sample are presented in Supplemental Table 4.7.

Between the beginning of data collection and the end of the Mbandaka EVD outbreak (Period 1), odds of always having access to cloth face masks decreased in Kinshasa, Kikwit, and Mbandaka but increased in Beni. In each of the four cohorts, odds of always having access to a cloth face mask at work decreased in Period 2, but a significant downward slope and slope change from Period 1 were observed in Kikwit and Beni only. Period 3 represents the time between two consecutive data collection intervals: the return from winter break and the beginning of the Beni-area EVD outbreak. Significant increases in the odds of cloth mask access occurred during Period 3 in each cohort except Kikwit and there was a significant change in slope at Knot 4 in each cohort. During Period 4, corresponding with the EVD outbreak near Beni, odds of cloth mask access significantly decreased in each cohort except Beni which had a negative slope that did not reach statistical significance. Following the conclusion of the EVD outbreak near Beni (Period 5) the fitted predicted probability of cloth face mask access became stable over time in Beni (58.5-59.7%) and in Kinshasa and Kikwit 29.4-33.8% and 36.2-37.3%, respectively). Odds of cloth face mask access among the Mbandaka cohort increased during

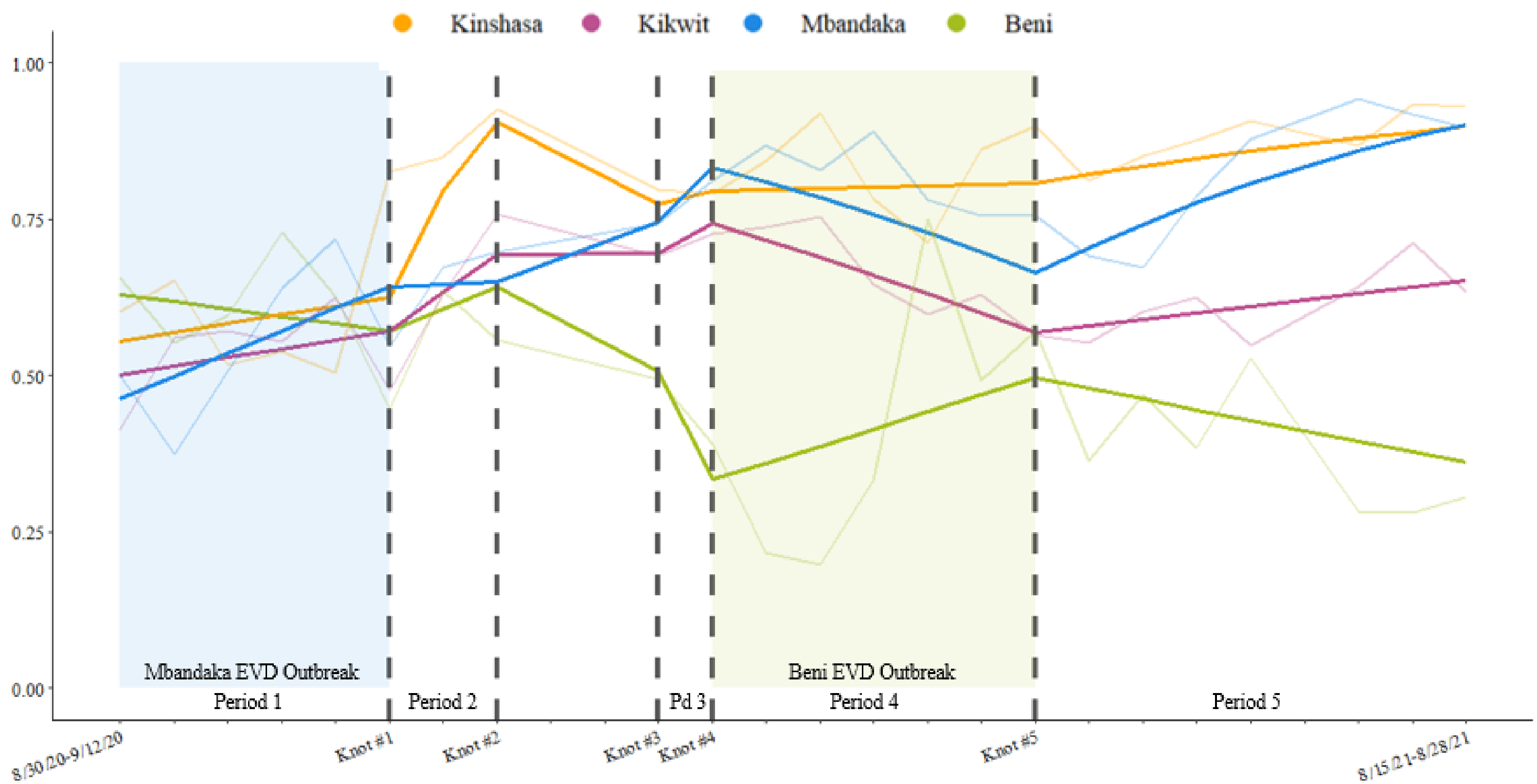
Figure 4.6. Fitted predicted probability of always having access to a cloth mask at work over time by cohort



	Period 1	Knot 1	Period 2	Knot 2	Knot 3	Period 3	Knot 4	Period 4	Knot 5	Period 5
Kinshasa					*	*	*	*	*	
Kikwit	*	*	*	*			*	*	*	
Mbandaka	*					*	*	*	*	
Beni	*	*	*		*	*	*			

Note. Observed proportions for each cohort displayed in lines with greater transparency. Probabilities presented for a 42 year old male. Asterisk in table indicates statistically significant estimate of change in odds of always having access to a cloth mask across time in the five periods of study and statisticallly significant estimated difference in slope of association at each of the five knots after adjustment for gender and age. Statistical significance is defined as $p < 0.005$. Shading indicates period corresponding to EVD outbreak in the region.

Figure 4.7. Predicted probability of always having access to a surgical mask at work over time by cohort



	Period 1	Knot 1	Period 2	Knot 2	Knot 3	Period 3	Knot 4	Period 4	Knot 5	Period 5
Kinshasa		*	*	*						
Kikwit								*	*	
Mbandaka	*							*	*	*
Beni						*	*	*	*	

Note. Observed proportions for each cohort displayed in lines with greater transparency. Probabilities presented for a 42 year old male. Asterisk in table indicates statistically significant estimate of change in odds of always having access to a surgical mask across time in the five periods of study and statisticallly significant estimated difference in slope of association at each of the five knots after adjustment for gender and age. Statistical significance is defined as $p < 0.005$. Shading indicates period corresponding to EVD outbreak in the region.

Period 5 although this slope was not significant.

In Period 1, the opposite relationships were observed in odds of always having access to surgical face masks compared to cloth face masks (i.e., increases among the Kinshasa, Kikwit, and Mbandaka cohort and a decrease among the Beni cohort) although all but the Mbandaka slope failed to reach statistical significance. Among the Kinshasa HCWs, odds of reporting surgical face mask access at work significantly increased in Period 2 but remained relatively stable in Periods 3-5 with a predicted probability ranging from 77.4-89.8%. The odds of surgical face mask access in the Kikwit and Mbandaka cohorts followed a similar path throughout the study: increases in Period 2 and 3, decrease in Period 4, and increase again in Period 5. The fitted predicted probability of surgical mask access was greater in Mbandaka than Kikwit particularly in Periods 4 and 5. Prior to the winter break in data collection (Periods 1 and 2), probability of access to surgical face masks in Beni was relatively stable between 57.1-64.1%. Following winter break (Periods 3-5), probability of access to surgical face masks among the Beni cohort fluctuated between 33.5-50.8%. During the nearby EVD outbreak (Period 4), the odds of surgical face mask access in Beni increased significantly and slightly attenuated following the outbreak.

4.5 Discussion

Overall, this study found that workplace prevention norms and safety perceptions over time were relatively stable among this sample of HCWs and fluctuations in these measures did not consistently correspond with EVD outbreaks. However, having access to cloth and surgical face masks were particularly dynamic measures over time among the respondents. In terms of cloth masks, significant declines in probability of access occurred among the Mbandaka HCWs during the period of an EVD outbreak in the region, but similar declines were also observed among the HCWs in Kinshasa and Kikwit. During this same period, the probability of surgical mask access significantly increased among the Mbandaka cohort only. During the EVD outbreak near Beni, the probability of cloth mask access remained stable among the Beni cohort between 52.6-71.3% while significant declines were observed among the other three cohorts. Further, significant increases in the probability of having access to surgical masks at work were observed among the Beni cohort during the nearby EVD outbreak while significant declines occurred among the Kikwit and Mbandaka cohorts. Despite the observed increase, the probability of surgical mask access never rose above 49.7% among HCWs from Beni during the nearby EVD outbreak. These patterns suggest that there were fluctuations in PPE access among HCWs in DRC during this year of the COVID-19 pandemic, but these fluctuations might not be consistent with EVD outbreaks.

Unexpectedly, within the periods of EVD outbreak in Mbandaka and near Beni, the proportion of HCWs reporting each of the prevention norms did not noticeably increase over time among HCWs in these communities. More so than in the other regions, an increasingly greater proportion of respondents in Beni perceived less social pressure towards basic IPC measures such as hand hygiene and physical distancing following the beginning of the study possibly due to reduced public health messaging in this area over the year of follow-up. Further, perceptions of safety in the workplace among the HCWs working in Mbandaka and Beni did not appear to decline during EVD outbreaks in these regions. In fact, the proportion of HCWs reporting positive workplace safety remained relatively stable over time but appeared to differ between cohorts. Therefore, perceptions of workplace safety might not be acutely related to relatively moderate outbreaks, even of a high concern pathogen such as Ebola virus, occurring in the area. Rather, these perceptions might be more related to factors at the community level, such as facility resources, infrastructure, and culture.[12] Further, location-specific fluctuations in morbidity and mortality related to COVID-19, or other common diseases such as measles or malaria, or, particularly in the case of Beni, violence and trust within the community towards HCWs are likely related to these perceptions but were not captured in the study.[25,26,32,33]

Due to a potential influx of PPE to regions experiencing EVD transmission to bolster IPC measures,[34] it was expected that always having access to PPE such as cloth, surgical, and N95 face masks would increase throughout a period of EVD outbreak. However, this was not consistently observed in this study. During the Mbandaka EVD outbreak, the probability of reporting access to cloth masks at work decreased significantly among HCWs in this region then rebounded again in early 2021. During this time, the probability of surgical face mask access increased slightly among the affected HCWs in Mbandaka, but this trend continued past the end of the outbreak. These patterns might reflect a depletion of cloth masks, which were more readily available to HCWs in DRC early in the COVID-19 pandemic, and an influx of surgical masks to the region spurred by both the COVID-19 and EVD outbreaks. However, the same patterns were generally observed among the Kikwit and Kinshasa cohorts suggesting that these patterns are more likely linked to fluctuations in PPE supply because of the COVID-19 pandemic rather than the Mbandaka EVD outbreak. For example, about the same time the Mbandaka EVD outbreak subsided (mid-November 2020), DRC was entering its second wave of COVID-19 transmission. It is possible that increased COVID-19 transmission spurred additional surgical face masks to be made available throughout the country increasing access to HCWs across the country.

During the EVD outbreak near Beni, the probability of having access to cloth masks was relatively stable among the Beni cohort while it declined in the other cohorts. At the same time, probability of surgical mask access increased significantly among the Beni cohort while it decreased among the Mbandaka and Kikwit cohorts and remained stable among the Kinshasa

HCWs. These patterns might reflect increased PPE supply to the area affected by the EVD outbreak. However, in terms of the entire study period, the Beni cohort consistently stood out as having unique patterns in reported cloth and surgical mask access that is likely not completely attributable to the nearby EVD outbreak.

First, reported cloth mask access increased among the Beni cohort from study baseline to the end of the Mbandaka outbreak while consistent declines were observed in the other three cohorts. At the start of the Beni outbreak, probability of cloth face mask access at work ranged between the four cohorts from 66.6-80.5%. While this probability remained relatively stable through the end of the study among the Beni cohort, significant decreases were observed in the other cohorts. It is possible that increased supply of cloth masks in response to the nearby EVD outbreak led to sustained access in the area or that HCWs in Beni rely on cloth masks as opposed to more effective mask types (e.g., surgical face masks) more so than HCWs in other areas. While surgical mask access increased within the Kinshasa, Kikwit, and Mbandaka cohorts throughout the study, access among the Beni cohort decreased from baseline to the beginning of the nearby EVD outbreak when the probability of surgical mask access rebounded slightly but remained below that observed in the other cohorts until the end of data collection. As the COVID-19 pandemic continued, PPE was likely more widely distributed throughout DRC increasing surgical mask access to HCWs across the country. However, there was likely poorer surgical mask access among HCWs in Beni compared to the other areas perhaps due to transport difficulties to the eastern part of the country, complications in supply distribution related to ongoing conflict in the area, or poorer allocation of PPE to the health facility level in this region.

These results should be interpreted in light of study limitations. First, this is not a representative sample; therefore, the findings cannot be generalized to the health workforces in the four regions from which participants were recruited. Second, several community-level factors are not considered when assessing these outcomes over time. For example, COVID-19 transmission in each of the four communities likely impacted perceptions of safety as well as access to face masks but subnational COVID-19 case information from DRC was unavailable. Donations and programmatic-level efforts to produce and distribute face masks throughout the country[35,36] also likely impacted access to these resources among the HCWs in this study. Further, fluctuations in the effectiveness and consistency of public health messaging from trusted authorities might impact the social pressures and norms the HCWs perceived related to proper IPC measures. Third, this study uses imperfect measurements of concurrent EVD outbreak with the COVID-19 pandemic. The timing of the two EVD outbreaks were defined as the two-week data collection intervals in which the official start and end dates of the outbreaks fell rather than the calendar dates themselves.

Further, the calendar dates of the beginning and end of a declared EVD outbreak in DRC do not capture the intensity of the outbreaks or level of transmission in the community. For example, the 11th outbreak in Mbandaka led to 130 cases of EVD compared to 12 cases in the 12th EVD outbreak near Beni. While an EVD outbreak is declared in DRC when the first case is confirmed, the outbreak is not declared over until there has been an absence of any new cases in the area for 42 days thereafter. Therefore, it is likely that no EVD transmission takes place during this latter period of each outbreak. Mismeasurement of the period when these EVD outbreaks were most likely to impact the outcomes of interest among the study participants likely led to an attenuation in the associations bounded by the EVD outbreak-related knots. Further, this study began about midway through the country's 11th EVD outbreak in Mbandaka. This weakened the ability to detect a possible true impact of the outbreak on the outcomes over time because only the last few months of the outbreak, when transmission had slowed to non-detectable, contributed measurements to the analysis. Future research to quantitatively assess the impact of dual outbreaks on safety perceptions and other workplace factors among HCWs should focus on more precise measurement of the timing of the outbreaks. The official dates of the start of an outbreak and its end are likely insufficient measures of the strain placed on the health system, additional pressures and risk to HCWs, or the effects of more training [37]and resources directed to a region for response.

This study has several strengths as well. This is the only study to assess the impact of dual EVD and COVID-19 outbreaks on outcomes among HCWs longitudinally in DRC. The use of mobile technology for data collection purposes has often been deemed too difficult or not possible in low and middle-income countries (LMICs) and thus, there has been strong precedence for in-person data collection methods. However, during the COVID-19 pandemic, and particularly during EVD outbreaks in certain regions, in-person data collection might not be feasible or safe for research staff. This study proves that phone survey methods and good study retention are possible in a setting such as DRC and particularly suited for repeated measure data collection. Prior to this study, no quantitative data had been collected to explore the extent of fluctuations in workplace safety and perceptions among HCWs in DRC during these periods of increased risk and stress. The outcome-wide epidemiology framework[38] utilized in this study maximizes the assessment of factors related to HCW safety and workplace functioning, none of which have been previously analyzed over time in this population, informing future research within this population. The use of spline regression further facilitated the evaluation of changes in the associations with outcomes of interest and time during the periods of dual outbreak and not. Significant changes in the direction of association at the knots justified the specific knots selected in this analysis and use of spline functions. However, there is an opportunity for more advanced modeling of the outcomes possibly resulting in better fitting models.

Although the impact of EVD outbreaks on HCWs' perceptions of workplace safety and IPC expectations as well as access to necessary PPE for protection was not always consistent in this study, several important patterns emerged. Compared to the other cohorts, the HCWs in Beni reported less expectations for IPC measures (hand hygiene and physical distancing) and positive perceptions of safety throughout the year of the study. Clear communication from local public health authorities and management at the health facility level are essential to how HCWs respond to IPC guidelines.[37] Although this cohort consistently reported high levels of compliance with hand washing and avoiding gatherings across the year,[29] the frequency and quality of that compliance were likely impacted by external social pressures at the workplace. Future research should focus on understanding how public health messaging, particularly targeted at the health workforce, differed between the Beni area and other parts of the country throughout the pandemic. The descriptive differences observed between cohorts further reinforces the need to study these factors at a subnational level to detect differences in workplace factors, such as culture, infrastructure, or training, that would influence the ability or willingness of HCWs to practice proper IPC measures.

The fluctuations observed in face mask access indicate probable lapses in the proper protection of frontline workers amidst an emerging infectious disease outbreak; and, in some cases concurrent emerging infectious disease outbreaks. Of note, access to N95 face masks was low in all four cohorts across the year of data collection despite being the most effective of the three mask types studied for COVID-19 prevention[39] and, more generally, for reducing the exposure of individual workers in high-risk situations.[40] Further, a relatively low proportion of the HCWs consistently reported positive perceptions of workplace safety. Health authorities in DRC need outbreak preparedness plans for rapid release of increased resources to facilitate procurement of adequate PPE and distribution throughout the country to HCWs, prioritizing areas that might be combatting multiple high-profile outbreaks. It must be noted that the feasibility of such a plan is complicated by issues wholly out of the control of health authorities in any one low-income country, such as global health equity, unreliable supply systems, and market forces.[41] Nonetheless, in a setting such as DRC, with an already limited health workforce, any loss of frontline workers to illness, isolation, death, or attrition can be devastating to the functioning of the health system.[42]

This study attempted to leverage repeated quantitative measures collected during a year of the COVID-19 pandemic to assess the impact of concurrent EVD outbreaks among HCWs in the affected regions. Results indicate that while important descriptive patterns in perceptions of workplace safety and access to essential PPE emerged, measuring the impact of dual outbreaks proved to be difficult. Future research should be done to improve understanding of the complexity of concurrent outbreaks on HCW wellbeing, including taking factors at the societal, community, interpersonal, and individual level into account particularly in DRC, an apt setting for this research as the country consistently battles infectious disease outbreaks and is vulnerable to future emergent outbreaks. Overall, this study highlights the need to conduct subnational analyses in a setting such as DRC where the experiences of HCWs are strongly related to their community setting. Further, this study supports the feasibility of a repeated measures phone survey to monitor HCW safety during outbreaks in real-time to be able to respond with speed and agility at the programmatic level to better protect this vital population to public health.

4.6 Appendix

Supplemental Table 4.1. Matrix of mixed effect models for four parameterizations of random effects using both Cholesky and unstructured covariance structures per outcome

Random effect:	***Type 1*** *Person*	***Type 2*** *Person & HZ*	***Type 3*** *Person & HF*	***Type 4*** *Person, HZ, & HF*
See colleagues wash hands frequently *(strongly agree)*	CH: converged* UN: converged*	CH: zero estimate UN: G NPD	CH: converged* UN: converged*	CH: zero estimate UN: G NPD
Health authorities urge me to wash hands frequently *(strongly agree)*	CH: converged* UN: converged*	CH: converged* UN: converged*	CH: converged* UN: converged*	CH: converged* UN: converged*
Health authorities urge me to avoid crowds *(strongly agree)*	CH: did not converge UN: converged*	CH: zero estimate UN: G NPD	CH: converged* UN: converged*	CH: zero estimate UN: G NPD
Employer urges me to avoid crowds *(strongly agree)*	CH: did not converge UN: converged*	CH: zero estimate UN: G NPD	CH: zero estimate UN: G NPD	CH: zero estimate UN: G NPD
Always have access at work: cloth face masks	CH: did not converge UN: converged	CH: zero estimate UN: G NPD	CH: zero estimate UN: G NPD	CH: zero estimate UN: G NPD
Always have access at work: surgical face masks	CH: did not converge UN: converged	CH: zero estimate UN: G NPD	CH: zero estimate UN: G NPD	CH: zero estimate UN: G NPD
Always have access at work: N95 face masks	CH: converged UN: converged	CH: G NPD UN: G NPD	CH: zero estimate UN: G NPD	CH: zero estimate UN: G NPD
Feel safe at work *(strongly agree)*	CH: converged UN: converged	CH: zero estimate UN: G NPD	CH: zero estimate UN: G NPD	CH: zero estimate UN: did not converge
Confident in employer's ability to protect wellbeing *(strongly agree)*	CH: converged UN: converged	CH: zero estimate UN: G NPD	CH: zero estimate UN: G NPD	CH: zero estimate UN: G NPD
Employer doing everything in power to protect me *(strongly agree)*	CH: converged UN: converged	CH: zero estimate UN: G NPD	CH: zero estimate UN: G NPD	CH: zero estimate UN: G NPD

Note. HZ = health zone; HF = health facility; CH = Cholesky; UN = unstructured; G NPD = G-matrix non-positive definite; zero estimate = at least one covariance parameter estimate calculated as 0; * = elevated covariance parameter estimate; each model included location and location*time as predictors.

Supplemental Table 4.2. Proportion of participants in subgroups who consistently responded 'yes', 'no', or changed response for each outcome across all responses in the study

	Kinshasa			**Kikwit**			**Mbandaka**			**Beni**			**Overall**		
	Yes	*No*	*Changed*	*Yes*	*No*	*Changed*	*Yes*	*No*	*Changed*	*Yes*	*No*	*Changed*	*Yes*	*No*	*Changed*
See colleagues wash hands frequently *(strongly agree)*	46.9	0.6	52.5	59.3	0.0	40.7	57.8	0.0	42.2	40.4	1.9	57.7	51.7	0.6	47.7
Health authorities urge me to wash hands frequently *(strongly agree)*	57.4	0.6	42.0	58.2	0.0	41.8	60.0	0.0	40.0	47.1	2.9	50.0	56.1	0.7	43.1
Health authorities urge me to avoid crowds *(strongly agree)*	58.6	0.6	40.7	69.8	0.0	30.2	76.7	0.0	23.3	52.9	2.9	44.2	64.4	0.7	34.9
Employer urges me to avoid crowds *(strongly agree)*	51.9	0.6	47.5	68.3	0.0	31.7	65.6	0.0	34.4	46.2	2.9	51.0	58.7	0.7	40.6
Always have access at work: cloth face masks	4.3	1.9	93.8	4.2	1.1	94.7	3.3	0.0	96.7	7.7	0.0	92.3	4.8	0.9	94.3
Always have access at work: surgical face masks	12.3	0.0	87.7	6.3	4.2	89.4	4.4	2.2	93.3	3.8	0.0	96.2	7.3	1.8	90.8
Always have access at work: N95 face masks	1.2	23.5	75.3	0.0	61.9	38.1	1.1	54.4	44.4	0.0	47.1	52.9	0.6	46.4	53.0
Feel safe at work *(strongly agree)*	21.0	3.7	75.3	29.1	0.5	70.4	23.3	1.1	75.6	6.7	9.6	83.7	21.5	3.3	75.2
Confident in employer's ability to protect wellbeing *(strongly agree)*	25.9	3.1	71.0	31.7	0.0	68.3	24.4	0.0	75.6	11.5	5.8	82.7	25.0	2.0	73.0
Employer doing everything in power to protect me *(strongly agree)*	28.4	3.7	67.9	31.2	0.5	68.3	28.9	0.0	71.1	11.5	5.8	82.7	26.2	2.4	71.4

Supplemental Table 4.3. Observed proportion of respondents in each data collection interval responding ‘strongly agree’ to each norm or perception with overall test of fixed effect of location

Data collection interval	**Num. of respondents**	**See colleagues wash hands frequently**	**Health authorities urge me to wash hands frequently**	**Health authorities urge me to avoid crowds**	**Employer urges me to avoid crowds**	**Feel safe at work**	**Confident in employer’s ability to protect wellbeing**	**Employer doing everything in power to protect me**
8/30/20-9/12/20	n=473	-	-	-	-	-	-	-
9/13/20-9/26/20	n=468	-	-	-	-	-	-	-
9/27/20-10/10/20	n=424	329 (77.6%)	330 (77.8%)	325 (76.7%)	326 (76.9%)	252 (59.4%)	261 (61.6%)	259 (61.1%)
10/11/20-10/24/20	n=436	-	-	-	-	-	-	-
10/25/20-11/7/20	n=397	356 (89.7%)	358 (90.2%)	356 (89.7%)	360 (90.7%)	287 (72.3%)	303 (76.3%)	293 (73.8%)
11/8/20-11/21/20	n=355	-	-	-	-	-	-	-
11/22/20-12/5/20	n=338	-	-	-	-	-	-	-
12/6/20-12/19/20	n=288	221 (76.7%)	216 (75.0%)	216 (75.0%)	213 (74.0%)	177 (61.5%)	179 (62.2%)	176 (61.1%)
1/17/21-1/30/21	n=345	287 (83.2%)	277 (80.3%)	264 (76.5%)	255 (73.9%)	202 (58.6%)	232 (67.2%)	231 (67.0%)
1/31/21-2/13/21	n=391	343 (87.7%)	333 (85.2%)	332 (84.9%)	305 (78.0%)	277 (70.8%)	286 (73.1%)	291 (74.4%)
2/14/21-2/27/21	n=286	249 (87.1%)	248 (86.7%)	251 (87.8%)	216 (75.5%)	196 (68.5%)	201 (70.3%)	201 (70.3%)
2/28/21-3/13/21	n=396	352 (88.9%)	353 (89.1%)	352 (88.9%)	332 (83.8%)	264 (66.7%)	283 (71.5%)	287 (72.5%)
3/14/21-3/27/21	n=320	278 (86.9%)	280 (87.5%)	275 (85.9%)	277 (86.6%)	176 (55.0%)	183 (57.2%)	187 (58.4%)
3/28/21-4/10/21	n=286	265 (92.7%)	257 (89.9%)	270 (94.4%)	267 (93.4%)	186 (65.0%)	191 (66.8%)	188 (65.7%)
4/11/21-4/24/21	n=336	297 (88.4%)	305 (90.8%)	308 (91.7%)	309 (92.0%)	219 (65.2%)	224 (66.7%)	224 (66.7%)
4/25/21-5/8/21	n=310	268 (86.5%)	278 (89.7%)	283 (91.3%)	285 (91.9%)	209 (67.4%)	218 (70.3%)	223 (71.9%)
5/9/21-5/22/21	n=360	298 (82.8%)	293 (81.4%)	310 (86.1%)	310 (86.1%)	234 (65.0%)	238 (66.1%)	246 (68.3%)
5/23/21-6/5/21	n=342	-	-	-	-	-	-	-
6/6/21-6/19/21	n=308	253 (82.1%)	250 (81.2%)	264 (85.7%)	262 (85.1%)	170 (55.2%)	174 (56.5%)	183 (59.4%)
6/20/21-7/3/21	n=305	236 (77.4%)	252 (82.6%)	269 (88.2%)	270 (88.5%)	187 (61.3%)	184 (60.3%)	204 (66.9%)
7/4/21-7/17/21	n=349					-	-	-
7/18/21-7/31/21	n=334	264 (79.0%)	284 (85.0%)	289 (86.5%)	290 (86.8%)	170 (50.9%)	180 (53.9%)	197 (59.0%)
8/1/21-8/14/21	n=335	270 (80.6%)	278 (83.0%)	287 (85.7%)	285 (85.1%)	192 (57.3%)	183 (54.6%)	185 (55.2%)
8/15/21-8/28/21	n=318	-	-	-	-	-	-	-
Total respondents		524	524	524	524	524	524	524
Total responses		5362	5362	5362	5362	5362	5362	5362

Note. F value and corresponding p-value are based on final models for selected outcomes.

Supplemental Table 4.4. Observed proportion of respondents in each data collection interval responding 'always' to frequency of access to each item with overall test of fixed effect of location

Data collection interval	Num. of respondents	Cloth face mask	Surgical face mask	N95 face mask
8/30/20-9/12/20	n=473	353 (74.6%)	250 (52.9%)	44 (9.3%)
9/13/20-9/26/20	n=468	358 (76.5%)	260 (55.6%)	27 (5.8%)
9/27/20-10/10/20	n=424	298 (70.3%)	233 (55.0%)	19 (4.5%)
10/11/20-10/24/20	n=436	322 (73.9%)	261 (59.9%)	24 (5.5%)
10/25/20-11/7/20	n=397	301 (75.8%)	242 (61.0%)	15 (3.8%)
11/8/20-11/21/20	n=355	222 (62.5%)	203 (57.2%)	66 (18.6%)
11/22/20-12/5/20	n=338	191 (56.5%)	237 (70.1%)	62 (18.3%)
12/6/20-12/19/20	n=288	135 (46.9%)	223 (77.4%)	36 (12.5%)
1/17/21-1/30/21	n=345	188 (54.5%)	233 (67.5%)	30 (8.7%)
1/31/21-2/13/21	n=391	266 (68.0%)	267 (68.3%)	38 (9.7%)
2/14/21-2/27/21	n=286	206 (72.0%)	198 (69.2%)	28 (9.8%)
2/28/21-3/13/21	n=396	291 (73.5%)	277 (69.9%)	22 (5.6%)
3/14/21-3/27/21	n=320	203 (63.4%)	209 (65.3%)	23 (7.2%)
3/28/21-4/10/21	n=286	188 (65.7%)	198 (69.2%)	28 (9.8%)
4/11/21-4/24/21	n=336	167 (49.7%)	236 (70.2%)	26 (7.7%)
4/25/21-5/8/21	n=310	115 (37.1%)	218 (70.3%)	36 (11.6%)
5/9/21-5/22/21	n=360	120 (33.3%)	219 (60.8%)	40 (11.1%)
5/23/21-6/5/21	n=342	102 (29.8%)	226 (66.1%)	34 (9.9%)
6/6/21-6/19/21	n=308	111 (36.0%)	208 (67.5%)	28 (9.1%)
6/20/21-7/3/21	n=305	112 (36.7%)	213 (69.8%)	17 (5.6%)
7/4/21-7/17/21	n=349	-	-	
7/18/21-7/31/21	n=334	138 (41.3%)	237 (71.0%)	24 (7.2%)
8/1/21-8/14/21	n=335	139 (41.5%)	244 (72.8%)	16 (4.8%)
8/15/21-8/28/21	n=318	126 (39.6%)	224 (70.4%)	19 (6.0%)
Total respondents		545	545	545
Total responses		8151	8151	8151

Note. F value and corresponding p-value are based on final models for selected outcomes.

Supplemental Table 4.5. Estimated change in odds of strongly agreeing with each item across time in the five periods of study defined by four knots

	Kinshasa			**Kikwit**			**Mbandaka**			**Beni**		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Cloth face mask												
Period 1	0.89	(0.81, 0.98)	0.01	0.87	(0.80, 0.94)	0.001	0.81	(0.71, 0.91)	0.0006	1.33	(1.17, 1.51)	<.0001
Period 2	0.84	(0.65, 1.08)	0.17	0.57	(0.45, 0.71)	<.0001	0.81	(0.56, 1.19)	0.29	0.47	(0.32, 0.69)	0.0001
Period 3	6.06	(3.57, 10.29)	<.0001	1.54	(0.99, 2.41)	0.05	3.42	(1.61, 7.26)	0.001	2.96	(1.72, 5.09)	<.0001
Period 4	0.65	(0.60, 0.70)	<.0001	0.77	(0.72, 0.82)	<.0001	0.76	(0.69, 0.84)	<.0001	0.9	(0.83, 0.98)	0.01
Period 5	0.97	(0.92, 1.02)	0.22	1.01	(0.96, 1.05)	0.74	1.09	(1.02, 1.17)	0.01	0.99	(0.93, 1.05)	0.79
Surgical face mask												
Period 1	1.07	(0.98, 1.17)	0.15	1.07	(0.99, 1.15)	0.08	1.19	(1.06, 1.33)	0.003	0.94	(0.85, 1.05)	0.27
Period 2	2.67	(1.85, 3.86)	<.0001	1.37	(1.09, 1.72)	0.01	1.02	(0.69, 1.51)	0.92	1.19	(0.85, 1.67)	0.31
Period 3	1.15	(0.62, 2.15)	0.66	1.32	(0.82, 2.12)	0.26	1.84	(0.76, 4.43)	0.18	0.43	(0.25, 0.73)	0.002
Period 4	1.01	(0.93, 1.11)	0.74	0.86	(0.81, 0.91)	<.0001	0.84	(0.75, 0.93)	0.001	1.14	(1.06, 1.23)	0.0009
Period 5	1.11	(1.03, 1.19)	0.01	1.05	(1.01, 1.1)	0.03	1.24	(1.13, 1.36)	<.0001	0.92	(0.87, 0.98)	0.01

Note. See Figure 4.1 for definition of each period. Briefly, 4-knot simple linear spline model used with following knots: 1) 11/8/20 to 11/21/20 (end of Mbandaka outbreak), 2) 1/17/21 to 1/30/21 (end of holiday break), 3) 1/31/21 to 2/1/21 (start of Beni outbreak), 4) 4/25/21 to 5/8/21 (end of Beni outbreak); all models adjusted for gender and age and account for clustering at the individual level; shading indicates period corresponding to EVD outbreak in the region.

Supplemental Table 4.6. Difference in slope of association of always having access to each item and time between the study period following each knot compared to the study period prior to each knot

	Kinshasa			Kikwit			Mbandaka			Beni		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Cloth face mask												
Knot #1	0.95	(0.69, 1.30)	0.73	0.66	(0.5, 0.87)	0.003	1.01	(0.64, 1.59)	0.97	0.35	(0.22, 0.56)	<.0001
Knot #2	1.01	(0.49, 2.07)	0.99	4.34	(2.26, 8.33)	<.0001	1.71	(0.55, 5.37)	0.35	1.34	(0.5, 3.59)	0.56
Knot #3	7.18	(2.76, 18.71)	<.0001	0.63	(0.27, 1.46)	0.28	2.45	(0.56, 10.59)	0.23	4.71	(1.63, 13.62)	0.004
Knot #4	0.11	(0.06, 0.19)	<.0001	0.5	(0.31, 0.8)	0.004	0.22	(0.1, 0.5)	0.0002	0.3	(0.17, 0.55)	<.0001
Knot #5	1.49	(1.33, 1.67)	<.0001	1.31	(1.19, 1.44)	<.0001	1.44	(1.24, 1.66)	<.0001	1.1	(0.97, 1.25)	0.13
Surgical face mask												
Knot #1	2.5	(1.65, 3.79)	<.0001	1.28	(0.98, 1.68)	0.08	0.86	(0.54, 1.36)	0.51	1.26	(0.85, 1.88)	0.25
Knot #2	0.12	(0.04, 0.37)	0.0002	0.74	(0.37, 1.47)	0.39	1.66	(0.48, 5.76)	0.43	0.44	(0.17, 1.13)	0.09
Knot #3	3.55	(1.01, 12.45)	0.05	1.3	(0.53, 3.23)	0.57	1.09	(0.2, 5.91)	0.92	0.83	(0.29, 2.36)	0.72
Knot #4	0.88	(0.45, 1.72)	0.71	0.65	(0.39, 1.09)	0.10	0.46	(0.18, 1.16)	0.10	2.64	(1.49, 4.68)	0.0009
Knot #5	1.09	(0.95, 1.26)	0.21	1.23	(1.11, 1.35)	<.0001	1.48	(1.24, 1.76)	<.0001	0.81	(0.71, 0.91)	0.0007

Note. 4-knot simple linear spline model used with following knots: 1) 11/8/20 to 11/21/20 (end of Mbandaka outbreak), 2) 1/17/21 to 1/30/21 (end of holiday break), 3) 1/31/21 to 2/1/21 (start of Beni outbreak), 4) 4/25/21 to 5/8/21 (end of Beni outbreak); All models are adjusted for gender and age and account to clustering at the individual level; shading indicates knots corresponding to the start or end of an EVD outbreak in the region; time is a categorical variable ranging from 0 to 24.

Supplemental Table 4.7. Fitted predicted probabilities overall in each data collection interval of responding always had access to each item

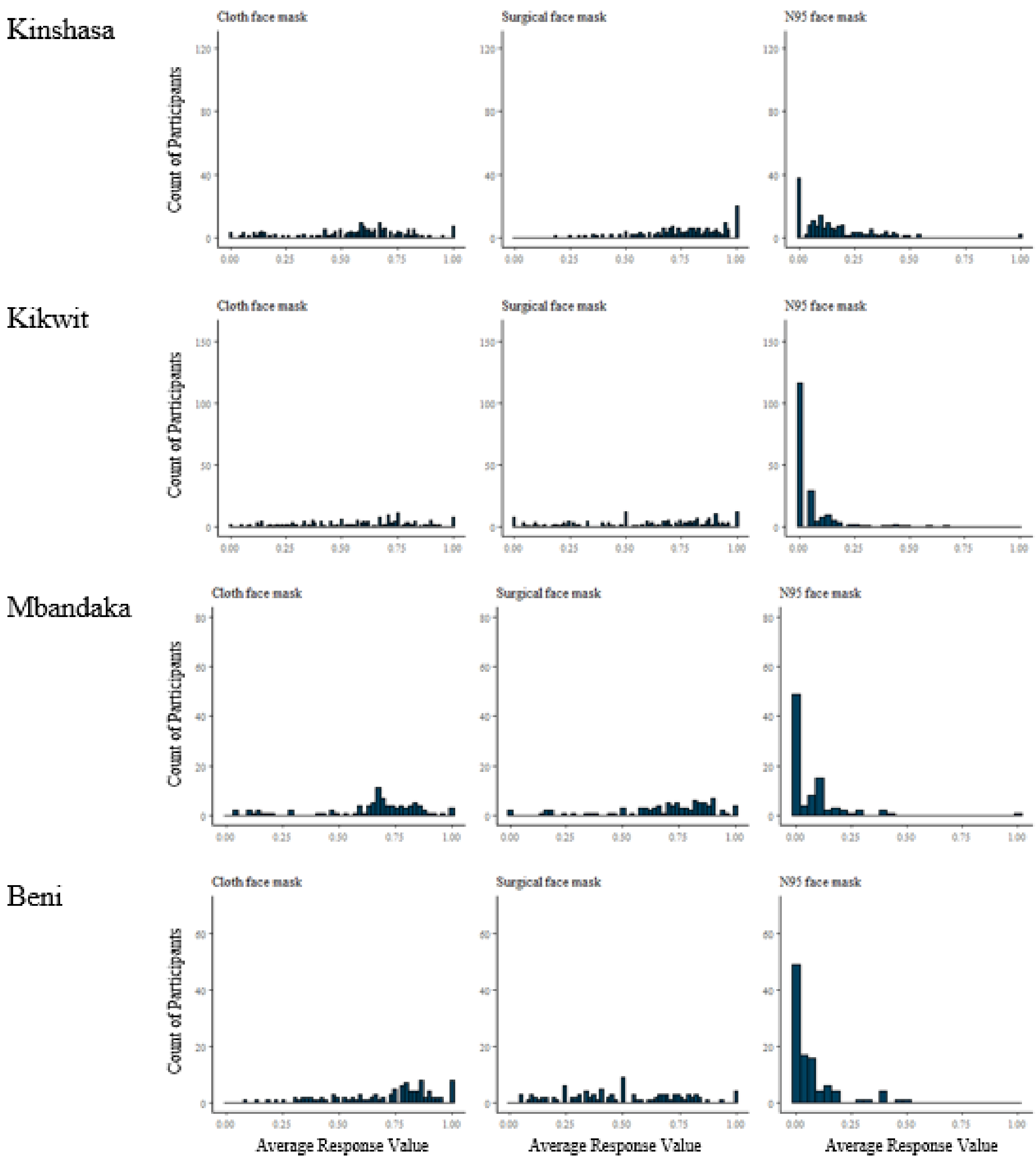
Data collection interval	Cloth face mask	Surgical face mask
8/30/20-9/12/20	70.2	53.7
9/13/20-9/26/20	69.5	55.0
9/27/20-10/10/20	68.7	56.4
10/11/20-10/24/20	67.6	57.7
10/25/20-11/7/20	66.4	58.9
11/8/20-11/21/20	65.0	60.2
11/22/20-12/5/20	57.8	67.1
12/6/20-12/19/20	49.8	72.2
1/17/21-1/30/21	52.7	68.0
1/31/21-2/13/21	73.3	67.6
2/14/21-2/27/21	69.0	67.1
2/28/21-3/13/21	64.3	66.5
3/14/21-3/27/21	59.2	65.8
3/28/21-4/10/21	54.0	65.1
4/11/21-4/24/21	48.7	64.3
4/25/21-5/8/21	43.6	63.5
5/9/21-5/22/21	43.9	64.6
5/23/21-6/5/21	44.2	65.7
6/6/21-6/19/21	44.5	66.7
6/20/21-7/3/21	44.8	67.6
7/18/21-7/31/21	45.4	69.2
8/1/21-8/14/21	45.7	69.8
8/15/21-8/28/21	46.0	70.3

Note. Fitted predicted probabilities presented for a 42 year old male.

Supplemental Figure 4.1. Within-person average values of repeated measures across data collection - responding ‘strongly agree’ to each norm or perception

Note. If a participant has an average value of 1.0 across the repeated measures contributed to the study, this indicates that the participant responded in the affirmative to the measure at each time point of response. Likewise, a participant with an average value of 0.0 dissented at each response point. An average value between 0.0 and 1.0 indicates the individual changed their response at least once throughout the study.

Supplemental Figure 4.2. Within-person average values of repeated measures across data collection - always having access to each item at work



Note. If a participant has an average value of 1.0 across the repeated measures contributed to the study, this indicates that the participant responded in the affirmative to the measure at each time point of response. Likewise, a participant with an average value of 0.0 dissented at each response point. An average value between 0.0 and 1.0 indicates the individual changed their response at least once throughout the study.

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Chapter 5. Concluding Remarks

5.1 Outcomes and Implications

The COVID-19 pandemic was an unprecedented challenge to modern public health necessitating rapid organization of infection prevention and control (IPC) activities, deployment of critical personal protective equipment (PPE), and dissemination of accurate guidance. However, as the pandemic has continued, control efforts and the impact of these efforts since early 2020 have evolved among frontline workers. Further, while the emergence of SARS-CoV-2 has highlighted the need for global response to emerging pathogens, experiences during the pandemic have differed immensely across the world. Healthcare workers (HCWs) in the Democratic Republic of the Congo (DRC) are an important population to study knowledge, attitudes, and practices (KAP) related to COVID-19 as they work within a complex country setting. One of the poorest nations in the world, DRC has an under-resourced and overburdened health system, but also, perhaps, one of the most experienced health workforces in outbreak response to emergent pathogens and other endemic infectious diseases. Specifically, more Ebola virus disease (EVD) outbreaks have occurred in DRC than anywhere else in the world including eight outbreaks in the last five years (between 2017 and 2022).[1] Despite suggestions that DRC had an advantage in mobilizing a response to COVID-19 due to existing infrastructure from previous outbreaks,[2,3] the extent of COVID-19-related KAP among HCWs over time and throughout DRC is not well understood.

This dissertation describes patterns in various repeated measures of KAP collected via phone surveys among HCWs in four regions of DRC during the COVID-19 pandemic (August 2020 to August 2021). In general, fluctuations in reported KAP throughout the study and differences observed between the four cohorts of HCWs varied widely across the repeated measures evaluated. The central findings of this work and corresponding implications for future research and public health are as follows:

1. The Beni cohort emerged as having the most distinct patterns of reported KAP over time among the four cohorts. Possible influences on KAP unique to Beni include ongoing armed conflict in the eastern region of DRC, widespread displacement, and events of violences towards HCWs;[4,5] however, other factors inherent in all communities (e.g., resources, culture, policies) likely contributed to the differences observed between each of the four study cohorts. Future research on disease- or outbreak-related KAP among Congolese populations should account for variation at a subnational level and further investigate factors related to these potential differences.
2. Perceptions of efficacy of standard prevention behaviors for COVID-19 were consistently high throughout the study and among all participants regardless of cohort. In comparison, much more fluctuation in IPC compliance (wearing a face mask, avoiding gatherings, social distancing) among the sample was observed over time. Therefore, although the HCWs in this study were consistent in their belief of the efficacy of COVID-19 prevention behaviors, they did not consistently practice these behaviors. Public health authorities in DRC should allocate less resources to education and training on the efficacy of IPC behaviors during an outbreak and rather, focus on efforts to facilitate the performance of these behaviors. Further research should be done in DRC to assess factors other than perceptions of efficacy that impact IPC compliance among HCWs.
3. Tangible fluctuations over time in access to cloth and surgical face masks at the workplace were observed among each cohort of HCWs. Comparatively, access to N95 masks was consistently low across the study regardless of location. These findings

indicate even if a participant wanted to wear a face mask, it was frequently unavailable at their health facility. Notably, lapses in the HCWs' ability to follow proper IPC took place amidst an infectious disease pandemic; and, for those HCWs living in EVD-affected areas during the study, amidst another concurrent high-profile infectious disease outbreak. Public health authorities in DRC should put preparedness plans in place for not only the rapid dissemination of necessary PPE throughout the country, but also for sustaining the supply of this PPE throughout the next outbreak.

4. Finally, these studies add to the growing literature that supports the feasibility of phone-based methods for public health surveillance and longitudinal collection of health-related measures in a low-income setting. The use of mobile technology for data collection purposes has often been deemed too difficult or biased in low and middle-income countries and thus, there has been strong precedence for in-person data collection methods. The ability of this research team to adapt to restrictions of the COVID-19 pandemic and successfully conduct a longitudinal phone-based study with relatively good retention is an achievement that can be replicated. Future research in DRC should consider adopting mobile systems for health monitoring for more cost-effective and less logistically complex data collection.

5.2 Limitations

Study findings should be interpreted considering the limitations of the data and analytic methods utilized. First, the study sample is not representative of the populations of HCWs in each community from which the cohorts were enumerated. Therefore, findings found among this sample cannot be generalized to HCWs in DRC but can be used as a basis for hypothesis generation or justification for future analyses. Second, in each of the studies, repeated measures of KAP related to COVID-19 are compared between the four cohorts of HCWs. While speculation as to why HCWs from one area might behave differently or report different beliefs is discussed, this study did not directly assess the impact of community-level factors on the outcomes of interest or account for these factors in analysis. For example, the KAP outcomes assessed within each of the cohorts were likely influenced by fluctuations in local COVID-19 transmission, but this was not taken into account because COVID-19 case data was not accessible below the national level. Third, certain study procedures likely introduced bias or mismeasurement into analysis. Specifically, a study participant typically completed their questionnaires with the same interviewer throughout the study. While this continuity of interviewer likely contributed to improved retention in the study, it also might have led to differential motivation, differential willingness to reveal information, or shortcutting (failure of respondent to optimally provide response) among participants dependent on the respondent-interviewer relationship. Further, given that 24 questionnaires with repeated measures were administered throughout a year, there is a potential of panel conditioning effects (previous survey responses “condition” responses on subsequent surveys) likely leading to an underestimation of fluctuation over time within KAP outcomes reported by respondents.

5.3 Conclusion

This dissertation is a novel contribution to the literature in that some of the KAP outcomes assessed have never been measured within HCWs in DRC and most have not been measured over time in HCWs from communities throughout the country. Assessing behaviors and attitudes towards COVID-19 throughout a year of the pandemic offers a critical opportunity to better understand the response among HCWs in DRC to an outbreak of a novel pathogen of global concern. The variation in responses over time and between cohorts observed in this study indicates that some KAP measures are likely to fluctuate throughout an outbreak and differ between communities of HCWs while others are more consistent. Identifying the behaviors and beliefs among HCWs that can be modified by targeted allocation of IPC training and resources will both enhance future outbreak response efforts and create opportunities to redirect resources that are unlikely to have an impact on KAP. Ultimately, protecting the health workforce throughout an infectious disease outbreak is of the utmost importance for greater public health.

5.4 References

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