COVID-19 OUTBREAK IN GHANA: EXPLORING THE DETERMINANTS, POLICY RESPONSES AND LONG-TERM CONSEQUENCES

BY

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Abstract

Background: Ghana implemented several COVID-19 policy responses to address the burden of the outbreak, given its unprecedented nature and the urgent need for mitigating strategies. To date, there is limited evidence on whether these policies met their intended influence on the COVID-19 burden in Ghana. Adequate evidence is warranted to inform more data-driven and socio-culturally acceptable policy decisions in the event of another COVID-19 wave or similar infectious disease outbreak in the future. In addition to the limited evidence on the policies' influence on the COVID-19 burden, there is also a limited understanding of whether the policies could mitigate any long-term consequences of the outbreak in Ghana. Such knowledge is critical to inform the policies' continuation. Further, there is data scarcity on the factors that determined severe COVID-19 health outcomes, like mortality, during the onslaught of the outbreak to inform initial, immediate, and context-relevant mitigating interventions in the event of a similar attack in Ghana. Therefore, this thesis examined the determinants of COVID-19-related mortality, prolonged hospitalisations and long COVID in Ghana. It also evaluated the effectiveness of Ghana's COVID-19 policies against their targeted COVID-19 burden and examined whether the policies could mitigate any long-term consequences of the COVID-19 outbreak in Ghana and, if so, the extent of the mitigation.

Methods: Seventy-two studies were first reviewed to identify the knowledge gaps around the effectiveness and long-term influence of Ghana's COVID-19 policies and the determinants of COVID-19 health outcomes in Ghana to provide the research questions and methodological directions for this study. After that, Dahlgren and Whitehead's determinants of health framework, logistic regression and negative binomial model were fitted to examine factors that determined prolonged COVID-19-related hospitalisations, mortalities, and long COVID in Ghana. Secondary data from Ghana's main COVID-19 treatment centre was used for the determinants analyses. Later, qualitative content analyses and experts' perspectives on the effectiveness of Ghana's COVID-19 policies were explored to provide evidence of the policies' influence on the COVID-19 burden in Ghana. An agent-based mathematical model, the CALMS model, was then used to predict the long-term consequences of the COVID-19 outbreak and examine the influence of the COVID-19 policies on the predicted long-term consequences.

Results: The determinants of COVID-19 health outcomes analyses showed that individuals with both hypertension and Diabetes Mellitus (DM) are 17 times more likely to die from

COVID-19 infection and four times more likely to experience long COVID than those with no comorbidities. In addition, they are more likely to spend two additional days in hospitals due to COVID-19 than those with no comorbidities. The content analyses and experts' evaluation also showed that public awareness campaigns and border closure policies are effective policies to educate and enhance adherence to COVID-19 prevention protocols and prevent COVID-19 case importation, respectively. In addition, the agent-based modelling demonstrated that the vaccination policy could reduce Ghana's long-term COVID-19-related direct healthcare costs, mortalities, long COVID, and hospital and ICU admissions in the next ten years by nearly 90%.

Conclusions: Ghana could consider persons with DM and hypertension when developing infectious disease policy guidelines for managing current and future outbreaks like COVID-19. Policies like diabetes and hypertension clinics nationwide to enhance regular clinical observations of persons with DM and hypertension to reduce their risk of severe disease outcomes could be considered in the guidelines. Others could include regular clinical and community-based screening for the early detection and management of DM and hypertension. Further, Ghana could also consider public awareness campaigns as one of its immediate interventions in the event of similar outbreaks. Finally, it could enhance and promote its vaccination intervention uptake to address/reduce the number of COVID-19-related deaths, hospitalisations, long COVID and direct healthcare costs in the long term.

Declarations

I, Shirley Crankson, declare that this thesis is my original work, except where otherwise acknowledged. I also declare that the materials contained in this thesis have not been submitted wholly or in part for any academic award or qualification other than that for which it is now submitted.

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Dedication

This thesis is dedicated to my children, Quabina Payne Baidoo and Kwame Duku Baidoo.

Thesis's Outputs and Other Research Engagements

1. Crankson, S., Mintram, K., Pokhrel, S., Anagnostou, A., & Anokye, N. (2023). Lockdowns and vaccines: did Covid-19 interventions help reduce the long-term health economic consequences in Ghana? *Research Square; 2023. DOI: 10.21203/rs.3.rs-2949196/v1.*

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3. Crankson, S., Pokhrel, S., & Anokye, N. K. (2022). Determinants of COVID-19-related length of hospital stays and long COVID in Ghana: a cross-sectional analysis. *International Journal of Environmental Research and Public Health*, *19*(1), 527.

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9. Contributed to the 2021 Joint Strategic Needs Assessment (JSNA) for Hillingdon Council, London.

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List of Abbreviations

WHO – World Health Organisation

SARS-CoV-2 – Severe Acute Respiratory Syndrome Coronavirus 2

CDC – Centre for Disease Control and Prevention

MERS-CoV – Middle East Respiratory Syndrome Coronavirus

CFR – Case Fatality Ratio

HIV/AID – Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome

NHS – National Health Service

A&E – Accident and Emergency

GDP – Gross Domestic Product

LOS – Length of Hospitalisation

PRISMA – Preferred Reporting Items for Systematic Reviews and Meta-Analyses

NOS – Newcastle-Ottawa Scale

AHRQ – Agency for Healthcare Research and Quality

CASP – Critical Appraisal Skills Programme

RoBANS – Risk of Bias Assessment tool for Non-randomised Studies

JBI – Joanna Briggs Institute

HIC – High-Income Countries

UMIC – Upper-Middle-Income Countries

LMICs – Lower-Middle-Income Countries

RT-PCR – Reverse Transcription-Polymerase Chain Reaction

IMD – Index of Multiple Deprivations

GLMs – Generalised Linear Models

VIF – Variance Inflation Factor

CKD – Chronic Kidney Disease

COPD – Chronic Obstructive Pulmonary Disease

CRP – C-Reactive Protein

CI – Confidence Interval

HR – Hazard Ratio

AHR – Adjusted Hazard Ratio

OR – Odds Ratio

AOR – Adjusted Odds Ratio

PCT – Procalcitonin

GEMH – Ga East Municipal Hospital

GOG – Government of Ghana

MoH – Ministry of Health

GHS – Ghana Health Service

GODI – Ghana Open Data Initiative

TPB – Theory of Planned Behaviour

G-DHS – Ghana Demographic and Health Survey

CALMS – Coronavirus Lifelong Modelling and Simulation

CHMLS – College of Health, Medicine and Life Sciences

MCAR – Missing Completely at Random

DM – Diabetes Mellitus

HPT&DM – Hypertension & Diabetes Mellitus

CVD – Cardiovascular Disease

GTI – Gastrointestinal disease

MOE – Ministry of Education

MOI – Ministry of Information

MoF – Ministry of Finance

NCCE – National Commission for Civic Education

GSS – Ghana Statistical Service

KIA – Kotoko International Airport

HCW – Healthcare Workers

GCARES – Ghana Alleviation and Revitalisation of Enterprises Support

MSMEs – Micro, Small and Medium-scale Enterprises

NBSSI – National Board for Small Scale Industries

IMF – International Monetary Fund

GDP – Gross Domestic Product

SMEs – Small and Medium Enterprises

PIS – Participant Information Sheet

NCDs – Non-Communicable Diseases

BMI – Body Mass Index

ICU – Intensive Care Unit

SIRD – Susceptible, Infected, Recovered, Death

CAP – Coronavirus Alleviation Program

DALYs – Disability Adjusted Life Years

PPEs – Personal Protective Equipment

OPD – Outpatient Department

CHARMS – CHecklist for critical Appraisal and data extraction for systematic Reviews of prediction Modelling Studies

PROBAST – Prediction model study Risk Of Bias Assessment Tool

SANRA – Scale for the Assessment of Narrative Review Articles

CHAPTER 1: INTRODUCTION

1.1 Background

In 2019, the world started experiencing a new viral outbreak, the COVID-19 disease, which resulted in unprecedented health and economic burdens, such as mortalities and job losses (World Health Organisation (WHO), 2020). The outbreak was caused by the novel coronavirus, Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) (WHO, 2020). Persons infected with the virus showed symptoms such as cough, fever, breathlessness, and loss of sense of taste (Centre for Disease Control and Prevention (CDC), 2021). The transmission of the virus was initially and transiently zoonotic and later transitioned into human-to-human transmission. The human-to-human transmission was through direct and indirect modes, such as direct contact with aerosol secretions of infected persons and indirect contact with SARS-CoV-2 through contaminated surfaces (Lotfi et al., 2020). Accordingly, individual-based interventions, like social distancing, handwashing techniques, and cough etiquette, were prescribed to reduce the disease's transmission (Barrett & Cheung, 2021; Dantas et al., 2022). Regardless of these interventions, the diseases' transmission continued to soar, particularly in 2020 and 2021.

As of 7th November 2023, the COVID-19 disease had been associated with over 772 million infections and more than six million deaths globally, with many of the infections and deaths recorded in 2020 and 2021 and a few in 2023 (WHO, 2023). Compared to other viral outbreaks, specifically SARS-CoV-1 (2002), HINI (2009), MERS-CoV (2012), Ebola (2014) and Zika virus (2016), the impact of the COVID-19 outbreak has been described as the worst human catastrophe in the 21st century (Chakraborty & Maity, 2020). Even though the Case Fatality Ratio (CFR) of some of the outbreaks were higher than COVID-19 (MERS: CFR = 9.5%; SARS-COV-1: CFR = 34.4%; COVID-19: CFR = 2.2%), the colossal and aggressive transmission rate of the COVID-19 disease, particularly during its early stages, and its associated significant global impacts made the COVID-19 experience comparatively unprecedented (Azamifirei, 2020). It was even estimated to have had a higher transmission rate than the reported rate in its early stages because of the tendency of an infected person to remain asymptomatic (Nishiura et al., 2020). Its CFR was also projected in 2020 to increase exponentially over the coming years (Yaun et al., 2020). This projection was experienced in 2021 in countries like India, which started recording increasing COVID-19 mortalities in 2021 compared to 2020 when the projections were made (WHO, 2021). However, the projected fatalities started plummeting globally with the advent and admission of vaccines (WHO, 2023).

The COVID-19 outbreak posed significant challenges to global health systems, from crippled health resources to paradigm shifts in healthcare delivery (Maia et al., 2020). For example, in 2020, most healthcare facilities were suddenly required to prioritise COVID-19 case management, resulting in observed disruptions in healthcare service delivery for other conditions, like hypertension and tuberculosis (Malik et al., 2020; Zhang et al., 2020). Although provisions were made in most facilities to ensure continuity of services for these conditions, like doorstep healthcare delivery, these provisions, in addition to the sudden and high COVID-19 demands on healthcare services, translated into mammoth healthcare expenditures (Iyengar et al., 2020). More importantly, in settings with limited geographic access to healthcare facilities, the COVID-19 case management prioritisation further decreased their healthcare accessibility and broadened their already existing healthcare accessibility inequalities (WHO, 2023). For such populations, particularly those at the bottom of the socioeconomic pyramid, this inaccessibility added another layer to their experiences with health inequalities (Coronini-Cronberg et al., 2020; Bambra et al., 2020). In addition to the service delivery disruptions, healthcare workers globally were psychologically saddled with the immense task of managing COVID-19 cases. For example, a study by Zhu et al. (2020) indicated that healthcare workers reported high levels of anxiety and burnouts, which were associated with providing direct and indirect care to persons with COVID-19. Additionally, evidence from a systematic review of the impact of COVID-19 showed that health workers experienced significant mental disorders, notably insomnia and depression, due to COVID-19 management (da Silva & Neto, 2020).

Based on the enormous burden of the COVID-19 outbreak on healthcare, as described above, telemedicine was developed to mitigate the inundating effect of the outbreak on health delivery and healthcare workers. One of the main objectives of telemedicine was to move health service delivery from face-to-face to virtual platforms (Iyengar et al., 2020). However, while this markedly lessened the physical pressures on health facilities, reduced the risk of COVID-19 infections and ensured timely health responses to acute and chronic conditions, it was limited in ensuring objective patient assessments owing to a lack of physical examinations (Barney et al., 2020). Also, its complete acceptance by populations was not guaranteed because of privacy and confidentiality-related concerns (Mubarak et al., 2021). In addition, its usage had severe financial implications for socioeconomically vulnerable populations, resulting in a further deepening of healthcare access inequalities.

Apart from the discussed health burden, the COVID-19 outbreak also significantly impacted economies. For example, its associated testing, treatment, and quarantine processes had dire monetary implications for individuals and institutions (Ornell et al., 2020). In addition, its nature and associated urgent demand for mitigating interventions resulted in unplanned fiscal expenditures at individual and national levels. Also, its informed lockdowns in several countries to curb its spread brought about closures of businesses, translating into substantial economic costs to governments and organisations (Amponsah & Frimpong, 2020). It also resulted in job losses, decreased profit generation and caused existential threats to several businesses. For example, reports from WHO (2020) revealed that almost half of the 3.3 billion global workforce lost their sources of livelihood due to the outbreak, thus plunging individuals into extreme poverty.

Notably, while the health and economic burden of the COVID-19 outbreak was consequential in both high-income and low-and-middle-income countries (LMICs), particularly during the onslaught of the virus, high-income countries, like Italy, were mainly fraught with high COVID-19 mortalities and LMICs, like Ghana, were comparatively more burdened with the associated economic hardships (Rubino et al., 2020; Adom et al., 2020), suggesting different mitigating policy options. However, given the unprecedented nature of the outbreak, its uncertainty, and the urgent need for interventions in the early stages, these contextual dynamics were mainly not considered in the policy management of the outbreak (Khoo, 2020). Accordingly, countries like Ghana relied extensively on mitigating policies in high-income countries, such as lockdowns and social distancing (Khoo, 2020). While these were useful, they plundered Ghana into more economic hardships in 2020, with its effect still observed in 2023, because they did not align with the socioeconomic characteristics of the country (Amponsah & Frimpong, 2020). These observations necessitate the need for context considerations and context-informed data in implementing mitigating policies as we advance in our management of infectious disease outbreaks.

Generally, the number of daily confirmed infections has declined since January 2022, possibly due to global COVID-19 vaccination efforts (WHO, 2023). Notwithstanding, some countries in the WHO regions of Europe and the Western Pacific continue to experience occasional spikes in the number of COVID-19 infections daily amidst the vaccination intervention (WHO, 2023). While the observed spikes could be due to the widely reported vaccine hesitancy in several settings, it could also result from disproportionate global distributions of the COVID-19 vaccine (Upadhyay et al., 2021). Nonetheless, global health systems must continue to address both vaccine hesitancy and disproportionate vaccine distribution concerns, as they could derail the progress made to mitigate the burden of the COVID-19 outbreak by prolonging the duration of the outbreak. Reflectively, the observed occasional spikes in the number of cases could also be due to the nature of the vaccine (not specific to any vaccine) to reduce the risk of severe COVID-19 outcomes, like mortality, more than the risk of COVID-19 infections (Mintram et al., 2022; Fridman et al., 2021). This argument is, however, inconclusive since the spikes are observed in only a few of the WHO regions, indicating that possible contextual factors could be driving the phenomenon (WHO, 2023). This contextual argument again corroborates the need for setting-based regular studies to provide a broader understanding of the key drivers of COVID-19 health outcomes to inform tailor-made interventions to address the burden holistically. Such studies could also provide findings on improving the vaccination intervention to align with contextual and societal changes so the intervention could effectively address any emerging burden. Figure 1 below details the burden of the COVID-19 outbreak using the input-output-outcomes-impact framework.

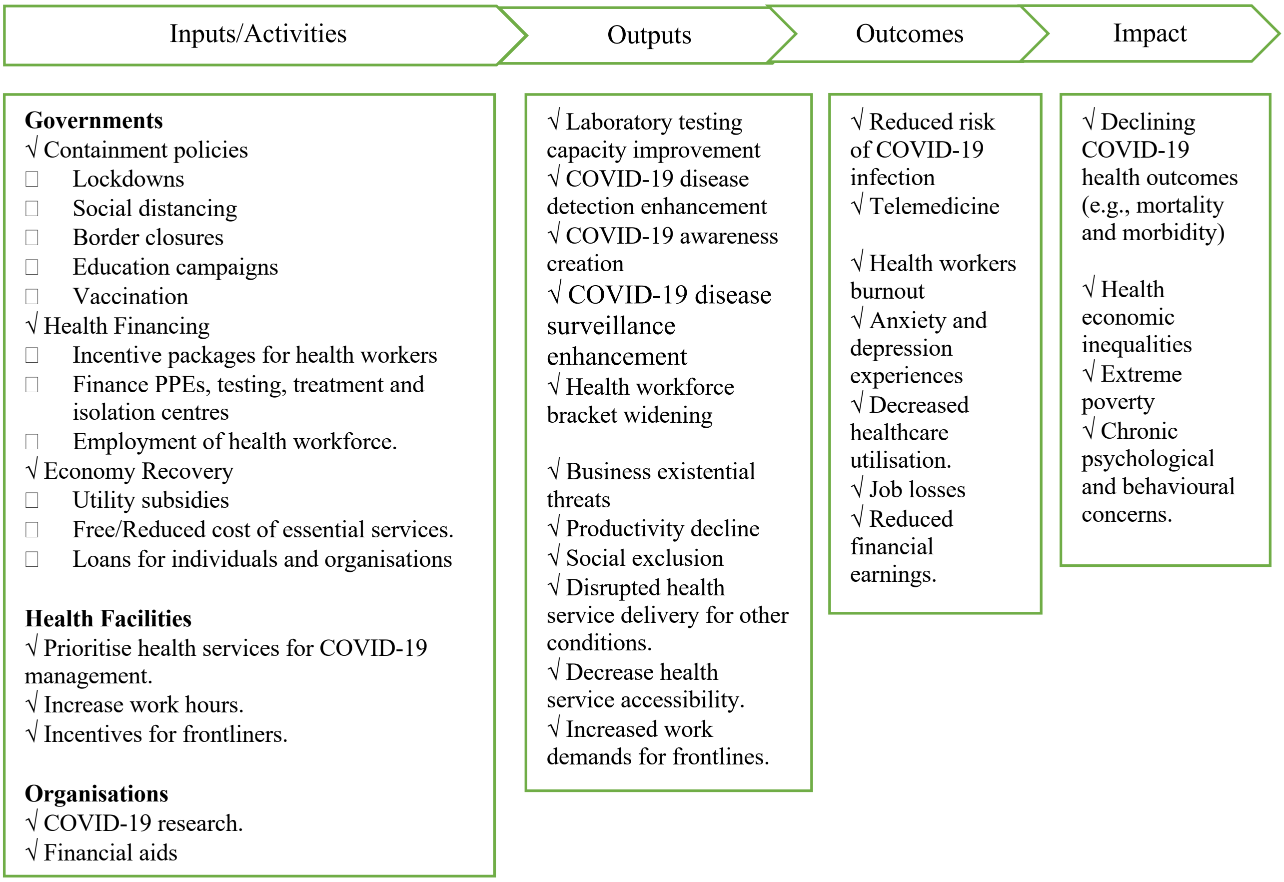

Figure 1: Conceptualised inputs and impacts of the COVID-19 outbreak. (Source: Author)[1]

1.2 COVID-19 in Ghana

Like the global depiction, the COVID-19 outbreak has, directly and indirectly, affected multiple sectors in Ghana, mainly the health and economic sectors. Regarding direct health impacts, Ghana recorded its first COVID-19 cases on 12th March 2020, and as of 4th November 2023, over 171,000 confirmed infections had been recorded, with most of the cases concentrated in the two major cities in the country, Accra and Kumasi (GHS, 2023). More than half of the confirmed infections were through enhanced contact tracing (59%), and the rest were from routine community surveillance (36.5%) and border screening at the Kotoka international airport (4.5%) (GHS, 2023). On mortalities, over 1,400 deaths associated with COVID-19 had been confirmed as of November 2023. These deaths and infections are nearly 10% higher among men than women (Yawson et al., 2020; Ayisi-Boateng et al., 2021).

[1] Framework is based on reports from the World Bank (2023) and WHO (2020).

Regarding indirect health effects, the outbreak has had severe ramifications for primary healthcare accessibility. For example, Kugbey et al. (2020) report a decreased geographic access to hospital care by cancer patients in Ghana since the outbreak began. This concern was re-echoed by Heuschen et al. (2022), who found a 43% decrease in access to malaria care among children under five years due to the COVID-19 informed movement restrictions in Ghana. Given the urgency and implications of non-malaria treatment, particularly for children under five in Ghana, the 43% decreased access to malaria treatment was consequential for Ghana's malaria eradication targets (Heuschen et al., 2022). Apart from the access to primary healthcare, the outbreak also impacted the risk of mental health diseases significantly, as more than 12% and 8% of depression and anxiety from domestic violence and abuse reported during the onslaught of the outbreak were associated with COVID-19 (Asiamah et al., 2021; Adu et al., 2021).

Concerning economic burden, as of 30th March 2020, a few weeks after recording the first COVID-19 cases, the country had lost over US$85,000 on initial preparations and response plans and over US$137,000 on COVID-19-induced import duties deficits (Amponsah & Frimpong, 2020). At the end of 2020, the country had also spent about US$35 million on COVID-19-related health workers incentives (Asamani et al., 2022), and it is further projected to spend over US$340 to US$440 million on COVID-19-related vaccination interventions (Nonvignon et al., 2022). Furthermore, the COVID-19 lockdown and other restrictions imposed by the government to reduce COVID-19 transmission also disrupted businesses and caused downsizing of employees. For example, over 40,000 people were reported to have experienced COVID-19-related job losses within the first eight weeks of the outbreak in Ghana (Aduhene & Osei-Assibey, 2021). Also, the country's Gross Domestic Product (GDP) colossally declined by about 27.5% in 2020 (Amewu et al., 2020). These economic exhaustions plunged livelihoods into extreme poverty (Adom et al., 2020). For example, evidence shows that the pandemic drove an additional 10% of the Ghanaian population into temporal poverty (Amewu et al., 2020). In addition to these direct economic impacts, the COVID-19-related economic fallouts also translated into heightened stress and anxiety among Ghanaians (Salifu & James, 2020).

From a reverse perspective, the COVID-19 outbreak also stimulated economic growth by enhancing in-house innovations and manufacturing, subsequently reducing consumption and overreliance on external imports (Amponsah & Frimpong, 2020). For example, the government empowered local manufacturers and the indigenes to locally produce essential COVID-19 consumables like nose masks, medical scrubs, and hand sanitisers (Afriyie et al., 2020). These empowered local productions are argued to have widened income brackets. However, when juxtaposed, the COVID-19-related direct economic burdens far outweigh any positive gains (Amponsah & Frimpong, 2020). Given the unprecedented nature of the COVID-19 outbreak, its overwhelming health and economic burden and the vagueness of knowledge on its appropriate mitigating interventions, Ghana explored and implemented several considered relevant interventions concurrently to alleviate the impacts of the outbreak (Khoo, 2020). The interventions included COVID-19 public awareness campaigns, bans on social gatherings, entry borders closures, closures of schools, incentivisation of healthcare workers, partial lockdown and the Ghana COVID-19 Alleviation and Revitalisation of Enterprises Support (GCARES) program.

The exploration and implementation of these policies were largely experimental, as the outbreak was novel, and as such, no nationally adopted policy guidelines existed to manage it, and the terrain was highly uncertain (Kenu, 2020). Nonetheless, even during the outbreak, the developed COVID-19 guidelines were focused on clinical management protocols with little consideration for national policy guidelines, even though such guidelines are critical to inform population-level interventions, especially as the outbreak bordered more around population health (Ministry of Health (MoH) – Ghana, 2023). The continuous absence of a national policy guideline possibly emanates from the scarcity of relevant and essential data on Ghana's COVID-19 outbreak dynamics (Khoo, 2020). Accordingly, this scarcity must be addressed through robust research that provides detailed evidence of the outbreak's epidemiological and policy dynamics in Ghana to inform the development of socioeconomic and culturally appropriate mitigating policy guidelines to direct policy decisions now and in the event of another COVID-19 wave or similar outbreaks in the future. Most importantly, the research to provide evidence for the policy guidelines must capture the factors that determined the severe outcomes of the COVID-19 outbreak in Ghana, such as mortalities and hospitalisations, during the onslaught and in the heightened stages of the outbreak, to offer early context-based shielding policy decisions in the event of similar outbreaks. As indicated earlier, such contextual evidence is critical to provide context-relevant policy options that could have more significant impacts than borrowed policies that may be inexpensive but culturally ineffective (Waage et al., 2010).

Concerning the implemented policies, there were concerns about their relevance, adherence, effectiveness, long-term benefits and sociocultural suitability in the event of another COVID-19 wave or similar outbreaks in Ghana (Khoo, 2020; Serwaa et al., 2020). For example, although the advent of the vaccination intervention has been associated with observed declining number of COVID-19 infections and subsequent dire outcomes, there are still uncertainties around its potential adverse effects and long-term consequences, and these uncertainties contribute to the drivers of vaccine hesitancy in Ghana (Okai & Abekah-Nkrumah, 2022; Alhassan et al., 2021). In addition to the vaccination concerns, the context-relevance and effectiveness of the partial lockdown policy have similarly been debated, mainly on whether it will be necessary for future outbreaks, given the limited knowledge of its effects on the COVID-19 outbreak (Afriyie et al., 2020; Tibiru et al., 2022). An evaluation of these policies could address these concerns and further enhance our understanding of the policies' influence on the COVID-19 burden.

A few studies have evaluated Ghana's policy responses to address these concerns (Adu-Gyamfi et al., 2022; Quakyi et al., 2021; Khoo, 2020). However, these studies were narrative reviews, which were characterised by subjective interpretations, thus, limiting the reliability of the generated evidence (Quakyi et al., 2021; Awekeya et al., 2021). This limitation indicated the need for more methodologically robust approaches to increase our understanding of the policies' actual effects on the COVID-19 burden and provide recommendations for these policies' continuity and future considerations (Ogden et al., 2019; Parks et al., 2005). Apart from the need for robust evaluations of the policies' influence, investigations on the long-term consequences of the outbreak are warranted to examine whether the current policies could sufficiently mitigate the long-term consequences of the outbreak. The findings from such examination could provide the background evidence for early policy decisions and implementations to prevent or reduce any catastrophic long-term COVID-19 burden.

1.3. Study Aims and Objectives

This study aimed to provide evidence on factors that determined the immediate and long-term COVID-19 health outcomes in Ghana, enhance the understanding of the effectiveness of Ghana's COVID-19 policy responses and offer evidence on the potential influence of the policies on long-term consequences of the outbreak to contribute to related policy decisions, discourses, and mitigating policy guidelines. The specific objectives and linked research questions were:

1. To examine the determinants of COVID-19 health outcomes in Ghana: (a) what factors determined the immediate COVID-19 health outcomes, i.e., prolonged COVID-19-related hospitalisations and mortality; and (b) what factors determined long COVID, the long-term COVID-19 health outcome?
2. To evaluate the effectiveness of Ghana's policy responses: were the policy responses effective in addressing the burden of the COVID-19 outbreak?
3. To explore the long-term consequences of the COVID-19 outbreak: (a) what are the long-term consequences of the COVID-19 outbreak in Ghana; and (b) to what extent could Ghana's current COVID-19 policies mitigate the long-term consequences?

1.4 Contribution of the Thesis to the Literature

The study's contributions to the literature are summarised here and detailed in Chapter 8. In summary, Chapter 2 highlighted key knowledge gaps in Ghana's COVID-19 literature space, particularly around determinants of long COVID and the effectiveness of the COVID-19 policies on the long-term burden of COVID-19 in Ghana. These gaps informed the empirical analysis in this thesis and provided further research directions for future studies. Compared to the existing literature on COVID-19, Chapter 4 was the first to examine the determinants of long COVID in Ghana. As such, it provided preliminary data that could inform further research and preventive and shielding interventions to address long COVID in Ghana. It also contributed additional evidence to the existing knowledge on the determinants of COVID-19-related prolonged hospitalisations in Ghana by demonstrating that gastrointestinal diseases significantly increase the number of days spent in COVID-19-related hospital admissions in Ghana, an uncaptured data in previous studies (Nachega et al., 2022; Afriyie-Mensah et al., 2021). Again, unlike the wider COVID-19 literature that provided data on the broader population level determinants of COVID-19 mortality in Ghana (Dubik et al., 2023), Chapter

4 is the first to show through sub-population analyses that men older than ≥ 60 years and persons ≥ 60 years with comorbidities are more likely to die from COVID-19 in Ghana, and this could inform a more targeted COVID-19 shielding interventions, such as regular tailored education on COVID-19 prevention practices and protocols for these populations.

Chapters 5 and 6 evaluated four more of the key Ghana's COVID-19 policy responses, i.e., vaccination, border closures, COVID-19 entry border screening and bans on public gatherings policies, than the existing literature, therefore, adding new evidence to broaden our understanding of how the policies influenced the COVID-19 burden in Ghana. In addition, Chapter 5 used data triangulation for the qualitative analysis and Chapter 6 adopted qualitative and quantitative approaches to examine the effectiveness of the policies. Thus, compared to the anecdotal and narrative reports on these policies' effectiveness in the literature, the data triangulation and multiple methodological approaches allowed the thesis to contribute more validated and robust evidence of the policies' effectiveness. This contribution could inform more relevant policy options in the event of similar outbreaks. The chapters collectively showed that the COVID-19 public awareness campaign effectively prevented COVID-19 transmission, and the GCARES policy was less influential in reviving the economic recession associated with COVID-19.

Compared to Frost et al. (2021), Dwomoh et al. (2021) and Acheampong et al. (2021), Chapter 7 of this thesis is the first to demonstrate the scale of influence of vaccination and lockdown interventions on the long-term consequences of COVID-19 in Ghana. It used individual-level data to show that Ghana could reduce its COVID-19 infections, hospital and Intensive Care Unit (ICU) admissions, long COVID and direct healthcare costs in the next 70 years by more than 90% if it implements a whole population vaccination and periodic lockdown interventions. Further, by being the first to conduct COVID-19 agent-based simulations in Ghana, the chapter sets a precedent for future infectious diseases modelling research that capture individual-level characteristics to explore anticipatory interventions sensitive to real-life population variations and applicable at both individual and population levels in Ghana.

Apart from the specific contributions of the chapters to the literature, the thesis as a composite also provided significant inroads to broaden our understanding of the COVID-19 outbreak in Ghana to inform relevant policy decisions. These broader contributions include:

1. Initiating discourses on effective COVID-19 policies to augment efforts at lessening the COVID-19 disease burden.
2. Providing data to inform COVID-19 policy decisions that could address any COVID-19-related health inequalities.
3. Providing evidence to guide developing comprehensive infectious disease policy guidelines to serve as 'first aid' in the events of future outbreaks.

1.5 Study's Methodological Approach

This thesis adopted a mixed-method research approach. It employed a quantitative approach to understand the determinants of COVID-19 health outcomes and the long-term consequences of COVID-19 in Ghana and qualitative and quantitative approaches to answer the research question on the effectiveness of Ghana's COVID-19 policy responses. The rationale for employing the mixed methods approach was to enhance this study's rigour, depth and level of methodological comprehensiveness (Lund, 2012). Most importantly, it was to allow the strengths of the quantitative and qualitative approaches to lessen each other's limitations while the thesis benefits from their advantages (de Souza Minayo, 2017; Kelle, 2006). For example, the objective nature of the quantitative approach was aimed at addressing the subjective interpretation characteristics of the qualitative approach (Lund, 2012; Taherdoost, 2022), while the qualitative approach's advantage of producing deeper contexts and insights to understand a research topic or phenomenon was to compensate for the limited nuances in qualitative approach (Rahman, 2020). This complementary advantage was observed in Chapter 6 when the thematic analyses section of that chapter provided nuances and insights to understand underlying factors that could have contributed to the policies' effectiveness rating in the statistical findings in that chapter. Further, the qualitative analysis in Chapter 5 provided themes on the types and objectives of Ghana's COVID-19 policies that informed the questionnaire development in Chapter 6. However, despite its methodological advantages, the mixed methods approach was time-consuming as it required multiple research ethics applications to access the quantitative secondary data and the qualitative and quantitative data from experts, thereby extending the duration of this study. Reflections on the influence of using mixed methods approach in this study are detailed in Chapter 8.

1.6 Structure of the Thesis

Figure 2 below is a snapshot of the thesis's eight chapters. Chapter 1 discussed the burden of the COVID-19 disease, provided the rationale for the thesis, and described the thesis's aim and objectives. Chapter 2 reviewed the literature on determinants of COVID-19 health outcomes and the effectiveness and long-term influence of Ghana's COVID-19 policy responses to identify literature gaps to inform the research direction of the thesis. Chapter 3 provided the methodological framework to analyse the gaps identified in Chapter 2. Chapter 4 adopted Dahlgren and Whitehead's determinants of health framework to examine the determinants of COVID-19-related mortality, hospitalisation and long COVID in Ghana. It used a novel dataset from Ghana's main COVID-19 treatment centre and conducted multiple regression analyses to examine the determinants. Chapter 5 adopted a qualitative content analysis approach to evaluate Ghana's COVID-19 policy responses against their objectives. Chapter 6 complemented the analyses in Chapter 5 by exploring experts' perspectives on the effectiveness of Ghana's COVID-19 policy responses. Chapter 7 used the CoronAvirus Lifelong Modelling and Simulation (CALMS) model to simulate the influence of lockdown and vaccination policies on the long-term consequences of COVID-19 in Ghana. The policies were varied in three hypothetical scenarios to explore their scale of mitigation on COVID-19 infections, hospital and ICU admissions, long COVID, mortality and healthcare costs in the next 5, 10 and 70 years. Finally, Chapter 8 concludes the thesis by summarising its findings, comparing them to the wider literature, detailing its contributions, discussing its limitations, and providing policy and future research recommendations.

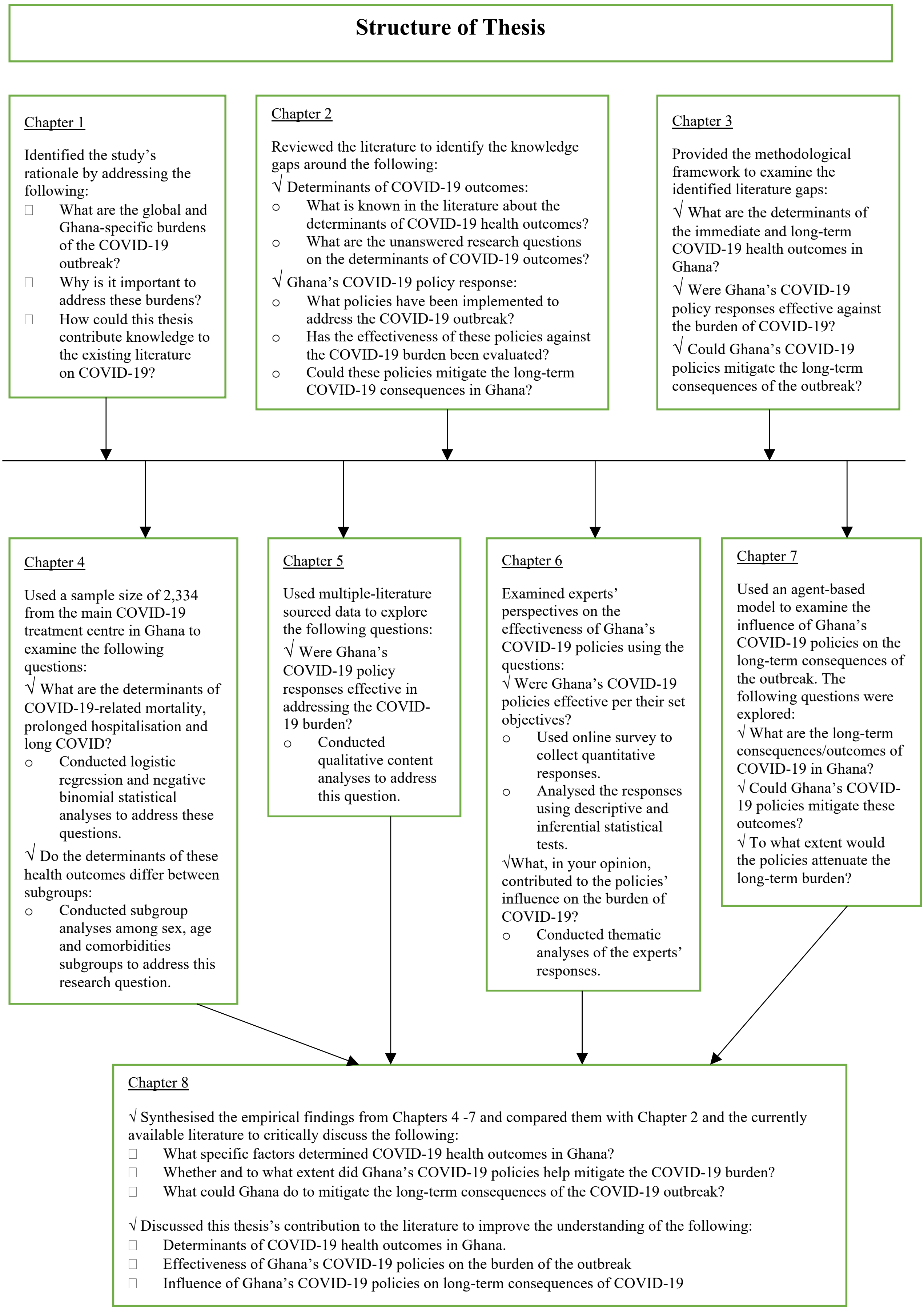

Figure 2: The thesis's structure.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The previous chapter of the thesis gave an overview of the burden of COVID-19 globally and in Ghana, highlighted the rationale for this research and presented the thesis aims and objectives. However, there remained the need for a systematic review of the wider literature to critically determine what is already known about COVID-19 so that the research direction and methodological approaches in this study could be informed. Therefore, this chapter systematically reviewed the existing literature to answer the following three questions:

- What are the determinants of COVID-19 health outcomes?
- Were Ghana's COVID-19 policy responses effective against the COVID-19 burden?
- Could Ghana's COVID-19 policy responses mitigate the potential long-term consequences of the COVID-19 outbreak in Ghana?

The literature review is presented in two main sections: Section 1 reviewed the literature on the determinants of COVID-19 health outcomes, and Section 2 examined the literature on Ghana's COVID-19 policy responses' effectiveness and their influence on the long-term consequences of COVID-19 in Ghana.

2.2 Section 1: A Review of the Determinants of COVID-19 Health Outcomes

2.2.1 Methods

The methods section presents the approaches followed to search, extract, appraise, and synthesise data from the identified relevant studies. The process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist[2] for systematic reviews (Page et al., 2021).

2.2.1.1 Search Strategy

Four electronic databases, Scopus, Google Scholar, CINAHL and Web of Science, were searched in December 2020 for relevant literature on determinants of COVID-19 health outcomes using the search terms in box 1. The databases and search terms were informed by a

[2] PRISMA checklist available at: http://prisma-statement.org/PRISMAStatement/Checklist

pilot review (appendix 1) that was conducted to inform the search strategy of this literature review. The search terms were combined with the ‘AND’ and ‘OR’ Boolean operators to ensure an exhaustive and targeted database search. In each database, the author applied database-specific filters to increase the sensitivity of the search outcomes. Where feasible, search alerts were activated in the databases for an immediate access to current articles on the research topic. The references of the identified studies were also tracked to avoid the potential exclusion of relevant literature. No date restrictions were applied since articles on COVID-19 are still current.

Box 1: Search terms

(Determinant* OR Risk factor* OR Predictor*) AND (COVID-19 OR Coronavirus OR 2019 nCOV-2 OR SARS-COV-2) AND (health outcome* OR clinical outcome*) OR (Death OR Mortality*) OR (hospitalisation stay OR Admission OR admission* length OR hospital* length)

2.2.1.2 Eligibility Criteria

Studies were eligible for this review if they met the following predetermined eligibility criteria:

- Population: individuals diagnosed with COVID-19
- Exposures: demographic, socioeconomic, lifestyle, environmental, clinical/medical factors
- Outcome: Any COVID-19-related health outcomes
- Full-text accessible.

2.2.1.3 Data Extraction

A data extraction template (table 1) informed by the Joanna Briggs Institute’s (JBI) data extraction guidelines was used to extract relevant data from the selected studies. The questions covered two main items, i.e., general data and methodology. The items were to direct the extraction of data relevant to the objectives of this literature review. The review questions were pilot tested on three selected papers to ensure their exhaustiveness in extracting all the essential data before their application to all the included studies. Finally, the extracted data from 50% of the studies were peer- reviewed to ensure the inclusion of all information related to this study.

Table 1: Data extraction template

Items	Data extraction questions
General Data	Who are the authors? Which year was the study conducted and published? What is the aim of the study? Where was the study conducted (Country/Setting of study)?

Methodology	What was the theoretical underpinning of the study?
	What was the population of focus?
	What study design was used?
	What was the sample size?
	What was the statistical basis of the sample size?
	What COVID-19 outcomes were examined?
	How were the outcomes specified?
	What variables were measured as determinants of COVID-19 outcomes?
	How were the determinants specified?
	How was data collected?
	If primary data:
	    what method was used to collect the data?
	    what sampling method was used?
	If secondary data:
	    what dataset was used?
	How was the data analysed?
	If statistical analysis:
	    what statistical tests were conducted?
	    were any statistical model diagnostics tests reported?
	What are the main findings?
	What were the author stated challenges?

2.2.1.4 Risk of Bias and Quality Appraisal

The Newcastle-Ottawa Scale (NOS) and the Agency for Healthcare Research and Quality (AHRQ) appraisal checklists (appendix 2) were used to appraise the quality of the selected studies. These checklists were informed by the quality appraisal recommendations by Zeng et al. (2015). The NOS provided eight items, grouped under three main domains, selection of cohorts, comparability of cohorts, and outcomes assessment, for the appraisal. A star (*) was awarded if a study met an item under the three domains. A maximum of one star was given to items within the selection and outcome domain, and a maximum of two stars was given to the item under the comparability domain. Therefore, studies with eight to nine stars were rated as high-quality, five to seven were rated moderate, and those with four stars or less were graded as low quality. The ARHQ also provided eleven (n = 11) items/checklists for assessing the quality of the selected study's methods and outcomes. A 'yes', 'no' or 'not applicable (NA)' was used to indicate whether a study met the AHRQ requirement. The number of 'yes' from a study represented the study's quality. Therefore, studies with eight to eleven 'yes' were rated high quality, five to seven 'yes' as moderate quality and four or less 'yes' as low quality. Finally, the Risk of Bias Assessment tool for Non-randomised Studies (RoBANS) was used to assess the risk of bias across all the included papers. Accordingly, the quality of the studies was rated with two tools, either the NOS or AHRQ and RoBANS.

2.2.1.4 Data Synthesis

A narrative synthesis was conducted to comprehensively describe the included studies' aims, methodological approaches, findings, and limitations. In the synthesis, studies examining similar COVID-19-related health outcomes were compared to identify common themes and findings. Where possible, the studies' effect sizes were synthesised per their statistical estimators to understand the magnitude of the effect of the determinants on the outcomes.

2.2.2 Results

The database search yielded 10,022 studies (table 2). Of this, 1,407 duplicates were removed, and an additional 8,552 studies were eliminated after title and abstract screening. The remaining 63 studies meeting the eligibility criteria were subsequently included in this review, as shown in the Prisma flow diagram in figure 3.

Table 2: Database search results

Database	**Date searched**	**Initial papers identified**	**Filters applied**	**Final papers identified**
Scopus	December 2020	1,824	Limit to open access (1,660) Limit to research article (1,031)	1,031

Database	Date searched	Initial papers identified	Filters applied	Final papers identified
Google Scholar	December 2020	1,590	-	1,590
CINAHL	December 2020	3,117	Limit to available full text (547)	547
Web of Science	December 2020	13,648	Limit to open access (8,002) Limit to research article (6,854)	6,854
				Total=10,022

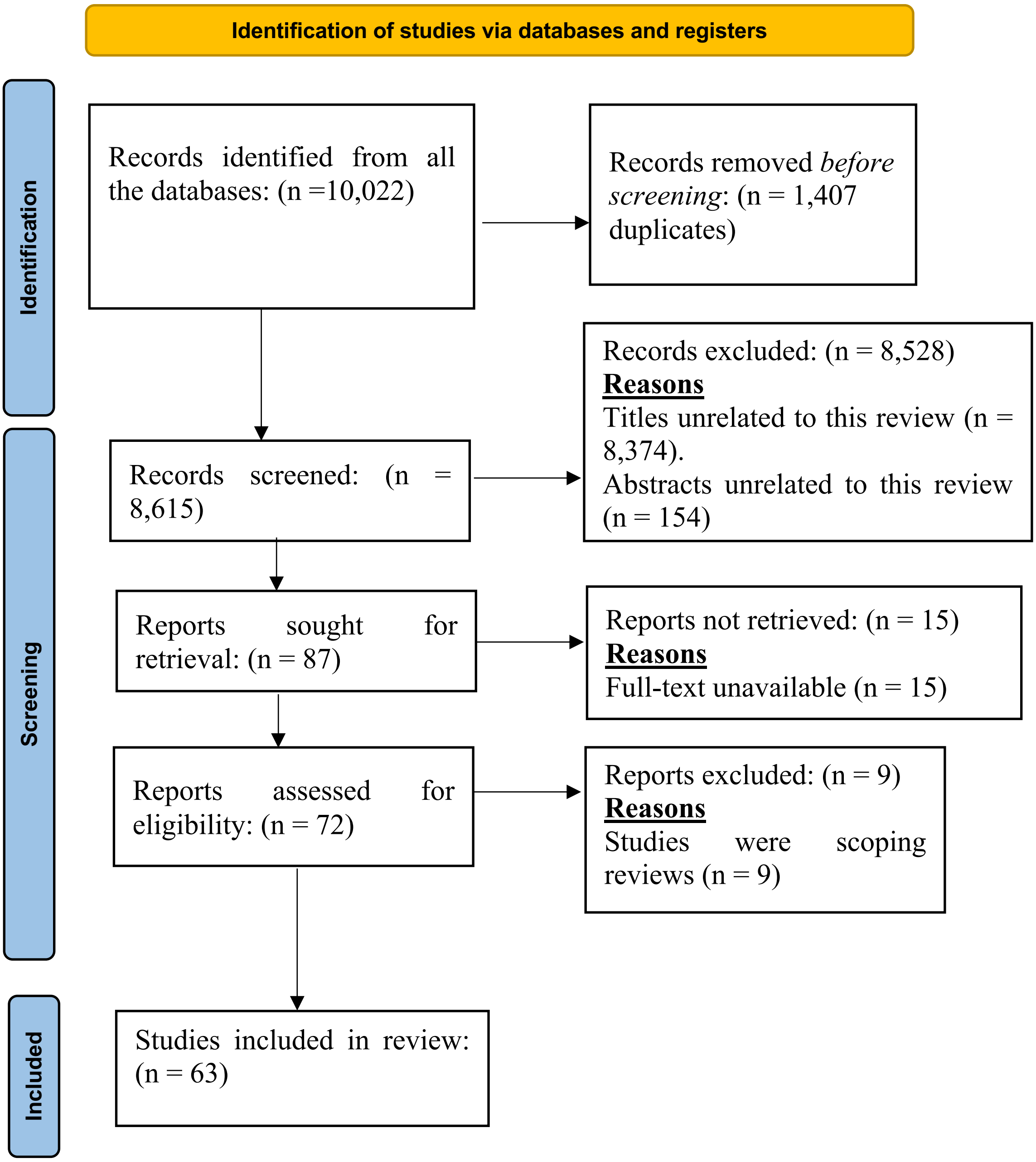

Figure 3: PRISMA flow diagram showing study selection process.[3]

2.2.2.1 Methodological Features of the Selected Studies

2.2.2.1.1 Study and Sample Characteristics

The sixty-three studies (n = 63) were from eighteen countries, twelve of which were High-Income Countries (HICs) and six from Low and Middle-Income Countries (The World Bank, 2023). The majority were from the USA (n = 15 studies), followed by China (n = 13), Spain

[3] PRISMA flow diagram available at: http://prisma-statement.org/PRISMAStatement/FlowDiagram

(n = 4), England (n = 5), Mexico (n = 3), UK (n = 3), South Korea (n = 3), Iran (n = 2), Italy (n = 2), France (n = 2), Turkey (n = 2) and one each from Kuwait, Austria, Nigeria, Congo, India, Brazil and Ireland. Two studies were multi-continent research, used data from Africa, Europe, Australia, Asia, and the Americas (Albitar et al., 2020; Alkhouli et al., 2020). All the selected studies employed the quantitative research approach and observational study designs. Many of them (n = 61) accessed only secondary data, retrieved mainly from patients' electronic medical records from the focused hospitals, except for Li et al. (2020) and Grasselli et al. (2020), who used both secondary and primary data. The primary data were collected through face-to-face (Li et al., 2020) and telephone interviews (Li et al., 2020; Grasselli et al. (2020).

The studies' sample sizes ranged from 45 to 47,0034, totalling 1,052,476 participants. All the studies had male and female participants; however, the men were in the minority, representing 47.1% of the population. Twenty-four (n = 24) of the studies were age-specific, i.e., they included persons of specific age groups. For example, seventeen (n = 17) included persons ≥18 years old, while the remaining used different age specifications, such as persons aged ≥60 (Cangiano et al., 2020; de Souza et al., 2020), 18 – 90 years (Harrison et al., 2020), 47 – 85 years (Ho et al., 2020) and those aged ≥16 (Javanian et al., 2020). Further, all the studies included persons with confirmed COVID-19 diagnoses, either through the Reverse Transcription-Polymerase Chain Reaction (RT-PCR) or nasopharyngeal swabs, except one of the studies conducted in Mexico that included all confirmed, negative, and suspected COVID-19 cases in their study (Bello-Chavolla et al., 2020). However, in identifying the predictors of COVID-19 outcomes, they included only those with confirmed COVID-19 diagnoses (n = 51633). Therefore, only those patients with confirmed COVID-19 diagnoses were included in this review. See figure 4 for a summary of the studies' characteristics and appendixes 3 and 4 for each study's characteristics.

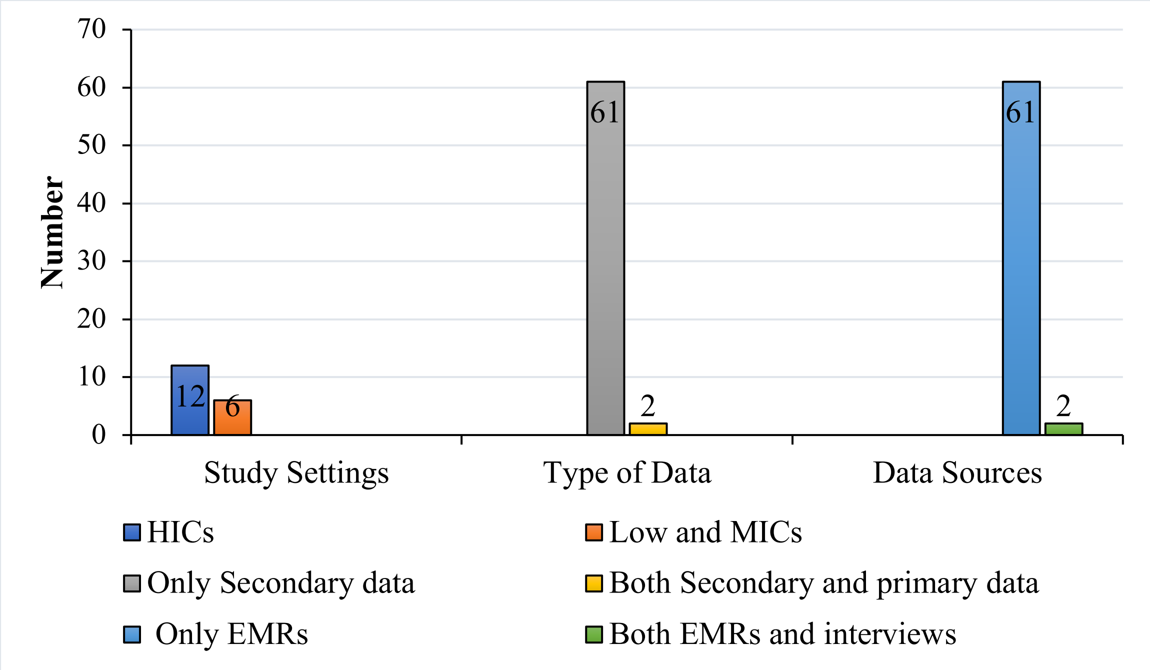

Figure 4: Summary of the study's characteristics.

Note: MICs – Middle-Income Countries; EMRS – Electronic Medical Records.

2.2.2.1.2 Results of the Quality Appraisal

The NOS appraisal tool was used to assess the quality of thirty-two (n = 32) of the selected papers because they were cohort studies. Their quality on the NOS ranged from six to nine, indicating moderate to high quality. Similarly, the quality of the cross-sectional studies (n = 31) on the AHRQ ranged from six to eleven, showing moderate to high quality. The common limitation across most studies (n = 35) was the inability to control potential confounders. This confounding limitation was evident in the RoBANS tool, indicating some concordance across the different quality assessment tools. As such, the findings of this review must be interpreted with caution as the identified confounding bias could have influenced the findings of the selected studies and, by extension, the findings of this review (Katrak et al., 2004). See table 3 for a summary of the number of moderate and high-quality studies, per the NOS and AHRQ tools, and appendix 6 for the detailed quality appraisal results for each quality tool and across all the tools.

Table 3: The number of moderate and high-quality studies per the NOS and AHRQ criteria

NOS scale		**AHRQ checklist**	
High quality	Moderate quality	High quality	Moderate quality
N = 25	N = 7	N = 26	N = 5

2.2.2.1.3 Underlying Framework

None of the included studies indicated their underlying healthcare framework or conceptual model. The apparent lack of a framework to guide these studies limited this review from establishing the basis for their methodological approaches, especially the rationale for the measured independent variables (Eccles et al., 2005). This limitation was because underlying frameworks could have provided the themes for understanding their research conceptualisation and progression (Grant & Osanloo, 2014; Eccles et al., 2005).

2.2.2.1.4 Specifications of COVID-19 Health Outcomes

The identified COVID-19-related outcomes were mortality and Length of Hospital Stay (LOS). Fifty-eight (n = 58) studies examined mortality as a COVID-19 outcome, three (n = 3) explored COVID-19-related LOS, and two examined both COVID-19-related mortality and LOS. So, in general, sixty studies (n = 60), with a total of 1,052,211 participants, were reviewed to identify the determinants of COVID-19-related mortality and five studies (n = 5), with a total of 1,168 patients, were explored in the determinants of COVID-19-related LOS review. Mortality was generally described as either in-hospital deaths, i.e., COVID-19 deaths occurring in a hospital or all-cause mortality, i.e., all deaths in COVID-19 patients, regardless of the cause, and LOS was commonly defined by four of the five included studies as the number of days in hospital admission due to COVID-19. The other study described it as normal or prolonged based on their measured average LOS (<17 days: normal; >17: prolonged) (Guo et al., 2020). Consequently, they assessed it as a binary outcome. See appendix 3 and 4 for the dependent variable specification for each identified study.

2.2.2.1.5 Determinants of COVID-19 Health Outcomes

The review identified several determinants of COVID-19 outcomes, and these were categorised into four groups: demographic, lifestyle, clinical/medical and socioeconomic variables, based on Dahlgren and Whitehead (1993)'s determinants of health model. The rationale for the categorisation was to provide context on the identified determinants of COVID-19-related mortality and LOS. Additionally, it was to help the researcher identify frequently and rarely explored determinants of COVID-19 outcomes to inform the subsequent empirical analyses in this research. The categorisation showed that demographic and clinical/medical variables are the commonly investigated determinants of COVID-19, while lifestyle and socioeconomic are the least explored. The identified independent variables are briefly explained below and detailed in appendix 5.

2.2.2.1.5.1 Demographic Determinants

The demographic variables described the characteristics of the participants in the selected studies. The common demographic variables were age (specified in years) (n = 55 studies) and gender/sex (male/female) (n = 48 studies). The others were geographic location (n = 1 study), place of residence (n = 2 studies), nationality (n = 1 study) and race/ethnicity (n = 16 studies). The race and ethnicity variable specification was similar across the studies that measured them. The common specifications included Hispanics, African Americans, Whites, and Asians. In addition, the place of residence described where the patients lived, while the geographic location was described by the only study that assessed it as the continents the participants were resident in (Albitar et al., 2020). Finally, the researchers did not specify the nationality variable (Bello-Chavolla et al., 2020).

2.2.2.1.5.2 Clinical/Medical Determinants

The studies described the clinical/medical factors primarily as comorbidities, i.e., other health conditions co-existing with COVID-19, laboratory findings, and the study participants' symptoms. The common comorbidities were cardiovascular diseases (n = 46 studies), diabetes mellitus (n = 45 studies) and hypertension (n = 37 studies). Also, the frequently explored laboratory findings were C-Reactive Protein (CRP) (n = 12 studies) and creatinine (n = 8 studies). The cardiovascular diseases specification included coronary heart disease, chronic heart disease, ischaemic heart disease, congestive heart disease, myocardial infarction and heart failure. Hypertension and diabetes mellitus were described as whether it was present, while

CRP and creatinine were described as elevated or normal. For participants' symptoms, the common was dyspnoea (n = 8 studies) and fever (n = 8 studies). Another examined clinical/medical determinant was hospitalisation timing relative to COVID-19 symptom onset (Alaa et al., 2020).

2.2.2.1.5.3 Lifestyle Determinants

Smoking and alcohol consumption were the only identified lifestyle variables. Twenty-two studies (n = 22) measured smoking as a determinant. However, only eight (n = 8) included it in their statistical analysis. It was generally described as 'never', 'former', and 'current' smokers. Alcohol consumption was measured by two of the studies, and it was described as 'yes consumption' and 'no consumption'.

2.2.2.1.5.4 Socioeconomic Determinants

Two of the studies included socioeconomic factors as independent variables in their analysis. One measured it based on the Index of Multiple Deprivations (IMD) scale – where '1' meant least deprived and '5' was most deprived (Williamson et al., 2020), and the others measured it using the Pobal HP Deprivation Index (Farrell et al., 2020).

2.2.2.1.6 Data Analysis and Model Diagnostics

All the studies conducted both descriptive and inferential statistical analyses. Of the inferential analysis, logistic regression (n = 28 studies) and Cox proportional hazard regression (n = 27 studies) were the common statistical methods used to estimate the determinants of COVID-19-related mortality. The other was the Poisson family of the Generalised Linear Models (GLMs), which was used by three studies to examine the determinants of mortality (Tartof et al., 2020; Ho et al., 2020; Javanian et al., 2020). Though these studies did not justify the choice of this model, it can be deduced that the model was possibly informed by the discrete nature of their dependent variable, i.e., mortality. Thus, it is likely that their dependent variable was measured as a count variable, i.e., the number of deaths due to COVID-19 (Hayat & Higgins, 2014). For the determinants of COVID-19-related LOS, the statistical estimators included GLMs, multiple linear regression, and multivariable logistic regression. A few of the studies conducted model diagnosis with tools such as the Variance Inflation Factor (VIF), the Hosmer–Lemeshow test, the Nelson-Aalen cumulative hazard function and the Schoenfeld residuals tests. The VIF was used to measure multicollinearity in the variables, while the Hosmer–Lemeshow test was used to determine the goodness of fit in the logistic models. Also, the Nelson-Aalen cumulative hazard function and Schoenfeld residuals test were used to assess assumptions in the Cox regression models. See appendix 5 for the statistical estimators used by the studies.

2.2.2.2 Empirical Findings of the Selected Studies

The empirical findings of the reviewed studies are synthesised and presented based on the COVID-19 health outcomes and the category of determinants they measured. The individual findings of the selected studies are detailed in appendixes 3 and 4.

2.2.2.2.1 Determinants of COVID-19-related Mortality

The studies investigated the determinants of COVID-19-related mortality with different effect size estimators. Therefore, the findings have been categorised per the effect size estimators and duration of mortality. Of the fifty-five studies (n = 55) on age and COVID-19 mortality, forty-three (n = 43) identified increasing age as a common demographic determinant of COVID-19-related mortality. Similarly, among the forty-eight (n = 48) studies that included sex in their regression analysis, seventeen (n = 17) found men with COVID-19 more likely to die from the infection than their women counterparts. Other identified demographic determinants of COVID-19-related mortality were race/ethnicity (n = 3 studies) and place of residence/geographic location (n = 2 studies).

Regarding clinical/medical risk factors, the studies identified comorbidities, such as cardiovascular diseases (n = 18 studies), Chronic Kidney Disease (CKD) (n = 10 studies), obesity/overweight (n = 10 studies), Chronic Obstructive Pulmonary Disease (COPD) (n = 10 studies), hypertension (n = 9 studies), diabetes mellitus (n = 12 studies) and malignancies (n = 6 studies), as determinants of COVID-19-related mortality. Additionally, laboratory factors, like creatinine (n = 6 studies), CRP (n = 6 studies) and D-dimer (n = 4 studies), were associated with COVID-19-related mortality. On lifestyle factors, only cigarette smoking was identified as a determinant of COVID-19-related mortality (n = 4 studies). For the socioeconomic factors, two (n = 2) studies discovered that socioeconomic deprivation determines COVID-19-related mortality. See table 4 for the synthesised findings on the determinants of COVID-19-related mortality and table 5 for studies that identified significant determinants of COVID-19-related mortality but whose findings have been separated from the main synthesised findings due to potentially unstable statistical estimators.

Table 4: Synthesised findings on determinants of COVID-19-related mortality (N = 60 studies)

variable	**Number of studies examining variable**	**Number of studies identifying it as a determinant of covid-19 mortality.**	**Range of effect sizes (95%CI)**				**Duration of mortality**		
			HR	AHR	OR	AOR	28-day	90-day	Undefined
Older/Increasing age	55	43	1.03–20.60 (1.01–22.68)	1.31-60.80 (1.1-124.61)	1.04–28.45 (1.01–168.79)	1.08–1.93 (1.05–2.94)	√	√	√
Sex (Male)	47	17	1.29–1.59 (1.13–1.65)	1.7 (1.0-2.8)	1.09–1.81 (1.04–2.92)	1.60 (1.02–2.58)	√	√	√
Race/ethnicity	16	3	1.48 (1.29–1.69)		1.50–3.44 (1.31–9.00)			√	√
Residence/geographi c location	2	2			4.04–7.44 (1.33–15.61)			√	√
*Cardiovascular diseases	46	18	1.16–1.84 (1.08–3.09)	1.76 (1.08-2.86)	1.332–6.25 (1.07–32.26)	3.59 (1.26–10.02)	√	√	√
CKD (yes)	22	10	1.28–3.17 (1.09–6.80)		1.47–3.11 (1.27–7.3)			√	√
Obesity/overweight	26	9	1.25–1.92 (1.03–1.84)		1.07–3.09 (1.04–7.23)		√	√	√
COPD (yes)	17	9	1.17–1.68 (1.08–2.19)	2.94 (1.48-5.84)	2.94 (1.48–5.84)		√	√	√
Hypertension (yes)	36	9	1.09–4.48 (1.01–5.45)		1.12–1.53 (1.01–4.74)		√	√	√
Diabetes mellitus (yes)	45	12	1.18–2.61 (1.01–3.29)		1.23–3.11 (1.14–4.71)				√
Malignancies (yes)	17	6	1.13–2.50 (1.02–3.06)			2.88 (1.01–8.22)	√	√	√
Pneumonia (yes)	8	5	5.21 (4.84–5.50)		1.24–2.57 (1.07–3.30)				√
Dementia (yes)	5	4	1.26–1.40 (1.04–1.53)		1.29–7.30 (1.07–16.21)			√	√

variable	Number of studies examining variable	Number of studies identifying it as a determinant of covid-19 mortality.	Range of effect sizes (95%CI)				Duration of mortality		
			HR	AHR	OR	AOR	28-day	90-day	Undefined
Presence of ≥2 comorbidities	4	4	6.73 (3.24–14.0)	1.93 (1.54–2.42)	2.10 (1.50–2.93)	2.71 (1.85–3.97)	√	√	√
Dyspnoea (yes)	8	6	1.45–1.83 (1.27–2.65)	1.78–5.67 (1.48–21.98)	2.1–2.92 (1.2–3.64)			√	√
Elevated CRP	12	6	1.65–1.96 (1.35–2.83)	1.15 (1.08–1.22)	2.42–2.92 (1.36–5.45)				√
Elevated Creatinine	8	6	1.13–4.55 (1.06–7.62)	3.79 (2.62–5.48)	1.70–3.04 (1.04–9.44)		√	√	√
Elevated D-dimer	7	4	1.19–3.00 (1.02–4.16)		3.79 (2.21–6.50)		√	√	√
Cigarette Smoking (current)	8	4	1.83–1.84 (1.17–2.92)		10.09–13.01 (1.22–83.40)				√
Socioeconomic deprivation (most deprived)	2	2	1.79 (1.68–1.91)		1.05 (1.01–1.09)			√	√

Note: COPD- Chronic Obstructive Pulmonary Disease, CKD- Chronic Kidney Disease, CRP – C-Reactive Protein, CI – Confidence Interval, HR-Hazard Ratio, AHR – Adjusted Hazard Ratio, OR- Odds Ratio, AOR – Adjusted Odds Ratio.
*Including coronary heart disease, chronic heart disease, ischaemic heart disease, congestive heart disease, myocardial infarction, heart failure
Duration of mortality – defined as the time between confirmed COVID-19 infection and mortality.

Table 5: Determinants of COVID-19-related mortality: findings of studies with unstable analytical estimators (n = 4 studies)

Study/Author	Findings
Almazeedi et al. (2020)	Asthma (OR = 4.92; 95%CI = 1.03–23.44), smoking (OR = 10.09; 95%CI =1.22-83.40) and elevated PCT (OR = 8.24; 95%CI = 1.95–43.74) are associated with COVID-19 mortality.
Zhang et al. (2020)	High D-dimer level ≥2.0μg/ml is a significant determinant of COVID-19 mortality with or without underlying disease (AHR = 22.4; 95%CI = 2.86 –175.7) when gender and age are adjusted.
Gonca et al. (2020)	Smoking status is not associated with COVID-19 mortality (p = 0.123)
Ibrahim et al. (2020)	Hypoxemia at presentation (AOR = 2.5; 95%CI = 1.3–5.1) and creatinine >1.5mg/dL (AOR = 4.3; 95%CI = 1.9–9.8) are independent predictors of COVID-19 mortality.

Note: PCT – Procalcitonin, CI – Confidence Interval, AOR – Adjusted Odds Ratio, OR – Odds Ratio.

2.2.2.2.2 Determinants of COVID-19-related LOS

Of the five studies (n = 5) that examined the determinants of COVID-19-related LOS, two (n = 2) identified sex/gender as a determinant of COVID-19-related LOS (Guo et al., 2020; Mendy et al., 2020). However, while Guo et al. (2020) found women less likely to spend more days in the hospital due to COVID-19, Mendy et al. (2020) indicated that men rather have a lesser likelihood of spending more days in COVID-19-related hospital admission. For the clinical/medical factors, three of the four studies examining diabetes mellitus indicated that it is more likely to prolong COVID-19-related LOS. Also, on lifestyle risk factors and COVID-19-related LOS, all the four studies (n = 4) that explored the relationship between smoking and LOS showed that smoking does not determine COVID-19-related LOS. See table 6 for the synthesised findings on determinants of COVID-19-related LOS.

Table 6: Synthesised findings on determinants of COVID-19 LOS (N = 5 studies)

Variable category	Variable	Number of studies examining variable as COVID-19 mortality determinant	Number of studies identifying variable as COVID-19 mortality determinant	Magnitude/direction of effect (95%CI)	
				β	AOR
Demographic variables	Men	5	1	0.39 (0.16–0.62)	
	Women	5	1		0.19 (0.05–0.63)
Clinical/medical variables	Diabetes mellitus	4	3	0.50 – 3.20 (-0.2–0.74)	
	Fever	2	2	3.5 (1.39–5.63)	8.27 (1.47–72.16)
	Pneumonia	2	1	3.4 (0.49–6.25)	
	CKD	2	1		3.73 (1.95–145.4)

Note: β - Correlation Coefficient, AOR – Adjusted Odds Ratio, CKD – Chronic Kidney Disease

2.2.3 Author Stated Challenges

The common author-stated challenge in this review was the possibility of residual or unmeasured confounders due to the studies' observational designs. This limitation could have influenced their findings and, by extension, this review. Other challenges included the inability to include all the literature-described laboratory variables of interest and the relatively smaller sample sizes that could influence results generalisation. Another common challenge was sample representation, as some studies indicated that they focused mainly on adults and single hospital centres. As such, they were restricted in generalising their results to the wider paediatric population and controlling for selection bias. Finally, the authors also mentioned recall bias and missing data estimation as limiting factors.

2.2.4 Discussion

This chapter reviewed the literature on the determinants of COVID-19 health outcomes. It identified mortality and hospitalisation length as the commonly examined COVID-19-related health outcomes. On the determinants, it observed that the specification and subsequent analysis of most of the determinants differed across the studies. For example, Berenguer et al. (2020) described elevated CRP as CRP >5mg/L, while Carrasco-Sánchez et al. (2020) described it as >60mg/L. Also, while Sourij et al. (2020) assessed CRP as a continuous variable, Kaeuffer et al. (2020) categorised it into two groups: CRP from 100 mg/L to 199 mg/L and CRP ≥200mg/L. Like CRP, older age was also specified differently across the studies. For instance, some described it as individuals ≥18 years (n = 17) and ≥65 years (n = 3), while the majority assessed age as a continuous variable (n = 34). Apart from these variations, the statistical models and effect size measures differed across the studies. Similarly, the study settings also varied. These methodological and geographical variations, including disparities in healthcare access, could have influenced the studies' findings and, by extension, this review's results (van Bavel et al., 2016). Despite these heterogeneities, some of the determinants were similar across the studies. For instance, forty-three of the fifty-five studies on age and COVID-19-related mortality indicated that increasing/older age determines COVID-19-related mortality. Likewise, six of the studies on CRP showed a significant association between CRP and COVID-19 mortality. Therefore, notwithstanding the methodological differences, the commonality in findings on the determinants of COVID-19 mortality could have public health implications for the broader global population, especially as the review included studies from multiple countries (Ioannidis et al., 2020).

On COVID-19-related LOS, the review identified contrasting findings on its determinants. For example, Mendy et al. (2020) indicated that men are less likely to stay longer in COVID-19-related hospitalisations. In contrast, Guo et al. (2020) showed that women are less likely to stay longer in COVID-19-related hospitalisations. Both studies had more male participants, 53% and 57%, than female participants, but the proportion of men in Guo et al. (2020) was marginally higher. However, in absolute figures, Mendy et al. (2020) included more male participants (n = 365) than Guo et al. (2020) (n = 43). These sample size variations, together with potential sex differences in the COVID-19 illness experiences between the two studies could account for their different reports on sex and LOS due to COVID-19. Moreover, these findings are from only two studies; therefore, they may not be enough to conclude the relationship between sex and COVID-19-related LOS. Further discussions on the review findings, based on the determinants of the health model, are provided below.

2.2.4.1 Demographic Determinants

The underlying mechanism for the association between older/increasing age and COVID-19-related mortality is unclear; however, several studies indicate that a decrease in immune responses coupled with an increased comorbid burden with ageing may account for this observation (Zhou et al., 2020; Mueller et al., 2020; Chinnadurai et al., 2020). Opal et al. (2005) further explained that age-related changes or defects in the immune system, particularly significant defect in cell-mediated immunity, affects immune responses to diseases. Also, evolution and ageing theories, like the antagonistic pleiotropy theory, postulate that even beneficial genes at an early age may be less efficient or deleterious with increasing age, which may inherently increase susceptibility to previously shielded diseases (Mitteldorf, 2019; Williams & Day, 2003). Besides, current evidence suggests that increasing age is a common risk factor for several health outcomes, like mortalities and morbidities (Australian Institute of Health, 2012; Eguchi et al., 2017; Johansson et al., 2017; Niccoli & Partridge, 2012).

Even though ageing generally decreases immune responses to diseases and infections, the innate human response is mainly safeguarded (Opal et al., 2005). Therefore, other factors may account for the relationship between ageing and disease outcomes, like COVID-19 mortality. These factors may include nutritional deficiencies, decreased functionality, exposure to pathogens, vaccinations, individuals' lived experiences and genetic makeup, and access to health care (Hernández & Verdecia, 2014). Furthermore, there are reports on good COVID-19 prognosis in elderly patients (Ma et al., 2020). Therefore, it may be imperative to understand how these factors cumulatively affect the immune system and further mediate ageing and decreased immune system relationship to provide exhaustive literature on the subject. Other studies have also reported severe COVID-19 consequences in children (Liu et al., 2020; Qiu et al., 2020). Consequently, studies must focus on children to offer a balanced argument to inform COVID-19 and ageing policies.

Like ageing, studies also attribute the sex disparities regarding COVID-19 mortality to sex-based differences in immunological responses to viral infections (Conti & Younes, 2020;

Bwire, 2020). The X sex chromosome has encoded immune regulatory genes that decrease susceptibility to viral infections (Conti & Younes, 2020). Since women have one extra X-chromosomes than men, they tend to have higher innate immunity to viral infections like COVID-19 and, by extension, a lower risk of severe COVID-19 outcomes than men (Conti & Younes, 2020; Elgendy & Pepine, 2020). Similarly, compared to oestrogen, testosterone has an immunosuppressive effect, attenuating men's immune responses to viral infections (Pradhan & Olsson, 2020). Additionally, it is reported that men are genetically more predisposed to produce higher levels of interleukin (IL)-6, which are unfavourable to longevity, compared to women (Marcon et al., 2020). Apart from these biological reasons accounting for the sex differences in COVID-19 mortality risk, behavioural and lifestyle factors like smoking and alcohol consumption have been implicated in the gender disparities in COVID-19 outcomes. Data indicate that men are more likely to engage in these lifestyle factors that increase the risk of COVID-19 deaths than women (Bwire, 2020), and women are more likely to comply with COVID-19 precautionary measures than men and are more likely to remain confined than men (De La Vega et al., 2020). Regarding LOS, the evidence is insufficient to indicate whether sex determines longer COVID-19 hospitalisation.

2.2.4.2 Clinical/Medical Determinants

This review's clinical/medical determinants encompassed comorbidities, clinical symptoms, and laboratory findings of the included studies' participants. The clinical determinants of COVID-19-related mortality included cardiovascular diseases, CKD, CRP, diabetes mellitus, hypertension, obesity, malignancies, and COPD. Diabetes mellitus was also a determinant of COVID-19-related LOS. Clinical data reveal that chronic conditions, such as the above, decrease innate immune responses in humans (Odegaard & Chawla, 2012; Schulkin, 2004). For instance, metabolic diseases/disorders, like diabetes mellitus, attenuate immunity and increase the risk of infections by weakening lymphocyte and macrophage activities (Oates, 2019). These chronic conditions are also associated with increased pro-inflammatory cytokines resulting from the dysregulation of systems like the hypothalamic-pituitary-adrenal and sympathetic nervous systems (Yang et al., 2014; Schulkin, 2004). The accumulation of pro-inflammatory cytokines subsequently impairs systemic and cellular immune functions (Odegaard & Chawla, 2012; McEwen, 2002).

Studies also hypothesise that using angiotensin-converting enzyme-2 (ACE-2) in the management of some of these chronic conditions increases COVID-19 infectivity (Ferrario et al., 2005; Watkins, 2020) and subsequent outcomes. This is because ACE2 also functions as a receptor for the COVID-19 virus (Hoffmann et al., 2020). This ACE-2 hypothesis recently sparked debates and discourses on gold standard medical management of comorbidities in patients with COVID-19. For example, one study indicated that sudden discontinuation of ACE-2 might have far worse consequences for patients with a high risk of COVID-19, particularly those with cardiovascular conditions like myocardial infarction (Kuba et al., 2005). However, their argument is hinged on the paucity of human studies corroborating the ACE-2 theory. Additionally, experimental studies in mice showed that ACE-2 downregulation facilitates lung injuries and increases viral loads (Yang et al., 2014; Reddy et al., 2021). Thus, several human studies are needed to substantiate the effect of ACE-2 in managing COVID-19 patients with comorbidities.

2.2.4.3 Lifestyle Determinants

The included studies examined alcohol consumption and cigarette smoking as lifestyle determinants of COVID-19-related mortality. However, only smoking was identified as a significant determinant of COVID-19-related mortality. The association between smoking and COVID-19 mortality is biologically plausible because smoking is a risk factor for several conditions, like coronary heart disease and COPD, associated with severe COVID-19 outcomes (Reddy et al., 2021). Also, a cohort study with an average of 9.6 years of follow-up showed that 11% (men) and 13% (women) of pneumonia and COPD deaths were attributable to smoking (Katanoda et al., 2008). Additionally, CDC reports that smoking is associated with about 113,000 respiratory deaths yearly in the United States (CDC, 2020). Since COVID-19 is a respiratory infection and based on the above evidence on smoking-related respiratory deaths, it may be reasonable to indicate that smoking determines COVID-19-related mortality and morbidity.

Furthermore, data shows that smokers have increased upregulation or expression of ACE-2, the reported enzyme receptor for COVID-19 (Leung et al., 2020), which may increase their risk of severe COVID-19 outcomes compared to non-smokers. A single-cell sequencing experiment further demonstrated that cigarette smoking upregulates ACE-2 in humans' lungs and increases their susceptibility to COVID-19 infections and subsequent mortality (Smith et al., 2020). Therefore, it was inferred that smoking cessation could reduce ACE-2 expression and subsequently decrease the risk of severe COVID-19 outcomes, advancing the above argument on the benefit or otherwise of ACE-2 dysregulation in humans to reduce the COVID-19 disease burden. All the same, this review is limited in drawing any meaningful conclusion on the association between cigarette smoking and severe COVID-19 outcomes because only half of the included studies examining smoking and COVID-19-related mortality (n = 4) identified it as a determinant of COVID-19 mortality. Also, none of the studies on smoking and LOS identified it as a determinant of prolonged COVID-19-related hospitalisation.

2.2.4.4 Comparing Review's Findings to the Literature

The result of this review is consistent with Dahlgren and Whitehead (1993)'s determinant of health framework. Like the Dahlgren and Whitehead (1993) model, this study demonstrated that multiple interrelated factors, including individual and social factors, determine COVID-19 outcomes. These factors could inform COVID-19-related clinical and policy interventions. The review findings also corroborate the results of Ssentongo et al. (2020), Sanyaolu et al. (2020), Sepandi et al. (2020) and Mesas et al. (2020). They also showed that cardiovascular diseases, diabetes mellitus, CKD, increasing age and male sex determine COVID-19 outcomes. However, the association between smoking and COVID-19 mortality was inconsistent with Lippi & Henry (2020). While their study indicated that cigarette smoking does not determine COVID-19 outcomes, after synthesising the findings of five relevant primary studies, this current study could not conclude the relationship between cigarette smoking and COVID-19-related mortality due to the balanced evidence from the included studies. The divergent findings in this review and Lippi & Henry (2020)'s could also be a function of potential differences in the sociodemographic characteristics of the participants included in the reviewed papers. For example, characteristics like the type and frequency/intensity of smoking among the included participants, and contextual characteristics, like access to healthcare, could account for inconsistent reports in the two reviews. Perhaps, a synthesis of studies from participants with similar characteristics and from a defined context could provide robust evidence on the association between COVID-19 health outcomes and smoking to inform specific interventions for specific populations. For example, a systematic review of studies on smoking and COVID-19 in Ghana could identify contextual evidence unique to the Ghanaian population to inform interventions specific to Ghana.

Regarding the review's strengths and limitations, the relatively higher sample size (n = 60 studies; 1,052,211 participants) included in the determinants of COVID-19-related mortality review could ensure the application of the findings to broader populations. In addition, the identified contextual determinants of COVID-19-related mortality, based on the determinants of health model, could inform specific COVID-19 interventions to reduce the disease's burden. Additionally, to the researcher's knowledge, this is the first systematic review to synthesise evidence on determinants of COVID-19-related LOS. The generated novel evidence may help prevent potentially overwhelming health systems due to prolonged COVID-19 LOS. However, only five studies were identified and included in the LOS synthesis, demonstrating a research dearth on determinants of COVID-19-related LOS and the need for further research. Therefore, the generated evidence may be insufficient to inform mitigating policies on prolonged COVID-19-related LOS. Hence, caution must be taken when interpreting the COVID-19 and LOS findings. Furthermore, the included studies' methodological heterogeneity limited the conduct of a meta-analysis to estimate precise effect sizes between the determinants and COVID-19 outcomes. On limitations from the included studies, all of them were observational studies; therefore, no causal association interpretations could be inferred from the findings. In addition, there were possibilities of residual or unmeasured confounders due to their retrospective nature, and this could have influenced their findings and, by extension, the findings of this review. Additionally, a few had relatively smaller sample sizes, which may have influenced their statistical estimations. Further, some of them analysed data from a single health centre, potentially limiting the generalisation of their findings to the targeted wider population. Furthermore, all of them used secondary data from participants' medical records. Therefore, any omission or data entry error could affect their results and this review's findings. The review results must, therefore, be deduced cautiously.

2.3 Section 2: A Review of the Effectiveness of Ghana's COVID-19 Policies and the Influence of the Policies on the Long-term Consequences of COVID-19

2.3.1 Methods

2.3.1.1 Search Strategy

Based on the pilot review findings in appendix 1, Google Scholar and Scopus were searched in December 2021 to identify studies that have either evaluated the effectiveness of the

COVID-19 policies on the COVID-19 burden in Ghana or examined the influence of the policies on the long-term consequences of the outbreak in Ghana. Search terms (see table 7) were combined with Boolean operators for the database search. Database filters were applied to allow targeted search outcomes.

Table 7: Search terms.

Item	Search term
Setting	Ghana
Intervention	Policy OR Intervention; Lockdown*; Vaccine*; Border closure*; Social distance*; Quarantine.
Outcomes	Outcome* OR Consequence*
Other items	Effectiveness OR Influence OR Impact*; Long term OR Longer term; COVID-19 OR Coronavirus; Project* OR Forecast*

2.3.1.2 Eligibility Criteria

The predetermined eligibility criteria below were used to screen the studies for inclusion in this review:

- Studies evaluating the effectiveness of Ghana's COVID-19 policy responses.
- Studies examining the influence of Ghana's COVID-19 policies on the long-term consequences of the outbreak in Ghana.
- Studies with full-text available.

2.3.1.3 Data Extraction

A set of extraction questions, informed by the JBI[4] and the CHecklist for critical Appraisal and data extraction for systematic Reviews of prediction Modelling Studies (CHARMs)[5] guidelines, were used to extract the relevant data from the studies. The questions were centred around three key areas:

- General Information: Authors, year of publication, aim.
- Methodology: Included data on the studies' approaches and designs, examined COVID-19 policies, explored COVID-19 outcomes, measured COVID-19

[4] JBI guideline available at: https://jbi-global-wiki.refined.site/space/MANUAL/4687700
[5] CHARMS Checklist available at: http://methods.cochrane.org/sites/methods.cochrane.org.prognosis/files/uploads/CHARMS%20checklist.pdf

consequences, examined participants, underlying frameworks and analytical approaches.

- Finding and Limitation: Included data on the studies' findings and reported limitations.

2.3.1.4 Quality Appraisal and Data Synthesis

Based on the evidence from Baethge et al. (2019) and Wolff et al. (2019), the Scale for the Assessment of Narrative Review Articles (SANRA)[6] and the Prediction model study Risk Of Bias Assessment Tool (PROBAST)[7] for prediction models were used to appraise the quality of the studies. SANRA provides a six-item checklist: justification of review, review aim, literature search description, referencing, scientific reasoning and appropriate data presentation, to appraise the quality of narrative reviews. Three statements are used to assess each item, and a score of 0 to 2 is used to rate the responses to the items – 0 means the item is not met, 1 means it is not sufficiently met, and 2 means the study sufficiently met the item. A total score of ≥ 10 indicates good quality, a 9 to 6 as moderate and <6 as poor quality. The PROBAST tool also provides four domains: Participants, Predictors, Outcome, and Analysis, to examine the risk of bias in prediction studies. The participant domain is assessed with two questions, the predictor with three, the outcome with six and the analysis domain with nine questions. A 'yes' response to all the questions for a domain indicates a low risk of bias, a 'no' to all the questions indicates a high risk of bias, and a combined 'yes' and 'no' responses indicate an unclear risk of bias for that domain. Accordingly, studies were considered 'low risk of bias' if they recorded a low risk of bias for all the domains, 'high risk of bias' if at least one of the domains was rated high risk of bias, and 'unclear risk of bias' if at least one of the domains was rated unclear risk of bias. After the quality appraisal, a narrative data synthesis was conducted to synthesise the identified evidence on the effectiveness and long-term influence of Ghana's COVID-19 policy responses.

2.3.2 Results

The database searches yielded 1,248 papers (table 8). Two-hundred and thirteen (n = 213) duplicates were removed, and the remaining 1,035 were titles and abstracts screened for

[6] SANRA available at: https://researchintegrityjournal.biomedcentral.com/articles/10.1186/s41073-019-0064-8/figures/1

[7] PROBAST checklist available at: https://www.probast.org/wp-content/uploads/2020/02/PROBAST_20190515.pdf

inclusion. The screening resulted in the removal of 1,021 papers whose titles (n = 1,007) and abstracts (n = 14) were unrelated to the objective of this review. Of the remaining fourteen (n = 14) studies, five (n = 5) were excluded because of full-text unavailability and the remaining nine (n = 9) were included in the review. Figure 5 below illustrates the selection process. The characteristics of the selected studies are presented below per the two review themes: the effectiveness of Ghana's COVID-19 policy responses and the influence of the policies on COVID-19 long-term consequences in Ghana.

Table 8: Database search outcomes

Database	**Date searched**	**Search terms used**	**Initial hit**	**Filters applied**	**Final hit**
Scopus	December 2021	(Ghana) AND (COVID-19 OR Coronavirus) AND (Policy OR Intervention OR lockdown* OR Vaccine* OR Border closure OR Social distance* OR Quarantine) AND (Effectiveness OR Influence OR Impact*) AND (Outcome* OR Consequence*) OR (Long term OR longer term) OR (Forecast* OR Project*)	503	Limit to article: 349 Limit to open access: 288	288
Google Scholar	December 2021	(Ghana) AND (COVID-19 OR Coronavirus) AND (Policy OR Intervention OR lockdown* OR Vaccine* OR Border closure OR Social distance* OR Quarantine) AND (Effectiveness OR Influence OR Impact*) AND (Outcome* OR Consequence*) OR (Long term OR longer term) OR (Forecast* OR Project*)	12,300	Limit to articles: 960	960
					Total: 1,248

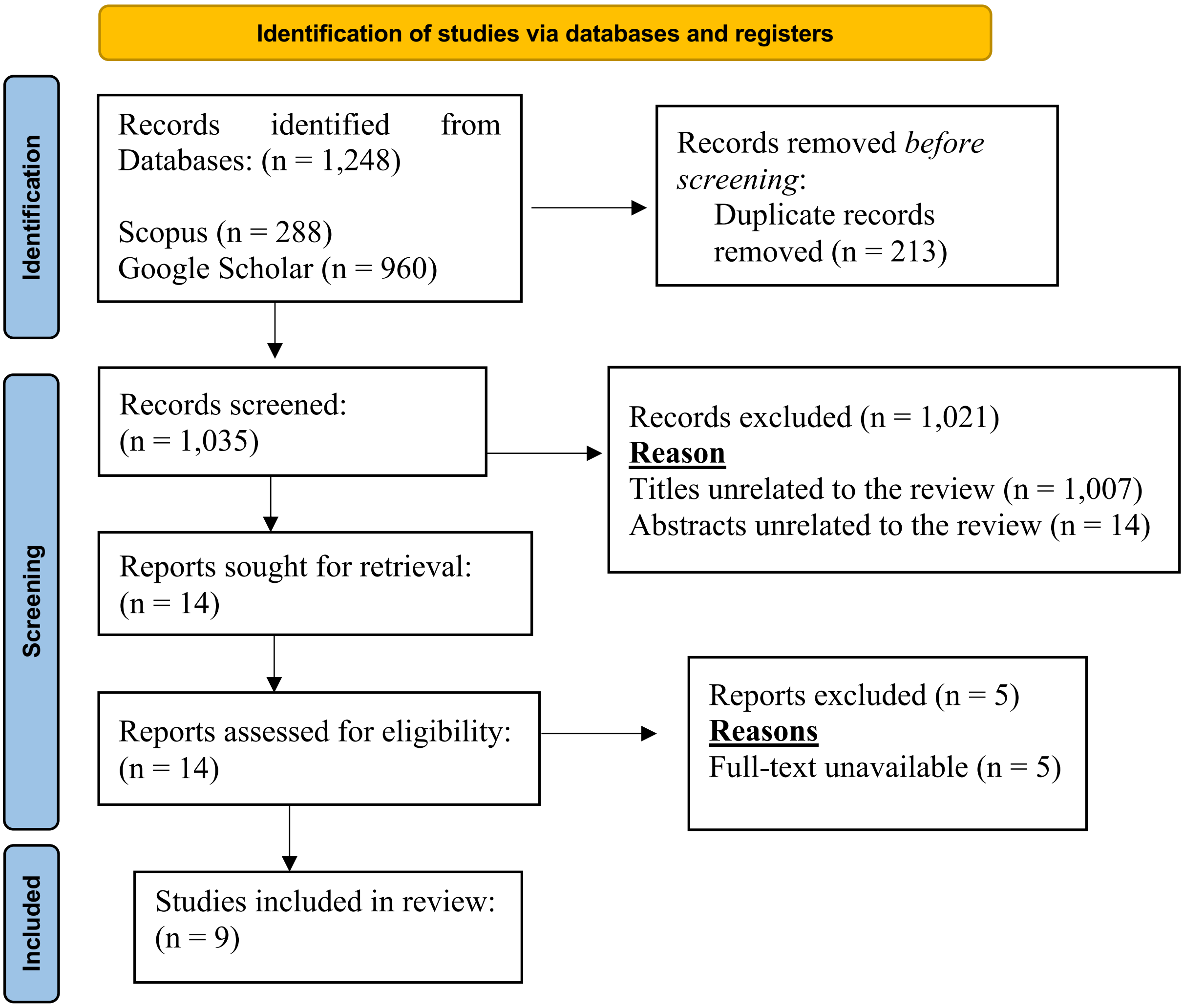

Figure 5: PRISMA flow diagram illustrating the study selection process.

2.3.2.1 Effectiveness Evaluation of Ghana's COVID-19 Policy Responses

2.3.2.1.1 Study Characteristics and Methodological Features

Five (n = 5) of the selected nine studies evaluated the effectiveness of Ghana's COVID-19 responses. Three were published in 2021, and the rest (n = 2) in 2020. Their evaluated COVID-19 policy responses included the partial lockdown (Khoo, 2020; Smith & Quartey, 2021; Antwi-Boasiako et al., 2021), COVID-19 public awareness policy (Khoo, 2020; Smith & Quartey, 2021; Quakyi et al., 2021), COVID-19 disease surveillance (Awekeya et al., 2021), healthcare workers incentives, water and electricity subsidies, Coronavirus Alleviation Program (CAP) (Antwi-Boasiako et al., 2021) and the 3-T (trace, test and treat) intervention (Antwi-Boasiako et al., 2021; Quakyi et al., 2021). They all adopted the descriptive/narrative review approach to evaluate the policies' effect on the COVID-19 burden in Ghana, and only one stated their theoretical underpinnings (Smith & Quartey, 2021). Their methodological quality per the SANRA checklist were moderate and good (see appendix 7 for the detailed quality assessment). Table 9 summarises the studies characteristics.

Table 9: Characteristics of the studies on the effectiveness of Ghana's COVID-19 policy responses

Studies	**Evaluated polices**	**Underpinning framework**	**Analytical approach**	**Quality rating**
Khoo (2020)	Partial lockdown COVID-19 public awareness campaign Social distancing	-	Descriptive review	Moderate
Smith & Quartey (2020)	Partial lockdown COVID-19 public awareness campaign	Racialisation theories	Narrative review	Good
Quakyi et al. (2021)	COVID-19 public awareness campaign 3-T (trace, test, treat) policy	-	Narrative review	Moderate
Antwi-Boasiako et al. (2021)	Partial lockdown Health workers incentives Coronavirus Alleviation Program (CAP) Electricity and water subsidies, 3-T policy	-	Descriptive review	Good
Awekeya et al. (2021)	COVID-19 disease surveillance intervention	-	Descriptive review	Good

2.3.2.1.2 Empirical findings

The studies on the effectiveness of the COVID-19 awareness campaigns indicated that the policy effectively addressed COVID-19-related misconceptions and myths and informed the public of prevention protocols and available health services (Smith & Quartey, 2020; Khoo, 2020). On the partial lockdown policy, Smith & Quartey (2020) indicated that the policy deepened socioeconomic inequalities and social exclusion in Ghana. This finding was corroborated by Antwi-Boasiako et al. (2021) and Khoo (2020). The evaluation findings from Awekeya et al. (2021) showed that the COVID-19 disease surveillance policy was 31% effective in the early detection of COVID-19 infection. Also, the findings from Quakyi et al. (2021) and Antwi-Boasiako et al. (2021) indicated that the 3-T policy enhanced the detection and subsequent management of COVID-19 in Ghana. Further, Khoo (2020) found the social distancing policy less impactful as it was logistically and socially unsustainable in Ghana. All the studies indicated the need for more comprehensive data to evaluate the policies' outcomes.

2.3.2.2 Influence of Ghana's COVID-19 Polices on the Long-term Burden of COVID-19

2.3.2.2.1 Study Characteristics and Methodological Features

Four (n = 4) of the nine selected studies forecasted the long-term consequences of COVID-19 in Ghana. All of them were published in 2021. The forecasted long-term consequences were COVID-19 transmission rate (Frempong et al., 2021; Dwomoh et al., 2021; Frost et al., 2021) and COVID-19 mortality (Dwomoh et al., 2021; Tawiah et al., 2021). Three (n = 3) of them further explored the influence of Ghana's COVID-19 policy responses on the forecasted burden (Frempong et al., 2021; Dwomoh et al., 2021; Frost et al., 2021). The evaluated policies were lockdowns (Frempong et al., 2021; Frost et al., 2021) and social distancing and hygiene etiquettes (Dwomoh et al., 2021). Compartmental mathematical models (Dwomoh et al., 2021; Frost et al., 2021) and Generalised Linear Models (GLMs) (Frempong et al., 2021; Tawiah et al., 2021) were used for the forecasting. The compartmental models were broadly captured under the Susceptible, Exposed, Infectious, Quarantine, Hospitalised, Recovered and Susceptible (SEIQHRS) compartments. The studies' qualities on the PROBAST tool were low risk of bias (n = 3) and unclear risk of bias (n = 1). Appendix 8 details the quality assessment results, and table 10 below summarises the studies' characteristics.

Table 10: Characteristics of the studies on COVID-19 long-term consequences in Ghana

Studies	Examined long-term COVID-19 consequence	Examined COVID-19 policies	Model used	Quality rating
Frempong et al. (2021)	COVID-19 transmission rate	Lockdowns	GLMs	Low risk of bias

Studies	Examined long-term COVID-19 consequence	Examined COVID-19 policies	Model used	Quality rating
Dwomoh et al. (2021)	COVID-19 transmission rate COVID-19-related mortality	Social distancing face mask use Hand washing	SEIQHRS	Low risk of bias
Tawiah et al. (2021)	COVID-19-related mortality	-	GLMS	Unclear risk of bias
Frost et al. (2021)	COVID-19 transmission rate	Lockdowns	SEIR	Low risk of bias

2.3.2.2.1 Empirical Findings

Dwomoh et al. (2021) reported that adherence to social distancing, face mask usage and proper hand-washing techniques could reduce COVID-19 mortality by 99% in the long term. In addition, the lockdown policy was projected to reduce COVID-19 transmission by 36% (Frost et al., 2021) and 56% (Frempong et al., 2021) in the long term. Tawiah et al. (2021) predicted an increasing number of COVID-19 mortalities in the long term. Finally, they all indicated that the projections were based on reasonable assumptions; therefore, the results must be interpreted cautiously.

2.3.3 Discussion

This literature review explored what is already known in the literature on the influence of Ghana's COVID-19 policy responses on the immediate and long-term burden of the COVID-19 outbreak in Ghana. The synthesised findings from the selected studies showed that the COVID-19 awareness campaign policy effectively educated the public about COVID-19 and its prevention and dispelled related myths and misconceptions. However, the partial lockdown policy resulted in job losses, loneliness, anxiety, and reduced incomes. This observation was because the policy did not consider the sociocultural and economic characteristics of the populations in Ghana (Khoo, 2020). For example, a sheer proportion of the population in the locked cities lived in shared shelters, which increased their risk of COVID-19 infection following infection of a tenant (Smith & Quartey, 2020). Many also used shared public sanitation facilities, so the lockdown resulted in poor sanitation behaviours because it limited access to sanitation facilities (Smith & Quartey, 2020). This influence of the lockdown policy is also documented in countries with socioeconomic characteristics like Ghana (Solymári et al., 2022; Iwuoha & Aniche, 2020).

Evidence from the reviewed forecasting studies showed that the lockdown policy could reduce COVID-19 transmission rate by at least 36% in Ghana in the long term. This finding may be because lockdowns could prevent/reduce human-human contacts, which is one of the direct modes of COVID-19 transmission, and subsequently slow down the spread of the disease (Bourdin et al., 2021). However, lockdown intervention could also be counterproductive, especially in slum settlements, as it could defeat its intended purpose and contribute to the disease's spread (Broadbent & Streicher, 2022). In addition, it could result in low financial earnings, which could also translate into poverty and broadened economic inequality (Smith & Quartey, 2020). Therefore, its benefits and potential dire outcomes must always be examined, with significant considerations for real-life demographic, socioeconomic and cultural characteristics, to inform its adoption and imposition in the management of infectious diseases (Al Zabadi et al., 2021; Broadbent & Streicher, 2022).

The review's findings on the socioeconomic and psychological impacts of the lockdown policy are also reported in literature reviews from other settings (Gathiya & Kumar, 2020). Gathiya & Kumar (2020) also demonstrated that the long-term adverse consequences of the lockdown policy could be more than its short-term containment of COVID-19 viral spread. This finding was corroborated by the evidence from Chu et al. (2020). Chu et al. (2020), after reviewing the influence of lockdowns from multiple countries, including Liberia, China and Canada, further showed that lockdown interventions during epidemics could heighten inequalities and gender-based violence and pose food insecurity and economic challenges for populations. Therefore, policymakers should consider other containment strategies, like intensive public education policies, health financing to enhance laboratory testing and treatment facilities capacities and digital healthcare delivery technologies, for the long-term management of epidemics like COVID-19 (Summers et al., 2020). In summary, this review could be limited by the scarcity of evidence on Ghana's COVID-19 policies' effectiveness in the literature. Subsequently, the findings herein may not mirror the comprehensive short and long-term influence of the policies in Ghana. Therefore, the reported evidence should be interpreted with caution.

2.4 Identified Literature Gaps

2.4.1 Literature Scarcity on the Determinants of COVID-19-Related Health Outcomes in Ghana

No study on the determinants of COVID-19-related mortality and LOS in Ghana was found in the literature, indicating knowledge scarcity on factors that contributed to these outcomes in Ghana. Arguably, Ghana could rely on the evidence from elsewhere on the determinants of COVID-19 health outcomes to inform its mitigating strategies. However, given its COVID-19 containment lessons on the impacts of borrowed strategies, particularly the lockdown policy, it may be prudent to identify its context-based determinants to ensure short and long-term containment policies that align with its socioeconomic fabric (Khoo, 2020). Notably, though the evidence from other settings on the determinants of COVID-19 health outcomes is comparable for some factors, like comorbid factors, they differed considerably for sociodemographic factors, like sex, across settings (Mendy et al., 2020; Guo et al., 2020); therefore, their mitigating policies may not be the same for all settings. For example, Mendy et al. (2020)'s study in the USA found men less likely to experience prolonged COVID-19-related hospitalisations, while Guo et al. (2020) found the reverse in China. This variation was also observed for lifestyle factors like smoking and COVID-19-related mortality (Almazeedi et al., 2020; Gonca et al. (2020). These literature differences suggest that context/geographic locations could have affected how these factors influenced COVID-19-related health outcomes. Therefore, contexts must be considered to direct the focus and approach to managing these factors. This consideration could help avoid adopting policies that may be inexpensive but context inappropriate.

2.4.2 Limited Evaluations of the COVID-19 Policy Responses in Ghana

Apart from the relatively fewer COVID-19 policy evaluations (n = 5) in Ghana's literature space, they also adopted narrative approaches to describe the policies' effectiveness. Despite their usefulness in exploring deeper nuances compared to structured analyses, like Likert-scale-based research, these approaches could introduce subjective interpretations, which could impact the validity and reliability of the policies' evaluation findings (Darawsheh, 2014; Overcash, 2003). Moreover, given the complexity of Ghana's COVID-19 policy responses, a single approach, especially only a narrative approach, may be insufficient to ensure an in-depth understanding of the effectiveness of the policies in Ghana. Such approaches could, therefore, be augmented with other approaches, like quantitative policy evaluations and Delphi studies, to ensure more comprehensive and validated evidence. For example, the augmentation of methodological approaches, where necessary, could address their limitations and improve their outcomes, especially in evaluating policies like Ghana's COVID-19 policy responses (Queirós et al., 2017). Furthermore, the studies did not clearly illustrate their data sources nor indicate whether the policies were assessed per their set objectives to estimate their actual outcomes to inform subsequent policy directions. Therefore, while their evaluations provided preliminary evidence, they were limited in methodological robustness and providing comprehensive information on the policies' overall impact to direct robust conversations on the policies' continuation.

2.4.3 Insufficient Analysis of the Long-term Consequences of COVID-19 in Ghana

Four (n = 4) studies examined the long-term consequences of the COVID-19 outbreak in Ghana. All of them used data aggregates to forecast the long-term COVID-19 infections and mortalities in Ghana. As such, they could not account for how individual characteristics could influence the long-term consequences of the COVID-19 outbreak. This consideration was particularly important given the influence of variations in sociodemographic characteristics, which could be identified in individual-level data, on infectious disease trajectory and outcomes and its subsequent mitigating efforts in the long term (Kong et al., 2016). Additionally, they all predicted only the long-term COVID-19 infections and mortalities, again highlighting the gaps in the lack of evidence on long COVID in Ghana. As discussed, such evidence is critical to understanding and informing current and anticipatory interventions to address long COVID in Ghana. Further, the studies simulated the influence of only movement impositions, like lockdowns, on the long-term consequences of COVID-19 in Ghana. It is possible that other interventions, like the vaccination intervention, were excluded from their analysis because they were not fully rolled out during the studies' investigations, hence, warranting further investigation. Accordingly, addressing these gaps around the long-term consequences of the COVID-19 outbreak would be in tandem with the WHO's comprehensive public health surveillance policy and ensure readiness for future public health emergencies (WHO, 2020).

2.4.4 Limited Report on Underpinning Framework

Only one of the selected studies in this review indicated their underpinning framework. This gap, therefore, limited this review from establishing the studies' methodological justification. For example, the framework was necessary to understand their methodological approaches and results (Collins & Stockton, 2018; Abraham, 2008). This understanding would have helped situate their findings in appropriate contexts (Grant & Osanloo, 2014). Therefore, given the learnings herein, this study adopted a relevant healthcare framework to guide its methodological approaches and findings interpretation.

2.5 Conclusion

This study's overarching aim was to review the literature on the determinants of COVID-19-related health outcomes and the effectiveness of Ghana's COVID-19 policy responses on the immediate and long-term term burden of COVID-19 in Ghana to identify knowledge gaps and methodological approaches that could direct the research questions in this thesis. The review found literature scarcity around determinants of COVID-19-related mortality and LOS and the influence of Ghana's COVID-19 policies on the immediate and long-term consequences of the outbreak in Ghana. The next chapter, Chapter 3, outlined methodological frameworks to examine these identified gaps.

CHAPTER 3: FRAMEWORK FOR EMPIRICAL ANALYSIS

3.1 Introduction

This thesis aimed to explore the COVID-19 outbreak in Ghana to contribute to its understanding and mitigating interventions. The previous chapter (Chapter 2) reviewed the existing COVID-19 literature and identified key knowledge gaps to direct the empirical chapters in this study. This current chapter outlines the methodological frameworks to investigate the identified knowledge gaps. The chapter first outlines the specific research questions to address each research gap from Chapter 2. After, it discussed the methodological approaches to explore the research questions and, by extension, the research gaps. Table 11 summarises the identified literature gaps, their related research questions, and the thesis chapter that addressed them. The ensuing texts explained how each thesis chapter investigated the research gaps and questions in table 11.

Table 11: Identified literature gaps and their related research questions.

Literature gap	Research questions	Thesis chapter
Literature scarcity on the determinants of COVID-19 related health outcomes	• What determines COVID-19-related health outcomes in Ghana? • Do these determinants differ among individuals with different risk profiles?	Chapter 4
Limited studies evaluating the effectiveness of implemented COVID-19 policy responses in Ghana	• What COVID-19 policy responses were implemented in Ghana? • Where these policies effective?	Chapters 5 and 6
Limited studies examining the influence of the COVID-19 policies on long-term COVID-19 consequences in Ghana	• What is the long-term consequences of COVID-19 in Ghana? • Can the COVID-19 policies address these consequences?	Chapter 7

3.2 Methodological Approaches

3.2.1 Gap 1: Literature Scarcity on the Determinants of COVID-19-Related Health Outcomes in Ghana

Secondary data was used to address the research questions for this literature gap. The data was accessed from Ghana's main COVID-19 treatment centre, Ga East Municipal Hospital (GEMH). The centre was earmarked for COVID-19 case management by the Government of Ghana (GoG) a few weeks after the country recorded its first two COVID-19 cases on 12th March 2020. Since its inception, the centre has admitted and managed over 2,000 laboratory-confirmed COVID-19 cases. In operation, the centre updates patients' data daily, both electronically and manually, at the records unit of the hospital. Therefore, given the COVID-19 informed movement restrictions, this study accessed the electronic data of the COVID-19 cases managed at GEMH using an Excel spreadsheet. The use of secondary data to address this gap was consistent with the data collection methods of the papers reviewed in chapter two of this thesis. Concerning data analyses, the statistical estimators identified in the literature review and the dependent variables in the research questions informed the data analysis techniques. The data analyses were conducted with SPSS software version 26. See table 12 for the specific statistical models conducted to address the first two questions under this literature gap.

Table 12: Statistical models used to address the research questions on determinants of COVID-19 outcomes in Ghana.

Research questions	**Statistical model**	**Justification of model**	**Model diagnostic test**
What are the determinants of COVID-19 mortality and long COVID in Ghana?	Logistic regression	- Dependent variables (mortality and long COVID) were assessed as a binary outcome. - Multiple independent variables were included in the analysis	- Hosmer–Lemeshow test to determine the goodness of fit.
What are the determinants of COVID-19 LOS in Ghana?	Generalised Linear Models (GLMs)	- Dependent variable (LOS) was assessed as a count variable. - Multiple explanatory variables were included simultaneously in the analysis	- Variance inflation factor to measure multicollinearity

Research questions	Statistical model	Justification of model	Model diagnostic test
What are the determinants of COVID-19-related mortality, long COVID and LOS among groups with similar risk profiles? (sub-group analysis)	Logistic regression and GLMs	The logistic regression was informed by the mortality and long COVID variables and the GLM was informed by the LOS variable	Hosmer–Lemeshow test and Variance inflation factor

3.2.1.1 Healthcare Frameworks

As already indicated in Chapter 2, none of the reviewed studies on determinants of COVID-19 health outcomes was informed by a healthcare framework to explain the research findings (Exworthy et al., 2008). However, there has been a proliferation of several relevant frameworks to provide a contextual explanation for factors associated with health outcomes in the last centuries. Examples of these theories are captured in table 13 below.

Table 13: Examples of determinants of healthcare frameworks

Authors	Description
Williams (1990)	Socioeconomic status is associated with individuals' health outcomes; and medical and psychosocial factors mediate this association, or directly predict health outcomes.
Dahlgren and Whitehead (1993)	Maps up five-layered multiple factors (constitutional, individual lifestyle factors, social and community networks, general socioeconomic, environment and cultural factors) as determinants of health.
Ansari et al (2003)	Psychosocial factors can directly or indirectly (as modifier or confounder) determine unequal health outcomes among populations with similar health – inducing behaviour and healthcare attributes. They must, therefore, be recognised in the analysis of determinants of health outcomes
Marmot and Wilkinson (2005)	Health outcomes are influenced by multiple interrelated factors such as social structure, early life, social environment, health behaviours, psychological and material factors.
Solar and Irwin (2010)	Maps up the inherent, structural, and intermediary determinants of health and well-being.

The frameworks posit that health, as a multidimensional subject, is influenced by interconnected social, economic, and structural factors. Also, health outcomes result from complex interactions between social, environmental, biological, and genetic factors (Marmot & Wilkinson, 2005). As such, the frameworks propose a comprehensive approach to understanding health determinants instead of traditional monotonic relationships for establishing relationships, such as the cause-effect and dose-response criteria (Ansari et al., 2003). For example, in the case of COVID-19 disease, it may be insufficient to attribute its morbidity experiences and mortality solely to SARS-CoV-2 exposure without considering the probable direct or indirect influence of social factors, like access to healthcare, even though the exposure is necessary for the outcome to occur. Therefore, by inference, though exposure to SARS-CoV-2 is required for COVID-19 morbidity, it may not be enough to establish causal links between the exposure and outcomes post-exposure. This argument suggests that monotonic relationships may be plausible but insufficient in the broader determinants of health outcomes (Marmot & Wilkinson, 2005). Therefore, to comprehensively understand the determinants of COVID-19 outcomes in Ghana, this study adopted one of the healthcare frameworks captured in table 13 above, i.e., the Dahlgren and Whitehead (1993) determinants of health framework.

The framework outlines how sociodemographic, lifestyle and environmental factors interact and influence health outcomes. Fundamentally, Dahlgren and Whitehead (1993) argue a paradigm shift in understanding health determinants to capture all plausible predictors of health outcomes. This thorough perspective can provide evidence for appropriate policies to address contemporary health issues, such as health inequalities (Exworthy et al., 2008). While Dahlgren and Whitehead's (1993) social determinants of health model provide methodological underpinnings for evaluating multiple causal relationships, it does not explicitly capture psychological factors, such as attitudes, beliefs, and perceptions, that could markedly impact health outcomes (Marmot & Wilkinson, 2005). Thus, like most social determinants of health models, the framework is tilted towards a biosocial approach than a biopsychosocial approach (Shokouh et al., 2017). However, Dahlgren and Whitehead's (1993) framework is still essential in research because it captures critical biosocial factors and provides bespoke guidelines for data collection and analyses at multiple levels. Therefore, it was a relevant model to inform the data collection and subsequent empirical analysis of the determinants of COVID-19 health outcomes in this thesis. Figure 6 shows Dahlgren and Whitehead's (1993) determinant of health framework.

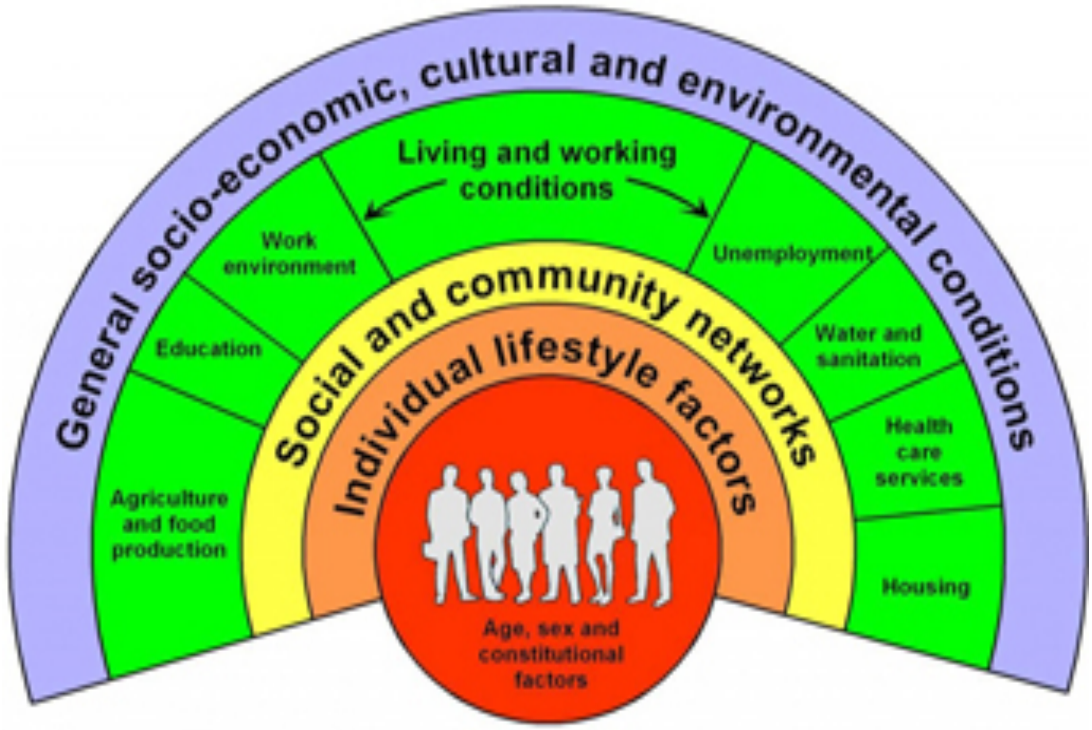

Figure 6: Dahlgren and Whitehead (1993) determinant of health framework. Image source: https://health-inequalities.eu/action/research-on-health-inequalities/

3.2.2 Gap 2: Limited Studies Evaluating the Effectiveness of Ghana's COVID-19 Policies

Given the review findings and arguments in Chapter 2, the thesis addressed this gap using two key complementary approaches: a qualitative content analysis and quantitative experts' analysis. For the qualitative content analysis (Chapter 5), multiple methods were used to access the required data:

- Literature search: Google and Scopus databases were searched for generic and published research papers on COVID-19 policy responses in Ghana. A combination of the following keywords: 'COVID-19', 'coronavirus', 'policy*', 'mitigating policy*', 'policy response*', and 'Ghana' was used in the search. All relevant data identified through the literature search were included in the analysis to address this research gap.
- Government of Ghana archives: Essential GoG data archives, such as the Ministry of Health (MoH) and the Ghana Health Service (GHS) data repository, and the Ghana

Open Data Initiative (GODI) database, were searched for all data relating to COVID-19 policy responses.

After accessing the data, content analysis was conducted to assess whether the policies were effective by mapping their objectives, inputs, outputs and outcomes using the logic model. The analysis focused on the policies implemented in 2020/21, as all the key COVID-19 policies were implemented within this period. The findings from the analysis were discussed against the backdrop of the Theory of Planned Behaviour (TPB).

Following the qualitative content analysis, an expert analysis of the effectiveness of the identified policies in Chapter 5 was conducted in Chapter 6 using qualitative and quantitative data to complement the findings in Chapter 5. Primary data was collected from the experts. The data was accessed from academics from health and economics disciplines with insights into Ghana's policy landscape. Purposive sampling, through a Gatekeeper, was used to select the academics for the expert analysis. Their data was collected online because face-to-face engagement was not a feasible data collection approach due to the outbreak's related restrictions. Qualtrics online platform was used to collect the required data for the policy evaluation.

3.2.3 Gap 3: Limited Studies Examining the Influence of Ghana's COVID-19 Policies on the Long-term Consequences of COVID-19 in Ghana.

After evaluating the effectiveness COVID-19 policy responses in Ghana, the study addressed the gap regarding the limited evidence on the long-term consequences of the COVID-19 outbreak in Ghana and whether the COVID-19 policies could address the long-term consequences. The rationale for addressing this gap was to explore the scale of mitigating of the COVID-19 policies on any long-term COVID-19 infections, hospital admissions, long COVID and mortalities to inform anticipatory mitigating interventions and related health planning. Data for the analysis was electronically accessed from GEMH database. It included all persons aged ≥ 18 with no diagnosis of COVID-19. It was populated in the CALMS model, a prediction agent-based model amenable to individual-based characteristics, like age, sex and comorbidities.

3.3 Conclusion

This chapter outlined the methodological approaches to address the research questions for the literature gaps identified in Chapter 2. The next chapter, Chapter 4, examined the first literature gap, i.e., the determinants of COVID-19 outcomes in Ghana.

CHAPTER 4: DETERMINANTS OF COVID-19-RELATED HEALTH OUTCOMES IN GHANA

4.1 Introduction

Chapter 3 of this thesis outlined the methodological approaches to address the research gaps identified in Chapter 2. This current chapter examined the research questions on the determinants of COVID-19-related mortality, prolonged hospitalisation and long COVID in Ghana. It also investigated whether the determinants of these outcomes would differ among subgroups to provide recommendations for tailor-made shielding interventions.

4.2 Methods

4.2.1 Data

Data for this chapter was accessed from the medical records of GEMH, the main COVID-19 treatment centre in Ghana. It included all patients seen at the centre from 21st March 2020 to 20th August 2021. The centre obtains data from its patients with COVID-19 as part of routine clinical practice. It stores the data electronically and manually in its records unit and updates it regularly until the patient is discharged from the centre. The data includes sociodemographic variables, such as age, sex and employment status, and past medical history of the patients. It also contains information on patients' admissions dates, follow-ups, and treatment outcomes, i.e., discharges, transfers, and deaths. Therefore, this study accessed the centre's electronic dataset as it contained the essential data for this study's objectives and increased access to the population of interest.

Since secondary data was used in this study, the patients were not directly involved in this research. The choice of secondary data was within the scope of such studies as all the reviewed papers in Chapter 2 of this thesis used secondary data. In addition, the secondary data ensured convenient access to a larger sample size, which might have been difficult for a single researcher to access, especially with the COVID-19 social restrictions. Further, the secondary dataset from GEMH was valuable in this study because it provided variables consistent with the Dahlgren & Whitehead (1993) model, the theoretical underpinning of this study. Also, it presented data on patients from most of the regions in Ghana since it was the national COVID-19 treatment centre. This advantage could influence the generalisation of the findings of this study to the wider population. At the time of accessing the GEMH dataset, the centre had managed over two thousand patients with PCR-confirmed COVID-19 diagnoses. Therefore, this study included the data of all the patients with COVID-19 from the GEMH who had definite treatment outcomes, i.e., their treatment endpoint was death or hospital discharge, for the LOS analysis. Consequently, the data of those transferred from the centre were excluded as it was difficult to estimate their total COVID-19-related LOS.

4.2.2 Dependent Variables

COVID-19-related mortality, long COVID and LOS were the dependent variables in this study. The mortality outcome was defined as all deaths related to COVID-19. It was assessed in this study as a binary variable, and it was coded '0' if the patient survived (outcome of interest absent) and '1' if they died (outcome of interest present). This specification was consistent with the reviewed literature. The LOS variable was documented in the GEMH dataset as the number of days the patient spent in the hospital for COVID-19. Hence, it was assessed as a continuous variable in this study. Long COVID was described as patients who still reported symptoms of COVID-19 for more than twelve weeks after the initial illness with no other medical diagnosis (NHS, 2021). Those that reported long COVID symptoms were coded '1', and those without long COVID symptoms were coded '0'.

4.2.3 Independent Variables

The independent variables included age, sex, nationality, marital status, education level, employment status and comorbidities. These variables were informed by Chapter 2 and were consistent with Dahlgren and Whitehead (1993)'s determinants of health framework. The patients' ages were described as the number of years lived and were categorised into three groups, 0 – 29 years, 30 – 59 years and ≥60 years. Their sex was described as either 'men' or 'women', and their nationality was their country of origin. Nationality was specified as 'Ghanaian' for those originating from Ghana and non-Ghanaian for those with different nationalities. The marital status described whether the patient was single, married, cohabiting, divorced/separated or widowed. Also, the employment and education level described the patient's employment status and educational attainment, respectively. Finally, comorbidities were defined as any other existing clinical condition of the patient. It included mainly hypertension (HPT), Diabetes Mellitus (DM), HPT and DM, pulmonary diseases, neoplasms, gastrointestinal diseases, cardiovascular diseases, and neurological diseases. See figure 7 for a summary of the independent and dependent variables.

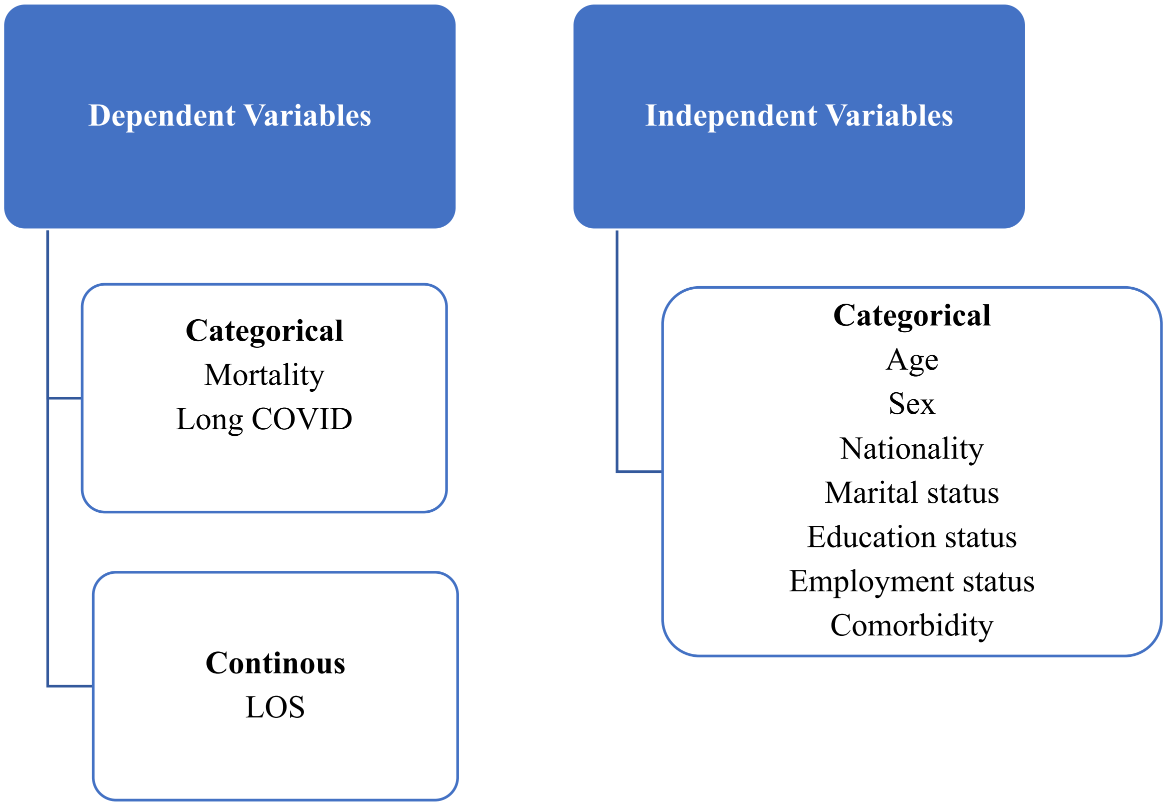

Figure 7: Variables explored in this Chapter.

4.2.4 Data Analysis

The data were analysed at three levels: 1. Descriptive analysis to explore the accuracy of the GEMH dataset and describe the characteristics of the patients; 2. Bivariate analysis to investigate associations between the dependent and independent variables, and 3. Regression analysis to unmask actual determinants of COVID-19-related mortality, long COVID and LOS in Ghana. The data were analysed with SPSS software version 26, and a $p \leq 0.05$ was used to determine statistical significance.

4.2.4.1 Descriptive Analysis

As mentioned above, descriptive analysis was conducted to check the accuracy of the GEMH dataset and show the sample's characteristics. The accuracy assessment was done to ascertain the dataset's consistency, check for outliers and, most importantly, ensure that the values were well specified and correctly inputted (Kleppner, 2010). After the accuracy assessment, the Kolmogorov-Smirnov and Shapiro-Wilk normality tests were conducted to examine the distribution of the continuous variables to inform the choice of either parametric or non-parametric statistical test in the subsequent bivariate analyses (Field, 2003). The sample characteristics were summarised with means/medians and standard deviations/Interquartile range (IQR) for the continuous variables, while proportions were used for the categorical variables. In addition to the integrity checks and sample description, missing data analysis was conducted to identify any missing data and their pattern of missingness and examine their influence on the dataset (Kang, 2013). The type of missing data informed the method used to address data missingness. For example, for data not missing completely at random, regression imputation was considered to account for the missing value to ensure the exclusive use of the data (Papageorgiou et al., 2018). However, for missing data less than 5%, the data with the missing values were completely removed since the 5% missing value was considered insignificant and their impact inconsequential, as established in the literature (Papageorgiou et al., 2018; Hamer & Simpson, 2009). While this study was aware that the deletion approach could result in the loss of vital information that could be crucial to the implication of this study's findings, the deletion approach was a robust approach to avoid imputing values that are not reflective of actual values (Papageorgiou et al., 2018).

4.2.4.2 Bivariate Analysis

Kruskal-Wallis, Mann-Whitney U and Chi-square tests were used to investigate associations between the independent and dependent variables. As already described, all the categorical variables were assessed as nominal variables because of their distinctiveness. Therefore, the Chi-square tests were used to compare the proportions and associations between these variables and mortality and long COVID. Also, Mann-Whitney U-test was used to test the associations between LOS and the categorical independent variables with two groups. For those with multiple distinct groups, like comorbidities, Kruska-Wallis was used to assess possible associations. The use of the non-parametric tests was informed by the distribution of the continuous variables.

4.2.4.3 Regression Analysis

Two regression models were used to estimate the determinants of COVID-19-related mortality, long COVID and LOS. First, binary logistic regressions were conducted to examine factors that could increase the risk of COVID-19-related mortality and long COVID. This was because these variables were binary, as explained earlier. In the logistic model, groups with the first value, i.e., ‘0’ or ‘1’ (dependent on variable coding) within the independent variables were marked as the reference group. All the independent variables were included in the base logit model, and the predictor variables that were significant in the bivariate analysis but insignificant in the base model were marked as confounders. Before conducting the regression analyses, model diagnostics were conducted (Stoltzfus, 2011). First, a Variance Inflation Factor (VIF) was used to examine correlations in the independent variables to detect any multicollinearity that could influence the model’s output (Senaviratna et al., 2019). Other tests included checks for random patterns among the observations in the dataset to guarantee their independence. Second, the Hosmer–Lemeshow test was used to check the model’s data fit (Paul et al., 2013). This was to ensure that the model accurately predicted the probability of the outcomes. Subsequently, based on the Hosmer–Lemeshow test output, a p-value <0.05 indicated a poor model fit, whereas a $p > 0.05$ indicated a good model fit (Nattino et al., 2020).

Second, a Generalised linear model (Negative binomial with log link) was used to examine the determinants of COVID-related LOS. The choice of the negative binomial test was informed by its sensitivity to non-normally distributed count variables whose variances are considerably higher than the means. Again, the rationale for the LOS analysis was to determine the predictive influence of the independent variables on COVID-19-related LOS when all other independent variables in the model are controlled. Like the previous regression model, the assumptions for negative binomial were checked before the model fit. Apart from these two primary analyses, the binary logistic regression and the negative binomial model were also used to examine COVID-19-related-mortality, long COVID and LOS determinants in further sub-population analyses. For instance, sex-based sub-populations analyses was conducted to investigate whether the determinants of COVID-19-related mortality, long COVID and LOS differed across men and women and how this would imply for COVID-19-related interventions.

4.2.5 Ethics Approval

Ethics approval for this chapter was granted by the Research Ethics Committee, College of Health, Medicine and Life Sciences (CHMLS), Brunel University London. The approval reference number is 25803-NER-Nov/2020- 28436-2.

4.2.6 Data Management

The dataset from GEMH was encrypted and stored on the researcher's Brunel University's assigned OneDrive. Also, the researcher's personal computer with access to the assigned Brunel University's OneDrive was password protected. The researcher intends to keep the dataset for ten years after completing and submitting this research to Brunel University London. This will align with Brunel University's data management regulations regarding data retention.

4.3 Results

The results of the analyses are presented in the following: 1. missing observations and data integrity checks, 2. sample characteristics and bivariate analyses findings, and 3. findings of the regression analysis.

4.3.1 Data Integrity Checks and Missing Data Analysis

The GEMH dataset was accurate, and the observations were correctly inputted and specified under their variables. Also, no outliers were identified. Concerning missing observations, one hundred and three (n = 103) patients, representing 4.2% of the eligible total sample (n = 2,437), had missing observations for mortality (n = 9; 8.7%), marital status (n = 97; 94.2%), employment status (n = 67; 65%), education level (n = 81; 78.6%) and comorbidities (n = 102; 99%). The pattern of missingness was data Missing Completely at Random (MCAR) for all the variables with missing data because the missingness was unrelated to the observed data values nor the missing data points (Pigott, 2009). All the missing data points were observed under the categorical variables. Therefore, none of the continuous variables had missing data. Since the patients with missing values were less than 5%, their information was completely removed from the dataset. Besides, the data were missing completely at random, so applying the deletion method was logical (Hamer & Simpson, 2009). The data of the remaining two thousand three hundred and thirty-four patients (n = 2,334) were included in the analyses.

4.3.2 Sample Characteristics and Findings of the Bivariate Analysis

Of the 2,334 patients included in the analyses, 60.1% were men (n = 1,402), and 39.9% were women (n = 932). Most of them were aged from 30 –59 years (n = 1,343; 57.5%), and the mean age was 40.2 ±15.9. The majority were married (n = 1,305; 55.9%), employed (n = 1,717; 73.6%) and tertiary educated (n = 1,085; 46.5%). Also, many of them had no commodities (n = 1,902; 81.5%), and among those with comorbidities, HPT (n = 239; 10.2%) and HPT&DM (n = 80; 3.4%) were the most common. Most of the patients were Ghanaians (n = 1,733; 74.3%). Among the non-Ghanaians (n = 601), Nigerians (n = 152; 6.5%) were the majority, followed by Americans (n = 57; 2.4%) and British (n = 49; 2.1%) – see figure 8. The others came from the countries specified in the footnote[8].

[8] Guyana (n=1), Guinea (n=2), Burkina (n=6), Italy (n=6), Macedonia (n=1), Tanzania (n=5), Austria (n=1), Turkey (n=9), Spain (n=6), UAE (n= 2), Cameroon (n=9), Gambia (n=1), Gabon (n=3), Germany (n=2), Sudan (n=3), Egypt (n=5), Ukraine (n= 3), Jordan (n=1), Benin (n=1), Kenya (n=8), France (n=11), Ireland (n=3), Belgium (n=4), Uganda (n=1), Senegal (n=4), Congo (n=4), Malawi (n=4), Czech Republic (n=1), Lithuania (n=1), Vietnam (n=1), Japan (n=3), Pakistan (n=1), Iran (n=1), Taiwan (n=1), Sierra Leone (n=8), Togo (n=6), Romania (n=1), Trinidad and Tobacco (n=1), Morocco (n=1), Namibian (n=1), Portugal (n=2), Serbia (n=1), South Korea (n=2), Niger (n=4), Mauritanian (n=1), Canada (n=8), Switzerland (n=2), Zimbabwe (n=3), Brazil (n=1), Syria (n=3), Holland (n=7), Philippians (n=8), Cuba (n=2), Cabo Verde (n=1), Zambia (n=1), Russia (n=6)

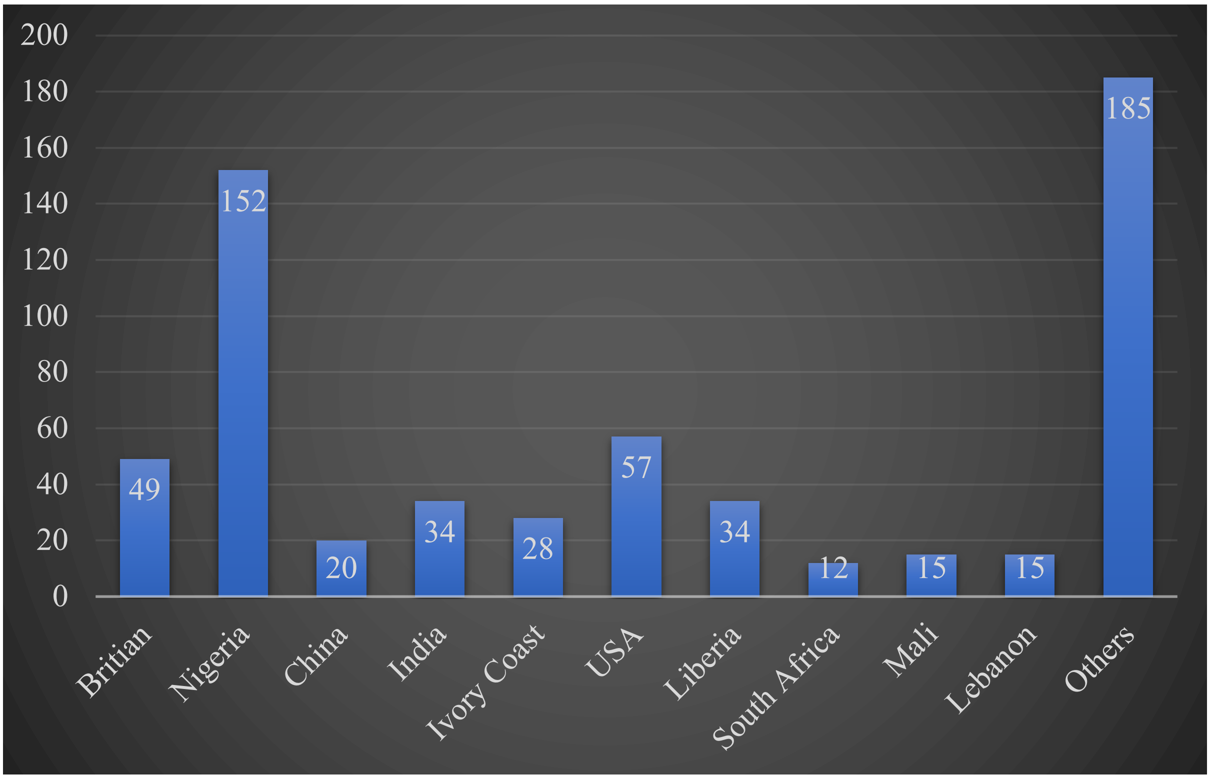

Figure 8: Bar graph showing the nationality of the non-Ghanaian patients (N = 601).

Regarding mortality, many of the patients survived (n = 2,289; 98%). Of the nearly 2% (n = 45) that died, 24.4% (n = 11) had DM, 15.6% (n = 7) had HPT and DM, and 46.7% (n = 21) had HPT. None of the patients with neurological, gastrointestinal, and pulmonary diseases died. The patients with tertiary education (n = 1,085; 46.5%) were marginally higher than those with secondary/vocational training (n = 1,048; 44.9%). However, more of those with secondary education died (n = 26; 57.8%) than those with tertiary education (n = 8; 17.8%). Concerning employment status, the proportion of deaths among those employed (n = 23; 51.1%) and unemployed (n = 22; 48.9%) was comparable. On long COVID, almost 2% (n = 50) of the study population (n =2,334) experienced long COVID. Most of patients (n = 30) with long COVID were aged 30 – 59 years. Also, many of the 2% with long COVID were men (n = 36), married (n = 31) and employed (n = 37). Finally, the maximum LOS due to COVID-19 was 74 days, and the average was 4.73±5.93 days. In the bivariate analysis, all the independent variables were significantly associated with mortality and LOS, except sex. Additionally, LOS was not associated with mortality. The patients' age, nationality, education level and comorbidities were also statistically associated with long COVID. See table 14 for the sample characteristics and bivariate findings on COVID-19 related mortality and LOS, and table 15 for the descriptive findings on long COVID.

Table 14: Sample characteristics and bivariate findings on COVID-19-related mortality and LOS (N= 2334)

Variables	**Number (%)/mean (SD)**	**Treatment outcome (Number (%))**			**LOS p–value**
		Survived (N = 2,289)	Died (N = 45)	p–value	
Age				<0.01	<0.01
0–29 years	664 (28.4)	664 (29)	0 (0)		
30–59 years	1343 (57.5)	1324 (57.8)	19 (42.2)		
≥60 years	327 (14)	301 (13.1)	26 (57.8)		
Sex				0.22	0.91
Men	1402 (60.1)	1371 (59.9)	31 (68.9)		
Women	932 (39.9)	918 (40.1)	14 (31.1)		
Nationality				<0.01	<0.01
Ghanaian	1733 (74.3)	1,691 (73.9)	42 (93.3)		
Non-Ghanaian	601 (25.7)	598 (26.1)	3 (6.7)		
Marital status				<0.01	<0.01
Single	872 (37.4)	870 (38)	2 (4.4)		
Married	1305 (55.9)	1269 (55.4)	36 (80)		
Cohabiting	16 (0.7)	16 (0.7)	0 (0)		
Divorced/separated.	82 (3.5)	80 (3.5)	2 (4.4)		
Widowed	59 (2.5)	54 (2.4)	5 (11.1)		
Education level				<0.01	<0.01
No formal	45 (1.9)	42 (1.8)	3 (6.7)		
Primary	156 (6.7)	148 (6.5)	8 (17.8)		
Secondary/vocational	1048 (44.9)	1022 (44.6)	26 (57.8)		
Tertiary	1085 (46.5)	1,077 (47.1)	8 (17.8)		
Employment status				<0.01	<0.01
Employed	1717 (73.6)	1694 (74)	23 (51.1)		
Unemployed	617 (26.4)	595 (25.9)	22 (48.9)		
Comorbidities				<0.01	<0.01
No comorbidity	1902 (81.5)	1,898 (82.9)	4 (8.9)		
Hypertension (HPT)	239 (10.2)	218 (9.5)	21 (46.7)		
Diabetes mellitus (DM)	47 (2.0)	36 (1.6)	11 (24.4)		
HPT&DM	80 (3.4)	73 (3.2)	7 (15.6)		
Neoplasms	4 (0.2)	3 (0.1)	1 (2.2)		
Neurological diseases	2 (0.1)	2 (0.1)	0 (0)		
Gastrointestinal diseases	17 (0.7)	17 (0.7)	0 (0)		
Pulmonary diseases	31 (1.3)	31 (1.4)	0 (0)		
Cardiovascular diseases	12 (0.5)	11 (0.5)	1 (2.2)		
LOS (days)	4.73 (5.93)			0.24	

Notes: SD – Standard Deviation, LOS – Length of hospital stay, HPT – Hypertension, DM – Diabetes Mellitus.

Table 15: Sample characteristics and bivariate findings on long COVID (N = 2,334)

Variables	**Number (%)**	**Long COVID**		
		No Number (%)	Yes Number (%)	p-Value
Age				0.05
0–29 years 30–59 years ≥60 years	664 (28.4) 1343 (57.5) 327 (14)	656 (98.8) 1313 (97.8) 315 (96.3)	8 (1.2) 30 (2.2) 12 (3.7)	
Sex				0.08
Men Women	1402 (60.1) 932 (39.9)	1366 (97.4) 918 (98.5)	36 (2.6) 14 (1.5)	
Nationality				0.05
Ghanaian Non-Ghanaian	1733 (74.3) 601 (25.7)	1689 (97.5) 595 (99)	44 (2.5) 6 (0.9)	
Marital status				0.32
Single Married Cohabiting Divorced/separated. Widowed	872 (37.4) 1305 (55.9) 16 (0.7) 82 (3.5) 59 (2.5)	859 (98.5) 1274 (97.6) 15 (93.8) 79 (96.3) 57 (96.6)	13 (1.5) 31 (2.4) 1 (6.2) 3 (3.7) 2 (3.4)	
Education level				<0.01
No formal Primary Secondary/vocational Tertiary	45 (1.9) 156 (6.7) 1048 (44.9) 1085 (46.5)	40 (88.9) 155 (99.4) 1023 (97.6) 1066 (98.2)	5 (11.1) 1 (0.6) 25 (2.4) 19 (1.8)	
Employment status				0.94
Employed Unemployed	1717 (73.6) 617 (26.4)	1680 (97.8) 604 (97.9)	37 (2.2) 13 (2.1)	
Comorbidities				<0.01
No comorbidity HPT DM HPT&DM Neoplasms Neurological diseases GTI Pulmonary diseases CVD	1902 (81.5) 239 (10.2) 47 (2.0) 80 (3.4) 4 (0.2) 2 (0.1) 17 (0.7) 31 (1.3) 12 (0.5)	1868 (98.2) 233 (97.5) 45 (95.7) 73 (91.3) 4 (100) 1 (50) 17 (100) 31 (100) 12 (100)	34 (1.8) 6 (2.5) 2 (4.3) 7 (8.7) 0 (0) 1 (50) 0 (0) 0 (0) 0 (0)	

Notes: HPT – Hypertension, DM – Diabetes Mellitus

4.3.3 Determinants of COVID-19 Mortality

For the determinants of mortality analysis, the age of the patients was recategorised to ensure a model fit since none of those aged 0 – 29 years died – the reference group in the initial categorisation. Therefore, the new categorisation coded those <60 years as '0' and those ≥60 years as '1'. The logit model showed that individuals aged ≥60 years have about three times (95%CI = 1.32 – 7.25; p = 0.009) the odds of dying from COVID-19 than those aged <60 years. Additionally, the presence of comorbidities, like HPT (OR = 26.15; p = 0.00), DM (OR = 83.14, p = 0.00), HPT&DM (OR = 17.89; p = 0.00), neoplasms (OR = 109.55; p = 0.002) and cardiovascular diseases (OR = 40.96; p = 0.003), increase the likelihood of COVID-19 mortality when compared to those with no comorbidities. However, the 95% Confidence Intervals (CI) for the Odds Ratio (OR) of these comorbidities were large, indicating a lower precision for the odds of mortality (Szumilas, 2010). The CIs, however, did not include one (1), the OR value suggesting a lack of association between the exposure and outcome. As such, the model findings indicate that HPT, DM, neoplasms and cardiovascular diseases are positively associated with COVID-19 mortality, though the precision of the odds is low (Szumilas, 2010). The model also showed that the sociodemographic variables, specifically nationality, marital status, employment status and education level, that were associated with mortality in the bivariate analysis were unrelated to COVID-19 mortality in the regression analysis. Therefore, they were thought of as potential confounders, as already indicated in earlier in this chapter. The model explained approximately 41% of the variation in mortality (Nagelkerke $R^2 = 0.406$). Regarding the model fit, the Hosmer–Lemeshow test showed that the model was a good fit for the dataset (p = 0.98).[9] See table 16 for a summary of the determinants of COVID-19-mortality.

Table 16: Determinants of COVID-19-related mortality (N= 2,334)

Variables	Odds Ratio (OR)	95% Confidence Interval (CI)	
		Lower CI	Upper CI
0 – 59years	[1,1]		
≥60 years	3.09**	1.32	7.25
Men	[1,1]		
Women	0.52	0.25	1.05
Ghanaian	[1,1]		
Non-Ghanaian	0.48	0.13	1.72
Single	[1,1]		
Married	2.89	0.64	13.21
Divorced/separated.	1.30	0.15	11.44
Widowed	3.47	0.54	22.15
No-formal education.	[1,1]		
Primary	2.54	0.51	12.68

[9] For the Hosmer–Lemeshow test, a chi-square output indicating a p-value <0.05 implies that the model is not a good fit for the dataset (Paul et al., 2013).

Variables	Odds Ratio (OR)	95% Confidence Interval (CI)	
		Lower CI	Upper CI
Secondary	1.26	0.30	5.35
Tertiary	0.66	0.14	3.36
Employed	[1,1]		
Unemployed	1.17	0.51	2.71
No-comorbidity.	[1,1]		
HPT	26.15**	8.54	80.02
DM	83.14**	24.14	286.32
HPT&DM	17.89**	4.74	67.57
Neoplasms	109.55**	5.91	2029.75
Cardiovascular diseases	40.97**	3.55	473.43

Notes: ** p-value <0.01, *p-value <0.05, [1,1] – reference group.

4.3.3.1 Determinants of COVID-19 Mortality Among Men and Women

In the sex subgroup analyses, the number of patients with comorbidities was high among men (n = 235) than women (n = 197). Also, within the comorbidities, more men had HPT (n = 130), DM (n = 31) and pulmonary diseases (n = 19) than women (HPT: n = 109; DM: n = 16, pulmonary diseases: n = 12). Conversely, more women had HPT&DM (n = 44) than men (n = 36). However, the number of women with neurological diseases and neoplasms was the same as men. Further, the number of mortalities from COVID-19 was high among men with comorbidities (n = 28) than among women with comorbidities (n = 13). A further within-group analysis showed significant differences between the patients who died and the survivors within both the male (p = 0.00) and female (p = 0.00) subgroups. See figure 9 and table 17 for the sex-based summaries.

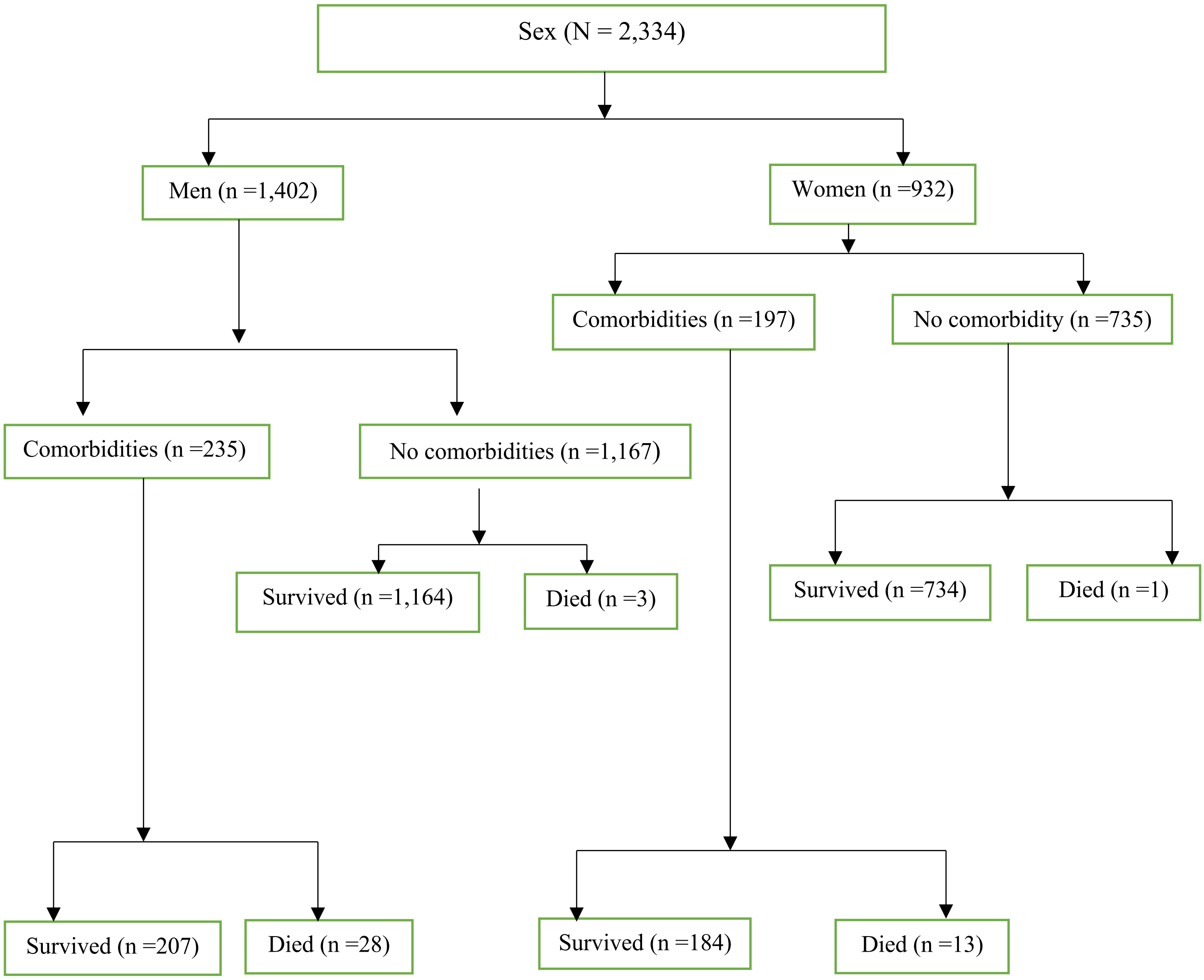

Figure 9: Proportion of comorbidities and mortality among sex subgroups (N = 2334)

Table 17: Number of comorbidities across sex (N = 2334).

Characteristics	**Men**	**Women**	**Total**
No comorbidities	1167	735	1902
HPT	130	109	239
DM	31	16	47
HPT&DM	36	44	80
Neoplasms	2	2	4
Neurological diseases	1	1	2
Gastrointestinal diseases	9	8	17
Pulmonary diseases	19	12	31
Cardiovascular diseases	7	5	12

Notes: HPT – Hypertension, DM – Diabetes Mellitus

In the sex subgroup regression analyses, men aged ≥60 had increased odds of COVID-19 mortality (OR = 5.98; p = 0.001) compared to women aged ≥60 years. However, the presence of HPT (Men: p = 0.00; Women: p = 0.003), DM (Men: p = 0.00; Women: p = 0.002), and HPT&DM (Men: p = 0.01; Women: p = 0.002) was associated with increased probability of COVID-19 mortality in both men and women. Nevertheless, like the general logit model, the 95% CIs for the odds ratio of these variables were wide, lowering the precision of the odds. The Hosmer–Lemeshow test showed a model fit for both models (Men: 0.94; Women: 0.99), indicating a good fit. See table 18 for the determinants of COVID-19 mortality among men and women.

Table 18: Determinants of COVID-19-related mortality among men and women (N = 2334)

Variables	**Men (N = 1402)**		**Women (N = 932)**	
	OR	95%CI	OR	95% CI
0 – 59years	[1,1]		[1,1]	
≥60 years	5.98*	2.04 – 17.68	0.95	0.22 – 4.09
Ghanaian	[1,1]		[1,1]	
Non-Ghanaian	0.42	0.85 – 2.05	0.79	0.08 – 7.928
Single	[1,1]		[1,1]	
Married	2.39	0.28 – 20.11	3.07	0.32 – 29.40
Divorced/Separated	0.86	0.04 – 18.79	2.23	0.09 – 53.21
Widowed	7.31	0.55 – 96.32	1.21	0.06 – 26.32
Employed	[1,1]		[1,1]	
Unemployed	0.73	0.25 – 2.17	2.36	0.60 – 9.26
HPT				
No	[1,1]		[1,1]	
Yes	29.51**	7.88 – 110.58	30.90**	3.23 – 295.41
DM				
No	[1,1]		[1,1]	
Yes	100.84**	23.45 – 433.68	64.80**	4.67 – 899.19
HPT&DM				
No	[1,1]		[1,1]	
Yes	11.91**	2.11 – 67.22	44.28**	3.94 – 498.24

Notes: ** p-value <0.01, *p-value <0.05, OR – Odds Ratio, CI – Confidence Interval, [1,1] – reference group, HPT – Hypertension, DM – Diabetes Mellitus.

4.3.3.2 Determinants of COVID-19 Mortality Among Patients with Comorbidities

Among the patients with comorbidities, women (OR = 0.44; p = 0.03) were found to have lower odds of COVID-19 mortality than men. Additionally, the patients aged ≥60 had about three times the likelihood of dying from COVID-19 than those <60 (OR = 2.55; p = 0.03). When the model was limited to only patients with HPT (n = 239), none of the independent variables determined COVID-19 mortality. See tables 19 and 20 for the comorbidities and HPT subgroup analyses.

Table 19: Determinants of COVID-19 mortality among patients with comorbidities (N = 432)

Variables	OR	Lower CI	Upper CI
0-59years ≥60 years	[1,1] 2.55*	 1.09	 5.93
Men Women	[1,1] 0.43*	 0.21	 0.91
Ghanaian Non-Ghanaian	[1,1] 0.77	 0.22	 2.73
Single Married Divorced/separated. Widowed	[1,1] 2.85 1.70 4.54	 0.63 0.20 0.74	 12.98 14.26 27.96
No-formal education Primary Secondary Tertiary	[1,1] 1.88 1.28 0.52	 0.40 0.33 0.11	 8.82 4.95 2.47
Employed Unemployed	[1,1] 1.39	 0.59	 3.25

Notes: *p-value <0.05, OR – Odds Ratio, CI – Confidence Interval, [1,1] – reference group.

Table 20: Determinants of COVID-19 mortality among patients with hypertension (N = 239)

Variables	OR	Lower CI	Upper CI
0-59years ≥60 years	[1,1] 2.24	 0.65	 7.65
Men Women	[1,1] 0.37	 0.13	 1.05
Single Married Divorced/Separated Widowed	[1,1] 0.78 1.16 0.75	 0.15 0.11 0.05	 4.13 11.89 11.23
No-formal education Primary Secondary Tertiary	[1,1] 1.70 1.99 0.73	 0.13 0.18 0.06	 23.11 21.36 9.71
Employed Unemployed	[1,1] 2.44	 0.73	 8.18

Notes: OR – Odds Ratio, CI – Confidence Interval, [1,1] – reference group.

4.3.4 Determinants of COVID-19-related LOS

In the LOS analyses, the patients who died from COVID-19 had fewer hospital admissions days (4.53±4.19 days) compared to the survivors (4.73±5.96 days). Similarly, the patients with comorbidities who died from COVID-19 spent fewer days (4.27±4.10 days) in admission than those with comorbidities who survived (7.19±6.45 days). The male patients with no comorbidities who died from COVID-19 spent more days (6.67±5.77 days) in the hospital than those who survived (4.31±5.94 days) (See table 21 and figure 10).

Table 21: Average LOS (days) among survivors and non-survivors of COVID-19 (N = 2,334)

Groups	**Number (N)**	**Survived (N = 2,289)**	**Died (N = 45)**	**Mean Difference p–value**
		LOS Mean (SD)	LOS Mean (SD)	
General population	2,334	4.73 (5.96)	4.53 (4.19)	0.24
Patients with comorbidities	432	7.19 (6.45)	4.27 (4.09)	0.01
Patients with no comorbidities	1,902	4.23 (5.7)	7.25 (4.86)	0.25
Female patients with comorbidities	197	7.25 (5.99)	4.15 (4.89)	0.06
Female patients with no comorbidities	735	4.09 (5.36)	9.00 **(-)**	0.26
Male patients with comorbidities	235	7.14 (6.85)	4.32 (3.77)	0.09
Male patients with no comorbidities	1,167	4.31 (5.94)	6.67 (5.77)	4.97

Notes: SD – Standard Deviation, (-) no SD was calculated because that sample contained only one participant.

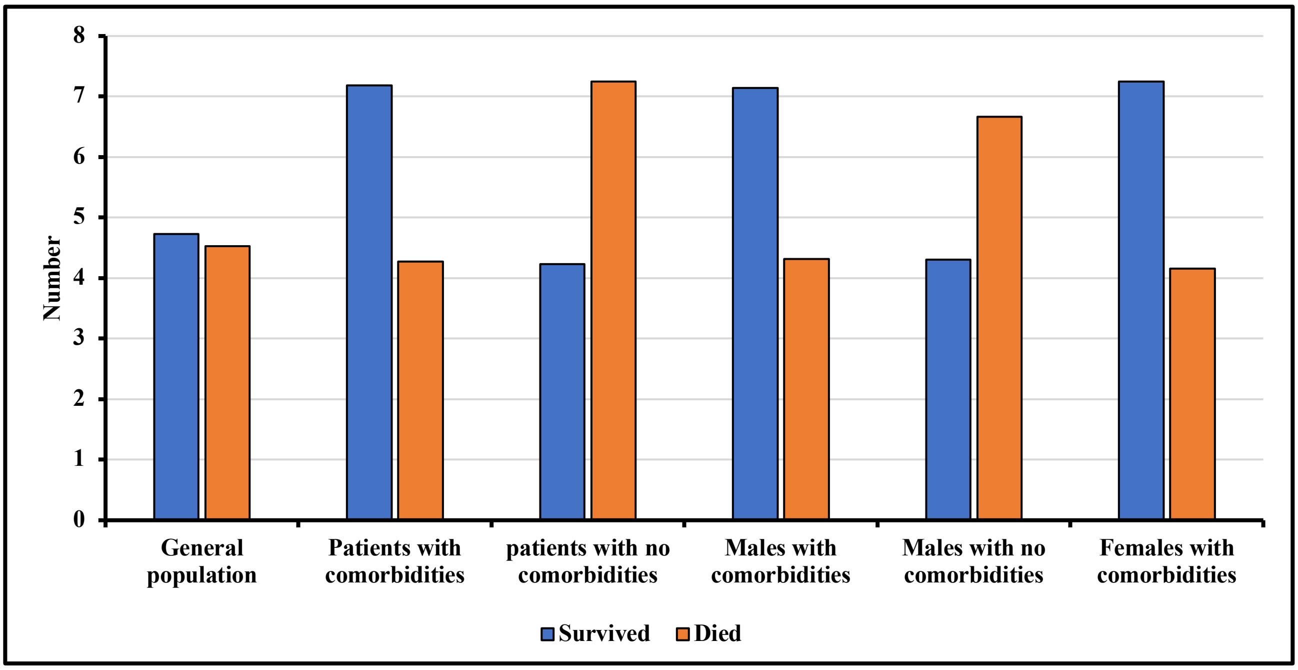

Figure 10: Comparison of average LOS among the COVID-19 survival and non-survivals per subgroups.

As indicated in the methods section, negative binomial regression was used to examine the determinants of COVID-19 LOS. The findings suggested that the tertiary (B = 0.55; 95%CI = 0.39 – 0.77), secondary/vocational (B = 0.62; 95%CI = 0.45 – 0.86), and primary educated patients (B = 0.61; 95%CI = 0.43 – 0.87), spend fewer days in hospital due to COVID-19 than the patients with no formal education. However, COVID-19 patients with HPT&DM spend almost two additional days in hospital than those with no comorbidities (p = 0.00; 95%CI = 1.42 – 2.33). Additionally, patients with HPT (B =1.26; 95%CI = 1.08 – 1.47; p = 0.003) and DM (B = 1.37; 95%CI = 0.99-1.88; p = 0.05), patients spend significantly longer days in COVID-19-related hospitalisation than those with no comorbidities.

The sex subgroup analysis showed that the women with COVID-19 aged 30 –59 years spend an additional day in COVID-19-related hospitalisation than those aged 0 –29 (p = 0.009; 95%CI = 1.07– 1.62). Similarly, the women (B = 1.88; 95%CI = 1.34 – 2.63; p = 0.000) and men (B = 1.67; 95%CI = 1.16 – 2.41; p = 0.006) with HPT&DM spend two extra days in COVID-19-related hospitalisation than those with no comorbidities. However, the men with HPT (B = 1.26; 95%CI = 1.02 – 1.54; p = 0.03), DM (B = 1.47; 95%CI = 0.99 – 2.17; p = 0.05), and gastrointestinal diseases (B = 2.82; 95%CI = 1.41 –5.61; p = 0.003) have prolonged

COVID-19-related hospital admissions than their comparative female population. Table 22 summarises these findings.

Table 22: Determinants of COVID-19-related LOS (N = 2334).

Variables	General population (N = 2334) B (95% CI)	Men (N = 1402) B (95% CI)	Women (N = 932) B (95% CI)
0-29 years 30-59 years ≥60 years	[1,1] 1.18 (0.97 – 1.43) 1.079 (.941 – 1.24)	[1,1] 0.934 (0.78 – 1.12) 1.15 (0.89 – 1.48)	[1,1] 1.32** (1.07 – 1.62) 1.27 (0.94 – 1.70)
Men Women	[1,1] 0.93 (0.85 – 1.02)		
Ghanaian Non-Ghanaian	[1,1] 0.45** (0.41 – 0.51)	[1,1] 0.53** (0.46 – 0.61)	[1,1] 0.34** (0.29 – 0.41)
Single Married Cohabiting Divorced/separated. Widowed	[1,1] 0.91 (0.80 – 1.03) 1.441 (0.84 – 2.46) 1.20 (0.92 – 1.56) 1.071 (0.79 – 1.46)	[1,1] 0.94 (0.8 – 1.11) 1.88 (0.99 – 3.57) 1.24 (0.87 – 1.76) 1.13 (0.72 – 1.79)	[1,1] 0.84 (0.69 – 1.02) 0.69 (0.25 – 1.88) 1.09 (0.74 – 1.63) 0.95 (0.62 – 1.46)
No-formal education Primary Secondary/vocational Tertiary	[1,1] 0.61 (0.43 – 0.87) 0.62* (0.45 – 0.86) 0.55** (0.39 – 0.77)	[1,1] 0.63 (0.38 – 1.03) 0.61* (0.39 – 0.95) 0.51** (.327 – 0.80)	[1,1] 0.604(0.36 – 1.03) 0.68 (.420 – 1.09) 0.65 (.402 – 1.07)
Employed Unemployed	[1,1] 1.0 (0.88 – 1.14)	[1,1] 0.92 (0.77 – 1.10)	[1,1] 1.11 (0.91 – 1.34)
No-comorbidity HPT DM HPT&DM Neurological diseases GTI Pulmonary diseases CVD	[1,1] 1.26** (1.08 – 1.47) 1.37* (0.99 – 1.88) 1.82** (1.42 – 2.33) 2.03 (0.48 – 8.69) 2.08* (1.25 – 3.46) 1.074 (0.73 – 1.59) 1.344 (0.73 – 2.47)	[1,1] 1.26* (1.02 – 1.54) 1.47* (0.99 – 2.17) 1.67** (1.16 – 2.41) 1.88 (0.43 – 8.21) 2.82** (1.41 – 5.61) 1.03 (0.62 – 1.71) 1.22 (0.55 – 2.73)	[1,1] 1.24 (0.98 – 1.56) 1.24(0.72 – 2.16) 1.88** (1.34 – 2.63) 0.59 (0.08 – 4.25) 1.24 (0.58 – 2.66) 1.13 (0.60 – 2.11) 1.48 (0.58 – 3.80)

Notes: **p-value <0.01, *p-value <0.05, B – Correlation Coefficient, CI – Confidence Interval, [1,1] – reference group, HPT – Hypertension, DM – Diabetes, GTI - Gastrointestinal diseases, CVD – Cardiovascular Diseases.

4.3.5 Determinants of Long COVID

The odds of long COVID were lower in women than men (OR = 0.52; 95%CI = 0.27 – 0.99; p = 0.05). Also, those with tertiary (OR = 0.23; 95%CI = 0.07 – 0.72; p=0.12), secondary/vocational (OR = 0.26; 95%CI = 0.09 – 0.77; p = 0.02), and primary education (OR = 0.73; 95%CI = 0.01 – 0.66; p = 0.02) were at decreased odds of long COVID than those not formally educated. Furthermore, COVID-19 patients with HPT&DM were four times more likely to experience long COVID symptoms than those with no comorbidities (p = 0.003; 95%CI = 1.61 – 10.85). The 0.91 Hosmer–Lemeshow test result indicated a good model fit. In sub-group analyses, the women with HPT&DM (OR = 5.69; 95%CI = 1.08 – 30.16; p = 0.04) had a higher likelihood of long COVID than their male counterparts (OR = 4.58; 95%CI = 1.32 –15.93; p = 0.02). Also, the men with secondary/vocational (OR = 0.23; 95%CI = 0.06 – 0.83; p = 0.02) and tertiary education (OR = 0.17; 95%CI = 0.04 – 0.69; p = 0.12) had lower odds of long COVID than the women with the same education levels. The model fitting test results for the men (0.63) and women (0.71) sub-population analyses were more than 0.05, indicating a good model fit. See table 23 for a summary of these findings.

Table 23: Determinants of Long COVID (N = 2334).

Variables	**General population (N = 2334) OR (95% CI)**	**Men (N = 1402) OR (95% CI)**	**Women (N = 932) OR (95%)**
0-29 years 30-59 years ≥60 years	[1,1] 1.22 (0.47 – 3.20) 1.43 (0.42 – 4.83)	[1,1] 0.75 (0.24 – 2.41) 1.14 (0.26 – 4.92)	[1,1] 3.22 (0.54 – 19.07) 1.98 (0.18 – 22.1)
Men Women	[1,1] 0.52* (0.27 – 0.99)	-	-
Ghanaian Non-Ghanaian	[1,1] 0.48 (0.19 – 1.15)	[1,1] 0.59 (0.22 – 1.57)	[1,1] 0.25 (0.03 – 2.03)
No-formal education. Primary Secondary/Vocational Tertiary	[1,1] 0.73* (0.01 – 0.66) 0.26* (0.09 – 0.77) 0.23* (0.07 – 0.73)	[1,1] - 0.23* (0.06 – 0.83) 0.17* (0.04 – 0.69)	[1,1] 0.59 (0.03 – 11.62) 0.44 (0.04 – 5.24) 0.68 (0.06 – 8.21)
Employed Unemployed	[1,1] 1.83 (0.35 – 1.95)	[1,1] 0.86 (0.31 – 2.39)	[1,1] 0.69 (0.13 – 3.59)
No-comorbidity. Hypertension HPT&DM	[1,1] 1.23 (0.49 – 3.05) 4.18** (1.61– 10.85)	[1,1] 1.29 (0.42 – 4.01) 4. 58* (1.32 – 15.93)	[1,1] 1.34 (0.26 – 6.88) 5.69* (1.08 – 30.16)

Notes: ** p-value <0.01, *p-value <0.05, OR – Odds Ratio, CI – Confidence Interval (95%), [1,1] – reference group.

4.4 Discussion

This chapter examined the determinants of COVID-19-related mortality, LOS and long COVID, the long-term sequel of COVID-19. The data of 2,334 patients from the electronic medical records of the main COVID-19 treatment centre in Ghana from March 2020 to August

2021 were included in the analyses. Of the 2,334 COVID-19 patients, about 2% died, almost 2% had long COVID, and their average COVID-19-related LOS was 4.73±5.93 days. The patients who died spent about 2 hours less in admission than those who survived. However, their mean LOS difference was insignificant ($p = 0.24$). In addition, the patients with comorbidities who died spent three days shorter on hospital admission than those with no comorbidities who died, regardless of their sex. The decreased LOS among the non-survivors were consistent with a recent similar study (Biswas et al., 2021; Elliot et al., 2021). Generally, the findings indicated that Ghana had a lower COVID-19 mortality rate in 2020/21 than other countries reporting COVID-19 mortalities within similar periods. For example, Kaeuffer et al. (2020) found a mortality rate of 11% among 1,045 COVID-19 patients in France, while Mikami et al. (2020) reported a 13.2% COVID-19 mortality rate in 6,493 patients in the USA. Perhaps, the age characteristics of the patients in this current study and the studies mentioned above accounted for the mortality variation. For instance, this current study had relatively younger patients than the studies by Kaeuffer et al. (2020) and Mikami et al. (2020), further corroborating the above reasons for the mortality variations between the countries, especially as ageing has constantly been identified as a common determinant of COVID-19 mortality (Biswas et al., 2021). This argument was also observed in a similar study in Nigeria comprising 2,184 people with a median age of 43 years and a COVID-19 mortality of 3.3% (Osibogun et al., 2021).

Ghana, like most LMICs, has a smaller aged population (narrow top age pyramid) than most HICs, like France and the USA, due to a lower life expectancy associated with poor health structures and endemic diseases, like malaria (World life expectancy, 2021; Lawal, 2021). Ghana's relatively smaller aged population may have influenced the proportion of the older population in the GEMH dataset. It could have also inherently influenced this study's identified risk of COVID-19-related mortality. For example, the GEMH dataset had fewer people aged ≥ 60 years with COVID-19 ($n = 327$) than those aged <60 years with COVID-19 ($n = 2007$). Therefore, as already indicated, the COVID-19 mortality disparity between Ghana and the compared countries is likely a reflection of the smaller aged population in Ghana, probably owing to the relatively lower life expectancy in Ghana, and not necessarily due to a lower risk of COVID-19 infections and subsequent mortality among the older populations. To buttress this point further, many of the COVID-19 patients ≥60 years died ($n = 26$) than those <60 years ($n = 19$), even though they were the minority in the dataset. Again, this older age population and mortality characteristics were noticed in a similar study conducted in another LMIC (Osibogun et al., 2021). Of their 2184 patients, only 373 were aged ≥60 years, but they represented more than half of the proportion that died (Total deaths: n = 73; deaths among those aged ≥60 years: n = 44) (Osibogun et al., 2021).

The logistic regression findings showed that HPT, DM, individuals aged ≥60 years, HPT&DM, and cardiovascular diseases determine COVID-19-related mortality in Ghana. This finding is comparable to the literature review findings in Chapter 2, except for the relationship between men and COVID-19-related mortality. The sex mortality association was not observed in this study, but in the subgroup analysis, men ≥60 years had a higher probability of COVID-19 mortality than women ≥60. However, there were more older men (≥60 years old) in the analyses than older women (≥60 years old), which could have substantially influenced this particular result. Nonetheless, this finding on older men and mortality is consistent with a similar study that found older men to have a higher risk of COVID-19 mortality than older women (Li et al., 2020; Li et al., 2021). Again, in the subgroup analysis, men with comorbidities were more likely to die from COVID-19 infection than women with comorbidities. This result is similar to Li et al. (2021)'s multi-country study. These sex attributes and COVID-19-related observations may result from sex variations in innate responses to viral infections, as discussed in Chapter 2 (Klein & Flanagan, 2016). Finally, among the patients with comorbidities, those ≥60 years were nearly three times more likely to die from COVID-19 than those below 60 years, confirming the findings of similar studies (Li et al., 2020; Mesas et al., 2020).

On LOS, the patients who died spent lesser days in hospital admissions than those who survived; however, their mean difference was insignificant (p = 0.24). This result agrees with the findings of Rees et al. (2020). They also found that COVID-19 non-survivors spent fewer days in the hospital than survivors. The patients with comorbidities who died in this study spent approximately three days shorter from admission to death than those with no comorbidities who died, regardless of their sex. Similarly, the patients with comorbidities who died also stayed three days less in the hospital than those who survived. This finding is also consistent with the results of Li et al. (2020). Arguably, those who died were probably admitted in a more critical condition than those who survived, explaining their shorter hospital stays. Regarding the determinants of COVID-19 LOS and long COVID, the regression analyses showed that

HPT&DM is associated with long COVID while DM, HPT and HPT&DM determine COVID-19 LOS. Further, men with gastrointestinal diseases, HPT and DM have higher odds of prolonged COVID-19-related hospitalisation than women with similar conditions. Additionally, women are less likely to experience long COVID than men. However, this finding is yet to be substantiated in the literature due to the research dearth on determinants of long COVID. The literature, however, supports the significant relationship between comorbidities, prolonged COVID-19 hospitalisation, and long COVID (Mendy et al., 2020; Crook et al., 2020; Li et al., 2020). A potential reason for these relationships is the prolonged effect of comorbidities on viral infections and related outcomes experiences because of possible weakened immunity (Mesas et al., 2020; Ssentongo et al., 2020). Most importantly, the relationship between COVID-19 and comorbidities is bidirectional, as they can worsen the experience of the other and worsen recovery (Sanyaolu et al., 2020).

Comparatively, the findings in this chapter are consistent with a multinational systematic review and meta-analyses study involving three West African, one South African and two East African countries (Bepouka et al., 2022). The study found a pooled COVID-19 mortality rate of 4.8%, and the mortality was determined by increasing age and HPT, as reported in this chapter. Further, a recent study in Nigeria found increasing age and HPT as significant independent determinants of COVID-19-related mortality (Dayyab et al., 2023). In summary, the available literature reports the identified risk factors in this study as significant determinants of obesity irrespective of the COVID-19 variant being experienced (Molla et al., 2023; Nafilyan et al., 2022; Lu et al., 2022). Essentially, this chapter's results imply that the government of Ghana could consider prioritising persons with comorbidities and those ≥60 years when managing epidemics like the COVID-19 outbreak. For those with comorbidities, specialised clinical services, such as HPT and DM clinics, could be considered to facilitate regular medical screening to inform timely containment policies that could reduce their risk of severe health outcomes during viral epidemics like COVID-19.

Concerning the study's strengths and limitations, this chapter addressed the paucity of knowledge in the literature on the determinants of COVID-19 health outcomes in Ghana, specifically COVID-19-related mortality, long COVID and LOS. Its generated evidence could direct population-appropriate public health interventions for defined groups, particularly as the risk factors could differ across sub-groups. For example, policies like COVID-19 vaccination could prioritise older men as they were found to have an increased risk of COVID-19 deaths than older women. In addition to the subgroup analyses, the study used a relatively larger sample size than most of the studies identified in Chapter 2. This advantage of increased statistical power could enhance the external validity of the findings in this chapter (Ross & Bibler, 2019). However, the observational design of this study limited any causal association interpretation for the determinants and the COVID-19 health outcomes (Tofthagen, 2012). A causal association interpretation could have ensured more precise evidence to address the factors that influence COVID-19-related mortality, long COVID or LOS effectively. However, such causal association interpretations may not always be practically feasible, given the potential influence of confounders, especially the unconsidered and unmeasured ones (MacIntyre et al., 2021). The data in this analysis were from only one treatment centre; hence, it may reflect only some of the broader characteristics of all the persons with COVID-19 in Ghana. Consequently, this limits the sample's representation and further generalisation of the findings to the wider related population. Therefore, the results of this chapter must be interpreted with caution.

4.5 Conclusion

This chapter examined determinants of COVID-19-related health outcomes, i.e., mortality, long COVID and LOS, in Ghana. The findings showed that comorbidities like HPT, DM, and HPT&DM determine the risk of COVID-19-related mortality, LOS and long COVID, corroborating the evidence on the determinants of COVID-19 health outcomes identified in Chapter 2. The next chapter evaluated the effectiveness of Ghana's COVID-19 policy responses aimed at shielding populations from the COVID-19 infection and its subsequent health outcomes and mitigating the overall impact of the COVID-19 outbreak in Ghana.

CHAPTER 5: AN EVALUATION OF THE EFFECTIVENESS OF GHANA'S COVID-19 POLICY RESPONSES

5.1 Introduction

This chapter evaluated the effectiveness of Ghana's COVID-19 policy responses to provide evidence of the policies' mitigating effect on the outbreak's burden in Ghana. It used a qualitative content analysis approach to evaluate the policies' effectiveness by mapping the policies' objectives, inputs, outputs, and outcomes. This approach to the policies' effectiveness evaluation was informed by the literature (Antwi-Boasiako et al., 2021; Hall & Steiner, 2020; Garbarino & Holland, 2009; Judd & Randolph, 2006) and its benefits of providing comprehensive data on the policies' effectiveness are discussed in the subsequent sections in this chapter. After the content analysis, a correlational analysis was conducted using Fischer's test to explore factors associated with effective COVID-19 policies. This additional analysis was to provide comprehensive understanding of the policies' effectiveness.

5.2 Methods

5.2.1 Study Framework and Evaluation Approach

The logic model guided the policy assessment in this chapter. A logic model is a graphical framework that displays and connects inputs and outcomes of an intervention/program/policy (Mills et al., 2019). It allows easy interpretation of how and whether a policy/intervention influenced an outcome because of its ability to graphically link specific inputs to specific outcomes (Knowlton & Phillips, 2012). However, critics of the model argue that it often linearises the input and outcome relationship, with little emphasis on potential nuances. For example, Rehfuess et al. (2018) indicate that the logic model is passive in representing tested theories on policy operationalisation. Also, it is usually not sensitive to real-life complexities associated with sequences in policy implementation (Rehfuess et al., 2018). Nonetheless, its reported advantage of communicating interrelationships between inputs and outputs makes it an appropriate guideline for assessing the influence of a policy or an intervention on an outcome (Vedung, 2017; Knowlton & Phillips, 2012; Schalock, 2001). This advantage made its application in this study feasible, given that it aimed to assess the influence of the COVID-19 policy responses on COVID-19 outcomes in Ghana. However, unlike its conventional application, the model was adapted in this chapter to map the objectives, intended and actual outcomes of the policies, given the unique nature of the policies. This adaptation is consistent with the literature (Liberato et al., 2014). Figure 11 shows the logic model as operationalised in this study.

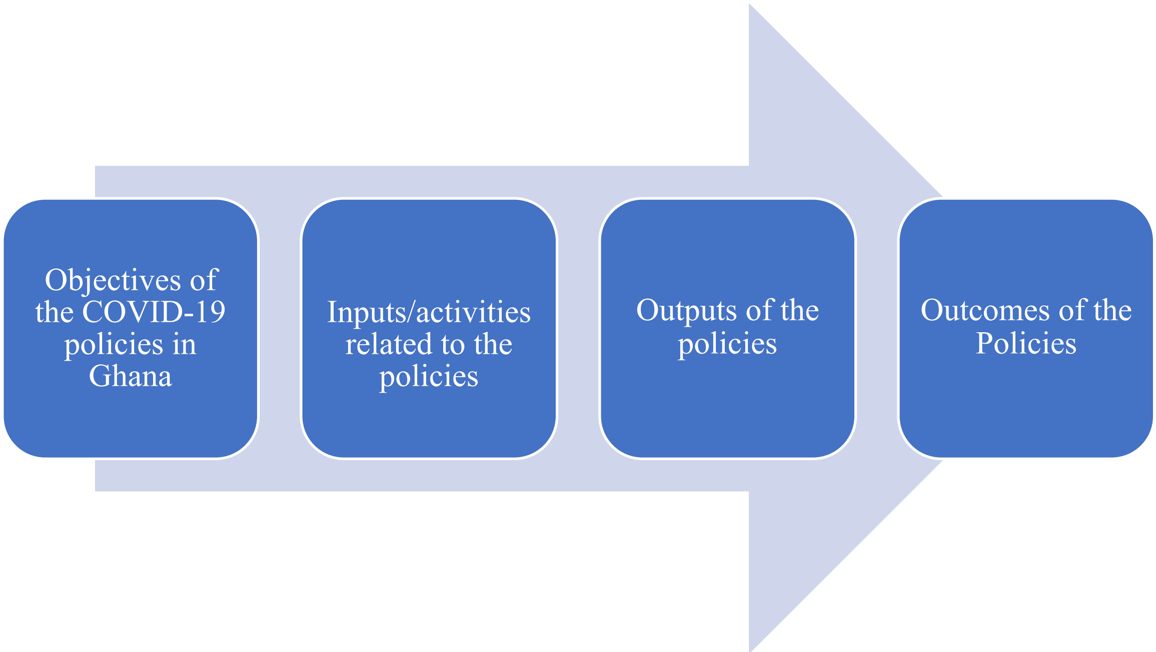

Figure 11: The Logic model.

There are several evaluation approaches to assess a policy's effectiveness. These methods include the process evaluation, cost-effectiveness analysis, and outcome evaluation methods, (Christie & Lemire, 2019). The process evaluation evaluates the performance of a policy during its operation to ascertain whether it is being implemented as planned while a cost-effectiveness analysis assesses the value for money of a policy (Tama et al., 2018; Vergue et al., 2016). The outcome evaluation evaluates the effectiveness of an implemented policy per its objectives (Langley et al., 2021). It compares the actual outcomes of the policy against its set objectives to inform further policy directions (Langley et al., 2021). This objective of outcome evaluation approach aligned with the aim of this assessment, making it the appropriate evaluation method for this chapter. Despite its strength of being an empirical method, outcome evaluation is restricted in quantifying an outcome that can be attributed to the intervention or policy (Woodhouse et al., 2015). However, this challenge can be addressed when there is comparable data. The availability of comparable data could also address issues of counterfactuals – what would have happened if the policy was not implemented (Prüss-Ustün et al., 2019). Thus, where possible, comparable data were used to determine outcomes attributable to the policy response.

5.2.2 Data Source

A deep dive multi-method approach was used to search and identify key COVID-19 policy responses in Ghana from the literature. First, the Scopus database was searched for published articles on COVID-19 policies using a combination of the following search terms: 'COVID-19', 'coronavirus' 'policy*', 'mitigating policy*', 'policy response*', 'Ghana'. The Scopus database was preferred because it is the largest database of peer-reviewed journals in diverse fields, including social sciences, medicine and technology, areas that are likely to capture the required COVID-19 policies, particularly given the nature of the policies (Baas et al., 2020). Moreover, it keeps the records of articles found in other databases, notably EMBASE, PubMed and Medline. Therefore, its singular use was justified in this study due to its comprehensiveness. Second, the Google database was searched for generic articles using a combination of the above search terms. Third, specific websites, including the WHO, Worldometer and GOG websites, and local news agencies, were searched for reports on COVID-19 policy responses in Ghana. The GOG websites were the GHS, MoH, Ministry of Education (MOE), Ministry of Information (MOI) and the Ministry of Finance (MoF) databases. The local media houses included Citi Fm, TV3 and Joy news, documented reputable local news agencies in Ghana. Additionally, other related audio-visuals on COVID-19 policies, like recordings for government press and media engagements, were included in this study. The search was not date restricted. This was to ensure the inclusion of all relevant policies, especially as the COVID-19 policies are not dated.

5.2.3 Data Analysis

Data were analysed at two levels, qualitative content analyses and correlation analyses. The qualitative content analyses were conducted to assess the effectiveness of the COVID-19 policy responses by mapping the set objectives of the policy against its intended outputs and actual outcomes using the logic model. This policy analysis/evaluation approach is documented in the literature (Antwi-Boasiako et al., 2021; Hall & Steiner, 2020; Garbarino & Holland, 2009; Judd & Randolph, 2006). As indicated earlier, data for the content analysis were collected from multiple sources, aligning with the content analysis methodology (Bengtsson, 2016). However, given that the source and depth of the data could affect the depth of the evaluation findings (Bengtsson, 2016), the identified data from generic sources were verified with data from the other sources, like the peer-reviewed articles sources. This double verification helped address errors and bias associated with unconfirmed and unsupported data (Krippendorff, 2018). In the analysis, sentences, phrases or words regarding a COVID-19 policy in Ghana, its duration, objectives, related activities/inputs, outputs and outcomes were extracted from identified articles. Next, the common phrases or words were compared and combined to represent the objectives, inputs, outputs and outcomes of the policy. While accessing the policies' outcomes the researcher was also cognizant of possible unintended outcomes. These unintended outcomes were also extracted and synthesised where necessary. Finally, following the logic model, the objectives, inputs and outputs of the policies were compared with their outcomes to assess their overall effectiveness on the COVID-19 burden.

The content analysis process was guided by the deductive content analysis approach, which helped the researcher remain focused on addressing the research question (Elo & Kyngäs, 2008). While this approach is critical, given that the bulkiness of qualitative data could sway researchers from the planned research trajectory (Graneheim et al., 2017), it could result in 'leftover data', whose exploration could inform enriching discourses. However, such leftover data may not necessarily provide new insights, and they may even lead to convoluted arguments that might leave the primary research questions unanswered (Graneheim et al., 2017). Therefore, comparatively, the deductive approach was best suited for this analysis, justifying its adoption.

Following the content analysis, a 3–score (0 – 2) valuation measure was used to estimate the policy's effectiveness. In the valuation, '0' was given when a policy failed to meet the objectives, '1' when some of the objectives were met and '2' when all objectives were met. Consequently, policies with '0' score were considered ineffective, those with '1' were perceived as somewhat effective, and those with a score of '2' were termed effective. Prior to the policy scoring, the valuation approach was discussed and agreed upon with an independent reviewer. The valuation measure became necessary in this chapter to provide a comprehensive and objective measure of the policy's effectiveness per its objectives, and this approach was adapted from an FCTC 2030 evaluation report by Siddiqi et al. (2023).

Apart from the objectives, inputs, outputs and outcomes of the policies, other policy characteristics, precisely the duration and type of policy, were also extracted from the identified data. After the extraction, distinct data categories were created based on the policy type and duration. For the policy duration, the categories were policies below and above six months, and for the policy type, the groups were social and economic interventions. These data informed the second-level analysis, i.e., correlational analysis. The correlation analysis was conducted to examine whether the policy type and duration influenced the policy's effectiveness. The Fisher exact test was used for the correlation analysis, given the relatively small number of policies sample (Kim et al., 2017). In the analysis, an effective policy was defined as one whose actual outcomes met or exceeded the set objectives (Czaika & De Haas, 2013). It was initially assessed based on the valuation measure described above, i.e., effective, somewhat effective, and ineffective. However, given the outcomes of the content analysis, the effectiveness was classified into dichotomous groups, i.e., effective, and somewhat effective. The effective policies were coded '0', and the somewhat effective policies were coded '1'. The explanatory variables included in the correlational analysis were policy duration ($\geq$ 6 months [coded '0'] and < 6 months [coded '1') and policy type (social [coded '0'] and economic [coded '1'] interventions). The analysis was conducted with the SPSS software version 26, and statistical significance was set at $p > 0.05$. See table 24 for a summary of data sources and types of analysis conducted.

Table 24: Policy mapping, data sources and the type of analysis

Policy mapping	**Data source**	**Type of analysis**
Policy objectives	Published literature, WHO, GOG data archives, local media reports and other related audio-visual recordings.	Qualitative content analysis
Inputs/Activities (Includes all inputted resources and activities)	Published literature, WHO, GOG data archives, local media reports and other related audio-visual recordings.	Qualitative content analysis
Outputs (Intended policy changes)	Published literature, WHO, GOG data archives, local media reports and other related audio-visual recordings	Qualitative content analysis

Policy mapping	Data source	Type of analysis
Outcomes (i.e., what the policies achieved)	Published literature, WHO, GOG data archives, local media reports, worldometer and other related audio-visual recordings	Qualitative content analysis
Policy effectiveness (i.e., the policy's gains when the objectives, inputs, outputs and outcomes are compared, e.g., decreased COVID-19 prevalence/incidence, and moratlity).	Published literature, WHO, worldometer, GOG data archives, COVID-19 infectious centres, local media sources. Experts' analysis (chapter 6)	Qualitative Content analysis Quantitative and qualitative analysis
Other Analytic Considerations		
Attribution of outcomes	Published literature, WHO, worldometer, GOG data archives, COVID-19 infectious centres, local media sources. Experts' analysis (chapter 6)	Narrative synthesis Quantitative and qualitative analysis

5.3 Results

5.3.1 Findings of the Content Analysis

Eight key COVID-19 policy responses were identified in the literature. They included partial lockdowns, public awareness campaigns, bans on public gatherings, vaccination, border closures, compulsory COVID-19 entry border screening, Ghana COVID-19 Alleviation and Revitalisation of Enterprises Support (GCARES) and government incentives for healthcare workers (HCWs). Most of the policies were social interventions (n = 6) and were implemented for six months and above (n =7). Regarding their effectiveness, the content analysis found the public awareness campaigns, COVID-19 entry border screening, entry border closures, and the incentives for HCWs as 'effective' policies per their set objectives. In contrast, the analysis identified the bans on public gatherings, vaccination, GCARES, and the partial lockdown policies as 'somewhat effective' per their set objectives. Table 25 and Figure 12 below show the policies' characteristics and effectiveness, respectively. The subsequent texts detail the findings of each policy.

Table 25: Characteristics of the COVID-19 policy responses

COVID-19 policy response	Policy type	Policy duration
Partial lockdown	Social intervention	<6 months
Public education and awareness campaigns on COVID-19	Social intervention	≥ 6months
Bans on public gathering	Social intervention	≥ 6months
Vaccination	Social intervention	≥ 6months
Border closures	Social intervention	≥ 6months
COVID-19 entry border screening	Social intervention	≥ 6months
Incentives for HCWs	Economic intervention	≥ 6months
GCARES	Economic intervention	≥ 6months

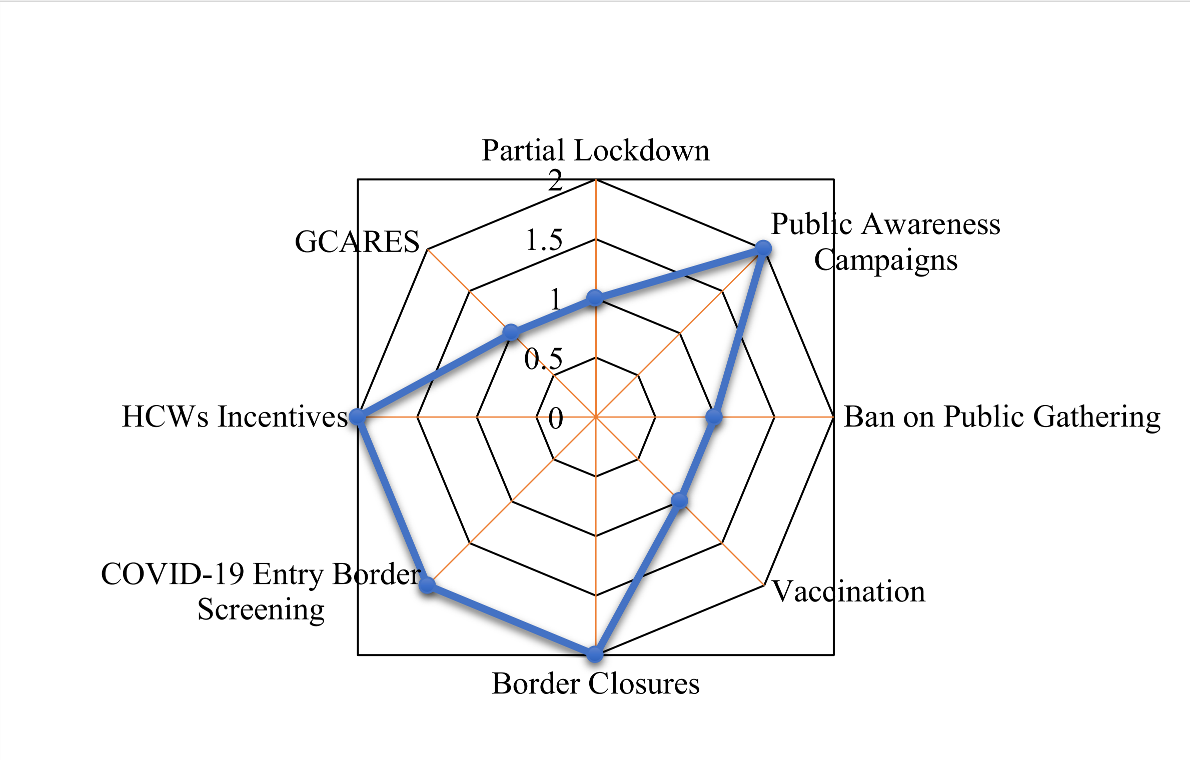

Figure 12: Effectiveness of the COVID-19 policy responses.

Note: 0 – Policy was ineffective; 1 – Policy was somewhat effective; 2 – Policy was effective.

5.3.1.1 Partial Lockdown

5.3.1.1.1 Context and Inputs/Activities

A partial lockdown policy was implemented in two major metropolises in Ghana – Greater Accra and Kumasi (identified as COVID-19 epicentres) from 30th March 2020 to 20th April 2020 to reduce the burden of the COVID-19 disease (MoH, 2020). The nature of the lockdown suggested that individuals in the targeted cities could access essential services, like food, pharmacy and banking services when needed, and members of the executive, judiciary, legislative, and media could operate. The security agencies were tasked to enforce and ensure the policy's compliance. The objective of the lockdown was to halt the spread of the virus, enhance disease surveillance and scale up COVID-19 testing capacity (The Presidency – Ghana, 2020). Before implementing the partial lockdown policy, 152 COVID-19 cases had been recorded, and this number increased to 1,042 when the lockdown was lifted, an 85% increase in the pre-lockdown case count (Worldometer, 2020). In addition, there were recorded unintended outcomes of the partial lockdown; notable among these were job losses for individuals and institutions, social exclusion, and severe economic hardship for people with low incomes (Smith & Quartey, 2020; Amewu et al., 2020). According to the president of Ghana, the enhanced COVID-19 testing capacity of the country and some of the unintended outcomes informed the lifting of the partial lockdown (Zurek, 2020). Regarding whether the policy's objectives were met, disease surveillance was enhanced, and testing capacity was scaled-up to some degree during the lockdown, but the viral spread was not halted. The objectives and outcomes of the partial lockdown policy are mapped below.

Partial Lockdown

Objectives	1. Halt the spread of the COVID-19 virus. 2. Enhance COVID-19 disease surveillance through contact tracing. 3. Scale-up COVID-19 testing and treatment capacities
Intended outputs	Reduced COVID-19 transmission. Scaled-up COVID-19 testing capacity and improved turnaround time for COVID-19 testing. Equipped health facilities for COVID-19 treatment.
Outcomes	**Halt the spread of the virus:** Before the partial lockdown policy, the number of COVID-19 cases was 152 (30/03/2020). This number had increased to 1,042 on 20/04/2020 when the lockdown was lifted, indicating an 85% increase in the case count (GHS, 2020;

	Worldometer, 2022). The increase in cases was attributed to intensified contact tracing, which was the second objective of the lockdown and testing backlog (GHS, 2020). Data also suggests that the increased in the number of cases could be attributed to the policy since it did not allow with the housing characteristics in Ghana (Khoo, 2020). The cases continued to rise steadily even after the lifting of the lockdown (Worldometer, 2022) **Enhance COVID-19 disease surveillance through contact tracing:** COVID-19 disease surveillance was heightened through enhanced contact tracing during the lockdown. Many of the contacts of the identified active COVID-19 cases were traced and tested (GHS, 2020). About 63% of active COVID-19 cases were identified through contact tracing (Kenu et al., 2020). **Scale-up COVID-19 testing and treatment capacities:** Before and during the partial lockdown, only two public laboratories, i.e., the Kumasi Centre for Collaborative Research (KCCR) and Noguchi Memorial Institute for Medical Research (NMIMR), were equipped to test for COVID-19 (GHS, 2020). The combined testing capacity of the laboratories before the lockdown was about 300 tests per day, and this doubled during the lockdown due to the adoption of 'pool testing system, where tests were conducted in groups of 10s instead of individuals (GHS, 2020). However, there were significant sample backlogs by the two labs during and post-lockdown, which affected the testing turnaround time considerably (Antwi-Boasiako et al., 2021; Ampofo, 2020). The pooling method was later abandoned when the case positivity rate increased (Sarkodie et al., 2020). Six hospitals were allocated for the management of COVID-19 during the lockdown, with one earmarked as the main treatment centre. Isolation and quarantine centres were also allocated in major cities during the lockdown period, with assistance from churches and private entities (Sarkodie et al., 2020). Capacity training was provided for the staff of these hospitals on COVID-19 testing, treatment, and appropriate use of Personal Protective Equipment (PPEs) (Sarkodie et al., 2020). These facilities, however, faced inadequate PPEs during the lockdown period which affected their management of COVID-19 patients (Quakyi et al., 2021).

5.3.1.2 COVID-19 Public Awareness Campaigns

5.3.1.2.1 Context and Inputs/Activities

Public education and awareness campaigns on COVID-19 were implemented in Ghana before the country recorded its first two cases on 12th March 2020 (The Presidency – Ghana, 2020). In the early stages of the COVID-19 outbreak, the education campaigns centred on public adherence to COVID-19 preventive practices (Khoo, 2020). The public was regularly reminded in several local languages through radio, TV and social media campaigns to wear face coverings in public, practice social distancing and coughing etiquette, and wash hands frequently (Smith & Quartey, 2020). They were also given practical training on appropriate hand-washing techniques, using sanitisers, and wearing and disposing of face coverings (Sibiri, 2021). The key agent in these education campaigns was the President. He regularly encouraged the public to adhere to the preventive protocols and updated them on the government's efforts to curtail the disease through frequent speeches through mass media. In one of his speeches, he made a passionate statement, "We know how to bring the economy back to life…. what we do not know is how to bring people back to life" (The Presidency – Ghana, 2020), which inspired and invoked a sense of public responsibility towards the fight against the virus.

Apart from the President, other agents, including health workers, the media, telecommunication companies, public figures, and traditional & religious leaders, were involved in the COVID-19 education campaigns (Kenu et al., 2020). Public institutions, like the GHS, also created COVID-19 databases for the 24/7 dissemination of COVID-19 information. However, regardless of these intensified campaigns, there were cases of public non-compliance, which warranted the need for campaign message evaluation to invoke a sense of public urgency toward the fight against the virus (Khoo, 2020; The National Commission for Civic Education (NCCE) – Ghana, 2020). As the COVID-19 disease advanced, the education campaigns began to focus on demystifying the COVID-19 disease, ensuring social inclusion of recovered individuals and promoting COVID-19 vaccine uptake. However, there were still reported COVID-19-related stigmatisations, like discrimination, social exclusion, and stereotyping (Atinga et al., 2021; Adom et al., 2021), and poor public engagement or education on COVID-19 vaccination, resulting in low vaccination uptake (Quakyi et al., 2021). In summary, data suggests that the COVID-19 awareness campaigns met its objective of creating public awareness of COVID-19, ensuring public adherence to COVID-19 prevention protocols and providing mass education on COVID-19 vaccination. The policy's objective and outcomes mapping are presented below.

COVID-19 Public Awareness Campaigns

Objectives	1. Create public awareness of COVID-19. 2. Ensure public adherence to COVID-19 prevention protocols 3. Public education on COVID-19 vaccination.
Intended outputs	Informed public about COVID-19. Enhanced COVID-19 protocol adherence. Increased knowledge on COVID-19 vaccination.
Outcomes	**Create public awareness of COVID-19:** There were mass media campaigns in local dialects on COVID-19 by advocacy groups (Smith & Quartey, 2020) and regular updates on COVID-19 on all government portals (MOH, 2020; GHS, 2020). Telecommunication companies also used push SMS to educate the public about COVID-19 (Khoo, 2020). Data showed that about 97% of Ghanaians knew about the COVID-19 disease and the COVID-19 emergency centre (Serwaa et al., 2020). The public could access COVID-19 information from multiple sources, including radio, TV, health personals and social media (Adu-Gyamfi & Asante, 2022), with the internet being the major source of information (Serwaa, 2020). The accessed information included COVID-19 causes, symptoms, effects, and preventive measures (Adu-Gyamfi & Asante, 2022). The study by Dubik et al. (2021) showed that COVID-19 education significantly influenced COVID-19 knowledge [AOR = 0.23; 95%CI = 0.01– 0.55]. Notwithstanding, there were also reported cases of misinformation, mostly channelled through social media, friends and families (Adu-Gyamfi & Asante, 2022; Tabong & Segtub, 2021), and COVID-19-related stigmatisation (Adom et al., 2021). The intensity of the COVID-19 education campaigns declined steadily post 2020. **Ensure public adherence to COVID-19 prevention protocols:** There were government and institutional directives on compulsory adherence to the preventive protocols, such as wearing nose masks and hand hygiene directives (Dzisi & Dei, 2020). However, studies demonstrate low public adherence to the COVID-19 protocols, especially on hand washing, social distancing and wearing face masks (Apanga & Kumbeni, 2021; Apanga et al., 2021; Dzisi & Dei, 2020; Fielmua et al., 2021). The low adherence to the protocols was

	linked to decreasing advocacy and awareness of COVID-19 by relevant agents, including the GOG (NCCE, 2020). **Public education on COVID-19 vaccination:** Education and awareness campaigns on vaccines were promoted by government agencies and health officials (GHS, 2020, Quakyi et al., 2020). Government officials took vaccines in public to create awareness of their safety (Quakyi et al., 2020). Regular vaccine information was also provided on the GHS website. However, media campaigns on vaccine education were reportedly low (Quakyi et al., 2020).

5.3.1.3 Ban on Public Gathering

5.3.1.3.1 Context and Inputs/Activities

On 15th March 2020, the President of Ghana announced a ban on public gatherings due to COVID-19. The ban included the closure of schools. In his televised speech, the President indicated that the ban was to curtail COVID-19 transmission to protect the population from getting infected (The Presidency – Ghana, 2020). The ban, which came into force the next day, suspended university, high and primary school activities and banned conferences, festivals, workshops, political rallies, religious activities, sporting events and all other social events for one month. However, private burials with a maximum of 25 attendees were permitted. Initially, the ban was imposed for four weeks and was extended until 5th June 2020, when the President eased the restrictions, citing low mortality and morbidity rates as reasons for the decision (The Presidency, 2020; Sibiri et al., 2021). Social activities, including conferences, workshops, and religious activities, were allowed with a maximum of a hundred persons following the lifting of the ban, and schools were reopened in batches for academic activities from 15th January 2021. However, in February 2021, the President re-introduced all the initial restrictions on public gatherings following a surge in COVID-19 cases (The Presidency, 2021). Generally, the enforcement of the public gathering ban was porous, resulting in several violations by individuals, government officials and religious leaders and members (Yeboah et al., 2020; Smith & Quartey, 2020). Additionally, the school closures resulted in significant learning loss and deepened social inequalities (Sabates et al., 2021). The President finally lifted the bans in March 2022. The policy mapping is illustrated below.

Ban on Public Gathering

Objectives	To protect the population from COVID-19 infection
Intended outputs	Reduced COVID-19 infections
Outcomes	**Protect the population from COVID-19 infection:** From March 2020 to March 2022 (the period of the ban policy), the incidence of COVID-19 infections showed a fluctuating trend, with the highest number of daily new cases (N = 2,521) recorded within the ban operationalisation. However, the reported high daily COVID-19 incidences during the public gathering ban period could have been influenced by spill overs from before the ban's imposition due to the observed delays in laboratory testing and case reporting. The reported daily COVID-19 numbers could also be higher than the actual daily case counts because of observed case under-reporting during the ban period (Khoo, 2020). Accordingly, these reasonings limit the assessment of the actual influence of the ban on COVID-19 transmission. Evidence from Ofori et al. (2022) showed that COVID-19 transmission did not decline following the bans on social gatherings, and relaxing the ban did not increase COVID-19 transmission. Therefore, by inference, the imposition or relaxation of the public gathering ban did not influence COVID-19 transmission. Reopening schools, however, increased the COVID-19 transmission rate in some regions of Ghana (Ofori et al., 2022). Several reports also allude to ban violations, especially by religious groups and government officials during the ban period, which may have increased COVID-19 transmission (Yeboah et al., 2020; Smith & Quartey, 2020; Adom et al., 2020; Khoo et al., 2020). For example, a survey by Durizzo et al. (2021) showed that only 24% of Ghanaians maintained a safe distance in public while the ban on social distancing was in place. However, no data estimating the proportions of COVID-19 infections attributable to the ban's violation was identified in the literature.

5.3.1.4 Vaccination

5.3.1.4.1 Context and Inputs/Activities

Ghana began mass COVID-19 vaccination on 1st March 2021 after receiving 600,000 doses of AstraZeneca on 24th February 2021 (Acheampong et al., 2021). The objective of the mass vaccination was to reduce the COVID-19 burden through vaccination-induced population-level (herd) immunity (GHS, 2021). To achieve COVID-19 herd immunity, Ghana needed to fully vaccinate about 60 – 70% of the vaccination-targeted population (WHO, 2020). Therefore, the President of Ghana aimed to fully vaccinate more than 60% of its 18.2 million Ghanaians aged ≥15 (target population) by the end of June 2022 to achieve herd immunity (The Presidency, 2022; GHS, 2023; Kyei-Arthur, 2023). As of 29th April 2022, Ghana had fully vaccinated 13% of its target population (WHO, 2023). This suggests that as of April 2022, 2,366,000 of the target population had received two doses of a COVID-19 vaccine. By extrapolation, between March 2021 and April 2022 (a 13-month period), Ghana fully vaccinated 182,000 persons per month. Based on this extrapolation, Ghana would have fully vaccinated 2,730,000 persons by the end of June 2022. This June 2022 projection would mean a 15% full vaccination uptake, 45% shy of the President's 60% minimum target. Therefore, by inference, Ghana may not achieve its herd immunity aim by June 2022. While vaccine inequity could be driving the observed lower number of fully vaccinated persons in Ghana, other data suggest vaccine hesitancy could be responsible for the relatively lower full vaccination uptake (Okai & Abekah-Nkrumah, 2022; Quakyi et al., 2021).

As of 30th June 2023, a year after the June 2022 target, Ghana had fully vaccinated 10,819,341 of its targeted population, representing 59% full vaccination uptake. While this is still 1% lower than the President's and the WHO's minimum population target to achieve herd immunity, it is 46% higher than the April 2022 uptake, indicating significant progress in full vaccination uptake since April 2022. Given this progress, it is possible that Ghana could achieve herd immunity by the end of 2023 if it enhances its vaccination effort. The vaccination policy evaluation herein assessed whether the policy has achieved its herd immunity target and aim. It did not assess whether the policy reduced the probability of COVID-19 infections and subsequent outcomes. Therefore, the policy's effectiveness rating was based solely on its herd immunity aim and not on its impact on COVID-19 infection and mortalities. The reported effectiveness findings must, therefore, be interpreted as such. The vaccine policy mapping is illustrated below.

COVID-19 Vaccination

Objectives	To reduce COVID-19 disease burden through vaccine-induced herd immunity
Intended outputs	Vaccine-induced herd immunity against the COVID-19 disease burden

Outcomes	**To reduce the COVID-19 disease burden through herd immunity:** The proportion of vaccinated Ghanaians as of 30th June 2023 was 59% (GHS, 2023), 1% shy of the June 2022 target. Findings from Acheampong et al. (2021) reveal that about half of the Ghanaian population >15 years indicate that they will take the vaccine when made readily available. This finding implies that just about half may not take the vaccine when readily available, indicating potential vaccine hesitancy which could impede the government's efforts at herd immunity. Several studies have reported vaccine hesitancy among Ghanaians, ascribing it to fear, religious beliefs, mistrust, poor communication, and safety issues (Quakyi et al., 2021; Alhassan et al., 2021; Lamptey et al., 2021; Agyekum et al., 2021). The total number of COVID-19-related deaths as of 1st March 2021, when the mass vaccination began, was 607. This number had increased to 1,462 as of 21st May 2023, showing 855 mortalities since the vaccination began (GHS, 2023, 2023; WHO, 2023). The 607 reported deaths were in the space of 12 months (between 12th March 2020 and 1st March 2021), representing approximately 51 deaths per month. The 855 additional deaths were also in the space of 26 months (2nd March 2021 to 10th May 2023), representing about 33 deaths per month. Therefore, by inference, the number of reported COVID-19-related deaths has decreased by about 35% since the vaccination policy began. However, this observed decrease cannot be attributed to the vaccination policy alone, as no empirical data currently supports such attribution.

5.3.1.5 Border Closures

5.3.1.5.1 Context and Inputs/Activities

On 15th March 2020, the GOG announced a non-admittance restriction on other nationals travelling from countries with over 200 confirmed COVID-19 cases, except those with resident permits (Duncan, 2020). Additionally, mandatory 14-day quarantine was instituted for all passengers allowed into the country within that period, with the government bearing the cost of the quarantine. During this restriction period, Ghanaians domiciled in other countries were encouraged to return to the country by the government (Duncan, 2020). The travel restriction continued until 22nd March 2020, when all borders, including air, sea and land, were completely closed to all outbound and inbound travellers; however, the movement of Cargo, essential goods and supplies was not restricted (Adogla-Bessa, 2020). The border closure and travel restrictions were to reduce COVID-19 prevalence by preventing case importation. This policy was complemented by the partial lockdown policy of the COVID-19 epicentres to contain the COVID-19 community spread and scale-up testing and treatment capacities (The Presidency, 2020). In September 2020, the air travel restriction was lifted, but the restrictions on land borders remained until April 2022. Studies report that the travel restrictions reduced COVID-19 case importations but also resulted in dire economic consequences, including job losses and import duties shortfall (Owusu et al., 2022; Sarpong & Obeng, 2020). The border closures policy mapping is shown below.

Border Closure

Objectives	To prevent COVID-19 case importation
Intended outputs	Reduced COVID-19 prevalence
Outcomes	**Prevent COVID-19 case importation:** The first two COVID-19 cases confirmed on 12th March 2020 were imported cases, which increased to 105 by mid-March 2020, necessitating border closures (GHS, 2020). The borders were opened for air travel on 1st September 2020. Data shows 705 imported cases were recorded from March 2020 to December 2020 (Sarkodie et al., 2020). This data suggests that 645 COVID-19 cases were imported after lifting the air travel restrictions, i.e., from September to December 2020, as 105 imported cases had already been reported pre-border closure. By estimation, an average of 161 cases were imported monthly for the first four months after lifting the border closure restrictions. By extrapolation, this could also mean that about 161 cases per month, representing 805 cases for the period between the ban imposition (March – September; 5 months), were averted by the policy. The observed decrease in COVID-19 importation by air alone was also corroborated by the literature (Sibiri et al., 2020; GHS, 2020). Findings from an interrupted time series analysis, however, showed that the border closures did not reduce the incidence of COVID-19 in Ghana during the period of policy imposition (Emeto, 2021). This incidence was, however, from community spread and not case importation.

5.3.1.6 Compulsory COVID-19 Entry Border Screening

5.3.1.6.1 Context and Inputs/Activities

Prior to the re-opening of air borders, Ghana introduced compulsory COVID-19 screening at the main international airport, the Kotoko International Airport (KIA), in September 2020 (The Presidency., 2020). This policy aimed to detect and isolate imported COVID-19 cases at entry points to reduce the spread of COVID-19 and decrease its prevalence. As part of the policy's operationalisation, GOG installed testing laboratories at the airport, recruited key health workers and provided relevant training for airport staff and international airline operators (Sarkodie et al., 2020). It also established a holding centre for positive cases and developed a road map for conveying positive cases from the airport holding centres to COVID-19 treatment centres (Khoo, 2020). However, passengers with negative COVID-19 test results at the airports were allowed to enter the country without self-quarantine requirements. The immuno-fluorescent antigen test, with about 30 minutes turnaround time, was used for the COVID-19 screening at the airport to ensure test results readiness by the time the passengers had completed the immigration processes (Sarkodie et al., 2020; Khoo et al., 2020). Apart from the airport testing, passengers were mandated to present a negative PCR test result from their country of embarkment (Sarkodie et al., 2020). However, the compulsory COVID-19 entry screening was not extended to land borders as they remained closed until March 2022. The compulsory entry screening was suspended when the land borders were finally opened for outbound and inbound travel (The Presidency, 2022). The compulsory COVID-19 entry border screening policy mapping is shown below.

Compulsory COVID-19 Entry Border Screening

Objectives	To detect COVID-19 and isolate imported COVID-19 cases
Intended outputs	Reduced COVID-19 disease burden
Outcomes	**Detect and isolate imported COVID-19 cases:** The on-arrival COVID-19 screening contributed to active COVID-19 case identification (GHS, 2020). Infographics from GHS showed that the COVID-19 testing at KIA identified and isolated 7,701 active cases during the policy's implementation period (GHS, 2020). However, it cannot be established whether the policy was sufficient in reducing COVID-19 infection transmission, particularly as a negative test at the point of entry may not indicate a 'true' negative COVID-19 status, given the influence of viral incubation periods on test results (Mina & Anderson, 2021). Nonetheless, the analysis did not find any study reporting on passengers with negative COVID-19 results from the airport who tested positive within 14 days post-entry. Also, such findings could be a function of the sensitivity of the testing kit and not entirely the policy's impact (Chau et al., 2020).

5.3.1.7 Government Incentives for Healthcare Workers (HCWs)

5.3.1.7.1 Context and Inputs/Activities

In March 2020, Ghana's health minister announced incentive packages for healthcare workers to enhance its healthcare workforce to fight against the COVID-19 outbreak (MOH, 2020). The incentives were to motivate the healthcare workers to sustain their numbers for the fight against the COVID-19 outbreak The packages included about US$60,000 in insurance coverage per person, free transportation and 50% of the basic salary allowance for all frontline workers, and tax-free salaries on employee emoluments for all health workers (MOH, 2020). These financial packages were rolled out from April 2020 to December 2020 (Amponsah et al., 2021; Arku, 2020). While providing these incentives, the government also recalled staff on approved study leave to return to work to avoid potential psychological impacts, like staff burnout and anxiety on those who were in active work (GHS, 2020). In addition, over 45,000 healthcare workers were recruited from March 2020 to November 2022, increasing the health worker capacity by about 35% (Asamani et al., 2022). By the end of 2020, Ghana had spent about US$35 million on health workers' financial packages and recruitment to sustain and boost its workforce capability against the COVID-19 outbreak (Asamani et al., 2022). Regardless of the increase in the healthcare workforce, about 6% and 11.4% of the health workers reported having experienced mild COVID-19-related anxiety and depression, respectively (Ofori et al., 2021). Similarly, about 20% and 4% of healthcare workers experienced high burnout and stress (Afulani et al., 2021). These reported psychological concerns were also corroborated by Darkwah (2022) and Arthur-Mensah et al. (2022). Ofori et al. (2021) mentioned that the psychological impacts experienced by health workers lessened with the government's financial packages. However, other similar studies did not report this observed influence of the financial packages on the psychological experiences of health workers (Asamani et al., 2022). There was generally, a limited information on the policy and its effect in both the peer-reviewed and grey literature. The incentives for HCWs policy mapping is demonstrated below.

Incentives for HCWs

Objectives	To widen the healthcare human resource capital against COVID-19
Intended outputs	Increased healthcare workers capacity

Outcomes	**To widen the healthcare human resource capital against COVID-19:** The incentive packages, staff recall, and related capacity training increased the number of healthcare workers by 35% (Asamani et al., 2022; Sarkodie et al., 2020; MOH, 2020). However, the government of Ghana did not indicate its estimated proportion of healthcare workforce growth for the defined period. Therefore, the study could not assess whether the 35% boost in the health workers' capacity aligns with the government's growth target. Nonetheless, the policy widened the healthcare human capital to manage the COVID-19 outbreak.

5.3.1.8 Ghana COVID-19 Alleviation and Revitalisation of Enterprises Support (GCARES) Program

5.3.1.8.1 Context and Inputs/Activities

Ghana established GCARES in May 2020 to stimulate economic recovery from the COVID-19 impact (The World Bank, 2020). The three- and half-year program was rolled out into two phases. The first phase focused on revamping the economy through tax exemptions, reduced cost of essential services and provision of loans up to 600 million cedis with two years repayment schedule for informal and formal Micro, Small and Medium-scale Enterprises (MSMEs) (MoF), 2020). In the loan operationalisation, enterprises were required to register for loans through the National Board for Small Scale Industries (NBSSI) website (Kwofi, 2020). According to Kwofi (2020), about 8,000 applicants had registered to access the loan to revamp their businesses as of 21st May 2020. The first phase ended in July 2020. The second phase, launched for three years (2021-2023), aimed to transform Ghana's economy through revived industries, such as manufacturing, construction, digitalisation and agri-business (MoF, 2020). Essentially GCARES policy provided stimulus packages to MSMEs to minimise the economic impact of the COVID-19 outbreak on individuals and institutions (MOF, 2020). The policy was supported by the International Monetary Fund (IMF) with a loan of one billion US dollars (Amewu et al., 2020). See below for the GCARES policy mapping.

GCARES Program

Objectives	To mitigate the COVID-19 economic impact by stimulating economic growth in Ghana
Intended outputs	Revamped and sustainable economy
Outcomes	**To stimulate economic growth:** According to GSS, the Gross Domestic Product (GDP) in the fourth quarter of 2021 (7%) was higher than the previous year's GDP (4.3%), indicating marginal economic growth (GSS, 2022). However, data indicate that the benefit of GCARES was more inclined towards the elites and middle-class citizens, further worsening the social inequality gap (Duho & Kauppinen, 2021). Other sectors, especially the private education sector, also continue to reel from the COVID-19 economic impact as they were not fully captured in the GCARES program (Antwi-Boasiako et al., 2021). This information was corroborated by Foli & Ohemeng (2022), whose report showed that GCARES did not include MSMEs in the informal sector. In addition to the inequalities, the loan disbursement process was also fraught with prolonged turnaround time, which impacted business operations (Antwi-Bosiako et al., 2021). Aidoo et al. (2021) also indicate that loans were inadequate for Small and Medium Enterprises (SMEs) to recover from the COVID-19 economic impact. The world bank projects that Ghana's economic growth will decline by 5.5% in 2022. In addition, the 2020 fiscal (15.2%) and public (81.1%) debts could further plummet the anticipated 2022 declining economic growth (The World Bank, 2022).

5.3.2 Findings from the Correlation Analysis

The Fisher correlation analysis findings showed that the policy response type was unrelated to the effectiveness of the policy (Correlation coefficient = 0.00; p = 0.79). However, the duration of the policy was associated with the policy's effectiveness (Correlation coefficient = 1.14), but the association was insignificant (p = 0.50). The findings from the Fisher analysis are shown in table 26 below.

Table 26: Findings from the Fisher correlation analysis

Policy characteristics	Correlation coefficient	p-value
Type of policy	0.00	0.79
Policy duration	1.14	0.50

5.4 Discussion

This chapter used a logic model, qualitative content analysis and Fischer tests to evaluate Ghana's COVID-19 policy responses. The policies were evaluated against their set objectives to avoid potential bias that could be introduced by including non-intended objectives. Eight policy responses were identified through an exhaustive generic and peer-reviewed literature search. They included a partial lockdown policy in two metropolises, bans on social gatherings, education campaigns, incentives for HCWs, and COVID-19 vaccination. The content analysis found the public awareness campaigns, HCWs incentives, border closures and the COVID-19 entry border screening policies as effective policies, and the GCARES, partial lockdown and bans on public gatherings as 'somewhat effective' policies. Observably, some of these policies were complementary, had similar intended outcomes and were implemented around the same time, therefore, blurring possible attribution of policy outcomes to specific policies. For example, the partial lockdown and bans on social gatherings policies, implemented around the same time, had the same intended outputs of reducing the prevalence and risk of COVID-19. This similarity posed a challenge in attributing specific COVID-19 outcomes to specific policies. Also, the time difference data between the duration of the two policies were insufficient to provide indications for policy-outcome attributions (Fuller, 2021). Nevertheless, the content analysis revealed that none of these policies reduced COVID-19 infections and during their implementation period, indicating that observed outcomes regarding reduced COVID-19 infections and prevalence may not be attributed to them.

Based on the evaluation's findings, the partial lockdown's objective to halt the transmission of COVID-19 was not met, given the number of recorded new cases in Ghana during and even after the lockdown was lifted (Worldometer, 2020). However, it is unclear whether the number of cases during and after the lockdown reflects the observed delays in reporting the daily new COVID-19 cases (Ofori et al., 2022), suggesting that the observed cases may be cumulative

COVID-19 cases before the policy was imposed. Nonetheless, there was also evidence of under-reported COVID-19 cases, implying that the reported cases during and after the lockdown were probably more than documented. However, these dynamics remain debatable as no empirical data showing the actual number of COVID-19 cases associated with the imposition or lifting of the lockdown policy was found in the literature. More importantly, it is uncertain whether the lockdown policy was aimed to halt COVID-19 transmission in only the locked-down metropolises, particularly as some of the recorded cases during the policy period were from areas that were not under the lockdown (Kenu et al., 2020). Assuming the policy aimed to halt COVID-19 transmission in the locked-down metropolises, the objective was still unmet, as evidence indicates that a significant number of the new COVID-19 cases recorded during the policy period were from the lockdown areas (GHS, 2020). Alfano & Ercolano (2020) argue that the lockdown policies reduce COVID-19 transmission in locked areas around ten days post-implementation. However, this was not the case in Ghana, as the number of COVID-19 cases continued to increase ten days after the lockdown, and a sheer number of the cases were from locked areas (Worldometer, 2020). Perhaps, settings and context differences, like the timing and the number of lockdown days, influence COVID-19 transmission during lockdown imposition (Kerekes et al., 2021). Data indicate that the increased number of COVID-19 cases during the partial lockdown could also be due to the second objective of the policy, i.e., enhanced COVID-19 disease surveillance through contact tracing (Sibiri et al., 2021). However, this is not suggestive of divergent policy objectives, given that the end goal of the contact tracing effort was to prevent COVID-19 transmission through early case identification and isolation (Asiimwe et al., 2021). Generally, the increase in COVID-19 cases during the lockdown period was expected, given Ghana's sociocultural and economic characteristics, like crowded housing, which is feasible because community spread had already begun before the lockdown imposition (Acheampong et al., 2022; Khoo et al., 2020).

The reported increased transmission of the COVID-19 disease during the partial lockdown policy might also be a function of the delayed testing turnaround time due to the relatively lower testing capacities, which probably hindered early identification and isolation of cases to prevent disease spread (Asiimwe et al., 2021; Sarkodie et al., 2020). It could have also resulted from the reported scaling down of contact tracers at some point during the lockdown imposition (Quakyi et al., 2021). In hindsight, the delays in case identification and isolation probably made the partial lockdown policy a 'breeding' policy for COVID-19 transmission, given the sheer numbers of slum living and crowding housing characteristics in Ghana. For example, delays in identifying a COVID-19 case living in crowded houses during a lockdown policy could translate into increased odds of disease transmission to co-residets. Therefore, a partial lockdown policy could be more effective if complemented with enhanced testing, treatment and isolation capacities (Quakyi et al., 2021). Data from other jurisdictions even suggest that enhanced COVID-19 testing capacity could control COVID-19 transmission without recourse to lockdowns (Plümper & Neumayer, 2022; Kerekes et al., 2021). This study demonstrated that the partial lockdown policy fairly met its objectives in Ghana. It possibly prevented case migration between the locked and unlocked areas but not within community transmission.

Like the partial lockdown, this study also found the bans on social/public gatherings policy as 'somewhat effective'. More critically, it was impractical to attain complete adherence to the social/public gathering policy at all population levels, given the socioeconomic inequalities in Ghana (Khoo et al., 2020). Like many developing countries, individuals at the bottom of the economic pyramid in Ghana face myriad challenges, including low purchasing power, shared and poor sanitation facilities, poor communication, transportation and housing conditions, and unequal access to healthcare (Asante et al., 2021). These challenges may limit their tendency to avoid social/public gatherings because practising social distancing in overcrowded houses and shared toilet facilities is practically impossible (Asori et al., 2022). Besides the sanitation and housing challenges, these impoverished individuals typically access public transport services that are usually overcrowded, making social distancing practice difficult (Yeboah et al., 2020). Moreover, even when the policy is practised in public transport through seating spacing, it would bring additional economic costs, worsening the plights of the already financially deprived individuals (Sogbe, 2021).

These socioeconomic underpinnings and their influence on the social/public gathering ban adherence were evident in Durizzo et al. (2021)'s findings. Their survey revealed that non-adherence to the social/public gathering guidelines by most poor urban dwellers in Ghana was due to crowded homes (17%), shared toilets (23%) and use of public transport (29%). These economic inequalities informed the lifting of the partial lockdown (The Presidency – Ghana, 2020). So, in retrospection, the compliance challenges to the social/public gathering ban were anticipated. These socioeconomic nuances imply that governments need to tout other equally important precautionary measures, like face coverings and hand hygiene practices, for individuals who cannot adhere strictly to social or public rules due to economic deprivation. For obvious reasons, resources to promote these practices must be freely provided.

Another hindrance to the functioning of the social/public gathering ban is Ghana's religious and cultural fabric (Khoo et al., 2020). For instance, funerals and weddings are core cultural practices in Ghana (Adom, 2020). Usually intertwined with religious activities, these cultural practices are typically characterised by huge gatherings lasting several days. Generally, most Ghanaians revel in these practices as they are deemed sources of social support and resilience in crises like COVID-19 (Pirutinsky et al., 2020). Additionally, in some religious dogmas, communal prayers were believed to be the catalyst needed to guide physicians and scientists to the best COVID-19 interventions (Sapkota, 2020). Therefore, there were heightened religious relevance and expectations to contribute to mitigating the COVID-19 outbreak, especially with the infiltration of conspiracy theories, which, to some extent, were fuelled by religious doctrines (Baker et al., 2020). These beliefs created a need for regular communal religious engagements, and for communities with limited access to telecommunication services, this meant physical engagements (Yeboah et al., 2020). Therefore, it appeared unlikely for optimal adherence to the restrictions on these socio-religious activities, given their significance in Ghanaian settings (Smith & Quarty, 2020). This unlikelihood was confirmed by Yeboah et al. (2020), who found religious leaders flouting the social/public gathering restrictions. Evidence on the association between socio-religious practices and non-compliance to COVID-19 preventive measures, like social distancing, is confirmed in similar studies (Zakar et al., 2021; Pirutinsky et al., 2020; Jaja et al., 2020).

Arguably, the ban on social gatherings was implemented in Ghana from a linear relationship perspective. Thus, little consideration was given to middle grounds, where there is a multidirectional interaction between sociocultural, religious and behavioural factors (Tong et al., 2020). This argument becomes more cogent when positioned in the theory of planned behaviour (TPB) (Ajzen, 2011). According to Ajzen (2011), an individual's intention to adopt certain behavioural practices is influenced by interconnected factors, such as behavioural, normative and control beliefs. These beliefs are mediated by the individual's perceived behavioural control, subjective norms, and attitudes towards the behaviour, and these are also determined by the individual's sociodemographic factors (Ajzen, 2011). Subjective norms encompass an individual's perceptions of others' attitudes towards observing them performing certain behaviours (Warner et al., 2020). So, by extension, the TPB suggests that individuals' intentions to practice certain behaviours can be predicted from their perceived control of the outcomes of performing that behaviour and their perception of subjective norms, and these perceptions could be determined by sociodemographic inclinations, like age, values, religion and cultural inclinations (Park et al., 2021; Ajzen, 2011).

Positioning the TPB in the context of COVID-19 and religion, one can predict individuals' intentions to adhere to the COVID-19 preventive measures, like ban on public gatherings and social distancing, based on the individual's perceived outcomes of adopting or adhering to the policies or measures (e.g., social exclusion, increase/decrease COVID-19 risk, economic hardships), their perception of other's attitudes towards them adhering to those measures (anger, discrimination, acceptance), and their religious beliefs (Chan et al., 2021; Ajzen, 2011). Thus, Ghana should explore these multiple and complex factors when instituting protocols or polices to promote public adherence. Such explorations could include engagements with key stakeholders, like religious and cultural leaders, to enhance compliance.

Regarding vaccines, Ghana did not achieve its herd immunity aim in June 2022, and even a year after, due to potential vaccine unavailability and vaccine hesitancy (Acheampong et al., 2021). Studies attribute vaccine hesitancy to poor knowledge, anxiety, conspiracy theories, safety concerns and misconceptions (Alhassan et al., 2021; Lamptey et al., 2021; Agyekum et al., 2021). However, this observation is not isolated to Ghana, as several studies from other jurisdictions have also reported COVID-19 vaccine hesitancy (Kreps et al., 2021; Bendau et al., 2021; Ullah et al., 2021). Furthermore, like the social distancing argument above, the intention to receive the COVID-19 vaccine can be examined from the TPB perspective (Breslin et al., 2021). For instance, Cordina & Lauri et al. (2021) demonstrated that among social media users, individuals' beliefs on vaccine efficacy determine vaccine uptake, while women predict vaccine hesitancy. Fan et al. (2021) also showed that COVID-19 vaccine uptake is determined by knowledge of the vaccine and not subjective norms or perceived behavioural control. Haggar & Hamilton (2022) also identified subjective norms and perceived behavioural control as unrelated to vaccine hesitancy. Nevertheless, they revealed that political alignment is significantly associated with vaccine hesitancy and that free-will beliefs predict political alignments. However, free-will beliefs do not influence vaccine hesitancy (Haggar & Hamilton, 2022). These findings align with the TPB's explained diverse predictors of health behaviours and provide implications for health policy (Fernandes et al., 2021). Therefore, policymakers in Ghana should strategically explore the TPB framework in delivering its vaccination intervention to avoid possible persistent vaccine hesitancy that could impede efforts at reducing the COVID-19 disease burden.

Regarding strengths and limitations, this chapter used data triangulation to increase our understanding of the effectiveness of the eight key COVID-19 policy responses in Ghana. Using data triangulation ensured more reliable evidence of the policies' effectiveness compared to the policy evaluation studies identified in Chapter 2. The chapter also provided data on the effectiveness of the border closure, vaccination, entry border screening, and the bans on public gatherings policies, data that was scarce in the existing literature prior to this evaluation. However, as associated with content analyses, this chapter was possibly limited by some subjective data interpretations, which could have biased the findings of this study (Vaismoradi et al., 2016; Roller, 2019). Nonetheless, using multiple data sources to corroborate any identified information regarding the policies' effectiveness enhanced the reliability and validity of the data, limiting the probable subjectiveness associated with the content analysis (Cho & Lee, 2014). The chapter was also faced with attribution of effects limitations, given the non-availability of comparable data to address counterfactuals. For example, the researcher could not attribute the identified COVID-19 outcomes to any single policy, as most of the evaluated policies in this study were implemented concurrently. Therefore, by inferences, the COVID-19 outcomes discussed here could be interpreted as the outcome of all the policies combined.

5.5 Conclusion

This chapter identified and evaluated the effectiveness of eight key COVID-19 policy responses in Ghana against their set objectives. The policies included partial lockdowns, public awareness campaigns, bans on public gatherings, vaccination, border closures, compulsory COVID-19 entry border screening, GCARES and government incentives for HCWs. The evaluation provided evidence of the effectiveness of these policies to inform future policy directions in the event of another COVID-19 wave or other infectious disease outbreaks. The next chapter, chapter 6, evaluated the effectiveness of these identified policy responses from the perspectives of academic experts in Ghana. The rationale for this complementary analysis was to offer robust and comprehensive data on the policies' effectiveness and explore the possibility of addressing this chapter's attribution concerns.

CHAPTER 6: EXPERTS' ANALYSIS OF THE EFFECTIVENESS OF GHANA's COVID-19 POLICY RESPONSES

6.1 Introduction

This chapter analysed the effectiveness of the identified Ghana's COVID-19 policy responses in Chapter 5 from the perspectives of experts in Ghana. The rationale for the complementary analyses was to address the literature gap on the single approach to the Ghana's COVID-19 policies' evaluations and offer robust and comprehensive evidence on the policies' effectiveness to guide future policies, particularly in the event of pathogen X. The use of experts in this thesis, instead of other populations, like public participants, was consistent with the current literature on policy/interventions evaluations (Gupta et al., 2021; Osei-Kyei et al., 2017; Walters et al., 2015). An expert is someone who consistently demonstrates superior knowledge or performance in a defined subject area (Ericsson et al., 2007). Expert studies or research has been on the ascendancy in the last decades and are particularly useful when exploring technical and complex real-life issues that require critical insights and extensive knowledge (Baker et al., 2006). Hierarchically, experts' opinions are argued to present weaker evidence. However, Jorm (2015) contends this position by indicating that the quality of any evidence is more likely a function of the rigour and robustness of the study that produced the evidence and not based entirely on the study design. Jorm (2015) 's argument further alluded to the opinion that the quality of experts included in expert research, like this current one, determines the quality of its produced evidence.

Experts' research or survey has been used to develop quality assessment tools, like the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist, one of the robust tools used to appraise the quality of systematic reviews and meta-analysis – the gold standard in evidence identification (Page et al., 2021). Given the robustness of the PRISMA checklist, it can be established that expert research could be a valid and rigorous methodological approach to generating evidence, particularly around policy evaluations. On the other hand, expert study or research can be time-consuming and are sometimes fraught with attrition bias (Barrett & Heale, 2020). However, these limitations can be addressed when the required data is collected at one point and the data collection time is effectively managed. Therefore, apart from complying with Jorm (2015)'s approach to expert analysis, this study also collected the needed data for the policy evaluation at one point to avoid the limitations highlighted above.

6.2 Methods

6.2.1 Study Population and Sampling Technique

As mentioned in the introduction, this chapter surveyed experts familiar with Ghana's health and economics policy landscape. The recruitment of experts in this evaluation was consistent with the current literature on expert's perspectives in policy evaluation (Vercammen et al., 2018; Martínez-Paz et al., 2016; Shi et al., 2008), thus, substantiating its use in this study. The experts were academics from diverse health and economics disciplines from universities in Ghana. The choice of academics as experts in this study was supported by their documented thoroughness, scientific rigour, and broader perspectives in developing, reviewing, and evaluating policies (Qu et al., 2010). It was also supported by their analytical skills and extensive knowledge of global and local issues, which are updated regularly given their performance requirements and key role in contributing solutions to real-life issues confronting policymakers (Oliver et al., 2014; Cairney & Oliver, 2020). While expert groups are not limited to only academics, they are often explored as experts in several national concerns because they are more likely to provide more transparent and independent perspectives (Fischer et al., 2014; Williams et al., 2020).

The academics were purposively selected for the study. Purposive sampling is a non-probability method used to select study populations whose characteristics align with a study's sample requirements or overarching aim (Etikan et al., 2016). The non-probability sampling approach was instrumental in this study as it aimed to select populations based on their knowledge base and policy experiences rather than a random population (Berndt, 2020). However, unlike the probability sampling method, the non-probability sampling method in this study was limited in results generalisation (Berndt, 2020). Nonetheless, this limitation was inconsequential in this study as the researcher aimed to achieve insight and knowledge depth rather than breadth of the evaluated policies (Etikan et al., 2016). There are other approaches within the non-probability sampling methods, such as the convenient sampling approach. However, given the context of this chapter, the purposive sampling approach was used to select the experts because it allowed data collection from populations specific to the epistemology of this study and not necessarily from those who are ‘readily’ available as characterised by the convenient sampling method (Cambell et al., 2020; Etikan et al., 2016).

6.2.2 Data Collection Procedure

6.2.2.1 Questionnaire

A self-administered questionnaire was used to collect the data from the experts (Appendix 9). The questionnaire included sociodemographic questions and a question each on the objectives of the eight COVID-19 policies evaluated in Chapter 5, i.e., the partial lockdown of Greater Accra and Kumasi, public awareness campaigns, bans on public gatherings, vaccination, border closures, compulsory COVID-19 entry border screening, HCWs incentives and the GCARES policy. The participants were required to rate the effectiveness of these policies on a scale of 1 to 5 (where 1 = not effective, 2 = not very effective, 3 = do not know, 4 = effective, 5 = very effective), except for the vaccination policy which was rated on a 1 to 3 scale (1 = no, 2 = maybe, 3 = yes) to assess whether the policy would achieve its aim of vaccine-induced herd immunity. They were also asked to indicate what they think contributed to the policies influence on the COVID-19 burden.

The researcher was cognisant of the advantages of using existing questionnaires, especially given their reported validity and reliability (Schrepp & Thomaschewski, 2019). However, using existing questionnaires was not possible in this study as no existing questionnaire specific to the policies in this study was found in the literature. The non-existence of such a questionnaire was likely due to the absence of some of Ghana’s COVID-19 policies in other contexts and potential differences in the objectives of similar policies. For example, the GCARES policy was specific to Ghana, as no other country was found to have implemented a similar policy. Therefore, a multi-item questionnaire was developed to allow a comprehensive and exhaustive assessment of the COVID-19 policies in Ghana. The questionnaire development was based on experts’ suggestions and a review of the literature on standard approaches to questionnaire development to ensure content and face validity, respectively (Boynton & Greenhalgh, 2004; Khubchandani et al., 2021; Lazarus et al., 2020).

The developed multiple-item questionnaire was made standard for the academic experts to avoid inconsistent questions, which could influence their responses (Dyda et al., 2020). Most of the questions on the questionnaire were close-ended with 5-point Likert scale responses. An open-ended question on each item on the questionnaire may have elicited a detailed response from the experts (Chen et al., 2020). However, given the reported low completion rate associated with open-ended questions (Liu & Wronski, 2018), especially for multi-items questionnaires like the one in this study, the close-ended questions appeared more applicable. All the same, one open-ended question was included in the questionnaire to explore deeper meanings into the experts' responses to the close-ended questions. This inclusion provided an added layer of robustness to the collected data.

6.2.2.2 Questionnaire Piloting

Questionnaire piloting is a standard approach to identify potential problems with a questionnaire before disseminating it to targeted study populations (Boynton, 2004). It allows amendments to issues associated with questionnaires, such as wrongful interpretation of questions, comprehension difficulties and ambiguities, which could introduce response errors (Boynton, 2004). The questionnaire piloting in this study was conducted among a sample representative of the definitive population. The piloted sample included three academics within the professional network of the researcher. They suggested including an open-ended question on the questionnaire that would explore reasons underlying the academic experts' responses to the close-ended questions. These reasons could provide nuances and increase understanding of the experts' perceived effectiveness of a policy.

6.2.2.3 Experts Recruitment and Questionnaire Dissemination

A Gatekeeper was used to recruit the academic experts. He informed eligible experts of this study and furnished them with a Participant Information Sheet (PIS) (Appendix 10), which provided details of the study, its objectives and their expectations. The questionnaire was uploaded to Qualtrics, an online tool for data collection. This tool safeguarded complete participant anonymity, which complemented the anonymity-laced nature of the sociodemographic questions on the questionnaire. Consent information and question were also embedded in the online questionnaire, and the experts could only record their responses after agreeing to the consent question/statement. The link to Qualtrics was disseminated to the participants via email. The use of emails for data collection is consistent with the literature (McCoyd & Kerson, 2006). It was instrumental in this study, given the tight schedules of academics which sometimes make face-to-face meetings challenging. Additionally, it was relatively cheaper and helped reduce the likelihood of response conformity (Addington-Hall, 2007). Also, unlike the face-to-face approach, the online approach limited any researcher's influence on participants' responses (Lefever et al., 2007). Finally, its limitation of inaccessibility to participants with no internet access was passive in this research, given that academic experts had internet access due to their job nature (Addington-Hall, 2007). It must be mentioned, however, that internet access was not a prerequisite to study participation, as this could have introduced selection bias (Bethlehem, 2010).

6.2.3 Data Analyses

6.2.3.1 Descriptive Bivariate and Regression Analyses

Descriptive, bivariate, logistic regression and thematic analyses were conducted to provide meaning to the experts' responses. The descriptive analyses used frequencies and proportions to summarise the experts' characteristics. A spider chart, developed from the median ratings of the experts, was also used to illustrate the effectiveness of the policies. In the spider chart, a median policy rating ≥4 meant the experts perceived the policy as effective, and a median <4 meant the policy was perceived as ineffective. Each policy was later analysed to show the number of experts that rated it effective or otherwise. Bar/pie charts were used to illustrate the outcomes of the univariate analyses of each policy. A Cronbach's alpha test was also done to examine the reliability of the items on the survey questionnaire.

The bivariate analysis explored associations between the experts' sociodemographic characteristics and their policy ratings using Chi-square tests. Following the bivariate analyses, logistic regression models were fitted to examine whether the sociodemographic characteristics of the experts predicted their effectiveness ratings. The dependent variable in the bivariate and regression analyses was the policies' effectiveness as rated by the experts. Accordingly, responses' 1', '2' and '3' (representing 'not effective', 'not very effective' and 'don't know') were coded as '0', and responses' 4' and '5' (representing 'effective' and 'very effective') were coded as '1'. In the coding interpretation, '0' meant the policies did not meet their objectives (less effective), and '1' meant the objectives were met (effective). Similar codes were used for the vaccination policy. Responses ‘1’ and ‘2’ for the vaccination question (representing ‘no’ and ‘maybe’ responses) were coded ‘0’, indicating that the policy may/would not achieve its objectives. On the other hand, response ‘3’ was coded ‘1’, and ‘1’ meant the policy would achieve its objectives.

The bivariate and logistic analyses were to provide an in-depth understanding of whether the experts’ sociodemographic characteristics would influence their policy ratings and not for the conventional statistical interpretations necessarily. Most importantly, the analyses assessed whether the possible discipline variations within the two composite disciplines, e.g., physiotherapy, public health and health economics, would be associated with the experts’ opinions. Therefore, findings generalisations are not implied from the bivariate and logistic regression analysis. The statistical analyses were conducted with SPSS version 26, and the level of statistical significance was set at $p < 0.05$.

6.2.3.2 Thematic Analysis

Thematic analysis was conducted to identify common themes from the participant’s responses to the open-ended question on what they think contributed to the outcomes of the COVID-19 policies. In the thematic analysis, the responses from each expert were first read thoroughly to ensure familiarisation with the data. In the data familiarisation, codes were generated to represent phrases/sentences from the experts’ responses. The codes were then reviewed and observed for patterns regarding the policy’s effectiveness. Common codes from the experts were then combined into themes. After, an independent person reviewed the generated themes to ensure that they accurately represented the experts’ responses and allowed for reproducibility of findings (Braun & Clarke, 2006). The final themes were defined in sentences to provide meanings to enhance understanding of the policies’ effect. The analysis followed the thematic analysis guideline by Braun & Clarke (2006) to guarantee a thorough and comprehensive analysis.

6.2.4 Ethics Approval

The College of Health, Medicine and Life Sciences (CHMLS) Research Ethics Committee granted the ethics approval for this study. The ethics process was conscious of the psychological implications of reviewing policies around a condition that had a significant physical and mental impact on individuals and institutions. Therefore, the participants were given prior information on what the research entails through a PIS to allow them to decide on participation or otherwise. See appendix 10 and 11 for the PIS and ethics approval letter from the committee, respectively.

6.3 Results

6.3.1 Descriptive Findings

Thirty-four (n = 34) experts responded to the survey and evaluated the eight COVID-19 policies in this study, providing 272 main data points plus 68 data points for the two other policy objectives under the partial lockdown policy. Many of the experts were women (n = 25; 73.5%), aged 18 – 34 years (n = 17; 50%) and were from a health discipline (n = 30; 88.2%). The reliability analysis showed a Cronbach's alpha of 0.88, indicating a higher internal consistency between the questionnaire's items. Table 27 below shows the experts' characteristics.

Table 27: Experts' characteristics (N = 34)

Expert's characteristics		**Number (%)**
Sex	Men	9 (26.5)
	Women	25 (73.5)
Age	18 – 34 years	17 (50)
	35 – 50 years	15 (44.1)
	>50 years	2 (5.9)
Academic Discipline	Health	30 (88.2)
	Economics	4 (11.8)

On the policies' effectiveness, the experts rated the public awareness campaigns, bans on public gathering, partial lockdown and border closures policies as effective (Median rating ≥4), and the incentives for HCWs, COVID-19 entry border screening and GCARES policies as ineffective (Median rating <4). Figure 13 shows the median scores of the policies as rated by the experts, and the reports after figure 13 show the univariate findings of each policy.

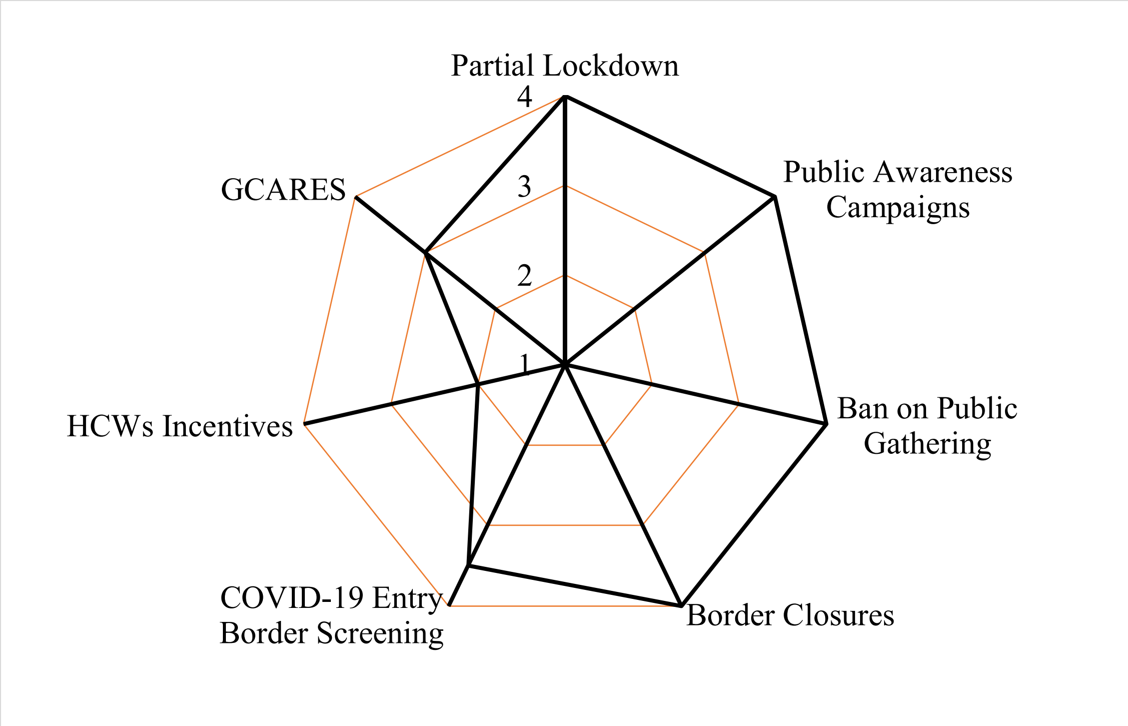

Figure 13[10]: Summarised experts' perceived effectiveness of Ghana's COVID-19 policy responses.

6.3.1.1 Experts' Perceived Effectiveness of the Partial Lockdown of Greater Accra and Kumasi Policy

The partial lockdown of Greater Accra and Kumasi had three key objectives:

- Reduce the spread of COVID-19
- Enhance COVID-19 disease surveillance through contact tracing.
- Scale-up COVID-19 testing and treatment capacities.

Among these objectives, twenty-two experts indicated that the partial lockdown policy was effective in enhancing COVID-19 disease surveillance (Effective: n = 17; Very Effective: n = 5), and nineteen of them said it was effective in reducing the spread of the virus (Effective: n = 15; Very effective: n = 4) and scaling up COVID-19 testing and treatment capacities (Effective: n = 15; Very effective: n = 4). For all the objectives, the number of experts who rated the partial lockdown policy as 'effective' was more than those who rated it as 'very effective', indicating discordance in the degree of the policy's effectiveness. Nevertheless, on

[10] The Vaccination Policy was excluded from this summary as it was not rated on a 1 to 5 scale. The policies on the graph were rated by 34 experts, except GCARES that was rated by 10 experts.

average, the median ratings showed that the policy was perceived as effective in addressing all its objectives. Figures 14 and 15 below provide a graphic presentation of the experts' partial lockdown policy rating.

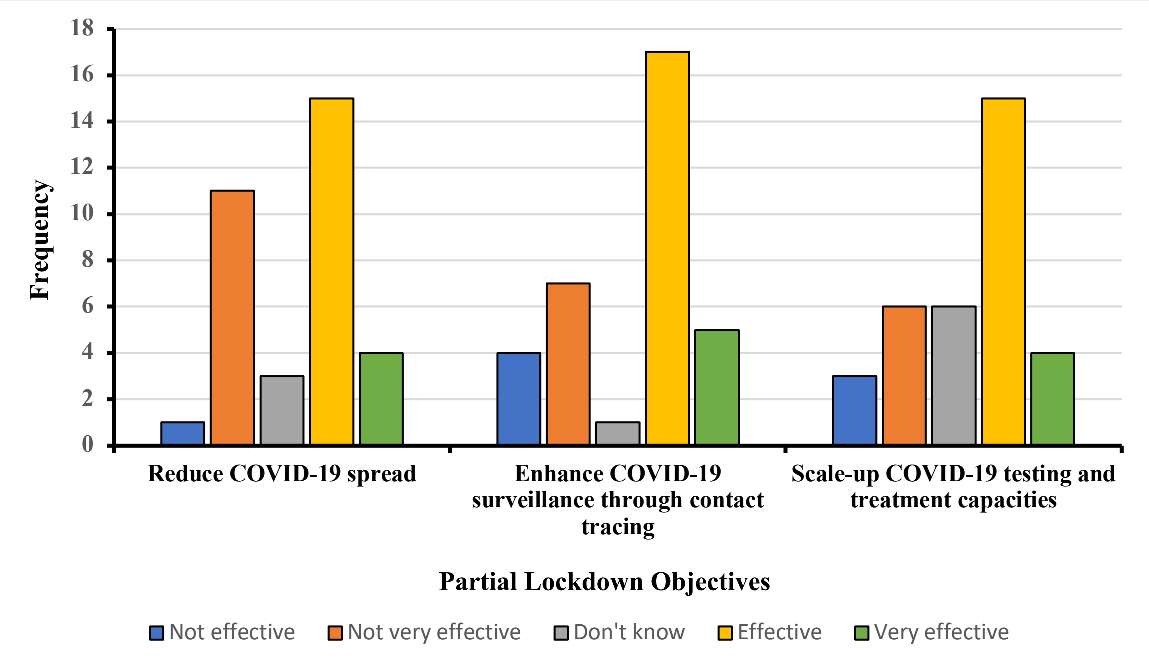

Figure 14: Experts' perceived effectiveness of the partial lockdown policy.

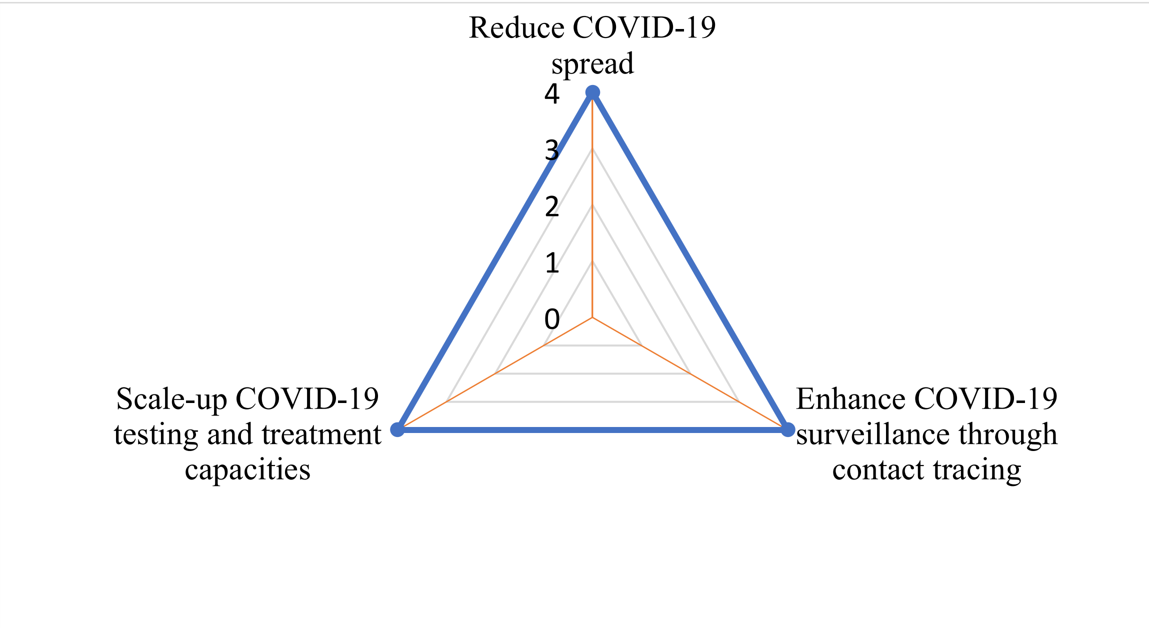

Figure 15: Median scores of the objectives of the partial lockdown policy.

6.3.1.2 Experts' Perceived Effectiveness of the COVID-19 Public Awareness Campaigns Policy

Figure 16 below shows that 30 experts rated the public awareness campaigns as effective (Effective: n = 21; Very effective: n = 9). The experts who rated it ineffective were divided equally between 'Not effective' (n = 2) and 'Not very effective' (n = 2). None of the experts indicated a lack of knowledge of the policy's effectiveness (There were no 'don't know' responses).

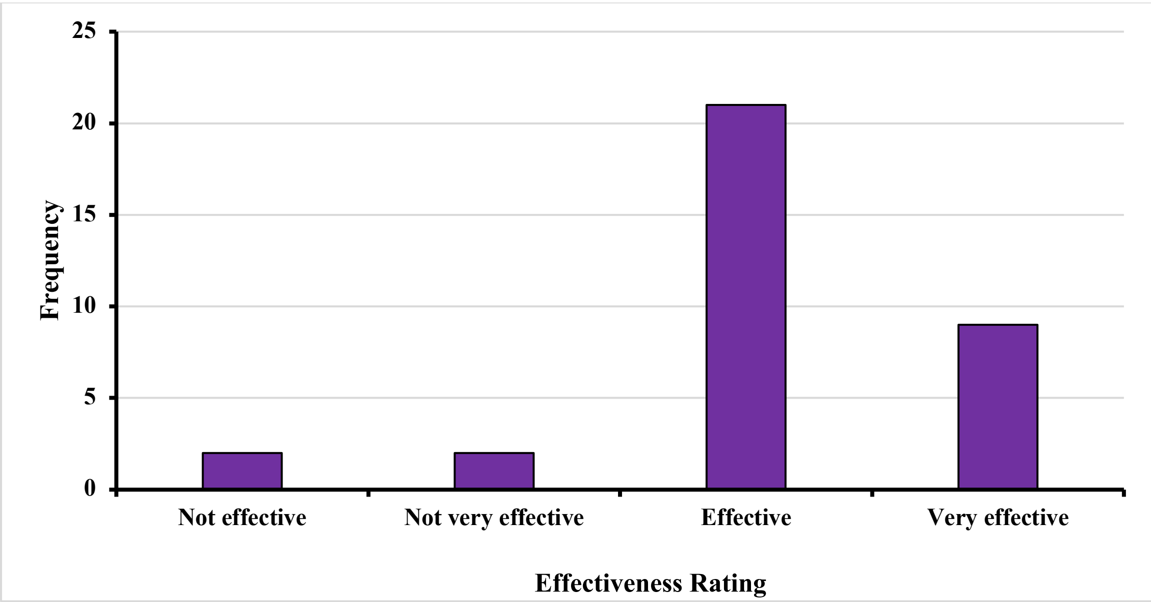

Figure 16: Experts' perceived effectiveness of the COVID-19 awareness campaign policy.

6.3.1.3 Experts' Perceived Effectiveness of the Ban on Public Gathering Policy

Twenty-four experts rated the ban on public gatherings policy as effective (Effective: n = 17; Very effective: n = 7) in reducing the spread of the COVID-19 virus. However, of those that said the policy was ineffective, six rated it as 'not very effective', and two rated it as 'not effective'. Figure 17 below summarises this finding.

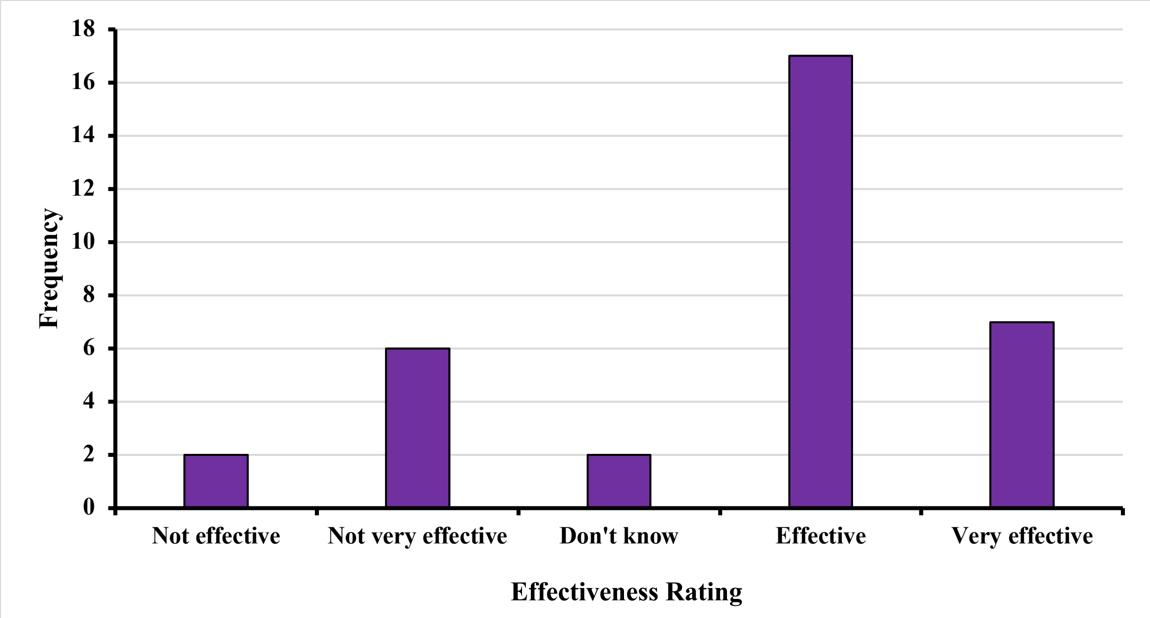

Figure 17: Experts' perceived effectiveness of the ban on public gathering policy.

6.3.1.4 Experts' Perceived Effectiveness of the Border Closures Policy

The border closures policy was rated effective (Effective: n = 13; Very effective: n = 7) by 20 experts. Observably, those who rated the policy as 'not very effective' (n = 9) were more than those who rated it as 'very effective' (n = 7). However, when summed, it was perceived more as effective ('effective' plus 'very effective') (n = 20) than ineffective ('not effective' plus 'not very effective') (n = 11). Figure 18 summarises this result.

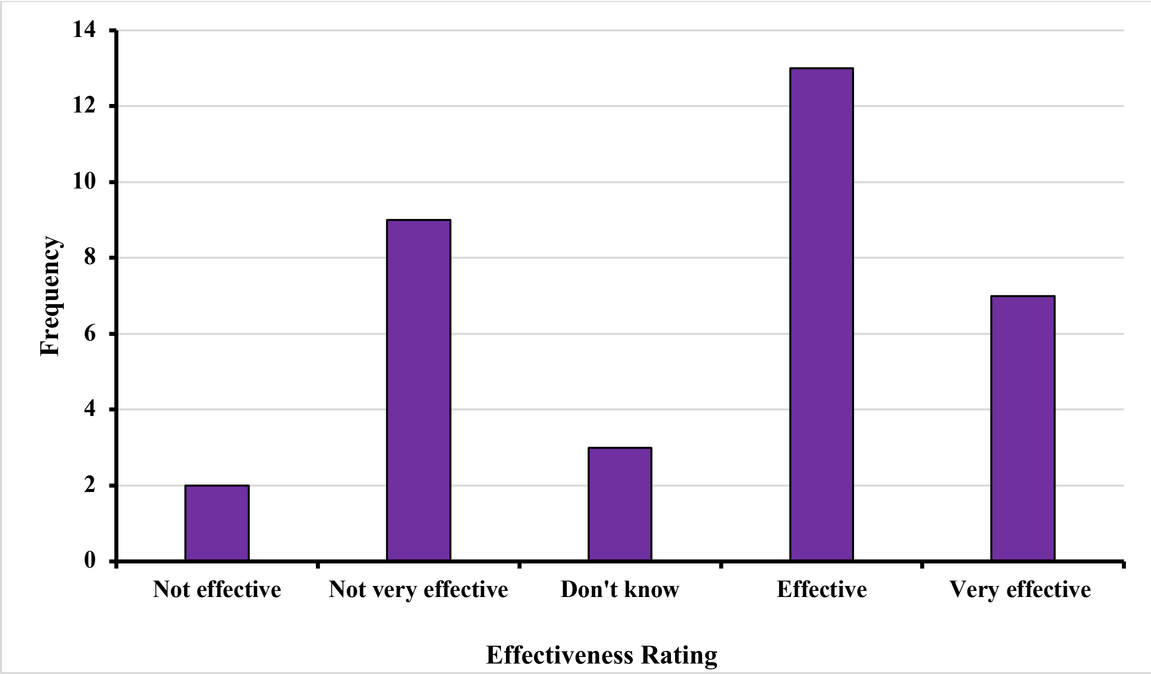

Figure 18: Experts' perceived effectiveness of the border closures policy.

6.3.1.5 Experts' Perceived Effectiveness of the Compulsory COVID-19 Entry Border Screening Policy

The effectiveness rating of the entry border screening policy was spread equally across 'effective' (Total = 17; Effective: n = 15; Very effective: n = 2) and 'ineffective/unsure of effectiveness' (Total = 17; Not effective: n = 2; Not very effective: n = 10; Don't know: n= 5). However, when fragmented, most experts (n = 15) rated the policy as 'effective' than 'not very effective' (n = 10), as captured in figure 19.

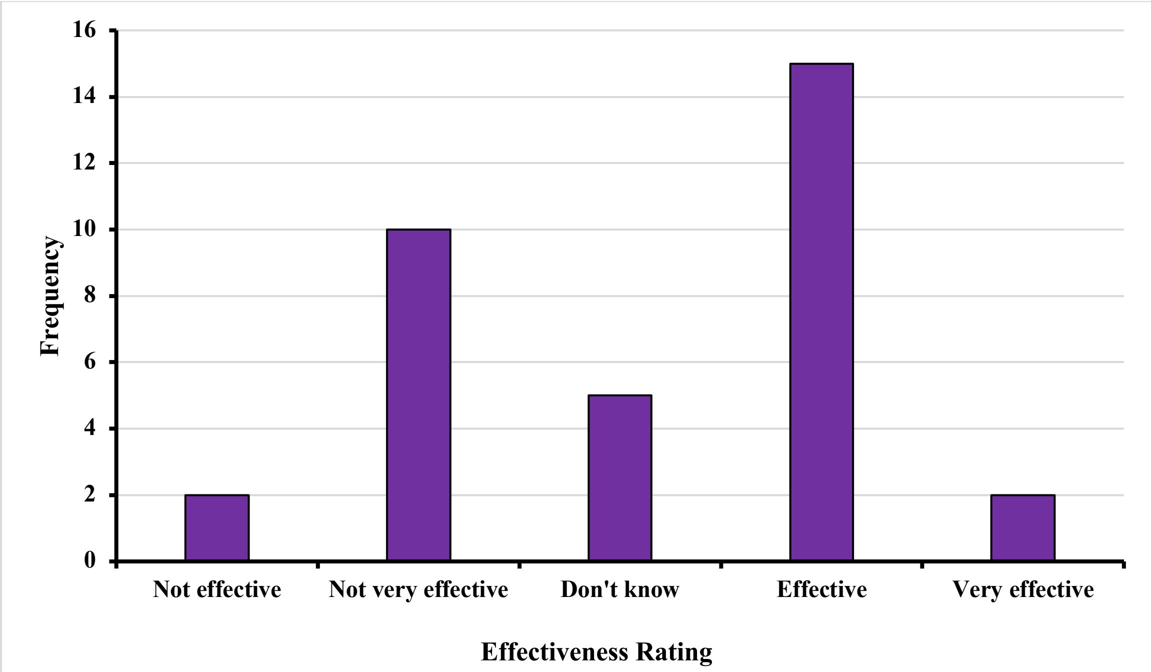

Figure 19: Experts' perceived effectiveness of the compulsory COVID-19 entry border screening policy.

6.3.1.6 Experts' Perceived Effectiveness of the COVID-19 Vaccination Policy

The experts were asked whether the vaccination policy could achieve its objective of reducing the COVID-19 disease burden through vaccine-induced herd immunity. Nineteen experts (56%) said the policy 'may' reduce the COVID-19 burden through herd immunity, two (6%) indicated that the policy would not achieve this objective, and thirteen (38%) were confident that the policy would achieve its objective. See figure 20 for the experts' rating of the COVID-19 vaccination policy.

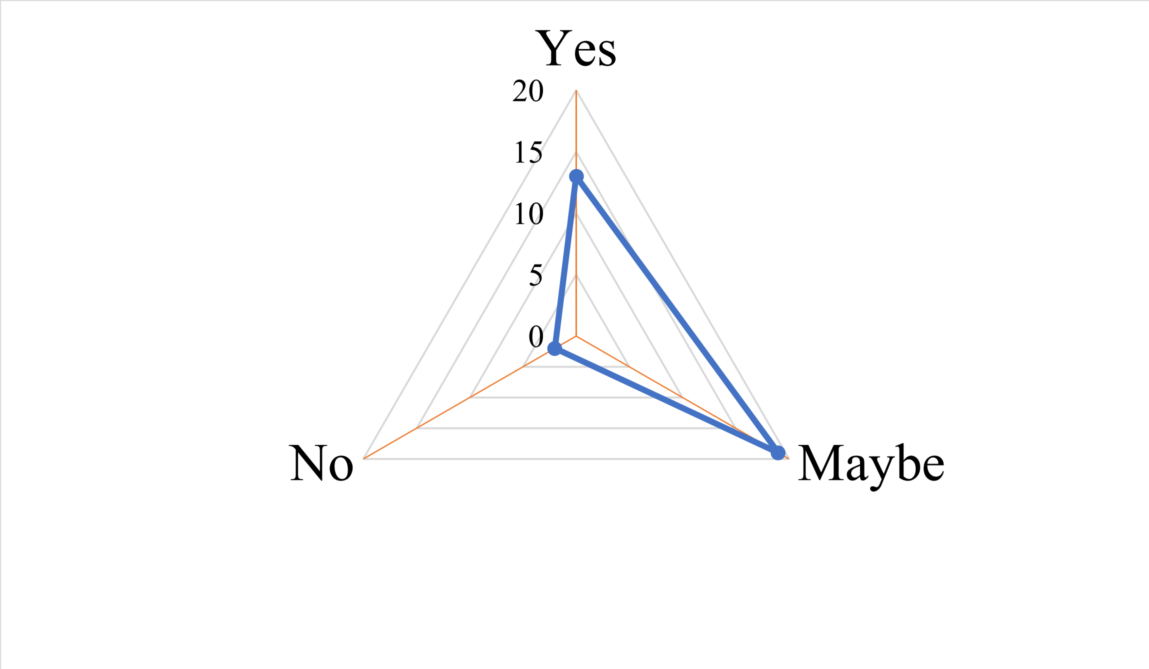

Figure 20: Experts' perceived effectiveness of the COVID-19 vaccination policy.

6.3.1.7 Experts' Perceived Effectiveness of Government's Incentives for HCWs Policy

The experts who rated the incentives for HCWs policy as 'effective' (n = 11) were marginally higher than those who rated it as 'not very effective' (n = 10). When combined, those who said the policy was effective (Total = 14; Effective: n= 11; Very effective: n = 3) were fewer than those who said the policy was ineffective (Total = 18; Not effective: n= 8; Not very effective: n = 10) in widening the human resource capital against COVID-19. Figure 21 shows this finding.

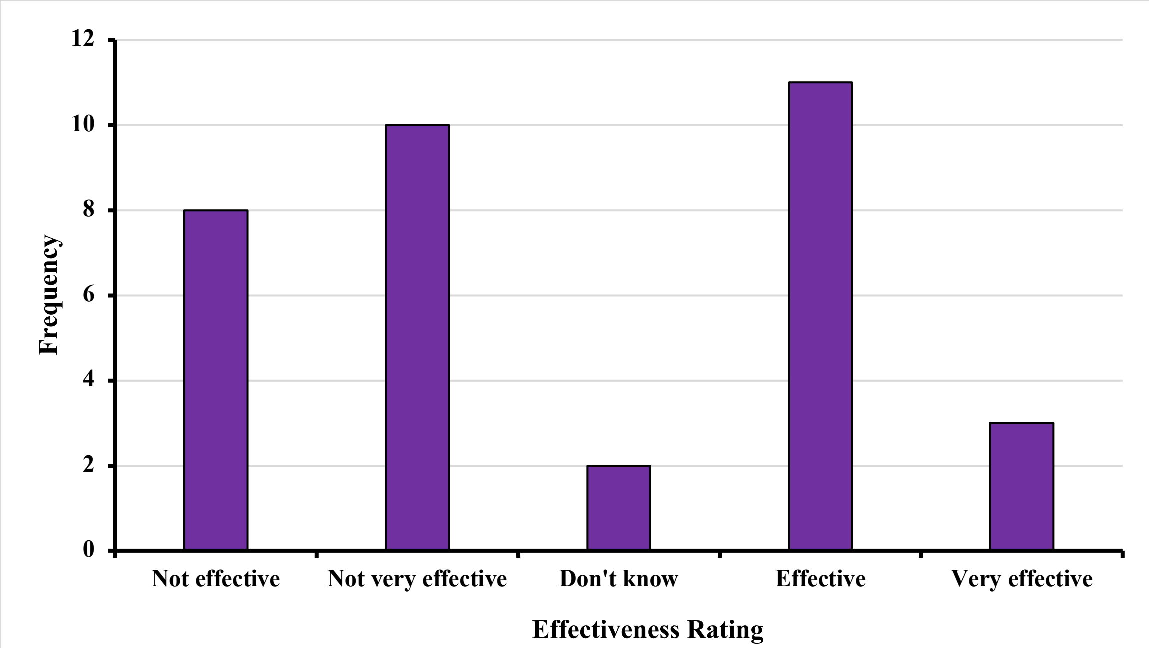

Figure 21: Experts' perceived effectiveness of the incentives for HCWs Policy.

6.3.1.8 Experts' Perceived Effectiveness of the GCARES Policy

Given the observed low popularity of the GCARES policy in the literature, the experts' knowledge of GCARES was assessed before they rated its effectiveness. Of the thirty-four (n = 34) experts, twenty-four (n = 24; 70.6%) did not know GCARES. Most of the ten experts (29%) that knew GCARES were men (n = 6; 60%), aged 35 – 50 years (n = 8; 80%) and were from a health discipline (n = 7; 70%). None of the experts aged >50 knew GCARES. Table 28 shows the experts' knowledge of GCARES.

Table 28: Experts' knowledge of GCARES

Expert's characteristics		**Yes (%) (n = 10)**	**No (n = 24)**	**Total (%)**
Sex	Men	6	3	9 (26.5%)
	Women	4	21	25 (73.5%)
Age	18 – 34 years	2	7	9 (26.5%)
	35 – 50 years	8	15	23 (67.6)
	>50 years	0	2	2 (5.9%)
Academic Discipline	Health	7	23	30 (88.2%)
	Economics	3	1	4 (11.8)

The ten experts who knew GCARES were asked to rate its effectiveness. The majority (n = 5) said the policy was ineffective (Not effective: n = 3; Not very effective: n = 2) in stimulating economic recovery from the COVID-19 impact. Of the remaining five experts, four (n = 4) did not know the policy's effectiveness, and one (n =1) said it was effective. See figure 22 below for the experts' perceived effectiveness of the GCARES policy.

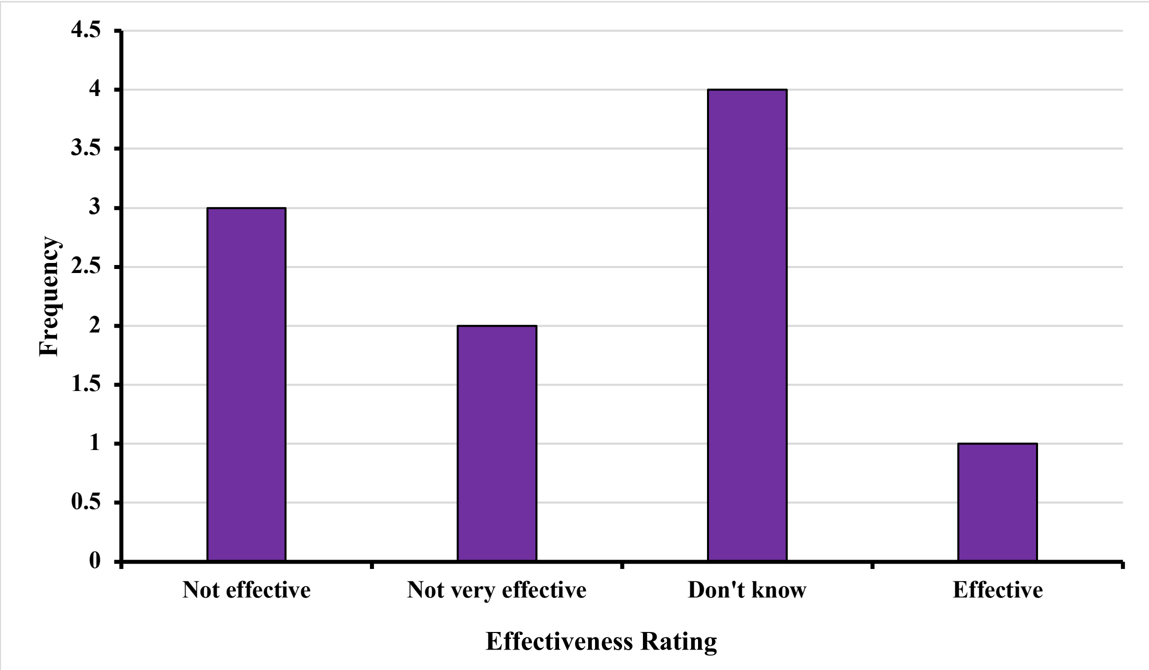

Figure 22: Experts' perceived effectiveness of the GCARES policy (N =10 Experts).

6.3.2 Bivariate Analysis

In the bivariate and the subsequent regression analysis, the age categories were collapsed into two groups, i.e., <35 and ≥ 35 years old, to account for the relatively smaller sample size for those aged >50 years. The GCARES policy was also excluded from the correlational analysis, given its fewer respondents to avoid sample sizes inconsistencies. The bivariate analysis showed significant associations between the incentives for HCWs policy and sex ($p = 0.01$) and age ($p = 0.04$). As already indicated, this statistical analysis indicated whether the sample characteristics influenced the policy's ratings and are not for the conventional statistical interpretations on findings generalisations to broader populations. The significant associations must, therefore, be interpreted cautiously. See table 29 for the bivariate results.

Table 29: Chi-square results showing associations between the experts' characteristics and their effectiveness rating.

Policies/Experts' characteristics		Sex p-value	Age p-value	Academic discipline p-value
Partial Lockdown	Reduce COVID-19 spread	0.45	0.73	0.19
	Enhance disease surveillance	0.08	1.00	0.65
	Scale-up testing and treatment capacities	0.12	0.73	0.19
Public Awareness Campaigns		0.20	1.00	0.44
Ban on Public Gathering		0.16	1.00	0.34
Border Closures		0.58	1.00	0.70
Entry Border COVID-19 Screening		0.69	0.30	1.00
Vaccination		0.21	0.29	0.56
Incentives for HCWs		0.01*	0.04*	0.70

Note: *significant at $p < 0.05$

6.3.3 Logistic Regression

The logistic regression showed no significant associations between the experts' characteristics and their perceived effectiveness of the COVID-19 policies. Notably, the probability of perceiving the incentives for HCWs (OR = 3.55, 95%CI = 0.21 – 60.49) and the vaccination policy as effective (OR = 6.19, 95%CI = 0.29 – 128.41) was higher among the experts from the health discipline than those from the economics discipline. This finding was also observed for the perceived effectiveness of the partial lockdown policy in enhancing COVID-19 disease surveillance (OR = 1.47, 95%CI = 0.08 – 29.05). However, as indicated above, none of these findings were significant. Most importantly, the findings must be interpreted cautiously, given that the study's sample size was insufficient to determine appreciable effect size. Table 30 below summarises the logistic regression findings.

Table 30: Results of the logistic regression

Experts' characteristics/policies	**Partial lockdown[11] OR (CI)**			**Awareness campaigns OR (CI)**	**Ban on public gatherings. OR (CI)**
	PL1	PL2	PL3		
Women Men	[ ] 5.76 (0.55–60.85)	[ ] 8.61 (0.69–106.08)	[ ] 1.6×10^{9} (0.00)	[ ] 2.5×10^{8} (0.00)	[ ] 1.16×10^{9} (0.00)
≥35 years <35 years	[ ] 1.59 (0.35–280.02)	[ ] 1.62 (0.34–7.75)	[ ] 1.11 (0.23–5.36)	[ ] 1.86 (0.21–16.18)	[ ] 1.27 (0.24–6.59)
Economics Health	[ ] 13.08 (0.61–266.9)	[ ] 1.47 (0.08–29.05)	[ ] 2.00×10^{9} (0.00)	[ ] 0.00 (0.00)	[ ] 1.08×10^{9} (0.00)
Experts' Characteristics/Policies	**Border Closures OR (CI)**	**Border Screening OR (CI)**	**Vaccination OR (CI)**	**Incentives for HCWs OR (CI)**	
Women Men	[ ] 2.12 (0.32–13.92)	[ ] 2.03 (0.33–12.41)	[ ] 9.31 (0.98–88.94)	[ ] 10.66 (1.03–109.37)	
≥35 years <35 years	[ ] 1.12 (0.26–4.84)	[ ] 2.51 (0.56–11.20)	[ ] 4.28 (0.69–26.31)	[ ] 0.30 (0.06–1.53)	
Economics Health	[ ] 2.23 (0.21–24.12)	[ ] 1.13 (0.11–12.11)	[ ] 6.19 (0.29–128.41)	[ ] 3.55 (0.21–60.49)	

[11] [ ] – Reference category; OR – Odds Ratio; CI – 95% Confidence Interval; HCWs – Health Care Workers
PLI – Partial lockdown to reduce COVID-19 spread.
PL2 – Partial lockdown to enhance COVID-19 disease surveillance.
PL3 - Partial lockdown to scale-up COVID-19 testing and treatment capacities.

6.3.4 Results of the thematic analysis

Ten (n = 10) of the thirty-four (n = 34) experts gave reasons for what contributed to the effectiveness of the COVID-19 policies. Many (n = 4) commented on the ban on public gathering policy. Some of their explanations of its effectiveness include:

'On the ban of the public gathering, it really helped to curb the spread of the virus. It was actually one of the effective measures employed' (Participant 010).

'The restriction on public gathering was very effective. This was because churches and club houses were closed, and anyone seen disobeying were punished' (Participant 009).

The other policies that were commented on were the incentives for HCWs and the COVID-19 entry border screening. Some of the experts said:

'The incentives to health workers did not mitigate the spread nor make case management easier because the required equipment was not available' (Participant 011).

'The closure of the borders in a way helped to reduce spread of Covid-19, but it affected traders a lot and people used unauthorized borders to go about their business. So, at the end it wasn't effectively controlled and not everyone got tested' (Participant 014).

Two experts made comments that encompassed all the policies. For example, participant 001 said:

'All policies helped in one way or the other to improve the COVID-19 outcomes' (Participant 001).

The thematic analysis identified some agreed and varied opinions on a policy's effectiveness. For example, the experts who commented on the incentives for HCWs and the public awareness policy agreed that the policies were ineffective and effective, respectively. However, on the partial lockdown policy, while one expert thought the policy was less effective, the other indicated that the policy was effective. The expert who indicated that the partial lockdown policy was effective associated the policy's effectiveness to fear of COVID-19 infection among the public. Similarly, the two experts who perceived the bans on public gatherings policy as effective attributed its effectiveness to punitive measures and the partial lockdown imposition. Table 31 shows the findings of the thematic analysis.

Table 31: Findings of the thematic analysis

Type of policy	Themes	Participant ID	Total number of participants
Bans on Public Gatherings	The policy curbed the spread of COVID-19	010; 030	2
	The Policy's effectiveness was facilitated by the lockdown	014	1
	Policy was effective because it had punitive measures.	009	1
Public Awareness Campaigns	The Public education campaign informed people about COVID1-19	007; 014	2
Incentives for HCWs	Policy was ineffective due to equipment unavailability	011; 014	2
Partial Lockdown	Migration of people to non-locked down areas before lockdown implementation made the policy ineffective	014	1
	The public fear of COVID-19 made the lockdown policy effective	033	1
COVID-19 Entry Border Screening	The usage of some unauthorised borders affected the policies effectiveness	014	1
GCARES	Most entrepreneurs did not benefit from the GCARES policy	035	1
Vaccination	The COVID-19 vaccination can reduce the disease's burden by preventing related complications	014	1
All policies	All the policies collectively improved the COVID-19 outcomes	001	1
	The COVID-19 outcomes were worsened by poor attitudes towards policies	004	1

6.3.5 Comparing this Chapter's Findings (Quantitative results) to Chapter 5's Findings.

There was concordance on the effectiveness of the public education campaigns and the border closure policy between the experts' findings and the findings in Chapter 5 – both indicated that the policies were effective. However, there were also inconsistencies in the effectiveness rating of the partial lockdown, bans on public gatherings, COVID-19 entry screening, incentives for HCWs and the GCARES policies between Chapter 5 and this chapter. For example, while the experts perceived the incentives for HCWs, and the COVID-19 entry border screening policies as ineffective, Chapter 5 found them effective. Similarly, the experts rated the partial lockdown and the ban on public gathering policies as effective, while Chapter 5 found them 'somewhat effective'. The different policy rating criteria and data sources in the two chapters may account for the observed variations. These differences are further discussed in the subsequent sections of this chapter. Table 32 below shows how the experts' findings compared with the findings in Chapter 5.

Table 32: Comparing the experts' findings to the findings in chapter 5.

Policy	**COVID-19 policies' effectiveness**			
	Experts' findings		**Chapter 5 findings**	
	Effective	Not effective	Effective	Somewhat effective
Partial Lockdown	×			×
Public Awareness Campaigns	×		×	
Ban on Public Gathering	×			×
Border Closures	×		×	
COVID-19 Entry Border Screening		×	×	
Incentives for HCWs		×	×	
GCARES		×		×

6.4 Discussion

This chapter explored experts' perspectives on the effectiveness of the COVID-19 policy responses in Ghana that were identified in Chapter 5. In summary, the experts perceived the partial lockdown, public awareness campaigns, ban on public gatherings and border closures as 'effective' policies, and the GCARES, incentives for HCWs and the COVID-19 entry border screening policy as 'not effective'. Their perceived effectiveness was consistent with the findings in Chapter 5 for some policies and inconsistent with others (See table 32 above). A case in point is the partial lockdown and the ban on public gathering policies, which were perceived as ‘effective’ in this chapter but ‘somewhat effective’ in Chapter 5. The inconsistent findings between the two chapters regarding some policies may emanate from the qualitative/subjective nature of the policy evaluations. Notably, most of the COVID-19 policies in Ghana had similar intended outcomes, limiting quantitative/objective assessments. For example, the ban on public gatherings and the partial lockdown policies were all intended to reduce COVID-19 virus transmission. Given this similar policy outcome, the study could not estimate the percentage or fraction of reduced COVID-19 morbidity (if any) attributable to either of the policies, thus, limiting precise objective assessments. This limited quantifiable assessment may have influenced the findings variations in the two chapters. The attribution limitation could have been addressed if these policies were implemented in different periods/times to allow a period analysis of their outcomes.

The observed non-availability of comparative data also contributed to the limited quantitative/objective assessments of the COVID-19 policies. For example, available and comparable COVID-19 morbidity data on the absence of a lockdown policy could have been juxtaposed with the available COVID-19 morbidity data during the lockdown imposition to objectively assess and quantify the policy’s effect on COVID-19 morbidity. Nonetheless, this comparative data analysis limitation was understandable, given the novelty of the outbreak in Ghana (Khoo et al., 2020). Still, this study’s evaluation exercise could have developed a policy counterfactual, like the lockdown counterfactual developed by Born (2021), to address the lack of comparative data concern and ensure an objective policy assessment. However, that approach could have introduced assumptions and potential macro researcher’s perspectives, as documented by Born (2021), which could have biased the results. Therefore, using existing empirical data from the literature in Chapter 5 and triangulating it with the data in this chapter appeared as a more robust tool compared to the counterfactual development approach to limit potential bias in the policy’s effectiveness evaluation.

The inconsistencies in the policies’ effectiveness between Chapters 5 and 6 could also stem from the different valuation scores used to ensure quantifiable policy assessments. For example, Chapter 5 used a 3-score valuation measure to estimate the policies’ effectiveness (2 = ‘effective’, 1 = ‘somewhat effective’, 0 = ‘not effective’), while Chapter 6 used a binary measure (median ≥4 = ‘effective’, median <4 = ‘not effective’). This variation made their ratings less comparable. However, regardless of their different valuation measures, the two chapters found the public awareness campaigns and border closure policies ‘effective’, indicating that other inherent factors may have influenced the valuations. For example, it was observed that while Chapter 5 reviewed the policies’ effectiveness based on the objectives and actual outcomes of the policies as reported in the literature, chapter 6 shows that some experts evaluated the policies’ effectiveness from other positions, such as logistic and enforcement viewpoints. While these positions were not mutually exclusive regarding the fundamental components of the policies, they offered divergent yet complementary data to fully understand the policies’ achievements, challenges, and limitations. For example, in the thematic findings, an expert rated the COVID-19 entry border screening policy as ‘ineffective’ because it was poorly enforced. Accordingly, some of the borders, mainly the land borders, were not monitored, and there were also unauthorised entry routes. Similarly, other experts rated the incentives for HCWs as ‘ineffective’ because of unavailable and inadequate equipment for clinical management of the outbreak. Further, another expert rated the bans on public gathering policy as ‘effective’ because its non-compliance came with punitive measures. These viewpoints could have accounted for the dissimilar effectiveness ratings between Chapters 5 and 6 for some policies. However, as mentioned earlier, the varied viewpoints justified the significance of the multiple approaches used to evaluate the policies in this study. The enforcement and logistics viewpoints should be explored further in future studies to provide more insight into the policies’ gains and challenges, given the fewer experts that expressed such viewpoints in this study.

Unlike the other policies, the vaccination policy was assessed prospectively, given that it is still in force. Therefore, its findings may not represent the policy’s gains at the end of its enrolment. As a recap, the policy was examined against its aim of addressing the COVID-19 burden in Ghana through vaccine-induced-herd-immunity, and not whether the vaccines would reduce the risk and severity of COVID-19 infection. Its evaluation findings in Chapter 5 were comparable to this chapter’s findings. Chapter 5 showed that although the policy could not achieve its targeted 60% herd immunity in June 2022, the number of reported COVID-19-related deaths has decreased by 35% since the policy began. Chapter 6 also found 38% (n = 13) certainty that the policy could reduce the COVID-19 health burden through herd immunity. Nonetheless, these data are not conclusive of the policies’ effectiveness, particularly as the 35% reduction in the COVID-19 mortality in Chapter 5 may not be attributable to the vaccination intervention, and 56% of the experts (n = 19) were also uncertain that the policy could achieve its aim.

Generally, the findings in the two Chapters 5 and provided data on the vaccination policy's current gains regarding its herd immunity aim and offered some insights into its possible future achievements. However, they were limited in confirming whether the policy has/could effectively reduce COVID-19 transmission and mortality in Ghana. This limitation was due to the complexity and multifaceted nature of the vaccination policy (Lau et al., 2021). For example, according to Lau et al. (2021), COVID-19 vaccination effectiveness/success depends on several interrelated factors, including the type of vaccine, the SARS-CoV-2 variant, age, sex, beliefs, and geographic location, as espoused from the TPB perspectives in Chapter 5. Therefore, studies must consider these factors to comprehensively estimate the policy's impact and effectiveness (Lau et al., 2021). For example, evidence shows that some COVID-19 vaccines prevent/reduce the risk of COVID-19 infection while others reduce the risk of another COVID-19 infection among those who have previously been infected (Patel et al., 2021; Hall et al., 2021). Therefore, more pragmatic approaches may be required to estimate the vaccination policy's effectiveness. Cohort studies may be one of the pragmatic and robust approaches to examining the effectiveness of the COVID-19 vaccination policy. It could compare the COVID-19 outcomes of vaccinated and unvaccinated persons to draw meaningful conclusions on the effectiveness of the policy. However, given the above discussion on factors that could impact COVID-19 vaccination outcomes, the cohort study must focus on one vaccine at a time, as lumping all vaccines together may blur the interpretation and policy implications of the findings of such studies.

The suggested cohort studies must also consider the other indicated factors, like age, sex, geographic location, dosage, and local vaccine policies in their designs, to ensure robust evidence on the policy's impact and subsequent effectiveness, especially given the findings of Lau et al. (2021). While the suggested cohort study may be limited in inferring causal associations due to its observational nature, it may be more robust in assessing the effectiveness of the COVID-19 policy than narrative evaluation. Therefore, this study conducted a robust cohort analysis in the next chapter to examine the influence of the vaccination policy on the COVID-19 health burden in Ghana. This analysis helped to assess the policy's effectiveness by quantifying its impact on COVID-19 outcomes, such as infection, mortality, long COVID, hospital admissions, and direct healthcare costs. The further analysis in the next chapter complemented the findings herein and enhanced the understanding of the COVID-19 vaccination policy's effectiveness in Ghana.

Comparatively, no single study was found in the literature to have evaluated all the policies contained herein at a go, as done in this chapter. This observation is probably due to the variations in the COVID-19 policy responses across countries because of contextual responses to the outbreak. For example, some countries implemented a total lockdown, while others, like Ghana, had a partial lockdown. Even the duration of the policies differed across countries. Therefore, the findings presented here could not be compared to the literature as a composite. However, when defragmented, the chapter's findings on the public awareness policy align with Quakyi et al. (2021)'s policy evaluation in Ghana. Although both studies found the policy effective in the context of its objectives, the government of Ghana can further strengthen this policy by blocking sources of misinformation that could result in non-data-driven directives. If not addressed, it could counteract the policy's current achievements. For example, evidence from the literature shows that reduced COVID-19 vaccination education, misinformation, and uncontrolled reportages influence vaccine hesitancy among populations (Lockyer et al., 2021; Garett & Young, 2021). Addressing these low awareness and misinformation concerns could reduce vaccine hesitancy attributable to misinformation.

The findings on the effectiveness of the partial lockdown in Chapter 5 aligned with Assan et al. (2022) evaluation results. Both studies agreed that the policy was not 'very effective' in Ghana. Thus, Assan et al. (2022)'s results are inconsistent with this chapter's findings, which found the policy effective. Both Assan et al. (2022) and Chapter 6 evaluated the effectiveness of the partial lockdown policy from stakeholders/experts' perspectives; however, Chapter 6 explored the views of academic experts while Assan et al. (2022) focused on diverse stakeholder populations, including opinion leaders, students and media personnel. The diversity in the studies' populations may be responsible for the variations in the results. Again, while this chapter examined whether the partial lockdown policy achieved its objective of reducing COVID-19 transmission, Assan et al. (2022) examined whether the policy achieved its objectives before it was lifted. Therefore, Assan et al. (2022)'s inclusion of time in their analysis accounted for the differences between the two studies. However, while their time inclusion had significant implications for policy termination, it was limited in incorporating potential policy spill-over to ensure comprehensive data on the policy, as done in this chapter.

Further, Assan et al. (2022)'s analysis was conducted a few weeks after the lockdown policy was lifted (23rd April 2020 to 1st July 2020), and this chapter explored the experts' opinions from December 2022 to January 2023. So, while Assan et al. (2022) probably circumvented potential respondents' recall bias, this chapter included the experts' knowledge of the policy's possible spill-over impact in the analysis, ensuring comprehensive findings. Additionally, the partial lockdown policy had three objectives; therefore, exploring its effectiveness based on one objective, as done by Assan et al. (2022), may provide insufficient findings on its overall effectiveness. Nonetheless, based on the findings in Chapter 5, the thesis agrees with Assan et al. (2022) that the partial lockdown policy was not fully realised before it was lifted, especially when it is juxtaposed with the WHO's recommendations for lifting lockdowns (WHO, 2023).

Regarding strengths and limitations, this chapter integrated two methodological approaches, quantitative and qualitative analysis, to enhance our understanding of the effectiveness of Ghana's COVID-19 policy responses. The complementary approaches reduced the impact of any potential bias that could limit the reliability of the generated findings by maximising the advantages of the two methods and minimising the influence of their limitations. However, given the unavailability of comparative data, the policy's assessment findings here may not be attributable to any single COVID-19 policy in Ghana, as discussed in Chapter 5. Also, the relatively smaller sample size in this chapter limits the study's statistical estimation in the regression and bivariate analyses, and by extension, the statistical power and the interpretation of the findings as a reflection of all academic experts' viewpoints (Hackshow, 2008). Nonetheless, this limitation is inconsequential to this study as the analyses were to provide an indication of whether the discipline and demographic diversity among the experts influenced their policy ratings and not necessary to draw any statistical conclusions based on effect sizes nor draw any findings generalisations, as characterised by quantitative studies.

6.5 Conclusion

This chapter complemented the analyses in Chapter 5 by examining the effectiveness of Ghana's COVID-19 policies from the perspectives of policy experts. It was observed that most of the COVID-19 policy responses in Ghana were population-level policies, with a few focusing on sub-populations, like the incentives for HCWs. Therefore, by inference, the policies targeted all populations, not necessarily those at risk of severe COVID-19 outcomes, such as mortality and prolonged hospitalisation. As we advance, it may be prudent to have some policy specificities in future policy developments, in addition to the wider population policies, particularly as the risk of severe viral infectious disease outcomes differs across populations (as seen in Chapter 4). These policy specifications, such as policies to promote regular medical check-ups for persons with comorbidities, may ensure equitable shielding interventions in the fight against infectious diseases.

Chapters 5 and 6 had some similarities and heterogeneities in the effectiveness of the COVID-19 policies. The heterogeneities were attributed to the lack of comparative data for quantifiable and objective policy change analyses, different valuation measures and the inclusion of other viewpoints by the experts. The chapter concluded that all the policies collectively influenced the COVID-19 outcomes in Ghana because no outcomes could be attributed to a single policy. As hinted earlier, the next chapter of this thesis conducted a quantitative cohort analysis to explore the influence of the COVID-19 policies on any long-term consequences of the outbreak in Ghana. It used an innovative agent-based model to simulate the influence of lockdown and vaccination policies on COVID-19 infections, mortalities, hospital admissions, long COVID and healthcare costs in the long-term to inform forethought mitigating strategies in Ghana.

CHAPTER 7: CAN THE COVID-19 POLICIES INFLUENCE LONG-TERM CONSEQUENCES OF THE COVID-19 OUTBREAK IN GHANA?

7.1 Introduction

Chapters 5 and 6 evaluated the effectiveness of Ghana's COVID-19 policies implemented to address the burden of COVID-19 outbreak in Ghana. Given that the policies were targeted at the immediate burden of COVID-19 (GHS, 2023), this thesis deliberated on whether the policies could address the long-term consequences of the outbreak in Ghana. Accordingly, this chapter examined the influence and extent of mitigation of the policies on the long-term consequences of COVID-19 in Ghana. In practice, the chapter first predicted the possible long-term consequences of COVID-19 in Ghana and then examined the influence of the policies on the predicted consequences.

7.2 Methods

7.2.1 Modelling Approach

The literature review in Chapter 2 identified several compartmental models used to examine the long-term consequences of COVID-19. The compartmental models included varied Susceptible, Exposed, Infectious, Quarantine, Hospitalised, Recovery and Susceptible (SEIQHRS) models (Dwomoh et al., 2021; Frost et al., 2021) and were aimed to provide an understanding of the epidemiological trajectory of the COVID-19 infection. Compartmental models are evidenced to forecast infectious disease outcomes by showing their transmission dynamics, epidemic growth, and the flow patterns between compartments (Dwomoh et al., 2021; Greenhalgh & Rozins, 2021). For example, the models can predict the number of susceptible, infected, hospitalised, recovered and deaths from infectious diseases over time (Kong et al., 2016). They can also illustrate the non-linear transmission progression of an infectious disease, where an individual can move from infectious to recovery or death without moving to the hospitalisation compartment (Greenhalgh & Rozins, 2021). These characteristics of the compartmental models are useful to inform pre-emptive mitigating interventions, such as targeted vaccinations, lockdowns, hospital financing, contingency plans on human resources and logistics, to avert deaths, prolonged morbidities, and health service delivery breakdown (Lutz et al., 2019).

Most of the COVID-19 modelling studies in Ghana used the compartmental modelling approach (Dwomoh et al., 2021; Acheampong et al., 2022; Barnes et al., 2022), probably due to its espoused advantages above. Nonetheless, while they provide valuable data to guide anticipatory mitigating interventions, they assumed all persons in the population have an equal probability of COVID-19 infection following contact with an infectious person. This assumption, however, does not reflect real-life situations as population variations, such as age, pre-existing conditions and sex, could influence the probability of COVID-19 infection and the infection's trajectory (Kong et al., 2016). Further, as characterised by compartmental models, the studies used cumulative COVID-19 cases to forecast the long-term burden of COVID-19, which again, do not account for the influence of population variations on the long-term trajectory of the outbreak in Ghana (Dwomoh et al., 2021; Acheampong et al., 2022). Accounting for the influence of variations in sociodemographic, health profiles and lifestyle characteristics on the long-term trajectory of COVID-19 is necessary to delineate populations at increased risk of severe outcomes of the disease and ensure targeted interventions to avoid health inequities (Kong et al., 2016). Given the limitations of the compartmental models, the thesis explored the literature for other mathematical models that could account for population variations in forecasting the long-term consequences of COVID-19 in Ghana. The exploration identified agent-based models, mathematical modelling approaches responsive to the influence of population variations on the long-term trajectory of infectious diseases (Kerr et al., 2021; Silva et al., 2022).

Agent-based models account for population variations by using individual-based data or characteristics, like age, sex, health profiles and socioeconomic status, to examine long-term epidemiological trajectories of infectious diseases (Mintram et al., 2022; Hunter et al., 2018). As argued earlier, using individual-based data is necessary to inform targeted interventions that could protect all populations (Kong et al., 2016). In addition, agent-based models can predict the influence of interventions or policies on the long-term burden of diseases (Kerr et al., 2021). This advantage was particularly important for this chapter as it aligned with its objective to examine the influence of COVID-19 policies on the long-term COVID-19 consequences in Ghana. Several agent-based models were identified in the literature, such as the agent-based model by Hunter et al. (2018) to simulate the epidemiological burden and outcomes of measles and the model by Venkatramanan et al. (2018) to forecast the epidemiological outcomes of Ebola. On specific models for COVID-19 disease prediction, the study identified numerous agent-based models, including the COVID-19 model by Shamil et al. (2021), the Coronavirus Lifelong Model and Simulation (CALMS) agent-based model by Mintram et al. (2022), the COVID-19 agent-based simulator, Covasim, by Kerr et al. (2021) and COVID-ABS by Silva et al. (2020). Unlike the models by Shamil et al. (2021) and Kerr et al. (2021), which only predict and examine the influences of COVID-19 policies on the long-term health burden of COVID-19, the models by Mintram et al. (2022) and Silva et al. (2020) can predict and simulate the influence of COVID-19 policies on both health and economic burdens of COVID-19, presenting an added simulating advantage for this study. Therefore, they were further reviewed for potential adoption in this study. The further review resulted in the adoption of the CALMS model by Mintram et al. (2022). This choice was because Silva et al. (2020)'s model was designed to accommodate social distancing interventions, while Mintram et al. (2022)'s model was developed to incorporate COVID-19 vaccination interventions in addition to movement restriction interventions, warranting its selection as COVID-19 vaccination was one of the critical interventions in this study. Specifically, the CALMS model is an agent-based model developed to predict the long-term health and economic burdens of COVID-19 and simulate the influence of interventions on the predicted burden (Mintram et al., 2022). The CALMS modelling in this study was guided by the EPIFORGE checklist[12] for reporting infectious disease forecasting and simulation (Pollett et al., 2021).

7.2.2 Description and Validation of the CALMS model

CALMS is an agent-based model that predicts the number of COVID-19 infections, hospital admissions, long COVID, healthcare costs, and mortalities for any given population and simulates the mitigating influence of related interventions, like vaccination, on the predicted burden (Mintram et al., 2022). It uses individuals' (agents) data, including the literature established COVID-19 risk factors, such as age, sex and comorbidities, to estimate their risks of COVID-19 infections following exposure to the SARS-CoV-2 virus and further predict their risks of potential consequences, such as mortalities and admissions, following the COVID-19 infection. CALMS is a validated agent-based model. For its validation, it was run retrospectively for cohorts comprising 10,000 agents over nine months and the outputs, i.e., the number of infections, mortalities, long COVID and hospitalisations, and risk factors, such as

[12] EPIFORGE Checklist available at:
https://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.1003793

age, hypertension and diabetes, were compared with the observed COVID-19 outputs and risk factors from official COVID-19 databases, such as the UK's official COVID-19 dashboard and the Intensive Care National Audit & Research Centre (ICNARC), to ensure its validity (Mintram et al., 2022; Coronavirus dashboard – UK, 2023; ICNARC, 2023; Du et al., 2021). Figure 23 below shows the components of the CALMS model and the texts after that describe each component.

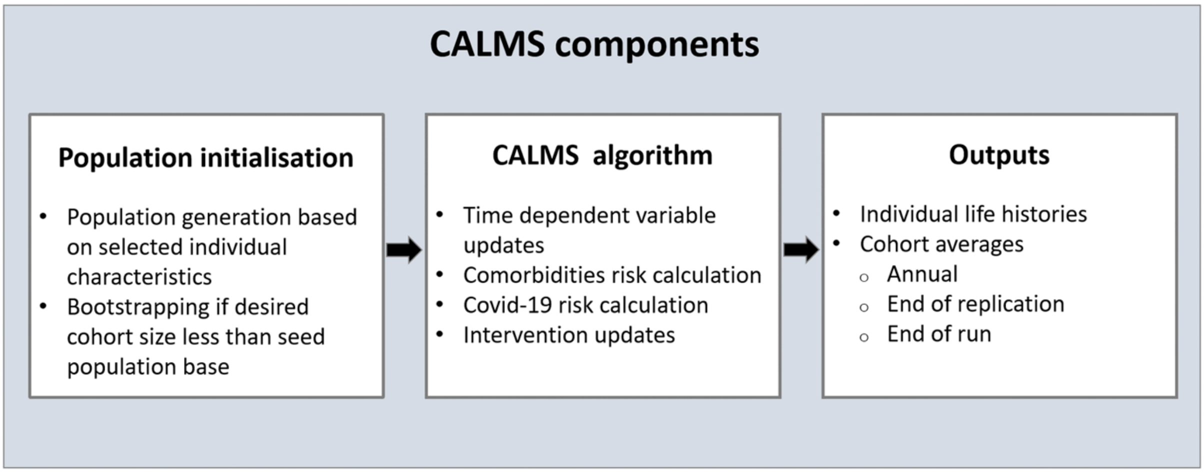

Figure 23: Components of the CALMS model. Image source: https://doi.org/10.1371/journal.pone.0272664.g001

7.2.2.1 Population Initialisation

At the population initialisation phase, populations/cohorts of interest for the modelling are generated. For this study, the population was accessed from the electronic database of the GEMH. It included all patients aged ≥18 with no COVID-19 diagnosis managed at the facility from October to December 2022. The anonymised data was accessed electronically in February 2023 and data integrity checks were conducted by the researcher and an independent reviewer to verify the quality and reliability of the data. The generated dataset included individual-based characteristics, such as sex, age and Non-Communicable Diseases (NCDs), like diabetes mellitus (DM), Cardiovascular Diseases (CVDs) and hypertension (HPT). The CALMS model was first modelled for a 10,000 seed UK population (Mintram et al., 2022). As such, it allows bootstrapping for subsequent populations whose sizes differ from the seed population. However, bootstrapping is not compulsory as the model is amenable to all population sizes.

Therefore, no bootstrapping was conducted for the generated population in this study to limit any sample generalisation limitations.

7.2.2.2 CALMS Algorithm

In the CALMS algorithm, the model updates the agents' time-dependent variables, such as age, and calculates their risks of comorbidities, such as DM, HPT and CVDs, using incorporated Q-risk algorithms, such as the QDiabetes algorithm (Hippisley-Cox & Coupland, 2017; Hippisley-Cox et al., 2008). These calculations are updated periodically to capture changing trends throughout the modelling years. For example, the model calculates and updates the agents' comorbidities risks at defined periods to reflect real-life scenario medical updates. After, it calculates the agents' risks of COVID-19 infection based on SARS-CoV-2's transmission rate/probability, the number of persons the agents come into contact with daily and the number of COVID-19 infections in the cohort using the formula in equation 1:

$$I_p = T_p C_n C_i$$

Equation 1: Formula for calculating the risk of COVID-19 infection[13].

Where Ip refers to the agent's risk of COVID-19 infection, Tp is the virus's transmission probability, Cn is the number of persons an agent comes into contact with within a day, and Ci is the number of COVID-19 infections in the cohort.

After predicting the risk of COVID-19 infection, the algorithm predicts the agent's probable COVID-19 outcomes based on the agent's risk factors, such as age, sex and comorbidities. The predicted outcomes include severity of the COVID-19 infection, mortality and long COVID. Agents with critical and severe COVID-19 infections are forecasted to be admitted into ICUs and hospitals, respectively. Based on predicted hospital and ICU admissions, the algorithm determines the COVID-19-related direct healthcare costs for each agent and the entire cohort. It estimates this cost by multiplying the hospital and ICU admission costs by the length of admissions – calculated using gamma distributions (Mintram et al., 2022). The algorithm runs

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[13] Equation accessed from https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0272664#pone.0272664.ref019

100 replications for each modelled year. Figure 24 summarises the processes in the CALMS algorithm.

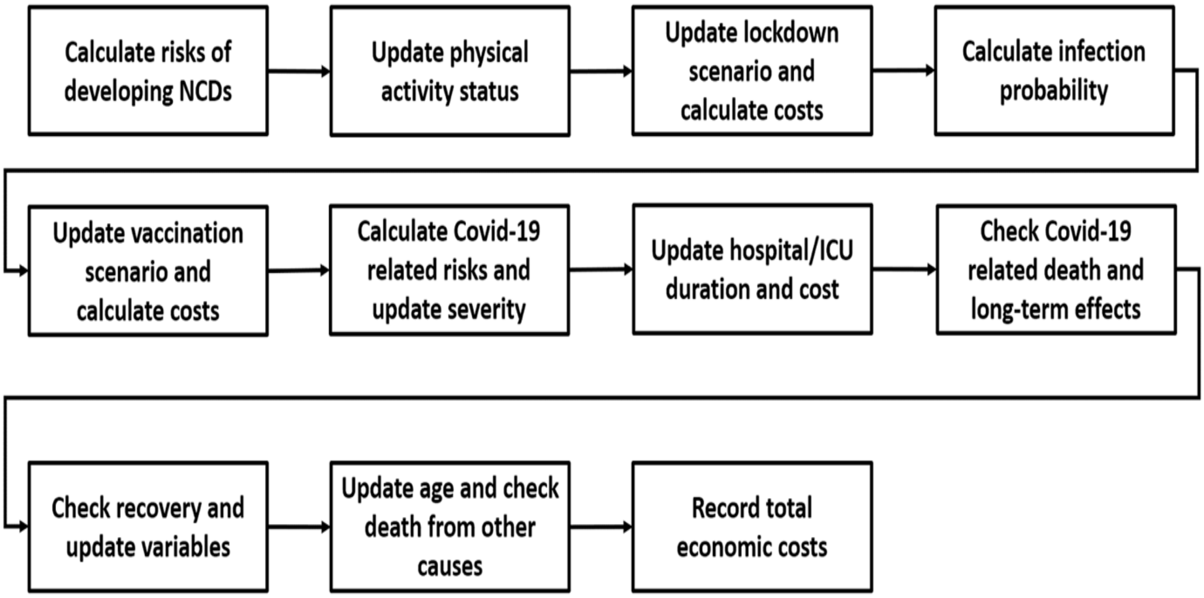

Figure 24: The CALMS algorithm. Image source: https://doi.org/10.1371/journal.pone.0272664.g002

During the modelling, the algorithm imbibes hypothetical intervention/policy scenarios, like lockdown and vaccination (Mintram et al., 2022). Therefore, this study used the CALMS model to predict the effect of four hypothetical policy scenarios (table 33) on the long-term COVID-19 impacts on health outcomes in Ghana. The scenarios were informed by the current COVID-19 intervention in Ghana and the recommended intervention to reduce COVID-19 spread when infections and admissions reach defined peak levels (GHS, 2023; Mintram et al., 2022). Throughout the modelling, the algorithm calculates the costs of each policy and sums the cost of the policies at the end of the simulation period. This policy cost output and the healthcare cost output provide bases for potential future cost-benefit analyses. The COVID-19 long-term predictions and simulations were projected for seventy (70) years when all the agents were assumed to have reached their lifespan. This assumed lifespan was informed by the life expectancy for both sexes in Ghana, which was estimated at 66.3 years as of 2019 (WHO, 2023).

Table 33: Examined hypothetical policy scenarios.

Scenarios	**Policy**
Scenario 1	No interventions
Scenario 2	Vaccinating clinically vulnerable populations (Described as those with comorbidities, such as hypertension, DM and CVDs, those aged ≥60 and have BMI ≥40kg/m^2.
Scenario 3	Periodic lockdown scenarios (Triggered when the number of hospital admissions reaches a predefined peak/threshold – as captured by Mintram et al. (2022).
Scenario 4	Combined whole population vaccination with periodic lockdowns

7.2.2.3 CALMS Output

After simulation, the model predicts the long-term outcomes/consequences of COVID-19 for each agent and the entire cohort from year one up to a defined year, when most of the individuals in the cohort are dead (the lifespan of the cohort). As mentioned earlier, the predicted outcomes include COVID-19 infections, hospital and ICU admissions, mortalities, long COVID and direct healthcare and intervention costs. The algorithm calculates the healthcare and intervention costs using UK estimates, given that CALMS was initially developed and modelled for the UK population. Therefore, to contextualise the findings, this chapter conducted additional healthcare cost analysis using the number of hospital and ICU admissions from the CALMS output and the cost of hospital and ICU admissions plus the average length of admissions reported by studies conducted in Ghana (Crankson et al., 2022; Ismaila et al., 2021).

The recalculation was done with a Microsoft Excel workbook, and it aimed to provide costs that reflect Ghana's situation. In the estimation, the CALMS output on hospital and ICU admissions was multiplied by the cost of hospital and ICU management in Ghana, as reported by Ismaila et al. (2021). Ismaila et al. (2021)'s hospital and ICU management costs were informed by the prevailing COVID-19 management protocols in Ghana and the average length of hospitalisation per the severity of the disease. They reported an average of 21 days of hospitalisation for severe and critical COVID-19 diseases. Based on this average, they estimated the total hospital management cost per patient as 20,305 and 23,382 dollars for severe (hospital admission) and critical (ICU admission) COVID-19 disease, respectively. Therefore, these costs were used to recalculate the total healthcare costs in this chapter using equation 2 below:

$$\textit{Total hospital admission cost (HC)} = \textit{Total number of hospital admissions} \times \$20{,}305$$

$$\textit{Total ICU admission cost (IC)} = \textit{Total number of ICU admissions} \times \$23{,}382$$

$$\textit{Total healthcare costs (THC)} = HC + IC$$

Equation 2: Formula used to re-estimate Ghana's total direct healthcare costs.

The study was, however, unable to re-estimate the total cost of the policy scenarios to mirror Ghana's context. This was because the costs needed to be incorporated into the model at the development stage to ensure their updates per the updated agent's health profile. This limitation indicates the need for agent-based algorithms explicitly developed for countries/populations. Nonetheless, this limitation was minimal given that the vaccination cost was informed by global estimates (Mintram et al., 2022). Apart from the CALMS outputs, the study also generated outputs on the cohort's initial characteristics and bivariate relationships using SPSS version 26. The findings from the CALMS model and SPSS are presented below.

7.3 Results

7.3.1 Descriptive Characteristics of the Cohort

A total of 4,344 cohort aged ≥18 was accessed from the GEMH. Most of them were women (n = 3053; 70.3%) and of black ethnicity (n = 3759; 86.5%). A few had DM (n = 134; 3.1%), HPT (n = 237; 5.5%), and CVDs (n = 183; 4.2%). Their mean BMI and age were 24.55±1.47kg/m^2 and 35.07±17.02 years, respectively. See table 34 for the population's characteristics.

Table 34: Sample description (N = 4,344)

Sample Characteristics	Total – N (%)	Mean (SD)	Median (IQR)
Age		35.07 (17.02)	31 (20)
BMI		24.55 (1.47)	24.39 (3)
Men Women	1,291 (29.7) 3,053 (70.3)		
Ethnicity			

Sample Characteristics	Total – N (%)	Mean (SD)	Median (IQR)
Black White	3,759 (86.5) 585 (13.5)		
DM (Type 2 Diabetes)			
Present Absent	134 (3.1) 4,210 (96.9)		
HPT			
Present Absent	237 (5.5) 4,107 (94.5)		
CVDs			
Present Absent	183 (4.2) 4,161 (95.8)		

7.3.2 Bivariate Results

The bivariate analysis showed significant associations between age and HPT (p = 0.00) and CVDs (p = 0.02). Significant relationships were also identified between sex and DM (p = 0.03), HPT (p = 0.05), and CVDs (p = 0.00). BMI also correlated with HPT (p = 0.00) and CVDs (p = 0.00) but not with DM (p = 0.09). See table 35 for a summary of the bivariate findings.

Table 35: Findings of the bivariate analysis (Man-Whitney U and Chi-square tests: N =4,334)

Sample characteristics	DM			HPT			CVDs		
	Present	Absent	p-value	Present	Absent	p-value	Present	Absent	p-value
Age			0.88			0.00			0.02
Sex			0.03			0.05			0.00
Men Women	51 83	1,240 2,970		84 153	1,207 2,900		98 85	1193 2,968	
Ethnicity			0.12			0.55			0.46
Black White	122 12	3,637 573		202 35	3,557 550		155 28	3,604 557	
BMI			0.09			0.00			0.00

7.3.3 CALMS Prediction Outputs

The model predicted and simulated the influence of the policy scenarios for a thousand agents based on a 95% confidence level and a 5% error term. For each modelled year, 100 replications were run for each policy scenario to estimate the average of all possible policy outcomes for each consequence, i.e., COVID-19 infections, mortalities, long COVID and hospital admissions in the long term. Therefore, the number (N) of predicted long-term consequences shown in the results below represent the average of 100 replications per year, and the presented means and standard deviations (Mean ± SD) represent the average replication by the number of cohorts. The results of the policies' influence on the predicted long-term COVID-19 consequences are presented below:

7.3.3.1 Simulated Influence of Vaccinations and Lockdowns on COVID-19 Infections

All policy scenarios predicted a reduction in the total number of COVID-19 infections among the cohort in years 5 and 10 compared to the no-intervention scenario, except in year 70 (anticipated life span of the cohort), which predicted a 0.92% increase in the total number of COVID-19 infections when the clinically vulnerable populations are vaccinated compared to no intervention (Infections difference: n = 399). Among the interventions, the combined intervention, i.e., the whole population vaccination with periodic lockdowns scenario (scenario 4), was predicted to result in the highest reduction in the total number of COVID-19 infections throughout the lifespan of the cohort. See figure 25 and table 36 for the predicted COVID-19 infections.

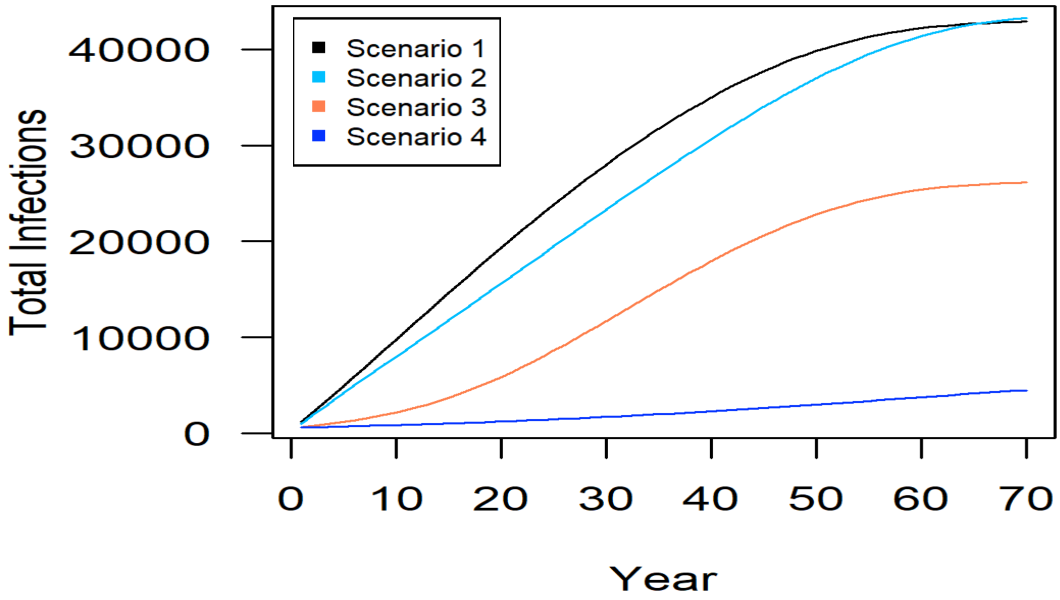

Figure 25: Simulated influence of lockdown and vaccinations on predicted COVID-19 infections.

Table 36: Simulated influence of lockdown and vaccinations on predicted COVID-19 infections

Year	**Scenario 1** **N (Mean ± SD)**	**Scenario 2** **N (Mean ± SD)**	**Scenario 3** **N (Mean ± SD)**	**Scenario 4** **N (Mean ± SD)**
5	4,888 (4.89±0.91)	4,160 (4.16±0.92)	1,167 (1.17±0.77)	705 (0.70±0.55)
10	9,712 (9.71±1.91)	7,947 (7.94±1.56)	2,152 (2.15±1.14)	857 (0.9±0.7)
70	42,883 (42.88±22.01)	43,282 (43.28±19.49)	26,118 (26.12±16.64)	4,465 (4.47±3.51)

Scenario 1: no intervention; Scenario 2: vaccinating clinically vulnerable individuals; Scenario 3: periodic lockdown; Scenario 4: periodic lockdowns and whole population vaccination.

7.3.3.2 Simulated Influence of Vaccinations and Lockdowns on COVID-19 Hospital Admissions

The total number of COVID-19-related hospital admissions is simulated to increase steadily throughout the lifespan of the cohort when no interventions are implemented, with the highest increase seen in year 70. The number is also predicted to increase with increasing years for all the interventions; however, this increase will be lower than the no-intervention scenario. For instance, vaccinating the clinically vulnerable (scenario 2) in the cohort is expected to decrease the total number of COVID-19 hospital admissions by nearly 92% compared to no intervention in year 5. This is comparable to the percentage reductions in years 10 (94%) and 70 (89%). No COVID-19 hospital admissions will be recorded in year 5 if the whole population with periodic lockdown intervention (scenario 4) is implemented. The total admission will, however, increase to 1 and 17 in years 10 and 70, respectively. Nonetheless, this number will still be about 99% and 98% lower than the no-intervention scenario in years 10 and 70, respectively. Among the interventions, the periodic lockdown policy (Scenario 3) will have the lowest reduction in COVID-19-related hospital admissions when compared to the baseline (no intervention). Figure 26 and table 37 summarise these results.

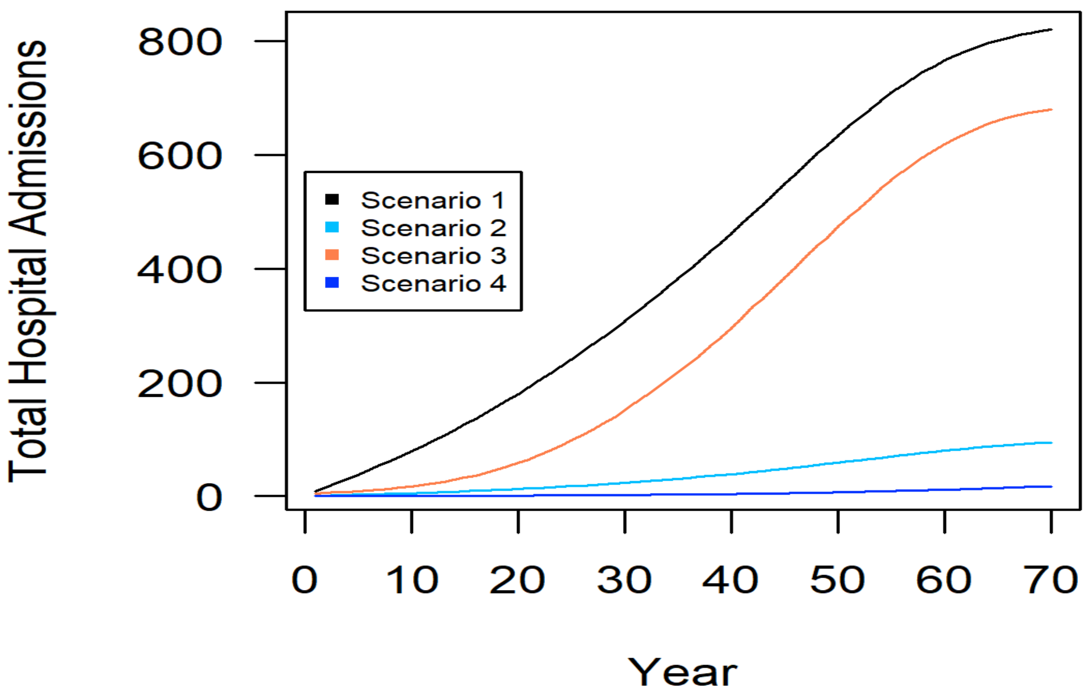

Figure 26: Simulated influence of lockdown and vaccinations on predicted long-term COVID-19 hospitalisation.

Table 37: Simulated influence of lockdown and vaccinations on predicted long-term COVID-19 hospitalisation.

Year	Scenario 1 N (Mean ± SD)	Scenario 2 N (Mean ± SD)	Scenario 3 N (Mean ± SD)	Scenario 4 N (Mean ± SD)
5	37 (0.04±0.19)	3 (0.00±0.04)	9 (0.01±0.09)	0 (0.00±0.01)
10	79 (0.07±0.29)	5 (0.01±0.07)	17 (0.02±0.12)	1 (0.00±0.01)
70	819 (0.82±0.84)	94 (0.09±0.30)	680 (0.67±0.79)	17 (0.02±0.11)

Scenario 1: no intervention; Scenario 2: vaccinating clinically vulnerable individuals; Scenario 3: periodic lockdown; Scenario 4: periodic lockdowns and whole population vaccination.

7.3.3.3 Simulated Influence of Vaccinations and Lockdowns on COVID-19 ICU Admissions

Implementing interventions will reduce the total number of COVID-19-related ICU admissions throughout the lifespan of the cohort compared to no interventions (scenario 1). For example, in year 70, the whole population vaccination with periodic lockdown intervention (scenario 4) and the vaccination of the vulnerable cohorts (scenario 2) will reduce the baseline (no intervention) ICU admissions by 98% and 89%, respectively and the lockdown scenario (scenario 3) will reduce it by 17%. By inference, at the end of the cohorts' lifespan (year 70), the scenario 4 intervention will reduce the number of baseline ICU admissions more than the other scenarios, with the lockdown scenario having the least reduction. Comparatively, the lockdown scenario will reduce the baseline scenario more in years 5 and 10 (% reduction: 75%) than in year 70 (% reduction = 17%), suggesting that the influence of the lockdown scenario in reducing baseline COVID-19-related ICU admissions will decrease with increasing years. See figure 27 and table 38.

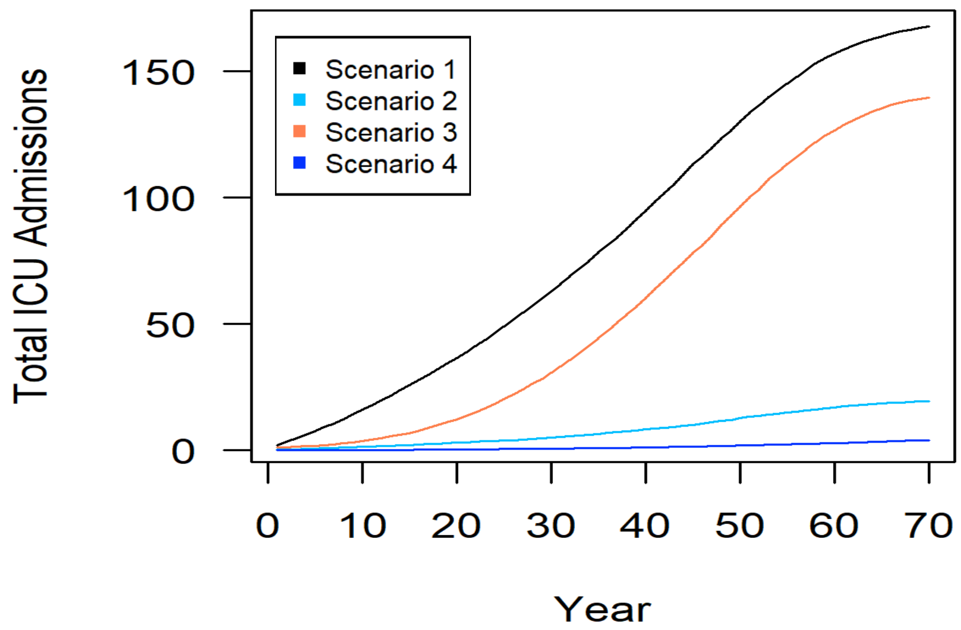

Figure 27: Simulated influence of lockdown and vaccinations on predicted long-term COVID-19 ICU admissions.

Table 38: Simulated influence of lockdown and vaccinations on predicted long-term COVID-19 ICU admissions.

Year	Scenario 1 N (Mean ± SD)	Scenario 2 N (Mean ± SD)	Scenario 3 N (Mean ± SD)	Scenario 4 N (Mean ± SD)
5	8 (0.01±0.08)	1 (0.00±0.01)	2 (0.00±0.03)	0 (0.00±0.00)
10	16 (0.02±0.13)	1 (0.00±0.03)	4 (0.00±0.05)	0 (0.00±0.00)
70	168 (0.17±0.39)	19 (0.02±0.14)	140 (0.14±0.37)	4 (0.00±0.04)

Scenario 1: no intervention; Scenario 2: vaccinating clinically vulnerable individuals; Scenario 3: periodic lockdown; Scenario 4: periodic lockdowns and whole population vaccination.

7.3.3.4 Simulated Influence of Vaccinations and Lockdowns on COVID-19 Mortalities

The model predicted an increasing number of COVID-19-related mortalities over the lifespan of the cohort, with no intervention resulting in the highest number of mortalities. Twenty-four (n = 24) COVID-19-related mortalities are estimated in year 5 when no interventions are implemented, and this could reduce by 92% if the clinically vulnerable groups are vaccinated (scenario 2) or 100% if the whole population vaccination with periodic lockdown scenario is implemented (scenario 4). Throughout the cohort's simulated years, the lockdown intervention (scenario 3) will have the lowest reduction in the total number of COVID-19-related mortalities among the intervention scenarios. Scenario 4 will have the highest reduction in the number of mortalities, reducing the lockdown (scenario 3) numbers by 100% in years 5 and 10 and 98% in year 70. See figure 28 and table 39.

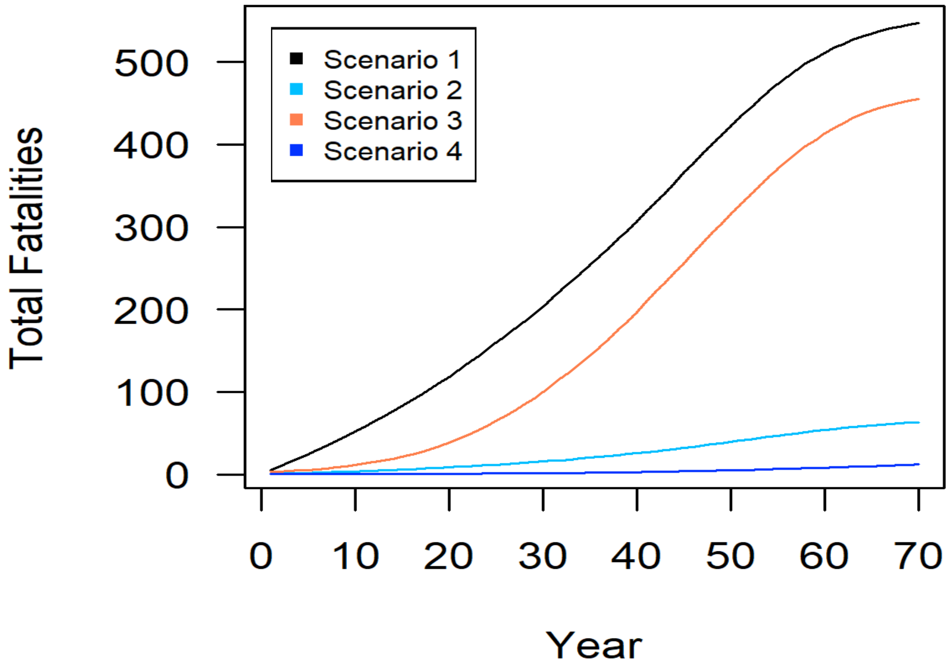

Figure 28: Simulated influence of lockdown and vaccinations on predicted long-term COVID-19 mortalities.

Table 39: Simulated influence of lockdown and vaccinations on predicted long-term COVID-19 mortalities.

Year	**Scenario 1 N (Mean ± SD)**	**Scenario 2 N (Mean ± SD)**	**Scenario 3 N (Mean ± SD)**	**Scenario 4 N (Mean ± SD)**
5	24 (0.02±0.15)	2 (0.00±0.03)	5 (0.01±0.06)	0 (0.00±0.01)
10	52 (0.05±0.22)	4 (0.00±0.05)	11 (0.01±0.09	0 (0.00±0.01)
70	547 (0.55±0.5)	63 (0.06±0.24)	455 (0.46±0.49)	11 (0.01±0.08)

Scenario 1: no intervention; Scenario 2: vaccinating clinically vulnerable individuals; Scenario 3: periodic lockdown; Scenario 4: periodic lockdowns and whole population vaccination.

7.3.3.5 Simulated Influence of Vaccinations and Lockdowns on Long COVID

The total number of long COVID cases in scenario 1 (no intervention) will be more than the predicted numbers in scenarios 2, 3 and 4 in years 5 and 10. Among the interventions, the whole population with periodic lockdown scenario (scenario 4) will reduce the baseline (no intervention) long COVID cases by 86%, 91% and 90% in years 5, 10 and 70, respectively, while the vaccinating the vulnerable cohort scenario (scenario 2) will reduce it by 15%, 18% in years 5 and 10, and increase it by 1% in year 70. The lockdown policy (scenario 3) will reduce the baseline cases by 76%, 78% and 40% in years 5, 10 and 70, respectively. Therefore, compared to the other intervention scenarios, scenario 2 will have the slightest reduction in the baseline long COVID cases in years 5 and 10. In year 70, it will have 1% more cases of long COVID than the baseline cases. Like the other health burden, the scenario 4 intervention will be the most case reduction intervention for long COVID, with its optimal reduction in year 10. See figure 29 and table 40 for details of this result.

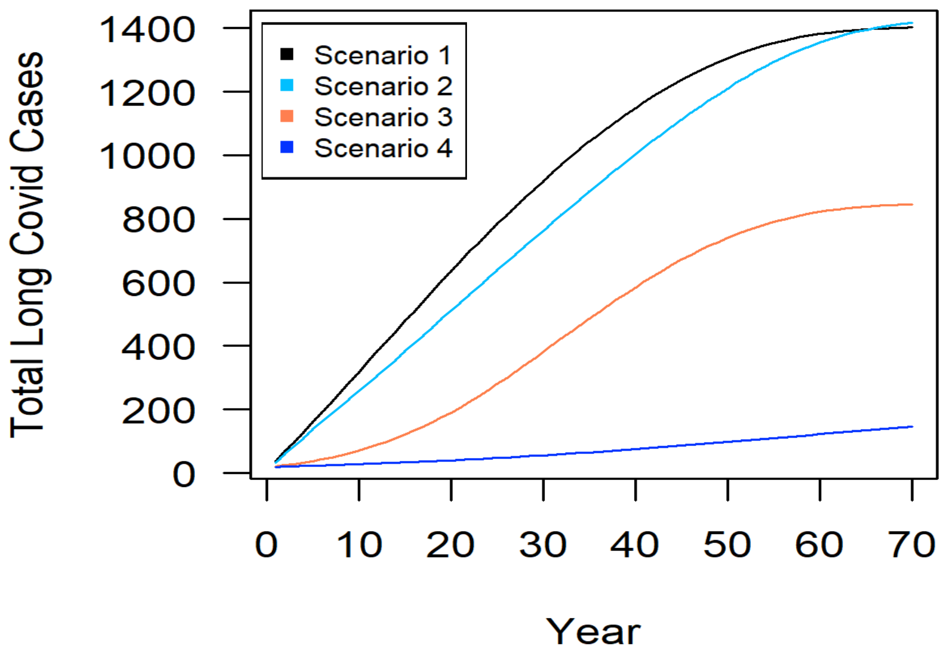

Figure 29: Simulated influence of lockdown and vaccinations on predicted long-term long COVID-19.

Table 40: Simulated influence of lockdown and vaccinations on predicted long-term long COVID-19.

Year	Scenario 1 N (Mean ± SD)	Scenario 2 N (Mean ± SD)	Scenario 3 N (Mean ± SD)	Scenario 4 N (Mean ± SD)
5	160 (0.16±0.39)	136 (0.14±0.36)	38 (0.04±0.19)	23 (0.02±0.15)
10	312 (0.32±0.56)	257 (0.26±0.49)	70 (0.07±0.26)	28 (0.03±0.16)
70	1402 (1.40±1.37)	1417 (1.41±1.33)	845 (0.85±1.05)	146 (0.15±0.38)

Scenario 1: no intervention; Scenario 2: vaccinating clinically vulnerable individuals; Scenario 3: periodic lockdown; Scenario 4: periodic lockdowns and whole population vaccination.

7.3.3.6 Simulated Influence of Vaccinations and Lockdowns on Healthcare Cost

CALMS predicts a higher healthcare cost if no COVID-19-related interventions are implemented throughout the lifespan of the cohort. However, the non-intervention healthcare cost could reduce by 92% in year five if the clinically vulnerable agents are vaccinated (scenario 2) and by almost 99% if the whole population is vaccinated and periodic lockdowns are triggered (scenario 4). In years 5, 10 and 70, the most healthcare cost reducing intervention is the whole population vaccination with periodic lockdowns (scenario 4), followed by the vaccinating the clinically vulnerable cohort intervention (scenario 2). Throughout the cohort's lifespan, the lockdown intervention (scenario 3) will produce the least reduction in healthcare costs compared to the other interventions. However, its associated cost will still be lower than no interventions. See figure 30 and table 41 for a summary of this result.

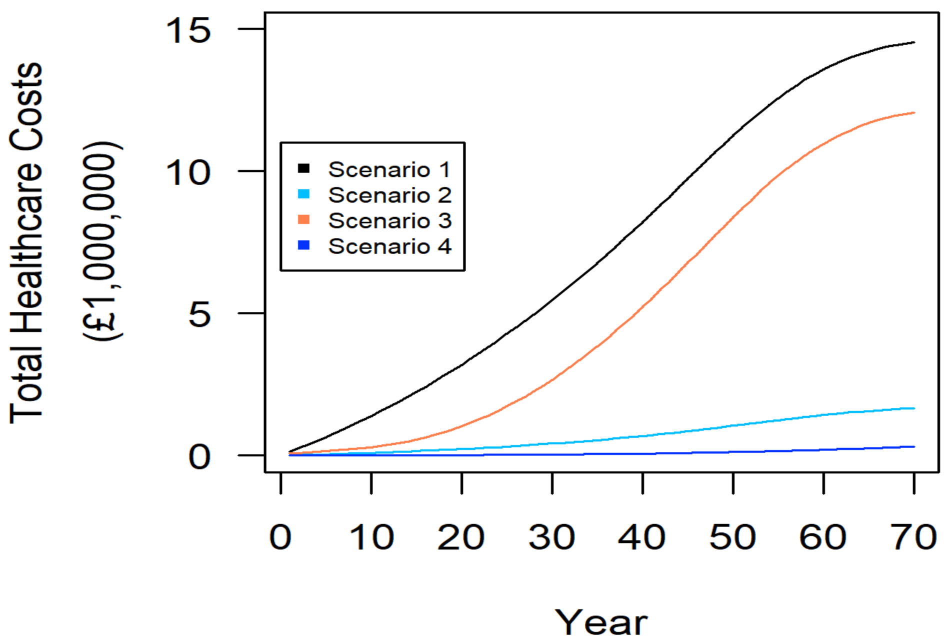

Figure 30: Simulated influence of lockdown and vaccinations on predicted long-term COVID-19-related direct healthcare cost (£).

Table 41: Simulated influence of lockdown and vaccinations on predicted long-term COVID-19-related direct healthcare cost (£).

Year	Scenario 1 N (Mean ± SD)	Scenario 2 N (Mean ± SD)	Scenario 3 N (Mean ± SD)	Scenario 4 N (Mean ± SD)
5	639,425.9 (639.4±4251.5)	49,995.5 (49.9±906.0)	156,639 (156.64±1998.69)	7,101.9 (7.10±180.1)
10	13.9×10^5 ($13.9\times10^2\pm65.7\times10^2$)	99,411.14 ($99.41\pm14.65\times10^2$)	295,595 (295.60±2772.14)	9,851.6 (9.85±210.4)
70	14.5×10^6 ($14.5\times10^3\pm21.9\times10^3$)	16.7×10^5 ($16.71\times10^2\pm69.6\times10^2$)	12.1×10^6 ($12.1\times10^3\pm2.0\times10^4$)	31.5×10^4 ($315.8\pm23.9\times10^2$)

Scenario 1: no intervention; Scenario 2: vaccinating clinically vulnerable individuals; Scenario 3: periodic lockdown; Scenario 4: periodic lockdowns and whole population vaccination.

7.3.3.7 Simulated Influence of Vaccinations and Lockdowns on Estimated Healthcare Costs per Ghana's hospital management costs

The results of the estimated total direct healthcare costs per Ghana's hospital management costs (table 42 below) are consistent with the CALMS predicted total direct healthcare costs output (table 41 above) regarding the influence of the hypothetical intervention scenarios. Like the outputs in table 41, the estimated healthcare costs also showed that scenario 4 is the most healthcare costs lessening intervention throughout the agents' lifespan, followed by scenario 2 and 3. However, the estimated healthcare costs in table 42 shows that no healthcare costs will be incurred in Ghana in year 5 if scenario 4 is implemented while results in table 41 show a healthcare cost of over £7,000 for the same year and scenario. This observation is likely resulting from the cost of long COVID management, which were excluded in this estimation given the lack of data on cost of long COVID management in Ghana. The healthcare costs represented in table 42 are for illustrative purposes and are not demonstrative of actual or anticipated healthcare costs because they are based on 2021 treatment costs; so, its reportage must be done with caution.

Table 42: Estimated total COVID-19 healthcare costs ($) using Ghana's treatment cost.

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4
5	938,341	84,297	229,509	0
10	19.7×10^5	124,907	438,713	20,305
70	20.6×10^6	23.5×10^5	17.110^6	438,713

Scenario 1: no intervention; Scenario 2: vaccinating clinically vulnerable individuals; Scenario 3: periodic lockdown; Scenario 4: periodic lockdowns and whole population vaccination.

7.3.3.8 Intervention Costs

Figure 31 and table 43 show the intervention costs for scenarios two, three and four. Vaccinating the clinically vulnerable policy (scenario 2) is predicted to be the least expensive intervention, followed by the lockdown policy (scenario 3) and the whole population vaccination and lockdown policy (scenario 4) at the end of the cohort's lifespan. However, the cost difference between the lockdown (scenario 3) and whole population vaccination and lockdown policy (scenario 4) in years 5 (0.3%) and 10 (0.5%) is relatively negligible.

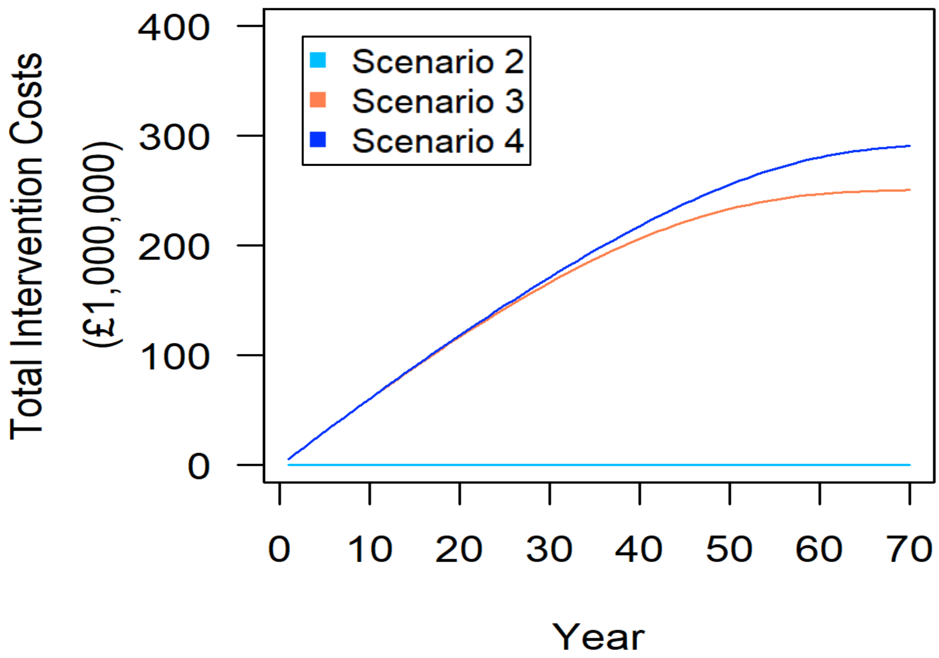

Figure 31: Cost (£) of interventions.

Table 43: Cost (£) of COVID-19 interventions

Year	Scenario 2 N (Mean ± SD)	Scenario 3 N (Mean ± SD)	Scenario 4 N (Mean ± SD)
5	2,168.51 (2.17±4.9)	30.1×10^6 ($30.1\times10^3\pm32.9\times10^2$)	30.2×10^6 ($30.2\times10^3\pm28.96\times10^2$)
10	4,625.59 (4.6±10.35)	60.2×10^6 ($60.2\times10^3\pm88.9\times10^2$)	60.5×10^6 ($60.5\times10^3\pm81.4\times10^2$)
70	42,114.9 (42.12±50.69)	25.1×10^7 ($25.1\times10^4\pm10.8\times10^4$)	29.1×10^7 ($29.1\times10^4\pm11.7\times10^4$)

Scenario 2: vaccinating clinically vulnerable individuals; Scenario 3: periodic lockdown; Scenario 4: periodic lockdowns and whole population vaccination.

7.3.4 Summary of the CALMS Output

In summary, implementing COVID-19-related interventions in Ghana could reduce the long-term consequences of COVID-19 compared to no interventions throughout the lifespan of the cohort. For the interventions, vaccinating the whole population with a periodic lockdown policy (scenario 4) will be the most effective intervention to reduce the potential long-term consequences of COVID-19 in Ghana. This policy is followed by vaccinating the clinically vulnerable populations policy (scenario 2) for hospital/ICU admissions, mortality, and direct healthcare costs and by the periodic lockdown policy (scenario 3) for COVID-19 infections and long COVID. In summary, the model showed that after scenario 4 policy, scenario 3 policy would be the most effective in reducing COVID-19 infections and long COVID, and scenario 2 would be the most effective in reducing COVID-19-related hospital and ICU admissions, mortality and direct healthcare costs in the longer term. By year 70, a no-intervention policy (scenario 1) would reduce the number of long COVID cases by 1% more than scenario 2. Regarding the cost of intervention, scenario 2 will be the least expensive policy, followed by scenario 3 and scenario 4. Table 44 below captures this summary.

Table 44: Summary of the CALMS output/findings

Policies → **Predicted COVID-19 burden** ↓	**No intervention**	**Vaccinating clinically vulnerable**	**Periodic lockdowns**	**Whole population vaccination and periodic lockdowns**
Infection	Least Influence	Low Influence	Medium Influence	Maximum Influence
Hospital Admission	Least Influence	Medium Influence	Low Influence	Maximum Influence
ICU Admission	Least Influence	Medium Influence	Low Influence	Maximum Influence
Mortality	Least Influence	Medium Influence	Low Influence	Maximum Influence
Long COVID	Least[14] Influence	Low[15] Influence	Medium Influence	Maximum Influence
Direct Healthcare Cost	Least Influence	Medium Influence	Low Influence	Maximum Influence
Intervention Cost		Least Expensive	Moderately Expensive	Most Expensive

7.4 Discussion

This chapter used the CALMS agent-based model to predict COVID-19 infections, mortalities, hospital, and ICU admissions, long COVID and healthcare costs in the next five, ten and up to seventy years in Ghana. It also examined how vaccination and lockdown scenarios could influence the predicted long-term COVID-19 burden. The findings showed that Ghana's

[14] Least in years 5 and 10 and low in year 70.
[15] Low in years 5 and 10 and least in year 70.

relatively lower COVID-19 mortality might remain unchanged in the next ten years (%Mortality = 0.54%: estimated based on the number of COVID-19 deaths and infections) even without interventions, and this projected mortality will be about 1.4% and 0.4% lower than the 2020 mortality in Ghana (1.93%) (Crankson et al., 2022) and the global mortality as of 30/08/2023 (0.90%) (WHO, 2023). Ghana's age characteristics may account for this projected mortality, particularly as the seed population for the modelling was comparatively younger (35.07±17.02 years) than the reported 2020's population (Crankson et al., 2022).

Other factors, like the ongoing COVID-19 vaccination, reported to increase an individual's resistance to severe COVID-19 outcomes (Knoll & Wonodi, 2021), and the probable decreasing virulence of the SARS-CoV-2 virus, could also account for the observation. Though these two factors could be mutually inclusive, the latter is still being studied while the effectiveness of the former has been confirmed in a recent systematic review (Pormohammad et al., 2021). It is also supported by the modelled findings from a UK study (Mintram et al., 2022) and corroborated by this chapter's hypothetical scenarios modelling which saw a 92% reduction in the baseline number of COVID-19 mortalities in years 5 and 10 when stratified vaccination intervention (scenario 2) was introduced. This reduction was also observed for the number of COVID-19 infections, which saw an almost 15% and 18% decrease in the baseline infections in years 5 and 10. As of 31/10/2023, Ghana had fully vaccinated 34.1% of its total population (GHS, 2023), and given the simulation findings herein, increasing this number may decrease COVID-19 mortalities in the coming years.

Noticeably, Ghana's 70-year projected baseline number of COVID-19 mortalities is 25% more than the 80-year projected mortality in the UK (Mintram et al., 2023), despite their comparatively younger seed population (Median age: Ghana = 31 years; UK = 45 years). This observation suggests that other sociodemographic and economic factors could account for Ghana's lifelong COVID-19 mortality or probably mediate the potential influence of Ghana's age characteristics on its COVID-19 mortality probability. Further comparisons to tease out the drivers of the mortality differences also showed that Ghana's seed population had a fewer proportion of NCDs (DM = 3.1%; CVDs = 4.2%) than the UK's (DM = 5.5%; CVDs = 10.8%) than the UK, and the median BMI between the countries were comparable, thus, precluding these conditions influence on the lifelong mortality differences, furthering the earlier argument that more inherent factors, such as wealth indices and healthcare accessibility, could be accounting for the high lifelong mortality in Ghana compared to the UK. Observably, Ghana's 70-year lifelong COVID-19 mortality reduced to 11, 71% lower than the UK's 80-year mortality (n = 39) (Mintram et al., 2022), when both settings introduced a whole population vaccination and periodic lockdown intervention, indicating that the combined intervention could attenuate the inherent drivers of the lifelong mortality in Ghana.

Of the three interventions introduced into the model, the whole population vaccination with periodic lockdowns policy was the most effective in reducing the long-term COVID-19 mortality, hospital, and ICU admissions, long COVID and direct healthcare costs in Ghana, and the most expensive policy at the end of the cohort's lifespan. However, its cost was relatively comparable to the periodic lockdown policy (scenario 3), the least influential intervention in reducing COVID-19 deaths, hospital and ICU admissions and direct healthcare costs. Notwithstanding, a robust cost-benefit analysis may be needed to ascertain its (scenario 4) cost-effectiveness, as the evidence herein is not indicative of cost-effectiveness. Such a deterministic study was recently simulated for over 83 million population in Turkey, and it found a whole population vaccination intervention as even a cost-saving intervention (Hagens, et al., 2021). However, albeit its robustness, the evidence is limited to the vaccination intervention only, still leaving queries on the cost-effectiveness of the combined periodic lockdown and whole population vaccination policy. No study on the effectiveness of the combined intervention was identified in the literature. However, a study comparing both interventions found population vaccination to be associated with a lower cost of preventing one COVID-19 mortality than national lockdowns (Arbel & Pliskin, 2022). Though they found vaccinations to be nearly 50 to 500-fold more cost-effective than national lockdowns in preventing COVID-19 deaths, it was unconfirmed whether the vaccination was targeted at the whole population, as per the referenced intervention in this study. Nonetheless, while a cost-effectiveness analysis on the combined intervention is still warranted, the evidence from Arbel & Pliskin (2022) is consistent with the literature (Jithesh, 2021; Joffe, 2021; Zachreson et al., 2021), demonstrating that when deciding between vaccination and lockdown policies, the former may be more preferred than the other, particularly for resource-constrained populations like Ghana.

Comparing the periodic lockdown (scenario 3) and vaccinating the clinically vulnerable (scenario 2) policies, scenario 2 is predicted to reduce the number of COVID-19 mortality, hospital and ICU admissions, and direct healthcare costs more than scenario 3, while scenario 3 is projected to reduce the number of COVID-19 infections and long COVID more than scenario 2. The comparatively lower influence of scenario 2 on infections and long COVID is because scenario 2 is assumed by the model to address the COVID-19 disease severity and not the infection risk or the duration of COVID symptoms (long COVID) (Mintram et al., 2022). This explains why the complementary intervention (scenario 4) was more effective in reducing the predicted long-term COVID-19 burden than the single interventions (scenarios 2 and 3). Apart from the model severity assumption, the influence of scenario 3 in reducing the long-term number of COVID-19 infections more than scenario 2 is also logical in the context of the Susceptible, Infectious, Recovered, Death (SIRD) model as it is more likely to reduce COVID-19 transmission probability than scenario 2 (Kharroubi and Saleh, 2020). Scenario 3's influence in a real-life situation could, however, be limited by contextual factors like socio-economic status and housing systems, which were not captured in the model. For example, implementing lockdown interventions in settings with household crowding characteristics, like Ghana, could amplify viral spread and defeat the purpose of the lockdown (Ayala et al., 2022).

The above argument was confirmed in Ghana when it saw an increase in the daily number of COVID-19 cases during and post its partial lockdown intervention (GHS, 2023). In Ghana's example, though the number of COVID-19 cases attributable solely to the partial lockdown is unclear, its related outcomes, such as starvation, decreased earnings and extreme poverty, particularly for those in the lower socio-economic echelon, made the intervention unsustainable (Khoo, 2020). Therefore, despite the study's findings on the influence of periodic lockdowns on long-term COVID-19 infections and long COVID, Ghana must assess the overall outcomes of period lockdowns comprehensively, focusing on their potential to trigger poverty before implementing them. Given the evidence in the literature (Mintram et al., 2022; Huang et al., 2021) and the one presented here, developing countries could consider introducing lockdown interventions at the beginning of outbreaks for outbreaks with similar characteristics like the COVID-19 outbreak to avoid overburdened healthcare systems. However, the timing of the introduction must be assessed critically to maximise its healthcare benefits and minimise any adverse spill-over effects.

Concerning policy implications, this chapter provided empirical data to augment ongoing efforts to mitigate any long-term consequences of COVID-19 in Ghana and offered policy directions to avoid wholesale and less data-driven interventions, as observed at the beginning of the pandemic. The simulation findings mean Ghana could reduce its long-term COVID-19 burden if it ensures a whole population vaccination with periodic lockdowns. While the cost-benefit of the lockdown is still debatable, the literature suggests that a whole population vaccination target alone may reduce the number of infections and deaths associated with the outbreak (Orangi et al., 2022; De Salazar et al., 2021). Therefore, Ghana could aim to increase its current vaccination effort, which currently stands at 36% (GHS, 2023), to prevent/reduce severe COVID-19 health outcomes. Even though the model could not account for cost-effectiveness, it demonstrated that the whole population vaccination could reduce any long-term direct healthcare costs than vaccinating only the populations with comorbidities. This output could guide Ghana's vaccination intervention implementation.

On effective strategies for future outbreaks like COVID-19, Ghana could implement a lockdown at the beginning of the outbreak to avoid potentially overwhelming health systems and introduce vaccinations at the early stage of the outbreak to reduce the population's risk of the disease and its outcomes. However, these recommendations will largely be informed by the outbreak's nature and the availability and affordability of the required vaccines. Given this pandemic's lessons on vaccine inequity, it is anticipated that global health systems will promote vaccine equity to avoid disproportionate burdens in future outbreaks. Most importantly, given that every pandemic/epidemic might be unique, the merit of the recommended future interventions, particularly the lockdown policy, should be assessed on a case-by-case basis to determine their suitability. The long-term effectiveness of the other evaluated policies in chapters 5 and 6, e.g., the border closure and the GCARES policy, were unconfirmed in this chapter as they could not be simulated in the model. Therefore, their adoption as future mitigating strategies should be informed by current literature.

Comparatively, this study's findings agree with a similar study in the literature that a combined whole population vaccination with periodic lockdown intervention could result in the highest reduction in the long-term consequences of COVID-19 (Mintram et al., 2021). However, while the study identified the lockdown intervention to result in the greatest reduction in the number of long COVID, this study found its influence in reducing the number of long COVID second to the combined whole population vaccination and periodic lockdown intervention. This heterogeneity is likely to result from the timing of the lockdown in the two studies, which was triggered by the predicted number of severe and critical COVID-19 cases in the cohort. Given the sample characteristics variations in the two studies, the predicted number of severe and critical COVID-19 cases was expected to differ with resultant differences in the lockdown timings. The projected COVID-19-related direct healthcare costs at the end of the cohort's lifespan also differed between the two studies, with this study predicting a higher direct healthcare cost, except for scenario 4. Again, possible differences in the predicted number of hospitalised agents between the two studies could have accounted for this variation. Also, using the UK's cost of hospital management to estimate the total direct healthcare costs in Ghana could have resulted in the higher healthcare costs reported in this study. However, when the direct healthcare costs were re-estimated using Ghana's hospital management cost, the total costs at the end of the cohort's lifespan were still comparably higher for Ghana when no interventions were implemented and lower when the vaccination with periodic lockdowns policy was implemented. Apart from the number of hospitalised agents in the two studies, dissimilarities in hospital management costs for COVID-19 patients could justify the variations in the healthcare cost burden between the studies. While these differences could be explored further in the context of healthcare disparity, the settings in the two studies must focus on implementing the most cost-effective COVID-19 interventions to reduce related healthcare costs.

Regarding strengths and limitations, this chapter is the first to provide insights into the number of COVID-19 infections, deaths, ICU and hospital admissions and healthcare costs for the next 70 years in Ghana using an agent-based model. It also offers evidence on the scale of influence of lockdown and vaccination policies on the potential long-term health COVID-19 infections, mortalities, long COVID, healthcare costs and hospital admissions in Ghana. Accordingly, its findings could be the basis for considering the simulated policies as forethought mitigating interventions to avert any long-term consequences of the COVID-19 disease. However, as characterised by all modelling research, the simulations in this chapter were informed by probable assumptions which may not reflect real-life scenarios. For example, the model could not account for potential deaths from other causes, such as deaths from other diseases, road traffic accidents and natural disasters over the 70-year projection. Accounting for these possibilities could have allowed more precise estimations of the influence of the policy scenarios on COVID-19-related deaths in the long term in Ghana. Also, the vaccination assumption does not capture any specific vaccine type and other inherent characteristics, such as diversity in the number of vaccines an individual will require based on their peculiar characteristics and individual willingness to vaccinate. These characteristics are essential as they could determine the overall impact and success of the vaccination policy in mitigating the COVID-19 burden, as reported by Lau et al. (2021).

The model was also limited in capturing the effect of potential socio-political changes over the projected 70-year period on the predicted COVID-19 burden in Ghana. In addition, it could not account for how other unmeasured sociodemographic characteristics, like physical activity, education level, employment status and wealth index, could influence the COVID-19 disease trajectory and dynamics over the projected period. These concerns are crucial as they are reported to determine the risk of infectious disease transmissions and related outcomes, like mortalities (Karmarkar et al., 2021; Drefahl et al., 2020). While a sensitivity analysis could have been considered to examine the impact of these other characteristics on the predicted COVID-19 burden, the chapter assumed the worse-case possible situation for each assumed policy, thus ensuring the consideration of utmost forethought interventions that are amenable to all potential determinants of COVID-19 long-term burden (Dwomoh et al., 2021). Finally, the chapter was limited in exploring how the policy assumptions could address the potential evolution of the SARS-CoV-2 virus and in predicting the long-term consequences for all the existing SARS-CoV-2 variants. Exploring these concerns could have resulted in data that could direct more targeted interventions to address the burden of each COVID-19 variant (Li et al., 2022). Nonetheless, this limitation was inconsequential in this study because it did not aim to explore the infection trajectory of all the COVID-19 variants in the long term. Future models could be developed for this purpose as they may present different long-term impacts, which may require different interventions. Most importantly, future studies could consider developing agent-based models specific to the Ghanaian context to tease out critical nuances that could inform context-specific interventions.

7.5 Conclusion

This chapter showed that a whole population vaccination with periodic lockdowns might be more effective in reducing Ghana's long-term COVID-19 infections, long COVID, mortalities, hospital admissions and healthcare costs. It further argued that given the evidence in the literature, a whole population vaccination policy alone could reduce the predicted long-term COVID-19 burden in Ghana. The study, therefore, recommends that Ghana boosts its COVID-19 vaccination programme to maximise the policy's influence in reducing the current and long-term burden of the COVID-19 outbreak. The next chapter, i.e., the last chapter of this thesis, summarised the knowledge gained from this research, critically discussed the thesis's literature contributions, compared the findings with results from other settings and discussed the policy and future research implications of this study.

CHAPTER 8: DISCUSSIONS AND CONCLUSIONS

8.1 Introduction

This chapter synthesised the findings presented in the previous chapters and critically discussed not only the policy and research implications of the findings but also how the findings have led to incremental but significant contributions to knowledge. In doing so, the chapter compared the thesis's findings with the wider literature, evaluated the strengths and weaknesses of the study's methods, and further conceptualised the direction of travel in this research area based on what we know now.

8.2 Summary of Key Thesis Findings

The thesis showed that individuals with both hypertension (HPT) and Diabetes Mellitus (DM) are 17 times more likely to die from COVID-19 infection and 4 times more likely to experience long COVID than those with no comorbidities. In addition, they are more likely to spend two additional days in hospital admissions due to COVID-19 than those with no comorbidities. It also showed from triangulated data that Ghana's COVID-19 public awareness campaigns and border closure policies were effective in educating the public about COVID-19 prevention protocols and preventing COVID-19 case importation, respectively. Finally, the study demonstrated that a whole vaccination and periodic lockdown policy could reduce Ghana's long-term COVID-19-related direct healthcare costs, infections, mortalities, long COVID, and hospital and ICU admissions in the next ten years by more than 90%. Figure 32 summarises this study's key findings.

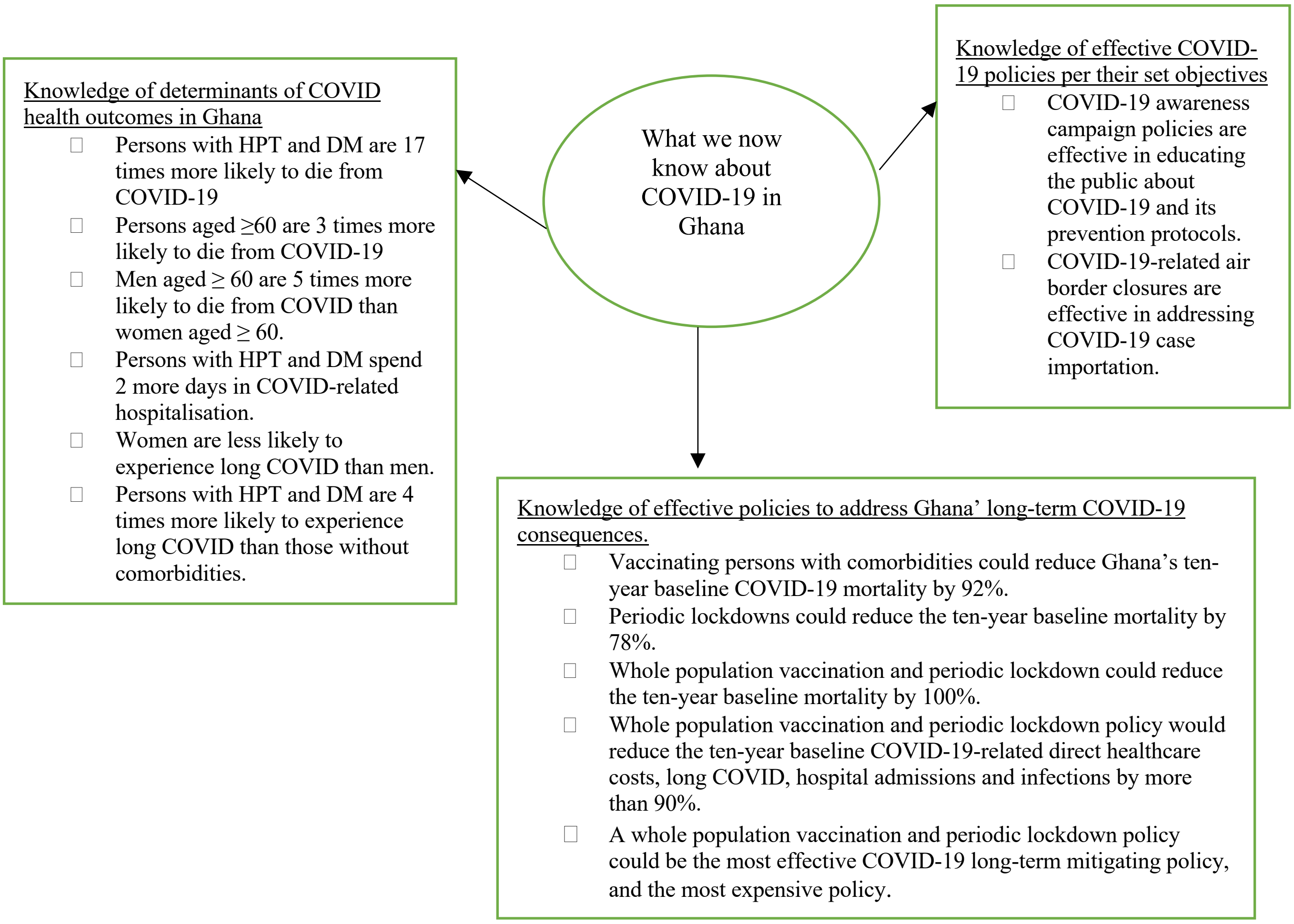

Figure 32: Key findings from the thesis

8.3 Comparisons of Findings to the COVID-19 Literature

The findings of this thesis are first compared to findings from similar studies in other countries and results from comparable studies in Ghana. Compared to studies from other countries, the findings on the determinants of COVID-19-related mortality are akin to results from Nigeria (Osibogun et al., 2021), Senegal (Diop et al., 2023), Kenya (Ombajo et al., 2022), South Africa (Jassat et al., 2021; Gesesew et al., 2021) and Egypt (Gesesew et al., 2021), irrespective of the diverse settings, population's characteristics, and sample sizes. For example, with a 787-sample size, Ombajo et al. (2022) demonstrated that increasing age is associated with increased odds of COVID-19-related mortality in Kenya, as confirmed in this study. The evidence from Ombajo et al. (2022) was also corroborated by Diop et al. (2023), who examined the data of 556 persons with COVID-19 in Senegal. It was also confirmed in the studies from Egypt and South Africa. Again, the associations between hypertension, diabetes, cardiovascular diseases and COVID-19 mortality were also documented in Kenya and Nigeria (Ombajo et al., 2022; Osibogun et al., 2021).

The significant association between male sex and COVID-19-related mortality reported by Ombajo et al. (2022) was not found in this study. Instead, this study found that men ≥60 years old are more likely to die from COVID-19 than their female counterparts, and not all men, as Omabajo et al. (2022) reported. Like this study (men = 60.1%; women = 39.9%), the proportion of men (64%) was also more than women (36%) in Omabajo et al. (2022). Therefore, the proportion of men and women in the two studies may not account for the heterogeneous findings. However, in further comparisons, the proportion of COVID-19-related deaths among the men (Men = 505; total deaths among the men = 75; proportion = 14.85%) in Omabajo et al. (2022) was more than the proportion of deaths among the men in this study (Men = 1,402; total deaths = 31; proportion = 2.21%). Consequently, this observation, together with other possible inherent socioeconomic, cultural and behavioural characteristics between the two studies, could be driving this varied finding on the relationship between male sex and COVID-19 mortality, as documented elsewhere (Pradhan & Olsson, 2020; Bwire, 2020).

On the influence of COVID-19 policies on the long-term consequences of COVID-19, this is the first study to use an agent-based model to simulate the effect of vaccinations and lockdown policies on the long-term health consequences of COVID-19 for the next 5, 10 and up to 70 years in Africa. Therefore, the findings could not be compared to similar data from other African countries. Nonetheless, a closely comparable study in Kenya showed that rapidly rolling out COVID-19 vaccination interventions with a targeted 30% population coverage could prevent more than 63% of COVID-19-related deaths in the next 1.5 years among persons aged >18 (Orange et al., 2022). They further indicated that it would be a more cost-saving intervention than a no-intervention policy, significantly averting Disability Adjusted Life Years (DALYs) (Orange et al., 2022). Therefore, their finding is comparable to the evidence generated in this thesis, as it also found COVID-19 vaccinations to reduce COVID-19-related deaths by 92% in the next five years. Nevertheless, the proportion of averted deaths per vaccination is inconsistent in the two studies because the thesis simulated a vaccination policy targeting persons with comorbidities, while Orangi et al. (2022) examined the vaccination intervention's effect on whole adult populations. In addition, there were variations in the attributes of the examined cohorts and the predicted number of years in the two studies, accounting for the different proportions in the predicted averted COVID-19-related mortality. Regardless of these differences, the two studies indicated that COVID-19 vaccination could be a critical intervention to reduce COVID-19 deaths. Policymakers in Africa could, therefore, enhance their COVID-19 vaccination coverage to achieve these anticipated outcomes.

8.4 Comparisons of Findings to Similar Studies in Ghana

The findings from this thesis are comparable to the results of similar studies conducted in Ghana. For example, on the determinants of COVID-19-related mortality, the findings in this thesis are consistent with the results of Nachega et al. (2022), as they also identified hypertension as a predictor of COVID-19-related mortality. In addition, they also indicated that the presence of comorbidities increases the odds of prolonged COVID-19-related hospitalisation, as identified in this study. However, they did not indicate the specific comorbidities associated with COVID-19-related LOS, and this limited an exhaustive comparison. More critically, despite the heterogeneities between the two studies, their findings on the determinants of COVID-19-related mortality and LOS are similar. For example, Nachega et al. (2022) focused on children and adolescents aged three months to 19 years, while this study analysed the data of persons aged up to 93 years. In addition, Nachega et al. (2022) used COVID-19 data from two facilities in Ghana, while this thesis accessed its data from the main COVID-19 treatment centre. Therefore, the similar findings between the two studies, notwithstanding the methodological heterogeneities, suggest that the findings could apply to all age groups, and addressing the confirmed determinants in the two studies could be critical in reducing COVID-19 mortality in Ghana.

The study's arguments on the effectiveness of the COVID-19 policies in Ghana were aligned with the positions of Quakyi et al. (2021), Khoo (2020) and Antwi-Boasiako et al. (2021). They also opined in their narrative reports that the government must ensure data-driven policies that suit Ghana's sociocultural dynamics to address this current outbreak and any similar future outbreaks comprehensively. Specifically, the findings on the effectiveness of the bans on social gatherings and COVID-19 awareness campaigns policies were consistent with Foli & Ohemeng (2022) and Khoo (2020), regardless of the different methodological approaches. For example, Foli & Ohemengs (2022)'s desk-research analysis confirmed that the socioeconomic inequalities in Ghana affected the effectiveness of the bans on social gatherings policy, and the policy further widened the inequality gap. Therefore, the policy must be examined thoroughly to inform their adoption in future outbreaks. Khoo (2020)'s narrative analysis also showed that the COVID-19 awareness policy informed the public about COVID-19 prevention protocols, which likely promoted compliance with the prevention measures. Therefore, they should be continued and adopted in any similar future outbreaks. Finally, the findings on the effectiveness of the border closures agreed with the results of Sibiri et al. (2021), who also documented that the policy effectively prevented COVID-19 case importations. However, both studies were limited in indicating whether the policy's health benefit regarding reduced case importations outweighed its consequence on international trade and economic growth. Nonetheless, given the President of Ghana's speech on bringing people and the economy back to life, it could be inferred that the policy was effective per the country's target, regardless of its possible unintended economic shortfalls. All the same, other studies should consider a cost-effectiveness analysis of the policy to inform future related policy decisions.

8.5 Thesis's Contribution to the Literature

The thesis provided novel and additional evidence to ensure an in-depth understanding of the COVID-19 outbreak in Ghana. For example, Chapter 2 highlighted key literature gaps around determinants of COVID-19 health outcomes, effectiveness of Ghana's COVID-19 policies, long-term consequences of COVID-19 and the influence of Ghana's COVID-19 policies on the long-term COVID-19 consequences. These gaps directed the empirical analyses in this chapter and provided research directions for future studies to ensure incremental knowledge on COVID-19 in Ghana. Chapter 4 also provided new knowledge on long COVID and populations at risk of long COVID in Ghana. Before the analysis in Chapter 4, there was no information in the existing literature on the determinants of long COVID in Ghana. Therefore, the findings from Chapter 4 provided the first data to inform discourses around effective strategies like targeted vaccinations, awareness campaigns, personal hygiene promotion and specialised clinics, to manage long COVID in Ghana. The findings also offers roadmaps for future interdisciplinary research, including collaborations among occupational therapy, public health, psychology, and physiotherapy researchers, to identify evidence-based approaches to address the potential socioeconomic and health implications, like isolation, physical activity, health expenditure, of long for the populations at risk in Ghana. Furthermore, this study's preliminary data could be the foundation for other studies to identify its peculiar, familiar, and rare symptoms to guide the clinical management of long COVID. Such studies could further direct the multidisciplinary team approaches to the clinical management of the condition.

In addition to long COVID, Chapter 4 contributed additional data to the limited evidence on the determinants of COVID-19-related mortality and prolonged hospitalisation in Ghana. Only two studies have conducted such analyses in the literature. Despite their novel contribution to identifying populations at risk of COVID-19-related mortality and prolonged hospitalisations in Ghana, they were fraught with limitations, which were addressed by this study to enhance our understanding of the determinants of COVID-19 health outcomes (Afriyie-Mensah et al., 2021; Nachega et al., 2022). For example, the studies used relatively smaller sample sizes (22 and 469), limiting their findings' generalisations. Arguably, their sample sizes were smaller because of probably fewer COVID-19 cases at the time of their analysis or decreased access to the relevant study population due to COVID-19 movement retractions. Regardless, this study addressed the previous studies' sample size limitation by including 2,334 participants in the analyses, almost 80% more participants than the maximum sample in the previous studies. This sample size advantage ensured precise estimations of individuals at risk of COVID-19 deaths and prolonged hospitalisations and further enhanced the potential for generalising this study's findings to the broader population. Most importantly, this study's findings contributed additional evidence to inform relevant shielding interventions, hospital resource management and contingency plans.

Chapters 5 and 6 contributed new and incremental knowledge on the effectiveness of Ghana's COVID-19 policy responses. Unlike the anecdotal commentaries on these policies' effectiveness in the literature, Chapters 5 and 6 adopted data triangulation to elucidate the policies' effectiveness. The triangulation allowed the thesis to contribute validated and reliable evidence on the policies' effectiveness. In addition to providing empirical evidence on the policies' effectiveness using data triangulation, the chapters used multiple methodological approaches to assess the policies' effectiveness. Therefore, unlike the single approaches in the reviewed studies in Chapter 2, the multiple integrated approaches allowed the thesis to contribute more comprehensive and robust data on the policies' effectiveness. As such, the identified findings could guide efficient future strategies to address the COVID-19 burden or any similar outbreak in Ghana.

Lastly, Chapter 7 added critical information to the existing literature by predicting the long-term consequences of COVID-19 on direct healthcare costs, mortality and hospital admissions in Ghana and simulating the potential influence of lockdown and vaccination interventions on the predicted long-term health burdens. It also contributed new knowledge on the influence of vaccination and lockdown interventions on the potential long-term burden of long COVID in Ghana. Most importantly, it addressed the paucity in the literature regarding the use of only compartmental models to forecast long-term burden of COVID-19 in Ghana. As discussed in the previous chapter, the compartmental models used in the previous studies did not account for the influence of population variations, like diverse sociodemographic characteristics, on COVID-19 outcomes. Accordingly, Chapter 7 offered innovative knowledge on the long-term COVID-19 infections, mortality, hospitalisations, long COVID and healthcare costs from an agent-based model perspective, thus, providing evidence to guide discussions and decisions on effective long-term individual and population-based COVID-19 interventions in Ghana. The predictions and simulations could also inform health services planning to avert or reduce the impact of any long-term COVID-19 burden.

8.6 Reflections on the Study's Multiple Methodological Approaches and Frameworks

The thesis used multiple frameworks/models to guide and interpret the study's findings. For example, it used the theory of planned behaviour to interpret the evaluation findings on the bans on social gatherings and vaccination policies in Chapter 5, and the Dahlgren and Whitehead (1993) determinants of health framework to guide the literature review in Chapter 2 and the determinants of COVID-19 health outcomes analysis in Chapter 4. In addition, it used the SIRD framework to explain the simulated influence of the lockdown intervention on COVID-19 outcomes in Chapter 7. The rationale for these multiple frameworks was to ensure robust investigations and appropriate interpretations of findings to inform relevant and suitable policy decisions. For example, the theory of planned behaviour showed and explained the multiple determinants of social gathering restriction adherence and the need to factor in these determinants when developing such policies to boost compliance (Elliot & Armitage, 2009). This explanation was critical to inform the policy implications of this study in guiding the implementation of behavioural change interventions for COVID-19 and other similar outbreaks in future. Similarly, the Dahlgren and Whitehead (1993) determinants of health framework directed the data collection and interpretation of factors associated with COVID-19 health outcomes in Ghana, enhancing the relevance of the study's findings to the studied population.

On methodological approaches, the study adopted a mixed-method approach, which allowed the integration of multiple perspectives to understand the COVID-19 outbreak in Ghana to inform comprehensive mitigating recommendations (Driscoll et al., 2007). It used quantitative approaches to examine populations at risk of COVID-19 health outcomes and qualitative and quantitative approaches to evaluate the effectiveness of Ghana's COVID-19 policy responses. Using the mixed-method approach added scientific rigour, ensured methodological exhaustiveness and enhanced the robustness of this thesis (Ivankova & Wingo, 2018). For example, the confirmatory nature of the quantitative approach allowed the study to test and validate the evidence in the literature on the determinants of COVID-19 health outcomes, and the explorative nature of the qualitative study allowed in-depth policy evaluations, producing insights to enhance the understanding of Ghana's COVID-19 policies' outcomes and factors that could have contributed to the policies' outcomes. The mixed-method approach also improved the methodological strengths of this thesis, particularly as the two approaches highlighted their strengths and compensated for their weaknesses (Rahman, 2020). For example, the quantitative approach to examining the determinants of COVID-19 health outcomes and simulating the influence of vaccination and lockdown interventions on the long-term effects of COVID-19 in Ghana increased the thesis's findings generalisation to the wider study population (Taherdoost, 2022). This advantage could have been unachievable if the study had adopted only a qualitative approach.

Similarly, the qualitative approach allowed the study to achieve detailed and more profound insights and nuances into the effectiveness of Ghana's COVID-19 policies. Again, this achievement could be missed with only a quantitative approach. Further, within the experts' analysis, the mixed-method approach allowed the consolidation of qualitative and quantitative data on perspectives on the effectiveness of COVID-19 policies (Driscoll et al., 2007). Also, it allowed for sequential exploratory policy analysis between Chapters 5 and 6, as the identified themes around the types of COVID-19 policies in Chapter 5 informed how the questionnaire in Chapter 6 was developed, enhancing the thesis's coherence (Kelle, 2006; Taherdoost, 2022). Based on these advantages, the mixed-metho approach helped the thesis address its research questions thoroughly. However, despite its advantages, the evidence generated from this approach may not be the only input needed to inform comprehensive policies to address infectious diseases, particularly as other real-life issues, like resource availability and sociocultural beliefs, are also critical inputs that require consideration in policy decision, development and implementation (Aminah et al., 2021). Nonetheless, its robustness could guarantee critical evidence that could direct relevant policy discourses encompassing all other essential policy implementation inputs. Further, its limitations of not ensuring participant anonymity (Leahey, 2007) were not observed in this study as the qualitative data was collected through an online survey on a platform that protects respondents' identities, and no identifiable questions were included in the survey instrument.

8.7 Reflections on Lessons from Previous Outbreaks to Support COVID-19 Management

The trajectory of the COVID-19 outbreak is comparable to other existing viral infections like HIV/AIDs. For instance, they were initially of zoonotic transmission before human-to-human transmissions (Illanes-Álvarez et al., 2021; WHO, 2020). Additionally, all of them were caused by biological viruses that cause a surge of proinflammatory cytokines and induce social exclusions (Illanes-Álvarez et al., 2021; Logie, 2020). Though their mode of human-to-human transmission differs considerably, as one is aerosol and the other is through fluids, their similarities, particularly their economic and social impact, suggest their management strategies are transferrable (Celum et al., 2020). Therefore, one of the key lessons from the HIV/AIDs pandemic, which has been crucial in managing COVID-19, is public education and awareness campaigns. It has helped dispel fear and misconceptions, which feed into stigmatisations and exclusions (Logie, 2020). The United Nations (2020) indicates that misinformation is one of the critical barriers to fighting a pandemic, as this could lead to conspiracies and related heightened fear and stigma. These stigmas may increase the burden of the outbreak more than the disease itself. As such, they must be addressed early in the outbreak through regular community engagements and scientific information sharing (Peprah & Gyasi, 2020). Okware et al. (2001) show that public education and awareness campaigns policy is one of the effective early interventions for addressing pandemics. This evidence was confirmed by Wu et al. (2007) in a later study in a different population/context and was corroborated in this study's policy evaluation findings. Therefore, the public awareness campaigns initiated by global health systems to address the COVID-19 outbreak must be sustained and possibly enhanced. Most importantly, global health policymakers must consider public awareness policies for potential future pandemics. In addition, the public should be actively involved in all research relating to pandemics to enhance their awareness of new trends and policy decisions (Celum et al., 2020).

Based on their nature and mode of transmission, pandemics are characterised by high infectivity rates (Jabbari et al., 2020). Therefore, early testing and diagnosis could translate into early case identification to prevent transmissions and reduce related burdens (Elderman et al., 2020). This argument was even apparent during this current pandemic as systemic delays in COVID-19 testing and subsequent management resulted in a surge of cases, which increased related health burdens (Gardner et al., 2021; Huq & Biswas, 2020). The lessons herein are that global systems continue to invest in disease surveillance, testing, health infrastructures and human resources to ensure adequate preparedness for outbreaks, especially as they may be inevitable (Hogmen et al., 2020). Such preparations could help increase health accessibility in under-resourced and impoverished areas and reduce associated inequalities (Kretzschmar et al., 2020).

Other lessons from past pandemics that must be adopted and sustained in the fight against COVID-19 and, by extension, pathogen X are interdisciplinary collaborations. Given that most outbreaks are of zoonotic origin, disciplines like animal and human researchers must collaborate to provide an understanding of human and animal interactions. Such knowledge could enhance the development of more effective interventions, such as vaccines and relevant public awareness campaigns. In addition to the interdisciplinary partnerships, collaborations between governments, the media, health systems and global technologies must be strengthened. These collaborations could promote health innovations, timely vaccine manufacturing, and real-time info-demographics to direct mitigating policy directions. They could also ensure vaccine equity, one of the critical pandemic concerns, to enhance local capacities against outbreaks. Furthermore, the collaborations could enhance central and peripheral disease surveillance, which could bolster global efforts at addressing the COVID-19 pandemic, its spill over, and any impending pathogen X.

8.8 Limitations of Thesis

The limitations of this thesis have been discussed under each empirical chapter and further highlighted here. Regarding the determinants of COVID-19 health outcomes, the study used data from only a single COVID-19 treatment centre in Ghana. The single-centre data use limited the extent of the finding's generalisation to the wider population of persons with COVID-19 in Ghana, particularly as the data may not comprehensively reflect all characterises of persons with COVID-19 that could determine severe COVID-19-related health outcomes (Cheng & Phillips, 2014; Ross & Bibler, 2019). However, the used centre was Ghana's main COVID-19 treatment centre earmarked to manage COVID-19 infections in Ghana. In addition, the centre has an increased treatment capacity than the other centres and manages more than 70% of the COVID-19 cases in Ghana (GHS, 2023). Therefore, its singular use may be less consequential on this study's external validity. Nonetheless, future studies should consider using data from multiple COVID-19 treatment centres in Ghana to explore more nuances on the determinants of COVID-19 outcomes in Ghana.

In addition to the single centre limitation, the study could not include some of the determinants of health outcomes variables espoused by Dahlgren and Whitehead (1993) 's framework, like the housing variables. Accounting for the housing variable in the analysis could have contributed empirical evidence to increase our understanding of how the housing characteristics in Ghana, especially its slum dwelling, shared sanitation facilities, influence COVID-19 outcomes, like mortalities, hospitalisations and long COVID. This limitation was due to using a secondary dataset. The secondary dataset also limited the inclusion of some of the determinants of COVID-19 outcomes identified in the literature review, like BMI and socioeconomic deprivation, in its analysis. Therefore, it could not account for how these variables influence COVID-19 mortality, long COVID and mortality. However, given the movement restrictions and novelty of the outbreak, the secondary dataset approach was critical to accessing the COVID-19 data. It also helped to access the information of 2,334 patients, a sample size that would have been challenging for a primary data approach to collect, again due to the movement restrictions. Nevertheless, with the easing of movement restrictions, future studies could explore primary data approaches that would allow the collection of the factors that were not included in this study.

On the COVID-19 policy evaluations, the study was limited in determining which policies resulted in the observed policy changes since all the policies were implemented concurrently. Specifically, it could not determine the proportion of policy changes to attribute to the evaluated policies. This limitation was due to the scarcity of comparative data and the timing of the policies, which were influenced by the nature of the COVID-19 outbreak. This precise attribution was warranted to understand the actual impacts of the policies to inform their consideration in the ongoing and future outbreaks (Hale et al., 2021). Apart from the policy attribution, the policy evaluations focused mainly on the policies' direct health and economic impacts. Therefore, it could not comprehensively account for their indirect health and economic impacts, even though it explored the policies' unintended outcomes, which included indirect burdens. However, the study's focus on the policies' direct health and economic outcomes was driven by the policies' objectives, which provided the roadmap for evaluating the policies' outcomes holistically. The evaluation was also limited in accounting for the policies' ripple and tendril effect on other sectors, like education, transportation, and agriculture. For example, although the bans on social gatherings and lockdown policies were primarily targeted at reducing health burdens, they significantly disrupted the education and transportation sectors. Therefore, their health impacts must be juxtaposed with their impacts on education and transportation to allow robust estimations of their overall effectiveness.

The relatively smaller sample size for the expert's policy evaluations limited any generalisation interpretations of the findings. In addition, using a research gatekeeper to recruit the academic experts in this study resulted in the inclusion of only academic experts within the academic reach of the gatekeeper. This limitation decreased the possibility of collecting wide-ranging opinions of all or many academic experts in Ghana, which could have enhanced the robustness of this study. However, the gatekeeper approach in this study was used due to the prolonged ethics applications turnaround time associated with accessing academics in Ghana. This prolonged ethics turnaround time could have constrained this study, affecting the thesis's deadline. Therefore, as we advance, academic institutions in Ghana could reduce their ethics application turnaround time to allow future studies to access relevant data from academics in record time to inform timely interventions or strategies. With improved ethics turnaround time, future studies could advance this study by recruiting significant numbers of experts from diverse disciplines to examine and provide comprehensive and validated evidence on the effectiveness of Ghana's COVID-19 policies. The ethics turnaround time recommendation espoused above could also apply to the operations of the GHS ethics committee, as it could enhance timely access and exploration of clinicians' perspectives on fast-paced conditions like COVID-19. Finally, future studies examining the effectiveness of COVID-19 policies could consider adopting multiple approaches, such as data triangulation, content and face validity through literature and expert review and pilot testing of instruments on representative samples, to enhance the quality and reliability of collected quantitative and qualitative data.

The thesis was also limited in predicting and simulating the influence of vaccination and lockdown policies for stratified populations, like men, women, socioeconomically deprived and chronologically younger populations. Accounting for these populations could inform targeted policy decisions. Also, it could not assess how individuals' physical activity status could influence long-term COVID-19 health outcomes. In addition, the study could not conduct a cost-effectiveness analysis to establish whether the policies offered value for money. Future modelling studies could address these limitations to improve our understanding of these concerns and inform targeted interventions.

8.9 Future Research Implications

While this thesis provides additional knowledge to the COVID-19 literature in Ghana, further studies are still warranted to enhance the understanding of the COVID-19 outbreak in Ghana. Therefore, the thesis recommends that future studies examine how lifestyle factors, like physical activity status and obesity, influence COVID-19-related mortality, LOS and long in Ghana. Although this investigation has been explored in the literature (Tartof et al., 2020; Salgado-Aranda et al., 2021), they were conducted in different contexts, so the findings may not apply to Ghana, justifying the call for such investigations. Future studies could also use data from multiple treatment centres in Ghana to examine the determinants of COVID-19 outcomes to provide more representative evidence to guide relevant policies.

On COVID-19 policy evaluations, the thesis recommends that future studies consider other approaches, like the Delphi approach, to establish consensus on the policies' effectiveness. In addition, they could conduct semi-structured interviews with policy experts to identify possible nuances that could ensure an in-depth understanding of the COVID-19 policies' effectiveness.

Furthermore, they could examine the policies' effectiveness from the perspectives of multiple and diverse populations, like policy think tankers, health practitioners and the general public, to ensure comprehensive evaluations. Also, this study's identified enforcements and logistics concerns from the experts on the policies' effectiveness should be examined further in future studies to inform current and future policy implementation strategies. Finally, future studies should conduct empirical analyses on the influence of the COVID-19 policy responses on education, agriculture, transportation, and private businesses. They could also consider examining the influence of the COVID-19 policies on the wider economy of Ghana to complement the analysis and findings in this thesis. Regarding long-term impact analysis, the thesis recommends that future studies examine the impact of the GCARES policy in stimulating Ghana's economic recovery in the long term.

8.10 Policy Implications

The findings from this study regarding the determinants of COVID-19 health outcomes suggest that Ghana should continue prioritising persons with comorbidities, like hypertension and diabetes, and the elderly populations in COVID-19-related interventions, as already highlighted in Chapter 2 and corroborated in the literature (Van Zandvoort et al., 2020). Prioritising these identified high-risk populations may protect them from severe COVID-19 health outcomes and contribute to reduced demands on primary healthcare and health services (Van Zandvoort et al., 2020). In addition to the prioritised interventions, Ghana should continue investing and boosting its health speciality service industry, including supporting and investing in training more geriatrics and internal medicine specialists and extending its diabetic and hypertension clinics to remote areas. This boost could increase access to speciality services by the defined populations at high risk and add an extra layer of protection from COVID-19. It could also reduce their risk of severe health outcomes in the event of future infectious disease outbreaks like COVID-19.

Besides the shielding approach, Ghana could also consider strengthening and enhancing its resource preparedness to avert any adverse infectious disease impacts, particularly in the event of another similar outbreak. Specifically, the country should increase its testing, isolation and treatment capacities to avoid overwhelming health systems like observed at the peak of the COVID-19 outbreak. This policy should be complemented with relevant human resources development, enhanced disease surveillance and contingency plans on PPEs and other critical hospital equipment. It should also consider building at least two more infectious diseases centres to serve the western and northern sectors of the country, as the only infectious disease centre is in the capital city (south of the country), which is hard to reach by populations in the distal locations. Most importantly, Ghana must address its endemic hospital bed shortages, especially in major public hospitals nationwide, to avoid current and future catastrophic infectious disease health outcomes (Drayi, 2019; Armah, 2017).

Furthermore, Ghana should continue to create public awareness of the COVID-19 disease, particularly on its protective and prevention measures, services available for populations at high risk and those infected, where to access those services and the benefits of those services. This detailed information and awareness could address COVID-19-related misconceptions, myths, vaccine hesitancy, discrimination, and stigmatisation. In addition, given the country's language diversity, the awareness and information must be delivered in key languages to avoid lopsided awareness creation and ensure the information's uptake by the broader population. The uptake could further be enhanced through large-reaching audience platforms, like radios, TVs, social media, posters, documentaries, community health outreaches, push messages from telecoms, and incorporated into the primary healthcare Outpatient Department (OPD)'s education policy. Finally, given the findings in Chapter 7, Ghana should consider increasing its vaccination coverage to reduce any long-term COVID-19 health consequences.

8.11 Conclusion

The thesis used empirical and pragmatic approaches, consistent with mixed-methods methodology for public health research, to comprehensively analyse the COVID-19 outbreak in Ghana. The analysis and findings conclusively showed that:

1. The presence of hypertension and diabetes mellitus increases the odds of COVID-19-related mortality, prolonged hospitalisation and long COVID in Ghana. Also, men are more likely to experience long COVID than women. Additionally, men aged ≥60 and those with hypertension are more likely to die from COVID-19 and spend more days in COVID-19-related hospital admission, respectively, than their female counterparts.

2. Public awareness campaigns on COVID-19 could ultimately prevent or reduce COVID-19 transmission through increased adherence to prevention measures.
3. Whole population vaccination with periodic lockdowns could attenuate Ghana's long-term COVID-19 infections, mortalities, hospital and ICU admissions, and direct healthcare costs by more than 90% in the next five years. It could also be argued that given Ghana's socioeconomic status and the benefits and costs of the lockdown and vaccination interventions, vaccination intervention alone could address its long-term COVID-19 consequences.

This study has made incremental and significant contributions to knowledge. It is the first study to have examined the determinants of long COVID, specifically in Ghana, and to have used an agent-based model to simulate the influence of varied lockdown and vaccination interventions on COVID-19 infections, mortalities, long COVID, hospital admissions and healthcare costs in the next 5, 10 and up to 70 years in Ghana. The policy and research implications have been based on a critical discussion of the new evidence generated by innovative, mixed methodologies employed throughout.

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Appendixes

Appendix 1: Pilot Review

Introduction

This pilot review was conducted to identify databases and search terms used in systematic reviews examining determinants of COVID-19 health outcomes and evaluating the effectiveness and influence of Ghana's COVID-19 policy responses on the COVID-19 burden and long-term COVID-19 consequences, respectively, to inform the search strategy of this thesis's literature review.

Methods

Search Strategy

Scopus, the world's largest abstract and citation database of peer-reviewed journals, was searched in December 2020 for relevant systemic reviews to be included in this pilot review. The search terms used were: (Determinant OR Risk factor OR Predictor) AND (COVID-19 OR Coronavirus) AND (Health Outcomes) for the determinants of COVID-19 health outcomes review, and (COVID-19 OR Coronavirus) AND (Policy OR Response) AND (Effectiveness OR Influence) AND (Outcome OR Consequence) OR (Health Outcome Or Health Consequence) OR (Long term OR longer term) for the COVID-19 policy responses evaluation review. Database filters were used to limit the studies to open-access systematic reviews. See table 1 for the outcomes of the database search.

Table 1: Results of Database Search

Database	**Search terms**	**Initial hit**	**Filters applied**	**Final hit**
Scopus	(Determinant OR Risk factor OR Predictor) AND (COVID-19 OR Coronavirus) AND (Health Outcomes)	1,331	Limit to open access – 1,205 Limit to reviews – 242	242
	(COVID-19 OR Coronavirus) AND (Policy OR Responses) AND (Impact OR Effect	416	Limit to open access – 346 Limit to reviews – 63	63
				Total identified = 305

Database	Search terms	Initial hit	Filters applied	Final hit
	OR Influence) AND (Outcome)			

Eligibility Criteria

Studies were screened for this pilot review per the following eligibility criteria:

- Examined the determinants of COVID-19 health outcomes, such as mortality or evaluated the impacts of COVID-19 policy responses.
- Written in the English Language.
- Full-text available.

Data Extraction

Studies that met the eligibility criteria were retrieved, and the relevant data were extracted using the extraction questions below:

- Who authored the studies?
- Year of publication?
- Which databases and search terms were used?

Quality Appraisal

The Critical Appraisal Skills Program (CASP) appraisal tool[16] for systematic reviews was used to appraise the quality of the selected studies to ensure that the quality of the studies met the standard required of systematic reviews to avoid potential bias (Harris et al., 2014). The checklists for the appraisal included the following:

- What are the results?
- Are the results of the studies valid?
- Will the results help locally?

[16] CASP appraisal tool for systematic reviews available at: https://casp-uk.net/casp-tools-checklists/

Results

The database search yielded 305 studies. Two hundred and fifty-seven (n = 257) were removed after title screening and thirty-nine (n = 39) after abstract screening. The remaining 9 were further screened to examine their suitability for this pilot review. Six met the eligibility criteria and were included in this pilot review. The Prisma diagram below illustrates the selection process.

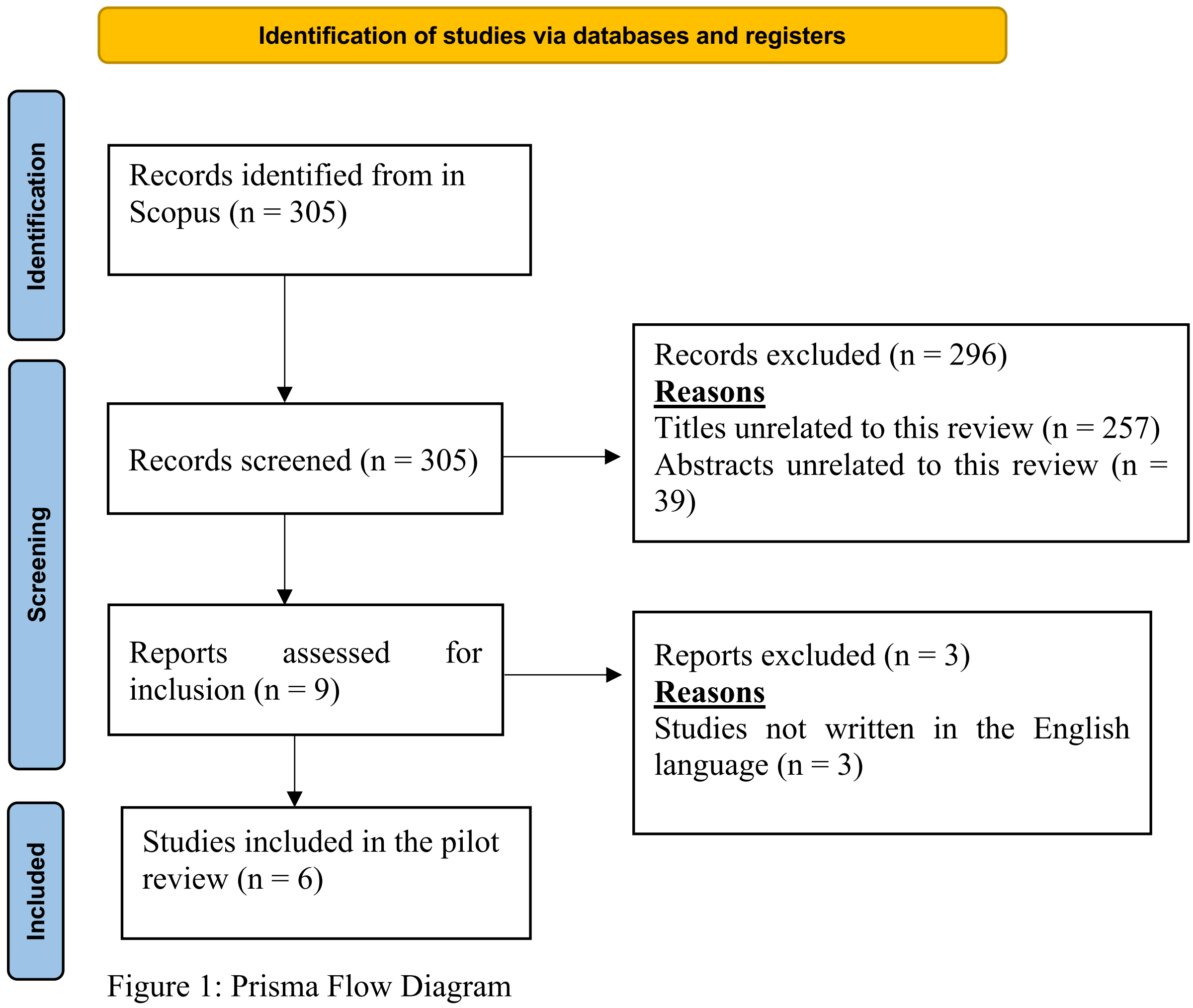

Figure 1: Prisma Flow Diagram

Characteristics and Quality of the Selected Reviews

The selected systematic reviews answered 'Yes (Y)' to all the items of the CASP checklists, except for items 6 and 7 which were inapplicable given the objectives of this review. The databases used to examine the determinants of COVID-19 health outcomes included Embase (n = 3), Medline (n =3), PubMed (n = 2), medRxiv (n = 2), Scopus (n = 2), Google Scholar (n = 1), arXiv (n = 1), bioRxiv (n =1), CINHAL (n = 1) and Web of Science (n = 1). For the

COVID-19 policy evaluation, the database were PubMed (n = 2) and Google Scholar (n = 1). The search terms included ‘SARS-CoV-2’, ‘COVID-19’, ‘Coronavirus’ ‘quarantine’, ‘lockdown’, ‘mortality’, ‘length of stay’ and ‘admission duration’. Table 2 below summarises the search strategies of the selected systematic reviews.

Table 2: The search strategy of the selected systematic reviews.

Author (Years)	**Study title**	**Databases used**	**Search terms**
Determinants of COVID-19 Health Outcomes			
Rees et al. (2020)	COVID-19-related Length of hospital stay: A systematic Review	EMBASE, Medline, medRxiv	‘Coronavirus’, ‘COVID-19,’ ‘2019-nCov’, ‘SARS-CoV-2’, ‘length of stay’, ‘admission duration’, ‘admission length’, ‘hospital*’.
Wynants et al. (2020)	Prediction models for diagnosis and prognosis of COVID-19: a systematic review and critical appraisal	PubMed, EMBASE, medRxiv, arXiv, bioRxiv	‘nCoV’, ‘corona’, ‘Wuhan’ ‘COVID-19’, ‘Prediction’
Seyedi et al. (2020)	COVID-19 outbreak in Paediatrics and the role of paediatricians: A systematics review	PubMed, Medline, Scopus, EMBASE, Google Scholar, CINAHL	‘COVID-19’, ‘Coronavirus’ ‘Pediatrics’ ‘Neonates’
Roncon et al. (2020)	Diabetic patients with COVD-19 are at a higher risk of ICU admission and poor short-term outcome	Medline, Scopus, Web of Science	‘COVID-19’ ‘ICU’, ‘Mortality’, ‘Diabetes’
Evaluation of COVID-19 Policy Responses			
Gathiya & Kumar (2020)	The psychosocial implication of quarantine and lockdown in India	PubMed and Google Scholar	‘quarantine’, ‘mental health’, ‘lockdown’, ‘psychosocial’
Summers et al. (2020)	Lessons from the Taiwan and New Zealand COVID-19 responses	PubMed, Google Scholar, medRxiv arXiv.	‘COVID-19′, ‘SARS-CoV-2’, ‘Coronavirus’ ‘Taiwan’ ‘New Zealand’

Conclusion

The aim of this pilot review was to identify databases and search terms used in systematic reviews examining determinants of COVID-19 health outcomes and evaluating COVID-19 policy responses. The identified databases included PubMed, Embase, Medline, medRxiv, Google Scholar, Scopus, arXiv, bioRxiv, CINHAL and Web of Science for the determinants of COVID-19 health outcomes, and Google Scholar and PubMed for the COVID-19 policy evaluation. Since Scopus is known to keep records from EMBASE, PubMed and Medline databases, it represented those databases in the main literature review. Similarly, since medRxiv, bioRxiv and arXiv archive studies that have not been or are yet to be peer-reviewed, they were excluded, as they may produce articles with unsubstantiated evidence. Therefore, Scopus, Google Scholar, CINHAL and Web of Science were used in the determinants of COVID-19 outcomes literature review and Scopus and Google Scholar were used in the COVID-19 policy evaluation literature review. The search strategy also included the key search terms identified in this pilot review. The pilot review used only Scopus, limiting the literature search. Nonetheless, using Scopus guaranteed an exhaustive literature search because it is the world's largest abstract and citation database of peer-reviewed journals (Baas et al., 2020).

Appendix 2: Quality Appraisal Tools

1. **Newcastle - Ottawa Quality Assessment Checklists for Cohort Studies**

Note: A study can be awarded a maximum of one star for each numbered item within the Selection and Outcome categories. A maximum of two stars can be given for Comparability.

Selection

1) Representativeness of the exposed cohort
   a) truly representative of the average *
   b) somewhat representative *
   c) selected group
   d) no description of the derivation of the cohort
2) Selection of the non-exposed cohort
   a) drawn from the same community as the exposed cohort *
   b) drawn from a different source
   c) no description of the derivation of the non-exposed cohort
3) Ascertainment of exposure
   a) secure record (e.g., surgical records) □
   b) structured interview □
   c) written self-report
   d) no description
4) Demonstration that outcome of interest was not present at start of study
   a) yes *
   b) no

Comparability

1) Comparability of cohorts on the basis of the design or analysis
   a) study controls for age and sex *
   b) study controls for any additional factor *

Outcome

1) Assessment of outcome
   a) independent blind assessment *
   b) record linkage *
   c) self-report
   d) no description
2) Was follow-up long enough for outcomes to occur
   a) yes *
   b) no
3) Adequacy of follow up of cohorts
   a) complete follow up - all subjects accounted for *
   b) subjects lost to follow up unlikely to introduce bias - small number lost less or equal to 5%, or description provided of those lost *
   c) follow up rate <80% and no description of those lost
   d) no statement

NB: **Good quality** - 3 or 4 stars in selection domain AND 1 or 2 stars in comparability domain AND 2or 3 stars in outcome/exposure domain.
Fair quality - 2 stars in selection domain AND 1 or 2 stars in comparability domain AND 2 or 3 stars in outcome/exposure domain.
Poor quality - 0 or 1 star in selection domain OR 0 stars in comparability domain OR 0 or 1 stars in outcome/exposure domain.

2. Agency for Healthcare Research and Quality (ARHQ) Checklist for Cross-Sectional Study

Item	Yes	No	Unclear
1) Define the source of information (survey, record review)			
2) List inclusion and exclusion criteria for exposed and unexposed subjects (cases and controls) or refer to previous publications			
3) Indicate time period used for identifying patients			
4) Indicate whether or not subjects were consecutive if not population-based			
5) Indicate if evaluators of subjective components of study were masked to other aspects of the status of the participants			
6) Describe any assessments undertaken for quality assurance purposes (e.g., test/retest of primary outcome measurements)			
7) Explain any patient exclusions from analysis			
8) Describe how confounding was assessed and/or controlled.			
9) If applicable, explain how missing data were handled in the analysis			
10) Summarize patient response rates and completeness of data collection			
11) Clarify what follow-up, if any, was expected and the percentage of patients for which incomplete data or follow-up was obtained			

Yes = *; No = -; Unclear = U; Not applicable = NA
(http://www.ncbi.nlm.nih.gov/books/NBK35156/)

Appendix 3: Study and Sample Characteristics of the Studies on Determinants of COVID-19-related Mortality (N=60 Studies; 1,052, 211 Patients)

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
Alaa et al. (2020)	To investigate the influence of timing of hospital admission on risk of mortality for patients with COVID-19 in England	England	6068	Individuals with COVID-19 in the CHESS database during the study period. Average age – 68 years, Men – 61%	COVID-19 related mortality (all cause-mortality)	Each additional day between symptom onset and hospital admission is associated with a 1% increase in mortality risk (HR 1.01, p<0.005).
Almazeedi et al. (2020)	To examine the demographics, clinical manifestations, and outcomes in patients with COVID-19	Kuwait	1096	All COVID-19 patients admitted to Jaber Al Ahmad Al-Sabah hospital in Kuwait, with COVID-19 diagnosis based on WHO guideline and confirmed Polymerase Chain Reaction (PCR) test. Median age=41(IQR:25-75) years, Men (n=888), Number of COVID-19 deaths (n=9)	COVID-19 related mortality (in-hospital mortality)	Asthma (OR=4.92, 95%CI=1.03-23.44), smoking (OR=10.09, 95%CI=1.22-83.40) and elevated PCT (OR=8.24, 95%CI=1.95-43.74) are associated with COVID-19 mortality.
Bello-Chavolla et al. (2020)	To examine the association between diabetes and SARS-CoV-2 infection and its consequent clinical outcomes	Mexico	51633	All confirmed COVID-19 cases in the Mexican MOH dataset. Mean age= (46.65±15.83) years, Men – (n=29803), Number of COVID-19 deaths (n=5,332).	COVID-19 related mortality	Age ≥65 years (HR=2.02, 95%CI=1.89-2.16), diabetes (HR=1.34, 95%CI=1.26-1.43), obesity (HR=1.25, 95%CI=1.17-1.34), pneumonia (HR=5.21, 95%CI= 4.84-5.60), CKD (HR=1.99, 95%CI=1.77-2.23), COPD (HR=1.40,

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
						95%CI=1.23-1.59) are associated with COVID-19 mortality.
Berenguer et al. (2020)	To examine the predictors of death in patients with COVID-19 in Spain	Spain	4035	Males (61%) and females (39%) with COVID-19 confirmed by real-time PCR assay in 127 Spanish centres. Mean age=70 years, Men (n=2433), Number of COVID-19 deaths (n=1131)	COVID-19 related mortality (all-cause mortality)	Men (HR=1.29, 95%CI=1.13-1.49), older age (HR=9.11, 95%CI=5.9-14.06), hypertension (HR=1.22, 95%CI=1.05-1.4), obesity (HR=1.53, 95%CI=1.28-1.84), liver cirrhosis (HR=2.03, 95%CI=1.31-3.13), chronic neurologic disorder (HR=1.2, 95%CI=0.99-1.45), cancer (HR=1.49 95%CI=1.24-1.79) dementia (HR=1.26, 95%CI=1.04-1.53), CRP>5mg/L (HR=1.96, 95%CI=1.35-2.83), dyspnoea (HR=1.45, 95%CI=1.27-1.66) are associated with COVID-19 mortality.
Carrasco-Sánchez et al. (2020)	To examine the association between blood glucose levels and in-hospital mortality in non-critically patients with COVID-19.	Spain	11312	Patients ≥18 years with COVID-19 confirmed by Reverse Transcription (RT)-PCR and hospitalized from 1 March 2020 to 31 May 2020. Mean age=67.06±16.24 years, Men (n=6445), Number of COVID-19 deaths (n=2289).	COVID-19 related mortality (all-cause mortality during hospitalization)	Increasing age (HR=1.05, 95%CI=1.049-1.061), blood glucose level 140-180mg/dL (HR=1.48, 95%CI=1.29-1.70), blood glucose level >180mg/dL (HR=1.50, 95%CI=1.31-1.73), men (HR=1.15, 95%CI=1.03-1.30), hypertension (HR=1.14, 95%CI=1.01-1.29), COPD (HR=1.27, 95%CI=1.08-1.49), frailty (HR=1.58, 95%CI=1.39-1.80), CRP>60mg/L (HR=1.65, 95%CI=1.47-1.85) are associated with COVID-19 mortality.

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
Halalau et al. (2020)	To provide risk assessment tools for patients with COVID-19.	USA	2025	Patients with positive COVID-19 on nasopharyngeal swabs at any Beaumont Health's eight emergency departments between 1 March 2020 and 1 April 2020. Men (n=1027), Number of COVID-19 deaths (n=223)	COVID-19 related mortality (in-hospital mortality)	Older age, end-stage renal disease, chronic pulmonary disease, and nursing home residence are significantly associated with COVID-19 mortality (AOR>1, p-value<0.05)
Kaeuffer et al. (2020)	To explore risk factors of severe COVID-19 disease and mortality	France	1045	Individuals ≥ 18years with confirmed COVID19, hospitalised in Strasbourg and Mulhouse hospitals - March 2020. Mean age=66.3±16 years, Men (n=612), Number of COVID-19 deaths (n=115)	COVID-19 related mortality (in-hospital mortality)	Advanced age (OR=2.7 per 10-year increase, 95%CrI=2.1–3.4), men (OR=1.7, 95%CrI=1.1–2.7), immunosuppression (OR=3.8, 95%CrI=1.6–7.7), CKD (OR=2.3, 95%CrI=1.3–3.9), dyspnoea (OR=2.1, 95%CrI=1.2–3.4), CRP of 100–199mg/L (OR=2.0, 95%CrI=1.1–3.2) are associated with COVID-19 deaths.
Li et al. (2020)	To investigate severity of COVID-19 outcomes	China	548	Individuals with COVID-19 admitted to Tongji Hospital from 26 January – 5 February 2020. Mean age=60 (IQR:48-69) years, Men (n=279), Number of COVID-19 deaths (n=90)	COVID-19 related mortality (in-hospital mortality)	Men (AHR=1.7, 95% CI=1.0-2.8), age ≥65 years (AHR=1.7; 95%CI=1.1-2.7), blood leukocyte count more than 10cells/mm^3 (AHR= 2.0, 95%CI=1.3-3.3), LDH more than 445 U/L at admission (AHR=2.0, 95%CI=1.2-3.3), cardiac injury (AHR=2.9, 95%CI=1.8-4.8), hyperglycaemia (AHR=1.8, 95%CI=1.1-2.8), and administration of high-dose corticosteroids (AHR=3.5,

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
						95%CI=1.8-6.9) are associated with COVID-19 mortality.
Okoh et al. (2020)	To examine the clinical features of COVID-19 outcomes in Black/African American and Latino Hispanic	USA	251	Adults ≥18-years admitted between March 10 and April 10, 2020. Median age=62 (IQR:49-74) years, Men (n=129), Number of COVID-19 deaths (n=97).	COVID-19 related mortality (in hospital death)	Older age (OR=1.04, 95%CI=1.01-1.06), HIV status (OR=0.07, 95%CI=0.03-0.52), serum Hb>10mg/dl (OR=0.26, 95%CI=0.07-0.78), Creatinine phosphokinase (OR=3.04, 95%CI=1.04-9.44) are associated with COVID-19 mortality.
Petrilli et al. (2020)	To explore in-hospital COVID-19 outcomes.	USA	5279	Laboratory confirmed COVID-19 patients in Single academic medical center, New York between 1st March and 8th April 2020, and followed up to 5th May 2020. Median age=54(IQR:38-66) years, Men (n=2615), Number of COVID-19 deaths (n=665)	COVID-19 related mortality	Age ≥75years (HR=10.3, 95%CI=6.4-16.8), heart failure (HR=1.8, 95%CI=1.4-2.2), men (HR=1.3, 95%CI=1.1-1.5), and cancer (HR=1.3, 95%CI=1.1-1.6) are associated with COVID-19 mortality.
Sourij et al. (2020)	To investigate predictors of in-hospital COVID-19 mortality in patients with prediabetes and diabetes.	Austria	238	People ≥18 years with confirmed COVID-19 and type 1 diabetes, type 2 diabetes, or prediabetes from 10 hospital sites in Austria. Mean age=71.1± 12.9 years, Men (n=152), Number of COVID-19 deaths (n=58).	COVID-19 related mortality (in-hospital deaths)	Age (AOR=1.099, 95%CI=1.048-1.153), presence of arterial occlusive disease (AOR=3.558, 95%CI=1.264-10.022), CRP levels (AOR=1.012, 95%CI=1.003-1.020), eGFR (HR=0.965, 95%CI=0.947-0.983) are significant predictors of COVID-19 mortality.

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
Wang et al. (2020)	To examine the characteristics and prognosis of COVID-19 infections	China	293	Patients with COVID-19 diagnosis based on the NHC- China formulated "Diagnosis and treatment of novel coronavirus pneumonia". Median age=59.2(IQR:42.8-73.1) years, Men (n=138), Number of COVID-19 deaths (n=116).	COVID-19 related mortality	Older age (HR=1.043, 95%CI=1.032-1.056), dyspnoea (HR=1.83, 95%CI=1.265-2.648), hypertension (HR=2.884, 95%CI=1.997-4.165), diabetes (HR=1.829, 95%CI=1.175-2.847), cerebrovascular disease (HR=2.413, 95%CI=1.476-3.945), CoHD (HR=1.771, 95%CI=1.103-3.097), chronic renal disease (HR=2.156, 95%CI=1.092-4.257), shock (HR=3.321, 95%CI=2.301-4.791), acute cardiac injury (HR=4.197, 95%CI=2.904-6.607), and acute kidney injury (HR=2.698, 95%CI=1.667-4.368) are predictors of COVID-19 mortality.
Zhang et al. (2020)	To examine the influence of D-dimer levels on COVID-19 mortality	China	343	Adults ≥18 years with laboratory-confirmed COVID-19 between 12 January and 15 March 15. Median age=62.0(IQR:48.0-69.0) years, Men (n=169), Number of COVID-19 deaths (n=13).	COVID-19 related mortality (in-hospital mortality)	High D-dimer level ≥2.0 µg/ml is a significant determinant of COVID-19 mortality with or without underlying disease (AHR=22.4, 95%CI=2.86-175.7) after adjusting for gender and age.
Zhou et al. (2020)	To investigate in-hospital COVID-19 risk factors.	China	191	≥18 years old adult patients with laboratory confirmed COVID-19 from Jinyintan and Wuhan Pulmonary Hospital. Median age=56(IQR+46-67) years, Men	COVID-19 related mortality (in-hospital death)	Older age -per year increase (OR=1.10, 95%CI=1.03–1.17), higher SOFA score (OR=5.65, 95%CI=2.61–12.23) and CoHD (OR=2.14, 95%CI=0.26-17.79) predict COVID-19 mortality.

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
				(n=119), Number of COVID-19 deaths (n=54)		
Tartof et al. (2020)	To determine the association between BMI and COVID-19 mortality.	USA	6916	Patients with COVID-19 from 13 February - 2 May 2020, accessed from health care organisations located throughout 9 counties in Southern California. Mean age=49.1±16.6 years, Men (n=3111), Number of COVID-19 deaths (n=206).	COVID-19 related mortality (in-hospital death)	Patients with BMI of 18.5kg/m^2 to 24kg/m^2 (RR=2.68, 95%CI=1.43-5.04) and those with BMI 40 kg/m^2 to 44 kg/m^2 determine COVID-19 mortality after controlling for confounders.
Williamson et al. (2020)	To investigate risk factors of COVID-19 mortality.	England	10926	≥18 years individuals with COVID-19 and currently registered as active patients in general practitioners' surgery. Men (n=6162).	COVID-19 related mortality	People≥80 have more than 20-fold-increased risk compared to 50–59-year-olds (HR=20.60, 95%CI=18.70–22.68), Men (HR=1.59, 95%CI=1.53–1.65), greater deprivation (HR=1.79, 95%CI=1.68-1.91), BMI≥40kg/m^2 (HR=1.92, 95%CI=1.72–2.13), haematological malignancy diagnosed 1-4.9 years (HR=2.5, 95%CI=2.14-3.06), diabetes (HR=2.61 95%CI=2.46-2.77), severe asthma (HR=1.55, 95%CI=1.30-1.73), black (HR=1.48, 95%CI=1.29–1.69) and south Asian (HR=1.45, 95%CI=1.32–1.58), HPT (HR=1.09, 95%CI=1.05-1.14) are associated with COVID-19 death.

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
Grasselli et al. (2020)	To determine risk factors associated with COVID-19 ICU mortalities.	Italy	3988	Critically ill patients with laboratory-confirmed COVID-19. Median age=63 (IQR=56-69) years, Men (n=3188), Number of COVID-19 deaths (n=1926).	COVID-19-related mortality	Older age (HR=1.75, 95%CI=1.60-1.92), men (HR=1.57, 95%CI=1.31-1.88), high FiO2 (HR=1.14, 95% CI=1.10-1.19), high positive end-expiratory pressure (HR=1.04, 95% CI=1.01-1.06), low PaO2:FiO2 ratio (HR=0.80, 95%CI=0.74-0.87) on ICU admission, COPD (HR=1.68, 95% CI=1.28-2.19), hypercholesterolemia (HR=1.25, 95% 95%CI=1.02-1.52), type 2 diabetes (HR=1.18, 95% CI=1.01-1.39) are associated with COVID-19 mortality.
Mikami et al. (2020)	To examine factors associated with COVID-19 mortality.	USA	6493	Patients with laboratory confirmed COVID-19 with from one of the 8 hospitals in New York City metropolitan. Median age=59 (IQR:43-72) years, Men (n=3538), Number of COVID-19 deaths (n=858).	COVID-19 related mortality (in-hospital mortality)	Age >50 years (HR=2.34, 95CI=1.47–3.71), systolic blood pressure <90 mmHg (HR=1.38, 95%CI=1.06–1.80), a respiratory rate >24 per min (HR=1.43, 95%CI=1.13–1.83), eGFR <60 mL/min/1.73m2 (HR=1.80, 95%CI= 1.60–2.02), IL-6>100 pg/mL (HR=1.50, 95%CI=1.12–2.03), D-dimer>2μL/mL (HR=1.19, 95%CI=1.02–1.39), and troponin>0.03ng/mL (HR=1.40, 95%CI=1.23–1.62) are associated with COVID-19 mortality.

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
Albitar et al. (2020)	To explore predictors of COVID-19 mortality among patients from worldwide open access data	Africa Asia America Australia Europe	828	COVID-19 patients with definite outcomes. Mean age=49.4±20.9 years, Men (n=489), Number of COVID-19 deaths (n=219).	COVID-19 related mortality	Older age (AOR=1.079, 95%CI=1.064–1.095 per year increase), men (AOR=1.607, 95%CI=1.002–2.576), hypertension (AOR=3.576, 95%CI= 1.694–7.548), diabetes mellitus (AOR= 12.234, 95%CI=4.126–36.272), and patients located in America (AOR=7.441, 95%CI=3.546–15.617) are associated COVID-19 mortality.
Mendy et al. (2020)	To identify factors associated with COVID-19 hospitalization and mortality among ethnically diverse cohort.	USA	689	Patients with COVID-19 confirmed with a RT-PCR from the University of Cincinnati health system between 13 March – 31 May 2020. Median age =49.5(IQR:35.2-67.5) years, Men (n=365).	COVID-19 related mortality	Age per 10-year increase (OR=1.94, 95%CI=1.47-2.58) and being non-Hispanic Black (OR=3.44, 95%CI=1.32-9.00), CKD (OR=4.48, 95%CI=1.81-11.08), Anaemia (OR= 2.58, 95%CI=1.05-6.38), coagulation defect (OR=8.81, 95%CI=3.11-24.98) and thrombocytopenia (OR=14.12, 95% CI=4.54, 43.84) are associated with COVID-19 deaths.
Acharya et al. (2020)	To identify risk factors of COVID-19 mortality among COVID-19 patients with type 2 diabetes.	South Korea	55	Patients with diabetes and COVID-19 being managed at two centres in Korea from 18 February to 30 June 2020. Mean age=69.8±13.5 years, Men (n=20), Number of COVID-19 deaths (n=24)	COVID-19 related mortality	Age ≥70years (OR=17.42, 95%CI=1.79–168.79, p=0.014) and high Lactate dehydrogenase (OR=9.703, 95%CI=1.81–51.96, p=0.008) are risk factors for COVID-19 among patients with diabetes.

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
Agarwal et al. (2020)	To examine determinants of mortality among patients with COVID-19 illness	India	95	Patients with COVID-19 diagnosis seen at All India Institute of Medical Sciences Patna, Bihar-India between 25th April and 12th July 2020. Mean age=47.7±15.9 years, Male (n=79) Number of COVID-19 deaths (n=27)	COVID-19 mortality	Place of residence (AOR=4.04, 95%=1.33–12.28) and patients requiring ICU at admission (AOR=7.22, 95%=2.54–20.52) determine COVID-19 mortality.
Alamdari et al. (2020)	To determine factors associated with COVID-19 mortality	Iran	459	COVID-19 patients managed at Shahid Modarres Hospital, Iran, from 30th January 30th to 5th April 2020. Mean age=61.79 ±11.89 years. Men (n=320), Number of COVID-19 deaths (n=63).	COVID-19 mortality	Age (OR=1.055, 95%CI=1.056-1.114), CRP (OR=2.915, 95%= 2.708-5.454), creatinine (OR=1.740, 95%CI=1.587-3.356) and magnesium level (OR=0.032, 95%CI=0.003-0.044) are determine COVID-19 mortality
Alkhouli et al. (2020)	To examine the influence of sex on COVID-19 mortality	Multinational (36% of the data from the USA)	4712	Patients ≥18 years with COVID-19 identified from the TriNetX COVID-19 database. Mean age=55.0±17.7 years, Men (n= 6387), Number of COVID-19 deaths (n=568).	COVID-19 mortality	Men (OR=1.81, 95%CI=1.55-2.11) have higher odds of COVID-19 mortality than women after propensity score matching.
Asfahan et al. (2020)	To explore the influence of age, sex, comorbidities, and health-care related occupation on COVID-19 mortality	China	44672	Persons with confirmed COVID-19 diagnosis released by China's Centre for Disease Control. Majority age group: 50-59years (n=9878), Men (n=22328), Number of COVID-19 deaths (n=1023).	COVID-19 mortality	The odds of dying from COVID-19 for every 10-year increase in age and for the presence of comorbidity is 3.4 and 10.3, respectively.

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
Atkins et al. (2020)	To examine whether pre-existing conditions predict COVID-19 mortality	UK	507	Patients aged >65years with COVID-19 diagnosis accessed from the UK biobank (England). Majority age group: 75-79years (n=197), Men (n=311), Number of COVID-19 deaths (n=141)	In-hospital COVID-19 deaths	Dementia (OR=7.30, 95%CI=3.28–16.21), diabetes (OR=3.11, 95%CI=2.06–4.71), COPD (OR=1.91, 95%CI=1.10–3.32), pneumonia (OR=1.88, 95%CI=1.07–3.30) and depression (OR=1.78, 95%CI=1.07–2.96) correlate with in-hospital COVID-19 deaths.
Al-Salameh et al. (2020)	To compare clinical outcomes of COVID-19 patients with COVID-19	France	433	Adult patients with COVID-19 hospitalised at Amiens University Hospital, France up until 21st April 2020. Median age=72 (IQR:59-84) years, Men (n=238), Number of COVID-19 deaths (n=89).	COVID-19 mortality	Age (per 10 years) (HR=1.80, 95%CI=1.40-2.32), total cardiovascular disease (HR=1.84, 95%CI=1.10-3.08), abnormal liver function tests (HR=3.34, 95%CI=1.61-6.94) determine COVID-19 deaths.
Bahl et al. (2020)	To examine risk factors of COVID-19 mortality	USA	1461	Patients with COVID-19 accessed from the Beaumont Health centres in Metro Detroit. Median age=62 (IQR:50-74) years, Men (n=770), Number of COVID-19 deaths (n=327)	In-hospital COVID-19 related mortality	Older age (HR=1.05, 95%CI=1.04-1.06), admission elevated respiratory rate (HR=1.06, 95%CI=1.04–1.09), Creatinine>1.33 mg/dL (HR=1.41, 95%CI= 1.08–1.85), procalcitonin>0.5 ng/mL (HR= 2.14, 95%CI=1.37–3.36), and lactic acid≥2.0 mmol/L (HR=1.57, 95%CI=1.17-2.12) predict in-hospital COVID-19 death
Bepouka et al. (2020)	To identify predictors of	Congo	141	Patients with confirmed COVID-19 diagnosis admitted at Kinshasa University Hospital from 23rd	COVID-19 mortality	Patients aged 40-59 years (AHR=4.07, 95%CI= 1.16 - 8.30), those aged ≥60 years (AHR=6.65, 95%CI=1.48-8.88)

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
	COVID-19 mortality			March to 15th June 2020. Mean age=49.6±16.5 years, Men (n=95), Number of COVID-19 deaths (n=41)		and those with dyspnoea (AHR=5.67, 95%CI=1.46-21.98) predict COVID-19 mortality.
Docherty et al. (2020)	To describe the clinical features of COVID-19 patients hospitalised during the growth phase of the first wave of the COVID-19 pandemic.	UK	20133	COVID-19 patients admitted in 208 acute care hospitals in the UK between 6 February and 19 April 2020 and enrolled in ISARIC, WHO Clinical Characterisation Protocol-UK. Median age=73(IQR:58-82) years, Men (n=12,068), Number of COVID-19 deaths (n=5165)	In-hospital COVID-19 mortality	Increasing age [50-59years (HR=2.63, 95%CI=2.06-3.35); 60-69years (HR=4.99, 95%CI=3.99-6.25); 70-79years (HR=8.51, 95%CI=6.85-10.57); ≥80years (HR=11.09, 95%CI=8.93=13.77)], chronic cardiac disease (HR=1.16, 95%CI=1.08-1.24), Chronic pulmonary disease (HR=1.17, 95%CI=1.09- 1.27), CKD (HR=1.28, 95%CI=1.18-1.39), obesity (HR=1.33 95%=1.19-1.49), Dementia (HR=1.40,95%CI=1.28-1.52), and malignancy (HR=1.13,95%CI=1.02-1.24) are associated with higher risk of COVID-19 mortality.
Bray et al. (2020)	To estimate predictors of COVID-19 mortality using and ecological analysis.	England	310 local authorities in England	Data involved the age-standardised COVID-19 mortality rates published by the ONS from 1st March to 17th April 2020 for each included local authority. The variables included percentage of white, overweight/obese population, people per square kilometre, median	COVID-19 mortality	Each percentage point increase in overweight/obesity is associated with a 0.7/100,000 increase in COVID-19 mortality rate.

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
				IMD and mean concentration of particulate matter.		
Cai et al. (2020)	The influence of fasting blood sugar on COVID-19 mortality	China	941	Patients with COVID-19 diagnosis admitted at the Renmin Hospital, University in Wuhan, China. Median age=57 (IQR:18-98) years, Men (n=454).	In-hospital COVID-19 related mortality	Age (HR=1.04, 95%CI=1.01–1.06), hypertension (HR=1.89, 95%CI=1.04–3.45), coronary heart disease (HR=0.42, 95%CI=0.18–0.96), chronic renal failure (HR=3.17, 95%CI=1.48–6.80), chronic heart failure (HR=3.44, 95%CI=1.52–7.83), CRP (HR=1.01, 95%CI=1.00–1.01) and fasting blood sugar≥7.0mmol/L (HR=2.20, 95%CI=1.21–4.03) are independent predictors of COVID-19 mortality.
Caliskan and Saylan (2020)	To examine the relationship between smoking rates, comorbidities, and COVID-19 mortality	Turkey	565	Adults ≥18 years old with confirmed COVID-19 diagnosis admitted at the Abdulhamit Han Training and Research Hospital in Turkey between 15th March and 10th May 2020. Mean age=48.0±19.7 years.	COVID-19 related mortality	Older age (OR=1.082, 95%CI=1.056-1.109), COPD (OR=3.213, 95%CI=1.224-8.431), CAD (OR=6.252, 95%CI=2.171-18.004), Congestive heart failure (OR=5.917, 95%CI=1.069-32.258), Current smoking (OR=13.014, 95%CI=5.058-33.480), former smoking (OR=6.507, 95%CI=2.731-15.501) are risk factors of COVID-19 mortality.
Cangiano et al. (2020)	To examine risk factors of COVID-19 mortality in adults	Italy	98	Adults aged 60-100 years who tested positive for COVID-19 in Mons. G. Bicchierari nursing home.	COVID-19 related mortality	The logistic regression identified older age (p=0.03) and Men (p=0.03) as determinant of COVID-19 mortality

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
	with COVID-19 in nursing homes.			Men (n=20), Number of COVID-19 deaths (n=42).		associated with COVID-19 mortality (p=0.03)
Carrillo-Vega et al. (2020)	To estimate risk factors for COVID-19 deaths among persons with COVID-19	Mexico	10544	Patients with confirmed COVID-19 diagnosis accessed from the epidemiological surveillance system for viral respiratory diseases of the Mexican ministry of health records. Mean age=46.47±15.62years, Men (n=6082), Number of COVID-19 deaths (n=968)	COVID-19 mortality	Men (OR=1.53, 95%CI=1.30–1.81), patients aged 50–74 years (OR=1.96, 95%CI=1.63–2.34), those aged≥75years (OR=3.74, 95% CI=2.80–4.98), presence of HPT/obesity/ diabetes (OR=2.10, 95%CI=1.50–2.93) and pneumonia (OR=2.57, 95%CI=I. 2.11–3.13)
Chen et al. (2020)	To examine risk factors of COVID-19 mortality in persons with COVID-19	China	1859	Patients ≥18 years with CT scan COVID-19 diagnosis seen at seven COVID-19 centres in Wuhan, China. Median age=59 (IQR:45-68) years, Men (n=934), Number of COVID-19 deaths (n=208)	In hospital COVID-19 mortality	Older age (HR=1.04, 95%CI=1.03-1.06), smoking (HR=1.84, 95%CI=1.17-2.92), increased admission temperature (HR=1.32, 95%CI=1.07-1.64), D-dimer per mg/l (HR= 3.00, 95%CI=2.17-4.16), and serum creatinine per µmol/L (HR= 4.55, 95%CI=2.72-7.62) are risk factors of COVID-19 mortality.
Gonca et al. (2020)	To examine the influence of smoking status on COVID-19 mortality among patients with COVID-19.	Turkey	114	Patients diagnosed with COVID-19 between 11th March and 30th April 2020. Mean age=51.14±14.97 years, Men (n=77), Number of COVID-19 deaths (n=16)	COVID-19 related mortality	Smoking status is not associated with COVID-19 mortality.

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
Cummings et al. (2020)	To identify predictors of in-hospital COVID-19 mortality	USA	257	Patients aged ≥18years with laboratory confirmed COVID-19 and admitted in 2 hospital in New York from 2nd March to 1st April 2020. Median age= 62 (IQR:51–72) years, Men (n=171).	In-hospital COVID-19 related mortality	Older age (AHR=1·31, 95%CI=1·09–1·57), chronic cardiac disease (AHR=1·76, 95%CI=1·08–2·86), chronic pulmonary disease (AHR=2·94, 95%CI=1·48–5·84), higher concentrations of interleukin-6 (AHR=1·11, 95%CI=1·02–1·20) and higher D-dimer (AHR=1·10, 95%CI=1·01–1·19) are associated with in-hospital COVID-19 mortality.
Dai et al. (2020)	To examine the influence of cigarette smoking and alcohol consumption on COVID-19 mortality	China	1547	Patients with COVID-19 diagnosis managed at four hospitals in Wuhan, China. Mean age=57.31±16.09 years, Men (n=802), Number of COVID-19 deaths (n=257).	COVID-19 mortality	Cigarette smoking is associated with COVID-19 mortality (HR=1.825, 95%CI=1.275-2.613)
de Souza et al. (2020)	To examine factors associated with COVID-19 mortality among older adults	Brazil	9807	Older adults ≥60 years old with COVID-19 disease in Alagoas, Brazil. Mean age=70.21±8.37 years, Men (n=4662), Number of COVID-19 deaths (1171)	COVID-19 mortality	Men (OR=1.54, 95%CI=1.35–1.76), Age ≥75 years (OR=2.40, 95%CI= 2.10–2.74), dyspnoea (OR=2.92, 95%CI= 2.34–3.64), diabetes (OR=2.33, 95%CI= (1.99–2.74), hypertension (OR=1.53, 95%CI= (1.20–1.94) and CKD (OR=2.02, 95%CI= (1.27–3.20) determine COVID-19 mortality.

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
Deng et al. (2020)	To explore clinical factors associated with COVID-19 mortality	China	44672	Patients with laboratory confirmed COVID-19 diagnosis identified in the Chinese centre for disease control and prevention records. Majority were aged from 60-69years (n= 8583), Men (n=22981), Number of COVID-19 deaths (n=1023)	COVID-19 mortality	Men (RR=1.67, 95%CI=1.47–1.89), cardiovascular disease (RR =6.75, 95%CI= 5.40–8.43), hypertension (HR=4.48, 95%CI=3.69–5.45), diabetes (RR=4.43, 95%CI=3.49–5.61), respiratory disease (RR=3.43, 95%CI=2.42–4.87) and cancers (RR=2.926, 95%CI=1.34–6.41) are associated with COVID-19 death.
Yu et al. (2020)	To identify risk factors associated with COVID-19 mortality	China	246	All patients with confirmed COVID-19 diagnosis seen at the Wuhan Third Hospital from January 2020 to February 2020. Number of COVID-19 deaths (n=42)	All cause COVID-19 mortality	Age (OR= 1.09, 95%CI=1.04-1.14), hypertension (OR=1.12, 95%=1.01–4.74) and creatinine (OR=1.13, 95%CI=1.06–1.19) predict COVID-19 mortality.
Yehia et al. (2020)	To examine the association between race and all-cause in-hospital mortality among patients with COVID-19.	USA	11210	Adults ≥18years with COVID-19 admitted to 92 hospitals in 12 states from 19th February to 31st May 2020. Median age= 61 (IQR:46-74) years, Men (n=5583), black race (n=4180), Number of	All cause in-hospital COVID-19 mortality	Race is not a significant predictor of COVID-19 mortality when sex, age, insurance, comorbidities, neighbourhood deprivation, and clinical variables are controlled.
Xu et al. (2020)	To examine the influence of demographic and clinical factors on COVID-19 outcomes	China	703	Patient with RT-PCR confirmed COVID-19 diagnosis admitted to 16 tertiary hospitals between 10th January and 13th March 2020. Mean age=46.1±15.2 years, Men (n=321),	In-hospital COVID-19 deaths	Comorbidities ≥2 (HR=6.734, 95%CI=3.239-14.003), leukocytosis (HR=9.639, 95%CI=4.572-20.321) and lymphopenia (HR=4.579, 95%CI=1.334-15.715) increased risk of COVID-19 mortality.

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
				Number of COVID-19 deaths (n=33).		
Larrauri (2020)	To identify risk factors for COVID-19 severity.	Spain	218652	Patients with laboratory confirmed COVID-19 diagnosis recorded in the Spanish national centre of epidemiology. Median age=61(IQR:46-78) years, Men (n=95769), Number of COVID-19 deaths (n=26121)	COVID-19 related mortality	Men (OR=1.33, 95%CI=1.24–1.42), patients ≥80 years (OR=28.45, 95%CI=19.85–40.78), pneumonia (OR=1.24, 95%CI=1.13–1.35), ARDS (OR=4.51, 95%CI=4.08–4.99), cardiovascular disease (OR=1.32, 95%CI=1.23–1.42), diabetes (OR=1.23, 95%CI1.14–1.33) and CKD (OR=1.47, 95%CI=1.29–1.68) increase the odds of COVID-19 mortality.
Farrell et al. (2020)	To identify COVID-19 mortality risk factors among patients with COVID-19	Ireland	257	Patients diagnosed with COVID-19 between 13th March and 1st May 2020 and managed at the Connolly hospital in Ireland. Men (n=153), Number of COVID-19 deaths (n=39)	COVID-19 related mortality	Overweight/obese (HR=3.09, 95%CI=1.32-7.23), Care home resident (OR=2.68, 95%CI=1.24-5.6), socioeconomic deprivation (OR=1.05, 95%CI=1.01-1.09), obesity (OR=3.09, 95%CI=1.32-7.23) and older age (OR=1.04, 95%CI=1.01-1.06) determine COVID-19 mortality.
Fox et al. (2020)	To examine the relationship between diabetes and COVID-19 clinical outcomes	USA	355	Patients ≥18 years with COVID-19 diagnosis admitted to the Einstein medical centre, Philadelphia from 1st March 2020 to 24th April 2020. Mean age= 66.21±14.21years, Men	In-hospital COVID-19 mortality	Age is an independent risk factor for COVID-19 mortality.

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
				(n=174), Number of COVID-19 deaths (n=80)		
Gayam et al. (2020)	To identify predictors of COVID-19 mortality in African American patients hospitalised with COVID-19	USA	408	African American patients with COVID-19 diagnosis admitted to an inner-city community hospital in New York. Median age= 67 (IQR:56-76) years, Men (n=231), Number of COVID-19 deaths (n=132)	In-hospital COVID-19 mortality	Age (OR=1.06, 95%CI=1.04-1.08), BMI (OR=1.07, 95%CI=1.04-1.11), CRP (OR=2.42, 95%CI=1.36-4.33) and D-dimer (OR=3.79, 95%CI=2.21-6.50) predict COVID-19 mortality among African Americans with COVID-19.
Goodall et al. (2020)	To examine independent associations between COVID-19 outcomes, demographic and clinical characteristics of patients with COVID-19	England	981	Patients ≥18 years old with PCR confirmed COVID-19 diagnosis admitted at the Northwick Park hospital in North-West London. Median age=69 (IQR:56–80) years, Men (n=631), Number of COVID-19 deaths (n=426)	In-hospital COVID-19 mortality	Age (AHR=1.53, 95%CI=1.37–1.71), respiratory disease (AHR=1.37, 95%CI=1.03–1.81), immunosuppression (AHR=2.23, 95%=1.23–4.05) and CRP (AHR=1.15, 95%CI=1.08–1.22) independently predict COVID-19 mortality in patients with COVID-19.
Gutiérrez-Abejón et al. (2020)	To examine predictors of COVID-19 outcomes in patients	Spain	7307	Patients with confirmed COVID-19 diagnosis during the first wave of the COVID-19 pandemic – between 1st March and 31st May 2020. Median age=76 (IQR:63–86) years,	In-hospital COVID-19 related mortality	Patients ≥65years old (OR=9.05), and Men (OR=1.18) have increased risk of COVID-19 mortality.

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
	hospitalised with COVID-19			Men (n=4169), Number of COVID-19 deaths (n=5522)		
Harrison et al. (2020)	To examine the association between comorbidities and COVID-19 mortality in adults with COVID-19	USA	31461	Patients aged 18–90years with COVID-19 diagnosis managed at 24 health centres in the USA between 20th January and 26th May 2020. Median age=50 (IQR:35–63) years, Men (n=14306), Number of COVID-19 deaths (n=1296)	COVID-19 mortality	older age (OR=1.063, 95%CI=1.058–1.068), men (OR=1.75, 95%CI=1.55–1.98), being black or African American (OR=1.50, 95%CI=1.31–1.71), myocardial infarction (OR=1.97, 95%CI=1.64–2.35), congestive heart failure (OR=1.42, 95%CI=1.21–1.67), dementia (OR=1.29, 95%CI=1.07–1.56), chronic pulmonary disease (OR=1.24, 95%CI=1.08–1.43), liver disease (OR=2.62, 95%CI=1.53–4.47), renal disease (OR=2.13, 95%CI=1.84–2.46) and metastatic solid tumour (OR=1.70, 95%CI=1.19–2.43) predict COVID-19 mortality.
Ho et al. (2020)	To assess whether mediating factors influence the association between older age and COVID-19 mortality risk.	UK	470034	Patients with COVID-19 aged 47-85 years as of 1st March 2020, accessed form 22 centres across the UK. Men (n=210019), Number of COVID-19 deaths (n=438)	COVID-19 related mortality	Patients aged ≥75 years with no additional risk factors (RR=12.13, 95%CI=2.79–52.66) have higher COVID-19 mortality risk than those aged <65 years with no risk factors.
Ibrahim et al. (2020)	To identify predictors of in-	Nigeria	45	Patients ≥18 years with RT-PCR confirmed COVID-19 diagnosis	COVID-19 mortality	Hypoxemia at presentation (AOR=2.5, 95%CI=1.3–5.1) and creatinine >1.5

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
	hospital COVID-19 mortality			admitted to the Federal Medical Center, Katsina, Nigeria, from 10th April to 10th June 2020. Mean age=43±16 years, Men (n=39), Number of COVID-19 deaths (n=7)		mg/dL (AOR=4.3, 95%CI=1.9–9.8) are independent predictors of COVID_19 mortality.
Imam et al. (2020)	To investigate predictors of COVID-19 mortality	USA	1305	Patients with RT-PCR confirmed COVID-19 diagnosis admitted from 1st March to 17th April 2020. Mean age= 61.0±16.3years, Men (n=702). Number of COVID-19 deaths (n=200)	In-hospital COVID-19 mortality	Age >60years (AOR=1.93, 95%CI=1.26–2.94) and Charlson comorbidity index >3 (AOR=2.71, 95%CI=1.85–3.97) are independent determinants of COVID-19 mortality.
Ioannou et al. (2020)	To examine risk factors of COVID-19 death among USA veterans with COVID-19 infection	USA	10131	US veterans who tested positive for COVID-19. Mean age= 63.6±16.2 years. Men (n=9221).	All-cause COVID-19 mortality	Older age ≥80years (AHR=60.80, 95%CI=29.67-124.61), Charlson comorbidity index (AHR=1.93, 95%CI=1.54-2.42), fever (AHR=1.51, 95%CI=1.32-1.72), dyspnoea (AHR=1.78, 95%CI=1.53-2.07) and creatinine level >3.80mg/dL (AHR=3.79, 95%CI=2.62-5.48) independently predict COVID-19 mortality.
Kammar-García et al. (2020)	To investigate the impact of comorbidities on COVID-19 positive patients	Mexico	13842	Patients who tested positive for COVID-19 in Mexico between 1st January and 25th April 2020. Mean age= 46.6±15.6 years, Men (n=7989), Number of COVID-19 deaths (n=1305)	All-cause COVID-19 mortality	Asthma (OR=1.1, 95%CI=0.8-1.6) is a single comorbid predictor of COVID-19 case fatality

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
Kim et al. (2020)	To examine the association between comorbidities and COVID-19 mortality	South Korea	9148	Patients with confirmed COVID-19 diagnosis identified in the Korea Centre for Disease Control and Prevention registry. Most were aged from 20-24 years (n=1352), Men (n=3556), Number of deaths (n=130)	COVID-19 mortality	Heart failure (OR=3.17, 95%CI=1.88–5.34), renal failure (OR=3.07, 95%CI=1.43–6.61), prostate malignant neoplasm (OR=2.88, 95%CI=1.01–8.22), acute myocardial infarction (OR=2.38, 95%CI=1.03–5.49), diabetes (OR=1.82, 95%CI=1.25–2.67), and other ischemic heart disease (OR=1.71, 95%CI=1.09–2.66) increase odds of COVID-19 deaths.
Kim et al. (2020)	To examine the association between BMI and COVID-19 outcomes among patients with COVID-19	USA	10861	Patients with confirmed COVID-19 diagnosis and admitted to Northwell health system hospitals between 1st March and 27th April 2020. Median age=65 (IQR:54-77) years. Men (n=6468), number of deaths (n=2,596).	COVID-19 mortality	Patients who are underweight (HR=1.46, 95%CI=1.17-1.81) or had obesity class III (HR=1.23, 95%CI=1.03-1.48) have increased risk of COVID-19 death.
Lee et al. (2020)	To examine risk factors for COVID-19 severity in patients with COVID-19	South Korea	7339	Patients aged ≥18 years diagnosed with COVID-19. Mean age= 47.1±19 years, Men (n=2970), Number of COVID-19 deaths (n=227).	COVID-19 mortality	Diabetes (OR=2.17, 95%CI=1.55–3.03), CKD (OR= 3.11, 95%CI=1.33–7.3), pneumonia (OR=1.6, 95%CI=1.07–2.39), Age (OR=1.12, 95%CI=1.11–1.14), Men (OR=2.10, 95%CI=1.51–2.92) are risk factors for COVID-19 mortality.
Javanian et al. (2020)	To investigate the risk factors for	Iran	557	Patients ≥16 years with COVID-19 diagnosis managed admitted to 3 central hospitals affiliated to Babol	COVID-19 mortality	Older age (ARR=1.03, 95%CI=1.01-1.05), cerebrovascular disease (ARR=1.96, 95%CI=1.20-3.19),

Studies	Aim	Settings	Sample size	Sample characteristics	Outcomes/dependent variables	Findings
	COVID-19 mortality			University of Medical Sciences from 1st March to 1st April 2020. Mean age= 60.2±15.3, Men (n= 305), Number of COVID-19 deaths (n=121).		pneumonia (ARR=2.09, 95%CI=1.22-3.55), ARDS (ARR=3.80, 95%CI=2.28-6.31), AKF (ARR=1.45, 95%CI=1.12-3.76) acute heart failure (ARR=1.63, 95%CI=1.01-2.62) are risk factors for COVID-19 mortality.

Notes: PCT- Procalcitonin, HR – Hazard ratio, CI - Confidence Interval, AOR – Adjusted odds ratio, OR- Odds ratio, AHR – Adjusted Hazard Ratio, LOS – Length of hospitalisation, CRP - C-Reactive Protein, CoHD – coronary heart disease, eGFR - estimated glomerular filtration rate, SOFA - quick sequential organ failure assessment, RR-Risk Ratio, ARR- Adjusted risk ratios, FiO2 – Fraction of inspired oxygen, PaO2 - arterial partial pressure of oxygen, IL-6 - interleukin-6, IQR – Interquartile Range, UK- United Kingdom, ISARIC - International Severe Acute Respiratory and emerging Infections Consortium, CKD – Chronic kidney disease, ONS- Office for National Statistics, IMD- Index of Multiple Deprivation (IMD), RT-PCR- Reverse-transcription–polymerase-chain-reaction, BMI- Body Mass Index, ARDS - Acute respiratory distress syndrome, AKF - Acute kidney failure, CAD – Coronary artery disease.

Appendix 4: Study and Sample Characteristics of the Studies on Determinants of COVID-19-related LOS – (N= 5 Studies; 1,168 Patients)

Studies	Aim	Settings	Sample size	Sample characteristics	Outcome/dependent variable	Findings
Wu et al. (2020)	To examine factors associated with longer length of COVID-19 hospital stay	China	58	Patients with COVID-19 and hospitalised in Qiaokou Fangcang Hospital. Median age=55.5(IQR:20) years, Men (n=22)	LOS (number of days spent on admission due to COVID-19)	COVID-19 patients with fever before admission (β =3.5, 95%CI=1.39-5.63, p=0.002), those with bilateral pneumonia (β =3.4, CI=0.49-6.25, p=0.023) and patients with diabetes (β =3.2) have longer COVID-19 related LOS.
Guo et al. (2020)	To investigate determinants of COVID-19 prolonged hospital length of stay	China	75	Patients with laboratory-confirmed COVID-19 and discharged from 20 January – 16 March 2020. Median age=47 (IQR:31-54) years, Men (n=43)	COVID-19 related LOS (<17 days median LOS-normal; >17days median LOS prolonged)	Women (AOR=0.19, 95%CI= 0.05-0.63), fever (AOR=8.27, 95%CI=1.47-72.16), CKD (AOR=13.73, 95%CI=1.95-145.4), each 1-unit increase in creatinine level (AOR=0.94, 95%CI=0.9-0.98) are associated with prolonged LOS.
Mendy et al. (2020)	To identify factors associated with COVID-19 hospitalization and mortality among ethnically diverse cohort.	USA	689	Patients with COVID-19 confirmed with a RT-PCR from the University of Cincinnati health system between 13 March – 31 May 2020. Median age =49.5(IQR:35.2-67.5) years, Men (n=365).	COVID-19 related LOS (number of days hospitalised for COVID-19)	Men (β=0.39, 95%CI=0.16- 0.62), presence of diabetes (β=0.50, 95%CI=0.26-0.74), asthma (β=0.50, 95% CI: 0.20-0.81), COPD (β=0.45, 95%CI=0.11-0.79), cardiovascular disease (β= 0.40, 95%CI=0.10, 0.70), vitamin D deficiency (β=0.47, 95%CI=0.20-0.75), anaemia (β=0.38, 95%CI=0.14-0.62), coagulation defect (β=0.57, 95%CI=0.26-0.88), and thrombocytopenia (β=0.67, 95%CI=0.30-1.30) are associated with prolonged LOS.

Studies	Aim	Settings	Sample size	Sample characteristics	Outcome/dependent variable	Findings
Alkundi et al. (2020)	To describe COVID-19 outcomes among patients with COVID-19	England	232	Patients with COVID-19 diagnosis admitted at William Harvey Hospital between 10th March and 10th May 2020. Mean age=70.5±15.7years Men (n=145), Mean LOS=11.5±8.2 days.	COVID-19 related LOS (number of days spent in hospital due to COVID-19)	Diabetes is associated with longer hospital stay among patients with COVID-19 ($p<0.0001$)
Gonca et al. (2020)	To examine the influence of smoking status on COVID-19 related LOS	Turkey	114	Patients diagnosed with COVID-19 between 11th March and 30th April 2020. Mean age=51.14± 14.97years, Men (n=77).	COVID-19 related LOS	Smoking status is not associated with COVID-19 related LOS.

Note: β - correlation coefficient, LOS- Length of hospitalisation, CKD – chronic kidney disease, COPD – chronic obstructive pulmonary disease, AOR – Adjusted odds ratio

Appendix 5: All Other Information Extracted from the Reviewed Studies (N=63)

Author (year)	Independent variables measured (description/specification)	Statistical estimators
Alaa et al. (2020)	Age:(years) Gender:(male/female) Ethnicity:(White, black, Asian) Timing of hospitalisation (number of days between symptom onset and admission to hospital; hospitalised before symptoms, hospitalised after symptoms) Obesity:(underweight, normal, overweight, obese, based on WHO BMI measure)	Cox proportional hazards regression model
Almazeedi et al. (2020)	Age:(years) Gender:(male/female) Asthma:(yes/no) Diabetes:(yes/no) Hypertension:(yes/no) CRD:(yes/no) PCT: (normal/elevated) Organ failure:(based on the qSOFA score) CRP:(mg/dL; measured as continuous variable) Obesity:(underweight, normal, overweight, obese, based on WHO BMI measure) Smoking:(yes/no)	Multivariable logistic regression
Bello-Chavolla et al. (2020)	Age:(years) Gender:(male/female) Nationality:(did not indicate) Diabetes:(yes/no) CKD:(yes/no) Pneumonia:(yes/no) Immunosuppression(yes/no) COPD:(yes/no) Obesity:(underweight, normal, overweight, obese, based on WHO BMI measure)	Cox proportional risk regression models

Author (year)	Independent variables measured (description/specification)	Statistical estimators
Berenguer et al. (2020)	Age:(years) Sex:(male/female) Birth country: (Spain/other) Ethnicity:(Arab/Asian/Latin-American/black/white/other) Hypertension:(yes/no) CHD:(yes/no) CND:(yes/no) Dementia:(yes/no) Solid active neoplasm (cancer):(yes/no) CKD stage 4:(yes/no) Inflammatory disease:(yes/no) Liver cirrhosis:(yes/no) Asthma:(yes/no) Diabetes:(yes/no) HIV/AIDs:(yes/no) COPD:(yes/no) Obesity:(underweight, normal, overweight, obese, based on WHO BMI measure) Active haematologic neoplasm:(yes/no) CRP:(normal(≤5mg/L)/high (>5 mg/L)) Current medication:(current drugs patient is taking) Dyspnoea:(yes/no) Pregnancy:((yes/no) Smoking: (current/former/never smoked)	Multivariable Cox regression
Carrasco-Sánchez et al. (2020)	Age:(years) Gender:(male/female) Admission Blood glucose:(normoglycaemia<140mg/dl; hyperglycaemia 140-180mg/dl; >180mg/dl) Diabetes:(yes/no) Hypertension:(yes/no) COPD:(yes/no) CRP>60mg/L:(yes/no)	Multivariate Cox proportional hazard regression

Author (year)	Independent variables measured (description/specification)	Statistical estimators
	Frailty/dependency:(yes/no)	
Halalau et al. (2020)	Age:(years) Sex:(male/female) CHD: (yes/no) Congenital heart disease:(yes/no) Congestive heart failure:(yes/no) End-stage renal disease:(yes/no) End-stage liver disease:(yes/no) Chronic pulmonary disease:(yes/no) Diabetes:(yes/no) Hypertension:(yes/no) Nursing home residence:(yes/no) Presence of pregnancy:(yes/no) Obesity:(WHO BMI obesity measure) Immunocompromised status:(HIV, receiving chemotherapy, receiving immunosuppressive agents)	Multivariate logistic regression
Kaeuffer et al. (2020)	Age:(years) Sex:(male/female) Diabetes:(yes/no) Chronic heart failure:(yes/no) Chronic respiratory disease:(yes/no) CKD:(yes/no) Chronic hepatic failure:(yes/no) Immunosuppression:(yes/no) Haematological malignancy (cancer):(yes/no) Pregnancy Pregnancy:((yes/no) Dyspnoea:(yes/no) CRP: 100– 199mg/L/ CRP Hypertension:(yes/no) ≥200mg/L	Bayesian version of Cox model

Author (year)	Independent variables measured (description/specification)	Statistical estimators
	Active smoking:(yes/no)	
Li et al. (2020)	Age:(years) Sex:(male/female) Hypertension:(yes/no) Diabetes:(yes/no) Tuberculosis:(yes/no) Asthma:(yes/no), Dyspnoea:(yes/no) Blood leukocyte count:(>10×10⁹/L vs≤10×10⁹/L) LDH:(>250/>445) Complications:(cardiac injury/hyperglycaemia) Corticosteroids:(no/low dose/high dose) BMI:(underweight, overweight, obese) Smoking:(never/current/former)	Cox proportional hazard regression model
Okoh et al. (2020)	Age:(years) Sex:(male/female) Race:(Africa-America/Latino Hispanic) Hypertension:(yes/no) Diabetes:(yes/no) Coronary artery disease:(yes/no) HIV: (yes/no) CKD:(yes/no) Baseline serum Haemoglobin:(> 10 mg/dl /<10 mg/dl) Creatinine phosphokinase(>1000u/l/<1000u/l) PCT (> 0.5/<0.5) BMI (kg/m^2): (< 25/25–29.9/30–35/ > 35) LDH:((> 500 u/l/<500 u/l)	Multivariable logistic regression
Petrilli et al. (2020)	Age:(years) Sex:(male/female)	Hazard risk model

Author (year)	Independent variables measured (description/specification)	Statistical estimators
	Race:(non-Hispanic white, non-Hispanic, African American, Asian, Hispanic, other/multiracial, and unknown) Smoking status:(never/current/former/unknown) Hypertension:(yes/no) Hyperlipidaemia:(yes/no) Coronary artery disease:(yes/no) Heart failure:(yes/no) Pulmonary disease (presence of COPD or asthma) Malignancy:(yes/no; excluding non-metastatic non-melanoma skin cancer) Diabetes:(yes/no) BMI:(<25/ 25.0-29.9/30.0-39.9/≥40)	
Sourij et al. (2020)	Age:(years) Sex:(male/female) Diabetes:(prediabetes/Type-1diabetes/type-2 diabetes) Hypertension:(yes/no) Coronary heart disease:(yes/no) Myocardial infarction:(yes/no) Heart failure:(yes/no) Arterial occlusive disease:(yes/no) Stroke:(yes/no) CKD:(yes/no) Cancer:(yes/no) Liver disease:(yes/no) Respiratory disease:(yes/no) CRP:(mg/dL; measured as continuous variable) eGFR:(mL/min/1.73m2; measured as continuous variable. BMI (kg/m^2; measured as continuous variable) Smoking:(never/current/former)	Logistic regression
Wang et al. (2020)	Age:(years) Sex:(male/female) Hypertension:(yes/no)	Cox proportional hazard regression

Author (year)	Independent variables measured (description/specification)	Statistical estimators
	Diabetes:(yes/no) Cerebrovascular disease:(yes/no) coronary heart disease:(yes/no), COPD:(yes/no) Dyspnoea;(yes/no) Chronic renal disease:(yes/no), Chronic liver disease:(yes/no) Malignancy (cancer):(yes/no) Complications:(shock/acute cardiac injury/acute kidney injury	
Zhang et al. (2020)	Age:(years) Gender:(male/female) D-dimer levels:(≥2.0 µg/ml, <2.0 µg/ml) Underlying disease: (Diabetes/ hypertension/stroke/cancer/CKD/coronary diseases/COPD) Dyspnoea:(yes/no)	Cox proportional hazard models
Zhou et al. (2020)	Age:(years) Sex:(male/female) Comorbidities present: (COPD/coronary heart disease/lung disease/Diabetes/Hypertension) SOFA score qSOFA score Smoking:(current smoker/non-smoker)	Multivariable regression
Tartof et al. (2020)	Age:(years) Gender:(male/female) Race:(Asian/black/Hispanic/white) BMI:(<18.5kg/m^2 (underweight)/18.5-24 kg/m^2 (normal)/25-29 kg/m^2 (overweight)/30-34 kg/m^2 (obese class I)/ 35-39kg/m^2 (obese class II)/>40kg/m^2 (obese class III or extreme obesity Smoking:(never/current/former	Multivariable Poisson regression
Williamson et al. (2020)	Age:(years) Gender:(male/female)	Cox proportional hazards model

Author (year)	Independent variables measured (description/specification)	Statistical estimators
	Ethnicity:(South Asian/black/mixed/white/other) CHD:(yes/no) Cancer:(non-haematological/no cancer) Haematological malignancy:(yes/no) BMI:(Not obese/obese class I - 30-34.9/obese class II - 35-39.9/obese class III - ≥40) Hypertension:(normal/high) Diabetes(yes/no) Asthma:(yes/no) Respiratory diseases excluding asthma:(yes/no Reduced kidney function:(yes/no)	
Grasselli et al. (2020)	Age:(years) Gender:(male/female) Comorbidities:(none/hypertension/hypercholesterolemia/type 2diabetes/heart disease/malignant neoplasm/COPD/CKD/liver disease/other disease) PaO2, mm Hg:(<76/76-93/94-127/>127) FiO2, %:(<60/60-69/70-85/>85) PaO2:FiO2 ratio:(<103/103-144/145-203/>203)	Multivariable Cox proportional hazards regression
Mikami et al. (2020)	Age:(years) Gender:(male/female) Race:(African American/Asian/black//white/others) Ethnicity:(Non-Hispanic/Hispanic/Unknown) Smoking:(history of cigarette use) Systolic blood pressure <90mmHg Diastolic blood pressure <60mmHg CRP:(>150mg/L) PCT(>0.5ng/mL) eGFR:(>60mL/min/1.73m^2; 30-60 mL/min/1.73m^2; <30 mL/min/1.73m^2) D-dimer>2µL/mL IL-6:(>100pg/mL) Hypertension:(yes/no) Diabetes:(yes/no)	Cox proportional hazard regression

Author (year)	Independent variables measured (description/specification)	Statistical estimators
	Obesity:(yes/no) CKD:(yes/no) HIV:(yes/no) Respiratory rate:(≤24per min/25-30 per min/>30 per min)	
Albitar et al. (2020)	Age:(years) Gender:(male/female) Geographic location:(Asia/Africa/America/Europe/Australia) Hypertension:(yes/no) Diabetes:(yes/no) Chronic lung disease:(yes/no) Cardiovascular diseases:(yes/no)	Multivariable logistic regression
Wu et al. (2020)	Age:(years) Gender:(male/female) Smoking (study did not specify Hypertension:(yes/no) Diabetes:(yes/no) Chronic liver disease:(yes/no) Chest CT scan:(none/unilateral pneumonia/bilateral pneumonia) levels of white blood cell:(did not specify) CRP:(yes/no) Fever:(present or absent on admission)	Multivariate linear regression
Guo et al. (2020)	Age:(years) Gender:(male/female) Smoking:(smoker/non-smoker) Fever:(yes/no) Hypertension:(yes/no) Diabetes:(yes/no) CKD:(yes/no) Liver disease:(yes/no) Elevated CRP mg/L:(assessed as continuous variable.	Multivariable logistic regression model

Author (year)	**Independent variables measured (description/specification)**	**Statistical estimators**
	Creatinine µmol/L:(assessed as continuous variable) PCT ng/ml: (assessed as continuous variable)	
Mendy et al. (2020)	Age:(years) Gender:(male/female) Ethnicity:(non-Hispanic whites/non-Hispanics blacks/Hispanics/other) Obesity:(yes/no) Diabetes:(yes/no) hypercholesterolemia:(yes/no) Asthma: :(yes/no) COPD:(yes/no) CKD:(yes/no) Cardiovascular disease:(yes/no) Neoplasm or history of neoplasm:(yes/no) Osteoarthritis:(yes/no) Vitamin D Deficiency:(yes/no) Anaemia:(yes/no) Coagulation defect:(yes/no) Thrombocytopenia:(yes/no) Smoking:(never/current/past	Generalized linear models. multinomial logistic regressions
Acharya et al. (2020)	Age (years) BMI (kg/m^2) Sex (Male/Female) Smoking (yes/no) Alcohol consumption (yes/no) CVD (yes/no) CVA (yes/no) Dementia (yes/no) Malignancy (yes/no) Dyspnoea (yes/no) Lactates dehydrogenate (yes/no) Creatinine (yes/no)	Multivariate logistic regression

Author (year)	Independent variables measured (description/specification)	Statistical estimators
	CRP (yes/no) Lymphocyte	
Agarwal et al. (2020)	Age (years) Sex (male/female) Place of residence (inside or Patna district) fever (yes/no) DM (yes/no) HTP (yes/no) cancer (yes/no) COPD (yes/no) CKD (yes/no) Chronic liver disease (yes/no)	Multivariable logistic regression
Alamdari et al. (2020)	Age (years) Sex (male/female) BMI ($<35kg/m^2$/$>35kg/m^2$) Smoking (current, former) DM (yes/no) CKD (yes/no) Malignancy (yes/no) Immune suppression (yes/no)	Multivariable logistic regression
Alkhouli et al. (2020)	Age (years) COPD (yes/no) CAD (yes/no) HPT (yes/no) DM (yes/no) Obesity (yes/no) Race/ethnicity (white/black or black American/Asian/native Hawaiian/American Indian or native Alaska) Sex (male/female)	Logistic regression
Asfahan et al. (2020)	Age (years) Sex (male/female)	Multivariate logistic regression

Author (year)	Independent variables measured (description/specification)	Statistical estimators
	Comorbidity	
Atkins et al. (2020)	Age (years) Sex (male/female) Ethnicity (white/black/south Asian/other-including mixed and Chinese) Education (none/school/college/professional qualification) CHD (yes/no) CVA (yes/no) HPT (yes/no) DM (yes/no) CKD (yes/no) Dementia (yes/no) Asthma (yes/no) COPD (yes/no)	Logistic regression
Al-Salameh et al. (2020)	DM (yes/no) Age (years) Sex (male/female) CVD (yes/no) Liver function test (LFT) (No abnormal tests/one abnormal test/two abnormal tests/three abnormal tests)	Multivariable Cox proportional hazards analysis
Bahl et al. (2020)	Age (years) Sex (male/female) Race (white or Caucasian/Black/African American) BMI (<25/25-30/30-35/35-40) kgm^2 Asthma(yes/no) Cancer (yes/no) CAD (yes/no) Chronic heart failure (yes/no) COPD (yes/no) CVA (yes/no) DM (yes/no)	Multivariable logistic regression

Author (year)	Independent variables measured (description/specification)	Statistical estimators
	Renal disease (yes/no) HPT (yes/no) Fever (yes/no) Creatinine (≤1.33/>1.33) mg/dL. Lactates dehydrogenate (≤245/>245) U/L D-dimer (≤500/500-1000/>1000) ng/mL CRP (<50/50-100/>100) mg/L PCT (<0.1/0.1-0.25/0.25-0.5/>0.5) ng/mL Lactic acid (<2/≥2) mmol/L	
Bepouka et al. (2020)	Age (years) HPT (yes/no) DM (yes/no) Fever (yes/no) Dyspnoea (yes/no)	Multivariate Cox regression.
Docherty et al. (2020)	Age (years) Sex (male/female) Chronic cardiac disease (yes/no) Chronic pulmonary diseases (yes/no) CKD (yes/no) Neurological disorder (yes/no) DM (yes/no) Obesity (yes/no) Dementia (yes/no) Malignancies (yes/no) Liver disease (yes/no)	Multivariable Cox proportional hazards model
Bray et al. (2020)	Percentage white Population density Percentage overweight/obese Median IMD	Multivariate linear regression models; ecological analysis.
Cai et al. (2020)	Sex (male/female) HPT (yes/no)	Multivariate Cox regression analysis

Author (year)	Independent variables measured (description/specification)	Statistical estimators
	DM (yes/no) CAD (yes/no) CRP (normal/elevated) mg/L PCT (normal/elevated) ng/mL CVA (yes/no) Chronic renal failure (yes/no) COPD (yes/no) Chronic heart failure (yes/no)	
Caliskan and Saylan (2020)	Age (years) Smoking (current/former/never smoked) COPD (yes/no) DM (yes/no) Dementia (yes/no) CAD (yes/no) HPT (yes/no) Chronic renal failure (yes/no) Congestive heart failure (yes/no)	Logistic regression analysis
Cangiano et al. (2020)	Age (years) Sex (male/female)	Logistic regression model
Carrillo-Vega et al. (2020)	Age (years) CKD (yes/no) HPT (yes/no) COPD (yes/no) Obesity (yes/no) DM (yes/no) Immunosuppression (yes/no) Number of comorbidities	Multiple logistic regression
Chen et al. (2020)	Age (years) Sex (male/female) Smoking (current/former smoker) Creatinine (normal/elevated) U/L	Multivariable cox regression model

Author (year)	Independent variables measured (description/specification)	Statistical estimators
	DM (yes/no) HPT (yes/no) Cancer (yes/no) Dyspnoea (yes/no) ARDS (yes/no) Tropnin (normal/elevated) ng/L PCT (normal/elevated) ng/ml	
Gonca et al. (2020)	Sex (male/female) Age (years) Smoking (active smoker/ex-smoker/non-smoker) Pulmonary comorbidities (yes/no)	-
Cummings et al. (2020)	Age (years) Sex (male/female) Pulmonary diseases (yes/no) CKD (yes/no) DM (yes/no) BMI (yes/no) D-dimer (normal/elevated) µg/mL HPT (yes/no) Chronic cardiac diseases (yes/no)	Cox proportional hazards regression
Dai et al. (2020)	Age (years) Sex (male/female) BMI (yes/no) Chronic lung diseases (yes/no) CVA (yes/no) CVD (yes/no) Smoking (smoker/non-smoker) DM (yes/no) HPT (yes/no) Alcohol consumption Cancer (yes/no)	Multivariable Cox regression analysis

Author (year)	Independent variables measured (description/specification)	Statistical estimators
	Lymphocyte CRP (elevated/normal) mg/L D-dimer (elevated/normal) mg/L	
de Souza et al. (2020)	Sex (male/female) Age (years) DM (yes/no) CVD (yes/no) Obesity (normal weight/overweight/obese) Chronic lung disease (yes/no) Fever (yes/no) Dyspnoea (yes/no) HPT (yes/no) CKD (yes/no)	Logistic regression
Deng et al. (2020)	Age (years) Sex (male/female) HPT (yes/no) DM (yes/no) CVD (yes/no) Respiratory diseases (yes/no) Cancer (yes/no)	-
Yu et al. (2020)	Age (years) D-dimer (did not specify) HPT (yes/no) Lactate dehydrogenase (did not specify)	Parsimonious logistic regression
Yehia et al. (2020)	Race (white/black/other) Age (years) Sex (male/female)	Cox proportional hazards regression
Xu et al. (2020)	Age (years) ≥2 comorbidities (CVD/HPT/DM/COPD/CKD/malignancy/Chronic liver disease) Leucocytosis (did not specify)	Multivariable cox regression

Author (year)	Independent variables measured (description/specification)	Statistical estimators
Larrauri (2020)	Sex (male/female) Age (years) Pneumonia (yes/no) ARDS (yes/no) CVD (yes/no) DM (yes/no) HPT (yes/no) CKD (yes/no)	Multivariable logistic regression
Farrell et al. (2020)	Age (years) Socioeconomic deprivation (measured using Pobal HP Deprivation Index) Sex (male/female) Ethnicity (white-Irish/white-other/BAME) Obesity (overweight/obese) Smoking (yes/no) Comorbidities (based on Charlson comorbidity index)	Multivariable Cox proportional hazards regression
Fox et al. (2020)	Age (years) BMI (normal/overweight) Sex (male/female) Race (African American/Caucasian/Hispanic/other) COPD (yes/no) Asthma (yes/no) CAD (yes/no) HPT (yes/no) CKD (yes/no)	Multivariate logistic regression
Gayam et al. (2020)	Age (years) BMI (normal/overweight) kg/m^2 D-dimer (elevated/normal) ng/L CRP (elevated/normal) mg/L Creatinine (elevated/normal) mg/dL Lactate dehydrogenase	Multivariable logistic regression

Author (year)	Independent variables measured (description/specification)	Statistical estimators
Goodall et al. (2020)	Age (years) Sex (male/female) Ethnicity (white/Black/Asian/other) DM (yes/no) HPT (yes/no) Respiratory diseases (yes/no) Malignancies/cancer (yes/no) Creatinine (elevated/normal) CRP (elevated/normal)	Cox proportional hazards model
Gutiérrez-Abejón et al. (2020)	Sex (male/female) Age (years) Steroids (yes/no)	Multivariate logistic regression model
Harrison et al. (2020)	Age (years) Sex (male/female) Ethnicity (white/black or African American) Myocardial infarction (yes/no) Congestive heart failure (yes/no) CVD (yes/no) Dementia (yes/no) Pulmonary diseases Liver diseases (yes/no) Malignancies (yes/no) DM (yes/no) Renal diseases (yes/no)	Multivariate logistic regression
Ho et al. (2020)	Age (years) Smoking (previous/never/current) BMI (underweight/normal/overweight)	Poisson regression
Ibrahim et al. (2020)	Age (years) Fever (yes/no) Hypoxemia (yes/no) DM (yes/no)	Multivariate logistic regression

Author (year)	Independent variables measured (description/specification)	Statistical estimators
Imam et al. (2020)	Age (years) Race (Caucasian/ African American/other) Comorbidities (based on Charlson comorbidity index) Sex (male/female) BMI (overweight/normal weight) Smoking (former/current/never) HPT (yes/no) DM (yes/no)	Logistic regression
Ioannou et al. (2020)	Sex (male/female) Age (years) Race (white/black/Asian/American Indian) Ethnicity (non-Hispanic/Hispanic) Obesity (underweight/normal/overweight/obese) DM (yes/no) Cancer (yes/no) HPT (yes/no) CAD (yes/no) Congestive heart diseases (yes/no) CVA (yes/no) CKD (yes/no) Liver cirrhosis (yes/no) Asthma (yes/no) Comorbidities (based on Charlson comorbidity index) Smoking (normal/former/current/unknowm) Creatinine (elevated/normal) mg/dL Fever (yes/no) Dyspnoea (yes/no)	Cox proportional hazards model
Kammar-García et al. (2020)	DM (yes/no) COPD (yes/no) Asthma (yes/no) Immunosuppression (yes/no)	Multivariate Cox proportional hazards regression

Author (year)	Independent variables measured (description/specification)	Statistical estimators
	HPT (yes/no) CVD (yes/no) Obesity (yes/no) CKD (yes/no)	
Kim et al. (2020)	Heart failure (yes/no) Renal failure (yes/no) Prostate malignant neoplasm (yes/no) Myocardial infarction (yes/no) DM (yes/no) Other Ischemic heart diseases (yes/no)	Multivariate logistic regression
Kim et al. (2020)	Age (years) Sex (male/female) BMI (underweight/overweight/obesity; class I-III) Race (Hispanic/non-Hispanic white/black/Asian/other)	Cox proportional hazards model
Lee et al. (2020)	Pneumonia (yes/no) Asthma (yes/no) DM (yes/no) HPT (yes/no) CVD (yes/no) CKD (yes/no) Chronic liver diseases (yes/no) Malignancies (yes/no) Age (years) Sex (male/female)	Cox proportional hazards model
Javanian et al. (2020)	Age (yes/no) Sex (yes/no) HPT (yes/no) CVD (yes/no) Pneumonia (yes/no)	Poisson regression analysis

Notes: DM- diabetes, HPT – hypertension, PCT- Procalcitonin, CRP - C-Reactive Protein, CoHD – coronary heart disease, eGFR - estimated glomerular filtration rate, SOFA - quick sequential organ failure assessment, RR-Risk Ratio, ARR- Adjusted risk ratios, FiO2 – Fraction of inspired oxygen, PaO2 - arterial partial pressure of oxygen, IL-6 - interleukin-6, IQR – Interquartile Range, CKD – Chronic kidney disease, IMD- Index of Multiple Deprivation (IMDBMI- Body Mass Index, ARDS - Acute respiratory distress syndrome, AKF - Acute kidney failure, CAD – Coronary artery disease.

Appendix 6: Quality Appraisal Results

Table 1: Quality Appraisal Scores of the Cohort Studies - Based on the Newcastle-Ottawa Quality Assessment Scale (NOS) (N = 32)

Studies	**Selection Domain**				**Comparability Domain**	**Outcome Domain**			**Total Score**
	1	2	3	4	1	1	2	3	
Alaa et al. (2020)	*	*	*	*	**	*	*	*	9
Almazeedi et al. (2020)	*	*	*	*	**	*	*	*	9
Berenguer et al. (2020)	*	*	*	*	*	*	*	*	8
Carrasco-Sánchez et al. (2020)	*	*	*	*	**	*	*	*	9
Halalau et al. (2020)	*	*	*	*	*	*	*	*	8
Kaeuffer et al. (2020)	*	*	*	*	*	*	*	*	8
Li et al. (2020)	*	*	*	*	*	*	*	*	8
Okoh et al. (2020)	*	*	*	*	*	*	*	*	8
Petrilli et al. (2020)	*	*	*	*	**	*	*	*	9
Sourij et al. (2020)	*	*	*	*	*	*	*	*	8
Wang et al. (2020)	*	*	*	*	*	*	*	*	8
Wu et al. (2020)	*	*	*	*	*	*		*	7
Zhou et al. (2020)	*	*	*	*	*	*		*	7
Tartof et al. (2020)	*	*	*	*	**	*	*	*	9
Williamson et al. (2020)	*	*	*	*	**	*	*	*	9
Grasselli et al. (2020)	*	*	*	*	*	*	*	*	8
Mikami et al. (2020)	*	*	*	*	**	*	*	*	9
Alkhouli et al. (2020)	*	*	*	*	**	*	*	*	9
Atkins et al. (2020)	*	*	*	*	**	*	*	*	9
Bahl et al. (2020)	*	*	*	*		*	*	*	7
Bepouka et al. (2020)	*	*	*	*	**	*	*	*	9
Docherty et al. (2020)	*	*	*	*	**	*	*	*	9
Caliskan and Saylan (2020)	*	*	*			*	*	*	6
Cummings et al. (2020)	*	*	*	*	**	*	*	*	9

Studies	Selection Domain				Comparability Domain	Outcome Domain			Total Score
	1	2	3	4	1	1	2	3	
Yehia et al. (2020)	*	*	*	*	*	*	*	*	8
Gayam et al. (2020)	*	*	*	*	*	*	*	*	8
Goodall et al. (2020)	*		*	*	*	*	*	*	7
Ho et al. (2020)	*	*	*	*	**	*	*	*	9
Imam et al. (2020)	*	*	*	*		*	*	*	7
Ioannou et al. (2020)	*	*	*	*		*	*	*	7
Kammar-García et al. (2020)	*	*	*	*	**	*	*	*	9
Javanian et al. (2020)	*	*	*	*	*	*	*	*	8

* Indicates study met the item for the domain. See the numbered domain items in appendix 2.

Table 2: Quality Appraisal Scores of the Cross-sectional Studies – Based on the Agency for Healthcare Research and Quality (ARHQ) Checklist (N = 31)

Studies/items	Items											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Total**
Bello-Chavolla et al. (2020)	Y	Y	Y	Y	N	N	NA	N	NA	Y	Y	6
Mendy et al. (2020)	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	8
Guo et al. (2020)	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	8
Albitar et al. (2020)	Y	Y	Y	Y	N	Y	NA	N	Y	N	Y	7
Zhang et al. (2020)	Y	Y	Y	Y	N	Y	NA	N	NA	Y	Y	7
Acharya et al. (2020)	Y	Y	Y	Y	Y	N	Y	Y	NA	Y	Y	9
Agarwal et al. (2020)	Y	Y	Y	Y	NA	N	Y	Y	NA	Y	Y	8
Alamdari et al. (2020)	Y	Y	Y	Y	N	Y	Y	Y	NA	Y	Y	9
Asfahan et al. (2020)	Y	Y	Y	Y	N	N	Y	Y	NA	NA	Y	7
Al-Salameh et al. (2020)	Y	Y	Y	Y	Y	Y	Y	Y	NA	NA	Y	9
Alkundi et al. (2020)	Y	Y	Y	Y	N	Y	Y	N	NA	Y	Y	8

Studies/items	Items											
	1	2	3	4	5	6	7	8	9	10	11	Total
Bray et al. (2020)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	11
Cai et al. (2020)	Y	Y	Y	Y	N	Y	Y	N	Y	Y	NA	8
Cangiano et al. (2020)	Y	Y	Y	Y	N	Y	Y	N	N	Y	N	7
Carrillo-Vega et al. (2020)	Y	Y	Y	Y	Y	Y	Y	NA	N	Y	NA	8
Chen et al. (2020)	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	NA	9
Gonca et al. (2020)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	11
Dai et al. (2020)	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	9
de Souza et al. (2020)	Y	Y	Y	Y	N	Y	Y	N	Y	Y	NA	8
Deng et al. (2020)	Y	Y	Y	Y	Y	Y	Y	N	NA	Y	N	8
Yu et al. (2020)	Y	Y	Y	Y	Y	Y	Y	Y	NA	Y	NA	9
Xu et al. (2020)	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	10
Larrauri (2020)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	11
Farrell et al. (2020)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	11
Fox et al. (2020)	Y	Y	Y	Y	NA	Y	Y	Y	Y	Y	Y	10
Gutiérrez-Abejón et al. (2020)	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	10
Harrison et al. (2020)	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	10
Ibrahim et al. (2020)	Y	Y	Y	Y	NA	Y	Y	Y	Y	Y	N	9
Kim et al. (2020)	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	10
Kim et al. (2020)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	11
Lee et al. (2020)	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	9

Y- yes, N- No, NA -not applicable. See the numbered items in appendix 2

Table 3: Risk of Bias Assessment – Based on the Risk of Bias Assessment Tool for Non-randomised Studies (RoBANS)

Studies	**Domains**					
	Participant Selection	Confounding Measurement	Exposure Measurement	Outcome Assessment	Study Attrition	Study Outcome Reporting
Alaa et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Almazeedi et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Bello-Chavolla et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk
Berenguer et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk
Carrasco-Sánchez et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Halalau et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk
Kaeuffer et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk
Li et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk
Okoh et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk
Petrilli et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Sourij et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk
Wang et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk
Zhang et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk
Zhou et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk
Tartof et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Williamson et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Grasselli et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk
Mikami et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Albitar et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Moderate risk	Low risk
Wu et al. (2020)	Low risk	Moderate risk	Low risk	Moderate risk	Low risk	Low risk
Guo et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk
Mendy et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk
Acharya et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Agarwal et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk

Studies	Domains					
	Participant Selection	Confounding Measurement	Exposure Measurement	Outcome Assessment	Study Attrition	Study Outcome Reporting
Alamdari et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Alkhouli et al. (2020)	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Asfahan et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Atkins et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Al-Salameh et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Alkundi et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk
Bahl et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk
Bepouka et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Docherty et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Bray et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Cai et al. (2020)	Low risk	Moderate	Low risk	Low risk	Low risk	Low risk
Caliskan and Saylan (2020)	Low risk	Moderate	Low risk	Low risk	Low risk	Low risk
Cangiano et al. (2020)	Low risk	Moderate	Low risk	Low risk	Low risk	Low risk
Carrillo-Vega et al. (2020)	Low risk	Moderate	Low risk	Low risk	Low risk	Low risk
Chen et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Gonca et al. (2020)	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk	Low Risk
Cummings et al. (2020)	Low risk	Moderate	Low risk	Low risk	Low Risk	Low Risk
Dai et al. (2020)	Low risk	Moderate	Low risk	Low risk	Low risk	Low risk
de Souza et al. (2020)	Low risk	Moderate	Low risk	Low risk	Low risk	Low risk
Deng et al. (2020)	Low risk	Moderate	Low risk	Low risk	Low risk	Low risk
Yu et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Yehia et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Xu et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk
Larrauri (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Farrell et al. (2020)	Low risk	Low risk	Low risk	Low risk	Moderate risk	Low risk
Fox et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Gayam et al. (2020)	Low risk	Moderate	Low risk	Low risk	Low risk	Low risk

Studies	**Domains**					
	Participant Selection	Confounding Measurement	Exposure Measurement	Outcome Assessment	Study Attrition	Study Outcome Reporting
Goodall et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Gutiérrez-Abejón et al. (2020)	Low risk	Moderate risk	Low risk	Low risk	Low risk	Low risk
Harrison et al. (2020)	Low risk	Moderate	Low risk	Low risk	Low risk	Low risk
Ho et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Ibrahim et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Imam et al. (2020)	Low risk	Moderate	Low risk	Low risk	Low risk	Low risk
Ioannou et al. (2020)	Low risk	Moderate	Low risk	Low risk	Low risk	Low risk
Kammar-García et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Kim et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Kim et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Lee et al. (2020)	Low risk	Moderate	Low risk	Low risk	Low risk	Low risk
Javanian et al. (2020)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk

Table 4: Assessing Level of Concordance in the Different Rating Tools

Studies	Rating on RoBANS	Rating on NOS Scale	Rating on AHRQ
Alaa et al. (2020)	Low risk	9	
Almazeedi et al. (2020)	Low risk	9	
Bello-Chavolla et al. (2020)	Low – Moderate risk		6
Berenguer et al. (2020)	Low – Moderate risk	8	
Carrasco-Sánchez et al. (2020)	Low risk	9	
Halalau et al. (2020)	Low – Moderate risk	8	
Kaeuffer et al. (2020)	Low – Moderate risk	8	

Studies	Rating on RoBANS	Rating on NOS Scale	Rating on AHRQ
Li et al. (2020)	Low – Moderate risk	8	
Okoh et al. (2020)	Low – Moderate risk	8	
Petrilli et al. (2020)	Low risk	9	
Sourij et al. (2020)	Low – Moderate risk	8	
Wang et al. (2020)	Low – Moderate risk	8	
Zhang et al. (2020)	Low – Moderate risk		7
Zhou et al. (2020)	Low – Moderate risk	7	
Tartof et al. (2020)	Low risk	9	
Williamson et al. (2020)	Low risk	9	
Grasselli et al. (2020)	Low – Moderate risk	8	
Mikami et al. (2020)	Low risk	9	
Albitar et al. (2020)	Moderate risk		7
Wu et al. (2020)	Moderate risk	7	
Guo et al. (2020)	Moderate risk		8
Mendy et al. (2020)	Low – Moderate risk		8
Acharya et al. (2020)	Low risk		9
Agarwal et al. (2020)	Low risk		8
Alamdari et al. (2020)	Low risk		9
Alkhouli et al. (2020)	Low Risk	9	
Asfahan et al. (2020)	Low risk		7
Atkins et al. (2020)	Low risk	9	
Al-Salameh et al. (2020)	Low risk		9
Alkundi et al. (2020)	Low – Moderate risk		8
Bahl et al. (2020)	Low – Moderate risk	7	
Bepouka et al. (2020)	Low risk	9	
Docherty et al. (2020)	Low risk	9	
Bray et al. (2020)	Low risk		11
Cai et al. (2020)	Low – Moderate risk		8
Caliskan and Saylan (2020)	Low – Moderate risk	6	

Studies	Rating on RoBANS	Rating on NOS Scale	Rating on AHRQ
Cangiano et al. (2020)	Low – Moderate risk		7
Carrillo-Vega et al. (2020)	Low – Moderate risk		8
Chen et al. (2020)	Low – Moderate risk		9
Gonca et al. (2020)	Low risk		11
Cummings et al. (2020)	Low – Moderate risk	9	
Dai et al. (2020)	Low – Moderate risk		9
de Souza et al. (2020)	Low – Moderate risk		8
Deng et al. (2020)	Low – Moderate risk		8
Yu et al. (2020)	Low risk		9
Yehia et al. (2020)	Low risk	8	
Xu et al. (2020)	Low – Moderate risk		10
Larrauri (2020)	Low risk		11
Farrell et al. (2020)	Low – Moderate risk		11
Fox et al. (2020)	Low risk		10
Gayam et al. (2020)	Low – Moderate risk	8	
Goodall et al. (2020)	Low risk	7	
Gutiérrez-Abejón et al. (2020)	Low – Moderate risk		10
Harrison et al. (2020)	Low – Moderate risk		10
Ho et al. (2020)	Low risk	9	
Ibrahim et al. (2020)	Low risk	7	
Imam et al. (2020)	Low – Moderate risk	7	
Ioannou et al. (2020)	Low – Moderate risk	7	
Kammar-García et al. (2020)	Low risk	9	
Kim et al. (2020)	Low risk		10
Kim et al. (2020)	Low risk		11
Lee et al. (2020)	Low – Moderate risk		9
Javanian et al. (2020)	Low risk	8	

Appendix 7: Results of the Narrative Reviews' Quality Appraisal

SANRA checklist/Studies	Khoo (2020)	Smith & Quartey (2020)	Quakyi et al. (2021)	Antwi-Boasiako et al. (2021)	Awekeya et al. (2021)
Justification of importance for readership	2	2	1	2	2
Statement of aims/research questions	1	2	1	2	2
Description of literature search	0	2	0	2	2
Referencing	2	2	2	2	2
Scientific reasoning	2	2	2	1	1
Appropriate presentation of data	2	2	1	2	1
Total	9	12	7	11	10

Appendix 8: Results of the Risk of Bias Assessment of the Studies on the Long-term Consequences of COVID-19

Studies	PROBAST's Domains				
	Participants	**Predictors**	**Outcome**	**Analysis**	**Overall Risk of Bias**
Frempong et al. (2021)	Low risk	Low risk	Low risk	Low risk	Low risk of bias
Dwomoh et al. (2021)	Low risk	Low risk	Low risk	Low risk	Low risk of bias
Tawiah et al. (2021)	Low risk	Low risk	Low risk	Unclear	Unclear risk of bias
Frost et al. (2021)	Low risk	Low risk	Low risk	Low risk	Low risk of bias

Appendix 9: Data Collection Instrument for the Expert Analysis in Chapter 6

Study Title: Exploring Experts' Perspectives on the Effectiveness of Ghana's 2020/21 COVID-19 Policies

This survey aims to explore your opinions on the effectiveness of key COVID-19 policy responses implemented during the first year (2020/21) of the pandemic in Ghana. The policies are ***Partial Lockdown of Greater Accra and Kumasi****,* ***Public Awareness Campaigns****,* ***Ban on Public Gatherings, Travel Restrictions and Border Closures****,* ***Compulsory COVID-19 Border Screening****,* **Ghana COVID-19 Alleviation and Revitalisation of Enterprises Support (GCARES), *G*overnment** ***Incentives for Healthcare Workers (HCW)*** *and* ***COVID-19 Vaccination.***

Collectively, these policies were aimed to reduce the spread of the COVID-19 virus, its associated deaths and hospitalisation, motivate health workers and stabilise the economy amidst the COVID-19 outbreak.

Your opinion on the effectiveness of these policies will contribute to this study's understanding of the COVID-19 policy architecture in Ghana. It could also help the research develop policy recommendations for potential future outbreaks in Ghana.

The survey instrument contains two sections. The first section focuses on sociodemographic characteristics. The second section, section B, will require you to rate the effectiveness of the above-mentioned policies on a scale of 1 to 5 (based on your expert opinion), where 1 is ineffective and 5 is very effective.

Section A: Sociodemographic characteristics

1. Please tick your sex/gender as applicable

   [ ] Male
   [ ] Female
   [ ] Other

2. Please tick your age category as appropriate

   [ ] 18 – 34 years
   [ ] 35 – 50 years
   [ ] > 50 years old

3. Please indicate your academic (teaching or research) discipline

   …………………………

Section B: Effectiveness analysis of COVID-19 policies in Ghana (Kindly tick your applicable responses)

1. In your opinion, how effective was the partial lockdown of Greater Accra and Kumasi in reducing the spread of the virus during its implementation period?
   [ ] 1= not effective
   [ ] 2= not very effective
   [ ] 3= don't know
   [ ] 4= effective
   [ ] 5= very effective

2. In your opinion, how effective was the partial lockdown of Greater Accra and Kumasi in enhancing COVID-19 disease surveillance through contact tracing?
   [ ] 1= not effective
   [ ] 2= not very effective
   [ ] 3= don't know
   [ ] 4= effective
   [ ] 5= very effective

3. In your opinion, how effective was the partial lockdown of Greater Accra and Kumasi in scaling-up COVID-19 testing and treatment capacities?
   [ ] 1= not effective
   [ ] 2= not very effective
   [ ] 3= don't know
   [ ] 4= effective
   [ ] 5= very effective

4. In your opinion, how effective were the COVID-19 public awareness campaigns in informing the public about COVID-19 prevention protocols?
   [ ] 1= not effective
   [ ] 2= not very effective
   [ ] 3= don't know
   [ ] 4= effective
   [ ] 5= very effective

5. In your opinion, how effective was the ban on public gatherings in reducing the spread of the COVID-19 virus?
   [ ] 1= not effective
   [ ] 2= not very effective
   [ ] 3= don't know
   [ ] 4= effective
   [ ] 5= very effective

6. In your opinion, how effective were the border closures in preventing COVID-19 case importation?
   [ ] 1= not effective
   [ ] 2= not very effective
   [ ] 3= don't know
   [ ] 4= effective
   [ ] 5= very effective

7. In your opinion, how effective was the compulsory COVID-19 border screening in detecting imported COVID-19 cases?
   [ ] 1= not effective
   [ ] 2= not very effective
   [ ] 3= don't know
   [ ] 4= effective
   [ ] 5= very effective

8. In your opinion, can the COVID-19 vaccination reduce the COVID-19 disease burden through vaccine-induced herd immunity?
   [ ] no
   [ ] maybe
   [ ] yes

9. In your opinion, how effective were the government's incentives for healthcare workers in widening the human resource capital against COVID-19?
   [ ] 1= not effective
   [ ] 2= not very effective

[ ] 3= don’t know

[ ] 4= effective

[ ] 5= very effective

10. Please do you know the Ghana COVID-19 Alleviation and Revitalisation of Enterprises Support (GCARES) Program

    [ ] no

    [ ] faintly

    [ ] yes

11. If yes to question 10, was the program effective in stimulating recovery of the economy from the COVID-19 impact during the first year of its implementation?

    [ ] 1= not effective

    [ ] 2= not very effective

    [ ] 3= don’t know

    [ ] 4= effective

    [ ] 5= very effective

12. Please indicate what, in your opinion, contributed to the policies’ influence on the COVID-19 burden.

Thank you.

Appendix 10: Participant Information Sheet (PIS)

College of Health, Medicine and Life Sciences

Department of Health Sciences

PARTICIPANT INFORMATION SHEET (PIS)

Study title

Exploring experts' perspectives on the effectiveness of Ghana's 2020/21 COVID-19 policies.

Invitation Paragraph

You are being invited to take part in the above study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

What is the purpose of the study?

The study aims to examine the effectiveness of Ghana's COVID-19 policy responses on the COVID-19 outbreak.

Why have I been invited to participate?

You have been invited to participate in this research because of your invaluable insight into Ghana's policy landscape as an academic from health or economics discipline. We are confident that your expert knowledge will contribute to this researcher's understanding of Ghana's policy responses to the COVID-19 outbreak. This understanding may inform forethought strategies to mitigate the long-term burden of COVID-19 and any similar outbreak in the future.

Do I have to take part?

As participation is entirely voluntary, it is up to you to decide whether or not to take part. You will be given this information sheet to help you decide on participation. If you decide to participate, you will be requested to access the survey link to the online data collection platform (Qualtrics) and respond yes to the consent form to submit your responses. If you decide not to participate, you are free to do so and will not be required to respond to the survey. You will, however, not be able to withdraw your participation once you submit your data on Qualtrics This is because the researcher will not be able to remove your data entry as no identifiable data will be collected. Therefore, withdrawing decisions must be made before submitting your data because the researcher will not be able to identify your responses for onward removal if you decide to withdraw after data collection. Withdrawing from this study will not affect the relationship you have with the researcher, if any.

What will happen to me if I take part?

If you agree to participate in this research, you will be directed to an online data collection platform – Qualtrics. The survey will ask you to rate the effectiveness of eight COVID-19 policies on a scale of 1 to 5, where '1' is not effective and '5' is very effective. The survey would also ask you what contributed to the policies influence and request your sociodemographic information, such as age, sex/gender and education level. This information will help provide insight into your responses. You will only be able to respond to the survey only after you have responded yes to the consent statement for participation. Since participation in this study is online, your physical presence will not be required. The online survey will take about ten (10) minutes to complete, and your data will be collected once on Qualtrics.

Are there any lifestyle restrictions?

There are no lifestyle restrictions associated with participating in this research.

What are the possible disadvantages and risks of taking part?

There will be no risk associated with participating in this research as the study is non-invasive and will not impose any physical discomfort on participants.

What are the possible benefits of taking part?

There will be no monetary benefits in this research. However, your responses will help the researcher understand Ghana's policy responses to infectious diseases and contribute to developing mitigating policy menus for any potential outbreaks.

What if something goes wrong?

If something goes wrong with this research, you may complain to the Chair of Brunel University's College of Health, Medicine and Life Sciences (CHMLS) Research Ethics Committee (Contact below).

Will my taking part in this study be kept confidential?

All information which is collected about you during the course of the research will be kept strictly confidential. Any information about you that leaves the university will have your name and address removed so that you cannot be identified.

Will I be recorded, and how will the recording be used?

You will not be recorded in this study. As indicated earlier, your participation in this study will be online. No voice or video recording will be taken in this research.

What will happen to the results of the research study?

The results may be published in an open-access journal after the study's completion. If published, you can access a copy of the publication at Brunel University's Library. You will not be identified in any such publications.

Who is organising and funding the research?

The researcher is organising this research as part of the requirements for the Doctor of Philosophy (PhD) in Public Health award. The Ghana Scholarships Secretariate (GSS) is sponsoring this PhD and, by extension, is sponsoring this research.

What are the indemnity arrangements?

Brunel University London provides appropriate insurance cover for research which has received ethical approval.

Who has reviewed the study?

This study has been reviewed by the College of Health, Medicine and Life Sciences Research Ethics Committee.

Research Integrity

Brunel University London is committed to compliance with the Universities UK Research Integrity Concordat. You are entitled to expect the highest level of integrity from the researchers during the course of this research.

Contact for further information and complaints:

For queries, in the first instance, please contact the supervisor or researcher:

Supervisor name: Professor Nana Anokye
Department of Health Sciences
Brunel University London
Nana.Anokye@brunel.ac.uk

Researcher name: Shirley Crankson
Brunel University London
bsrc001@brunel.ac.uk

For complaints and questions about the conduct of the research

Professor Louise Mansfield, Chair College of Health, Medicine and Life Sciences Research Ethics Committee Louise.Mansfield@brunel.ac.uk

Appendix 11: Ethics Approval Letter

College of Health, Medicine and Life Sciences Research Ethics Committee (DHS)
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

5 December 2022

LETTER OF APPROVAL

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 05/12/2022 AND 03/04/2023

Applicant (s): Ms Shirley Crankson

Project Title: Expert's perspectives on Ghana's COVID-19 policies

Reference: 39763-LR-Nov/2022- 42491-4

Dear Ms Shirley Crankson

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- **Please note your new start date is today's date 5/12/22. Please ensure you amend on all relevant documents before sending to participants.**
- **The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.**
- **Please ensure that you monitor and adhere to all up-to-date local and national Government health advice for the duration of your project.**

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- If your project has been approved to run for a duration longer than 12 months, you will be required to submit an annual progress report to the Research Ethics Committee. You will be contacted about submission of this report before it becomes due.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

LA—d

Professor Louise Mansfield

Chair of the College of Health, Medicine and Life Sciences Research Ethics Committee (DHS)

Brunel University London

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