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ANALYSIS OF EARLY-PHASE CONTACT TRACING DURING THE CORONAVIRUS DISEASE 2019 OUTBREAK IN MANGAUNG METRO, FREE STATE

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BY

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A thesis submitted in fulfilment of the requirements for the degree of

MASTER OF PUBLIC HEALTH

DEPARTMENT OF PUBLIC HEALTH

FACULTY OF HEALTH SCIENCES

UNIVERSITY OF FORT HARE

Supervisor: Prof. DT Goon

September 2022

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I, Priscilla K Monyobo, student number: 201928128, hereby declare that I am fully aware of the University of Fort Hare's policy on plagiarism, and I have taken every precaution to comply with the regulations.

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I, the undersigned, declare that this thesis entitled **"ANALYSIS OF EARLY-PHASE CONTACT TRACING DURING THE CORONAVIRUS DISEASE 2019 OUTBREAK IN MANGAUNG METRO, FREE STATE"** is my own work, and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete reference. I further declare that this work has not been submitted before for any other degree at any other institution.

Name: Priscilla Kesaletseng Monyobo

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CERTIFICATION

This mini-dissertation entitled **"ANALYSIS OF EARLY-PHASE CONTACT TRACING DURING THE CORONAVIRUS DISEASE 2019 OUTBREAK IN MANGAUNG METRO, FREE STATE"** meets the regulations governing the award of the degree of Master's in Public Health of the University of Fort Hare and is approved for its contribution to scientific knowledge and literary presentation.

……………………………….

Prof. DT Goon

Supervisor

Date: 13 September 2022

ACKNOWLEDGEMENTS

I would like to extend my appreciation to the Free State Department of Health for providing me with the opportunity to study for the Albertina Sisulu Executive Leadership Programme in Health (ASELPH). To Professor Goon, my supervisor, thank you for your academic and professional support, and for pushing me to complete this study project. Mr HM Combrink, a professional and academic friend whom I met during the Free State Department of Health COVID-19 response, for his encouragement and support throughout the course of this project.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

ABSTRACT

Background and Aim

Contact tracing is a critical public health measure for controlling and preventing the spread of infectious diseases. Although the principles underlying this strategy are not novel, understanding the changes in infectiousness of COVID-19 is indeed novel. As are the capacity and operating procedures required to support disease investigation in Mangang Metro during the SARS-CoV-2 (COVID-19) pandemic.

On 16 March 2020, the first coronavirus disease case in the area, which led to a larger outbreak, occurred in Mangaung Metro, Free State province, South Africa. To date, Mangaung Metro remains the epicentre of the COVID-19 pandemic and the primary driver of the caseload in the Free State province.

The aim of this study was to analyse contact tracing data in Mangaung Metro during the early phase of the COVID-19 outbreak (16 March 2020 – 30 June 2020) in order to measure the viral transmissibility of COVID-19 in the early stages of the outbreak, specifically in the context of Mangaung Metro.

Methods

A descriptive systematic analysis of index COVID-19 cases and their contacts in Mangaung Metro was conducted. The review period ran from 16 March to 30 June 2020, during which there was a total of 1 001 cases in Mangaung Metro. Data was captured on an Excel spreadsheet using the contact line list variables from the established National Institute of Communicable Disease contact line list framework. The inferential statistics were based on a time series analysis to compare the impact of contact tracing stratified by symptomatology and the root cause of the cases to the overall cases in Mangaung Metro. The study determined whether isolation, quarantine, and contact tracing were able to control outbreaks in the early phase using characteristics of disease transmission and parameters particularised to the COVID-19 pathogen.

Results

As of 30 June 2020, the Free State province had a total of 2 072 COVID-19 cases. Mangaung Metro contributed 1 001 cases (48%) of the total number of cases in the study period. Between March and June 2020, 3 553 contacts were traced in Mangaung Metro. This number translates to at least three investigated and traced contacts per index or laboratory confirmed positive case. From the traced contacts, 1 080 samples were collected and sent for laboratory testing. In April 2020, the greatest number of samples were collected. This high rate in sample collection is posited to be the result of the high rate of contacts traced, as well as the initial clinical guidelines followed for contact tracing. Most positive contacts were discovered in March 2020. One of the possible reasons for the high detection of COVID-19 confirmed positive contacts during the early stages of the outbreak was the focus and importance of contact tracing while the caseload remained relatively low. However, as the outbreak progressed in the Mangaung Metro context, the number and relative percentage of positive cases detected through contact tracing decreased. In total, the positive contacts recorded in March 2020 amounted to 92 (51.3%), 18 in April (10.5%), 41 in May (22.9%), and 28 in June (15.6%).

The March 2020 tracking rate was the highest at 73.2%, with an average contact tracing rate of 15.5% by the end of June 2020. Of all the contacts traced, 7.9% involved healthcare workers in the Free State.

Conclusion

The study's findings show that contact tracing was an effective control measure during the early stages of the COVID-19 outbreak in Mangung Metro district. Furthermore, the impact was greatest when the caseload was low and the burden on the healthcare system less severe. Mangaung Metro demonstrated the capability of tracing more contacts in the early-early phase of the outbreak; however, as the outbreak progressed to the latent early phase, the caseload increased and fewer contacts were traced. The consequence of contact tracing not being as effective during the latent early phase relates to the increase in both exposed and untraceable contacts, which in turn fueled the increase of new cases. This further impacted the at-risk and vulnerable population, especially the elderly, who were at an increased risk if not traced in a timely manner, possibly resulting in mortality.

Keywords

Contact Tracing, COVID-19, reproductive number, index case, early-early phase, latent phase, variants, outbreak

CHAPTER ONE: BACKGROUND

1.1. BACKGROUND

The outbreak of coronavirus disease 2019 (COVID-19), an infectious disease caused by the SARS-CoV-2 virus, started in Wuhan, China, in December 2019 (Bi, Wu, Mei et al., 2020; Burke, 2020; Whitworth, 2020; Lipsitch, Swerdlow & Finelli, 2020; Zhu, Wei & Niu, 2020). At the time, the epidemiological characteristics of SARS-CoV-2 disease multiplied at a startling rate (Kretzschmar, Rozhnova & Van Boven, 2020). Within a couple of weeks, COVID-19 had expanded across China and neighbouring continents and countries, the United States, as well as Europe, Asia, and Africa by March 2020 (Whitworth, 2020). The coronavirus disease has now become a global pandemic (Mustafa, 2021), and is still causing substantial morbidity and mortality around the world (Yousaf, Zahir, Riaz et al., 2020). This is likely since the COVID-19 SARS-CoV-2 virus is spreading faster than its two different lineages, the Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV) and the Middle East Respiratory Syndrome Coronavirus (Gebru, Birhanu, Wendimu et al., 2020). The World Health Organization (WHO) classified COVID-19 as a global health epidemic of global significance with the highest level of severity on 20 January 2020, due to its rapid continental outbreak and spread (Whitworth, 2020). At the time of the declaration, there were approximately 10 000 reported cases across twenty countries, with more than 200 mortalities, surpassing the 2003 Severe Acute Respiratory Syndrome (SARS) outbreak in terms of numbers and impact (Engbert, Rabe, Kliegl & Reich, 2020). On 30 June 2020, the global cumulative confirmed number of coronavirus disease cases stood at 995 418 with 30 184 new reported deaths.

Of the global cases, five African countries, namely South Africa (151 209 cases), Egypt (68 311), Nigeria (25 133), Algeria (13 907), and Ghana (17 351) accounted for the highest number of cases on the continent (Our World in Data, 2016). These countries had the highest cumulative number of cases in Africa by 30 June 2020 (Our World in Data, 2016). Of the 151 209 confirmed cases in South Africa on this date, the Free State Province (FSP) caseload was at 1 514 with 385 deaths recorded. Mangaung Metropolitan Municipality (MMM) exhibited the highest caseload (538) in the province. This rapid increase of MMM caseload demonstrated that decisive action was required from the start of the outbreak (National Institute of Communicable Diseases, 2018).

The African continent and the global community had to act quickly to safeguard the region from the potential irreversible impact of the COVID-19 pandemic, which was causing high levels of mortality and weakened livelihoods (Rutayisire, Nkundimana, Mitonga et al., 2020). Few weapons were available in the fight against COVID-19. Nonetheless, contact tracing was considered a critical and effective component of the public health response to the disease (Garry, Hope, Zajac et al., 2020), particularly in the early phase, since treatment options were either constrained or unavailable (Keeling, Hollingsworth & Read, 2020).

Contact tracing is considered a key primary public health response. It is an essential tool in the fight against pandemics and the importation of rare or emerging infectious diseases. It was implemented in the United Kingdom during the 'containment' period in 2009, when the influenza pandemic was in its early stages (Asamoah, Kwaku, Sarkodie & Maina, 2020). This intervention had previously proven effective with the emergence of new infectious diseases, where advanced contact tracing, quarantine, and isolation was implemented to prevent a major epidemic (James, Eagle, Phillips et al., 2021).

Such interventions are referred to as containment strategies. Containment approaches refer to early-stage epidemic management in a geographically constrained area, enacting efforts to prevent SARS-CoV-2 transmission from person to person, as well as infection importation and exportation (Li, Chen, Feng, Rodewald, Xia, Yu, Zhang, An, Yin, Chen, Qin, Peng, Zhang, Ni, Cui, Wang, Yang, Zhang, Ren, & Wu, 2020).

What aided in contact tracing in recent years was access to electronic location and communication data, which was not widely available during previous pandemics (Challen, Brooks-Pollock, Tsaneva-Atanasova et al., 2020). Contact tracing was previously commonly used to identify and treat people who had been exposed to other diseases, such as the Human Immunodeficiency Virus (HIV) or tuberculosis (TB). It has also been implemented as intervention to vaccinate those who had been exposed to Ebola, or to isolate those with measles exposure (Althoff, Coburn & Nash, 2020). Additionally, Breeher, Boon, Hainey et al. (2020) affirm that contact tracing is a critical component of communicable disease containment. The process entails identifying, quarantining, and monitoring infected people's contacts (Eames & Keeling, 2003).

However, even though contact tracing is a well-established evidence-based strategy in the community, the COVID-19 pandemic highlighted the difficulties of implementing labour-intensive contact tracing in the occupational setting of large healthcare digital technologies and how it can be very useful in these systems (Baker, Biazzo, Braunstein, Catania, Dall'Asta, Ingrosso, Krzakala, Mazza, Mézard, Muntoni, Refinetti, Mannelli & Zdeborová, 2021).

As a result, for the COVID-19 epidemic management, a comprehensive assessment of the application of a multi-pronged strategy, including early contact tracing aimed at limiting disease spread, was crucial (James, Eagle, Phillips, Hedges, Bodenhamer, Brown, Wheeler & Kirking, 2020). This was especially true during the early stages of the pandemic, when no therapy or immunisation was available, and only non-pharmaceutical measures were available. This approach was taken to minimise the overwhelming effect of the pandemic on Mangaung Metro's healthcare system.

Not only Mangaung Metro's healthcare system, but that of the entire country was under threat (Lone & Ahmad, 2020). The Minister of Health, Zweli Mkhize revealed on 5 March 2020 that the virus had spread to South Africa, with the first patient being a male citizen of KwaZulu-Natal (KZN) who tested positive after returning from a vacation in Italy (www.gov.za, n.d.). Following that, the South African Government implemented several measures aimed at curbing COVID-19's spread in the country. South African President Cyril Ramaphosa declared a national disaster on 15 March 2020 and imposed immediate travel restrictions and the closure of schools on 26 March 2020 (www.gov.za, 2020). On 17 March 2020, the National Coronavirus Command Council (NCCC) was formed to "lead the nation's plan to contain the spread and mitigate the negative impact of coronavirus" (SA, 2020). A national lockdown was announced on 23 March and became effective on 26 March 2020.

Further recognising the extent, duration, and difficulty of the COVID-19 pandemic, as well as the need to implement timely and efficacious public health preventive actions, the National Department of Health developed several response and containment strategies to assist the healthcare system and sector in coordinating, facilitating, and carrying out COVID-19 contact tracing activities (Kretzschmar, Rozhnova & van Boven, 2020a). Contact tracing can reduce the reproductive number (R0) by rapid identification, screening, and testing of contacts of infected individuals who are either symptomatic or asymptomatic, thereby interrupting virus transmission with further quarantine and isolation (Park, Cook, Lim, Sun & Dickens, 2020).

The Free State had its first confirmed COVID-19 case on 16 March 2020 in Bloemfontein, followed by the first wave of infections among tourists and those who had travelled from abroad to attend a church conference held in the city. Mangaung Metro has remained the epicentre of the COVID-19 pandemic in the Free State, mainly due to its density, having the largest population in the province, and being the economic hub of the province. The location of the province further compounded earlier control measures being implemented (COGTA, 2020). The Free State is located in South Africa's geographical centre, surrounded by the Northern Cape and Eastern Cape, Mpumalanga, Northwest KwaZulu-Natal, and Gauteng provinces, as well as Lesotho, the neighbouring country (COGTA, 2020). Containment of infectious diseases is dependent on stringent quarantine and isolation measures of both the infected and exposed individuals to minimise further transmissions (Asamoah et al., 2020). However, the centrality of the Free State province, and especially Mangaung Metro, poses additional risks due to the high level of community mobility within and outside the province, which had the potential to exacerbate the situation.

Data on the number and nature of all human interactions is essential to accurately forecast the impact of control measures, and diseases such as SARS-CoV-2, which are additionally spread by contacts (Kumar Das, Khatua, Kar & Jana, 2021). It is thus crucial to understand how contact patterns change because of various control methods before determining their effectiveness (AR, 2020). This is especially salient during the early phases of an infectious disease outbreak. Mangaung Metropolitan Municipality health district outbreak and response teams, supported by various technical stakeholders, employed extensive and aggressive case identification, contact tracing, screening, and testing within the first 24 hours after the outbreak at the church conference (Ruebush et al., 2021). Data from analysis of contact tracing, especially in the early stages, can accordingly continue to inform our understanding of SARS-CoV-2 transmission, as well as direct public health intervention in Mangaung Metro and the Free State province.

1.2. PROBLEM STATEMENT

To my knowledge, no systematic analysis of the preventative characteristics and effectiveness of COVID-19 transmission and infection through contact tracing has been done in relation to Mangaung Metropolitan Municipality. Given the discussion above, such research is crucial for effective prevention of the spread of the disease.

Efforts and control measures to avert further transmission and prevent future infectious outbreaks are in place globally (Eames & Keeling, 2003). These measures, strategies, and procedures have worked for several other novel epidemics; however, it is unclear whether they will work for COVID-19 (Ruebush, Fraser, Poulin, Allen, Lane & Blumenstock, 2021). The public's conduct is critical for outbreak management, especially in the early stages (Smith, 2006). For the purpose of this study, the early stage of the outbreak in Mangaung Metro refers to the time between March 2020 and June 2020. Early engagement, as well as guidance from the World Health Organization, enabled the health authorities to successfully implement early risk management. So far, early border controls, case management, and contact tracing have been some of the most effective preventive measures implemented. The detection of suspected and confirmed cases and surveillance of contacts are vital aspects of these control measures (Ng, 2020). Nevertheless, it is unknown at this time whether such methods would be effective in controlling COVID-19 transmission. As a result, it is currently unclear whether contact tracing and isolation interventions will be sufficient to contain the new COVID-19 outbreak in Mangaung Metro.

1.3. AIM OF THE STUDY

The aim of the study was to analyse contact tracing data in Mangaung Metro, Free State province during the early phase of the COVID-19 outbreak (16 March 2020 – 30 June 2020) to measure the viral transmissibility of COVID-19 in the early stages of the outbreak.

The standard COVID-19 line list data file with detailed variables developed by the National Institute of Communicable Diseases as part of the COVID-19 surveillance data was used as data collection tool (see Annexure A).

Each variable had an entirely unambiguous set of response sections for the purpose of maintaining set parameters and included collecting data on cases and close contacts, including demographic information, the type of contact, date of last exposure to the case, as well as the setting of the exposure (e.g., health care setting, household, etc.).

The data was analysed using the R and STATA software, and only data from 16 March 2020 to 30 June 2020 was included for analysis. The analysis began with data clean up to remove discrepancies and duplicates, followed by contact tracing indicator calculation (e.g., number of contacts per index case, location, relationship of contacts and case, proportion of contacts per cases and attack rates among contacts), concluding with analysis of epidemiological changes from March 2020 to June 2020 and during the different levels of lockdown.

1.4. RESEARCH OBJECTIVES

The objectives of this study are:

a) To determine the number of contacts detected from identified confirmed cases during the early stages of the COVID-19 outbreak;
b) To establish the epidemiological COVID-19 change as a result of contact tracing;
c) To demonstrate the transmission rate of COVID-19 of contacts during the early phase of the outbreak; and
d) To investigate the possible effects of contact tracing control measures on the trajectory of the epidemic.

1.5. RESEARCH QUESTIONS

The following research questions are addressed in this study:

a) How many contacts of confirmed cases were detected during the early-phase COVID-19 outbreak through contact tracing?
b) What epidemiological change was determined as a result of contact tracing?
c) What is the transmission rate of close contacts during the early phase outbreak of COVID-19?

d) What are the possible effects of contact tracing control measures on the trajectory of the epidemic?

1.6. SIGNIFICANCE OF THE STUDY

Despite studies and evidence of the effectiveness of contact tracing as a control measure in the early stages of the COVID-19 outbreak elsewhere, no data exist for Mangaung Metro in the Free State province. This study may provide insightful information for analysing COVID-19 surveillance data for contact tracing interventions and set health policies to sustain the contact tracing response achievement attained to manage future outbreaks.

1.7. DELIMITATION OF THE STUDY

The research was solely delimitated to confirmed COVID-19 cases and their contacts in Mangaung Metro during the early stages of the COVID-19 outbreak.

1.8. DEFINITIONS OF TERMS

1.8.1. Coronavirus Disease 2019

In this study, the definition of coronavirus refers to and is aligned with the definition of the International Committee on Virus Taxonomy and reviewed to be named the novel coronavirus (2019-nCoV) and provisionally titled the 2019 novel coronavirus. According to the International Committee on Virus Taxonomy, this strain is currently known as SARS-CoV-2 (World Health Organization, 2020).

1.8.2. Contact Tracing

In this study, contact tracing refers to rapid contact engagement alongside rigorous quarantine, isolation, and testing of contacts of laboratory confirmed COVID-19 cases, as a critical strategy for interrupting SARS-CoV-2 transmission chains and minimizing COVID-19-associated fatalities.

1.8.3. Close Contacts

In this study, the definition of contacts refers to and is aligned with that of the Centre for Disease Control, where "contacts" refer to individuals who may have had a connection with a confirmed COVID-19 case through a variety of situations or activities, such as family members, school friends, teachers, health professionals, and support sources. Contacts can be classified as close or general depending on the extent of the contact (CDC, 2020).

1.8.4. Confirmed COVID-19 Case

The term "confirmed case" will be used in this study to refer to a confirmed case that meets the COVID-19 notification standards after being tested positive with a real-time reverse transcriptase-polymerase chain reaction (RT-PCR) test in a laboratory (Kretzschmar, Rozhnova & Van Boven, 2020).

1.8.5. Exposure Window

For this study, the term “exposure window” or “timeframe period” is defined by the Centre for Disease Control as being the time from the first to the last day of the recorded confirmed case exposure based on the case investigation (CDC, 2021).

1.8.6. Secondary Clinical Attack Rate

The “secondary attack rate” was defined for this study as the number of nonindex contacts who received a positive test result within seven days of the index case's sample date, divided by the total number of nonindex contacts (Liu, Eggo & Kucharski, 2020).

1.8.7. Outbreak

For this study, the term “outbreak” was used, which is defined as an infection spread through person-to-person contact, animal-to-person contact, or from the environment, where the cases exceed what is expected (CDC, 2012).

1.8.8. Outbreak Control

The study used the definition of “outbreak control”, which is defined as no new infections occurring between 12 and 16 weeks after the initial cases. Uncontrolled outbreaks are defined as epidemics that have more than 5 000 cumulative cases and are too large to be managed in 12-16 weeks (Ameli, 2015).

1.8.9. Cluster

The study's definition of “cluster”, referred by the Centre for Disease Control and Prevention as cases that are related in time, geography, or by common exposures, was used (CDC, 2012).

1.8.10. R_0

The term R0 refers to epidemiology in this study; this metric is used to determine how contagious an infection is. Although COVID-19 research is still in its early stages, evidence suggests that its R0 is between 2 and 2.5, implying that an infected person will infect at least two to five other people (Gunderson & Woskie, 2020; Park et al., 2020).

1.9. CHAPTER OVERVIEW

This research project is organised into five chapters, and a summary of each chapter is provided below.

The first chapter introduces the research problems and the significance of the study. This chapter further contains the study's research aim, objectives, questions, delimitations, and the definition of terms.

Chapter two provides a review of the literature on the COVID-19 outbreak and contact tracing initiative as essential measures in reducing the spread of the virus.

In chapter three, a detailed explanation of the methodology used to achieve the research objectives is provided. It describes the research design, measures selected to obtain relevant information, and how the data was ethically analysed.

Chapter four discusses the data analysis and describes the research results. This chapter demonstrates how the analysed data answer the research questions and undertakes to align, explore, and accomplish the study objectives.

The final chapter discusses the research findings and provides a summary of the findings and conclusions of the study.

CHAPTER TWO: LITERATURE REVIEW

2.1. INTRODUCTION

This section undertakes a review of relevant articles, research, and surveys on the global COVID-19 pandemic, including literature on response measures and what mitigation strategies were explored and implemented by other countries worldwide. Furthermore, this chapter provides a review of contact tracing efforts and achievements, one of the main foci of the study. An assessment of the epidemiological pattern of COVID-19 is also performed in this section. Moreover, other frameworks developed in previous research on contact tracing are reviewed, including the effectiveness of such measures in controlling the transmission of the virus.

2.2. SEARCH METHODS

To gather reviews and data, a range of phrases linked to COVID-19 contact tracing were explored. If the papers initially reported on the possibilities of contact tracing to reduce or limit the spread of COVID-19, they would be included, or if they described the characteristics of effective tracing efforts. PRISMA guidelines were followed, as well as Global Health Embase MEDLINE, and All Evidence-Based Medicine data sets.

For this research project, a global and South African literature review was conducted on contact tracing amid the ongoing COVID-19 pandemic, reviewing benefits of contact tracing as a response, as well as control and containment during the early phases of the outbreak, and methods to control further virus transmissions that were devised. The association of emerging technological and infectious diseases was investigated further.

2.3. FINDINGS FROM THE LITERATURE REVIEW

2.3.1. Background to Contact Tracing

Contact tracing is not a novel technique, it has been used to aid in the control of HIV, sexually transmitted infections, and other infectious diseases (Bland, 2020). When the SARS outbreak began in the South of China in 2003, it was primarily handled by tracking contacts of reported cases and isolating confirmed patients, because a significant number of infections occur 2-14 days after exposure (Hellewell, Abbott, Gimma, Bosse, Jarvis, Russell, Munday, Kucharski, Edmunds, Sun, Flasche, Quilty, Davies, Liu, Clifford, Klepac, Jit, Diamond, Gibbs & Zandvoort, 2020). Historically, such interventions have been successful in managing a wide range of emerging infectious disease outbreaks, including smallpox and SARS. They have, however, been shown to be only marginally effective in controlling foot-and-mouth disease and are unlikely to be effective in controlling COVID-19 (He, 2020).

Contact tracing and case isolation have been employed to contain infectious disease outbreaks in the past and are now being utilized to combat the coronavirus disease (COVID-19). The viral characteristics and responses will determine whether or not this strategy will be effective (Chang, Wang, Zhang, Wang, Dong, Tsamlag, Yu, Xu, Yu, Long, Liu, Chu, Wang, Xu, Shen, Wang, Deng, Huang, Zhang & Wang, 2020).

Research studies reveal what could become a model for eradicating the coronavirus pandemic everywhere (Ouchetto, Drissi Bourhanbour & Boumhamdi, 2020). A study published in the journal Lancet Infectious Diseases by Chinese and American experts shows how a metropolis with a population of over 12 million people effectively stopped the transmission of COVID-19 by the middle of February 2020 (Goodwin, 2020). China's response showed that tracing of contacts could be achieved with the aid of extensive infection monitoring, including identification, and tracking of close contacts of infected individuals, accompanied by stringent isolation of cases and their contacts to avoid further transmission of infection (Goodwin, 2020).

Screening and testing of all close contacts provided an opportunity for those infected to be detected and removed earlier to minimise the spread of the virus (Centers for Disease Control and Prevention, 2019). Researchers have found that contact-based surveillance in Shenzhen decreased the time it took for infected people to spread to the general population by two days (Bi, Wu, Mei, Ye, Zou, Zhang, Liu, Wei, Truelove, Zhang, Gao, Cheng, Tang, Wu, Wu, Sun, Huang, Sun, Zhang & Ma, 2020). These findings are important for determining the extent of COVID-19's impact and for global strategic planning (CNEREMT & KCDCP, 2020). The World Health Organization's COVID-19 contact tracing guidelines highlight the need for and importance of "at least 80 percent of new cases [to] have their close contacts traced and in quarantine within 72 hours of case confirmation" (Juneau, Pueyo, Bell, Gee, Collazzo & Potvin, 2022).

2.3.2. Clinical Characteristics and Epidemiology of Cases

Using tracing, researchers were able to identify the transmission of COVID-19 based on important components. These include the domestic secondary attack rate, the percentage of household members infected by the infected individual (Rothan & Byrareddy, 2020), the serial median, duration between the onset of the primary case and the onset of the secondary causes of the symptoms, identified to be 6.3 days, as well as the reproductive number. Molloy, Tchervenkov, Hintermann and Axhausen () argue that expanded case-finding and contact tracing must be part of the broader-term response to this pandemic, which enables control of the spread of the disease.

Initially activated by monitoring programs set up after the outbreak of SARS-CoV-2 in 2002-2003, the resurgence of SARS-CoV-2 was characterised by a remarkable response from public health officials as well as scientists (Lake, 2020). These specific outbreak prevention steps typically included early detection and management of individuals with infections, recording of contacts with fever and/or symptom monitoring, and actively engaging with communities (Fisher & Heyman, 2020). Until vaccines are available, the only available infection control strategies include case isolation, contact tracing and quarantine, social distancing physical separation, decontamination, handwashing measures, and other non-pharmaceutical interventions (Ferretti, Wymant, Kendall, Zhao, Nurtay, Abeler-Dörner, Parker, Bonsall & Fraser, 2020).

Prompt surveillance of suspected cases, patient transfer, and isolation, as well as rapid diagnosis, monitoring, and follow-up of possible contacts is crucial. Every country's public health and laboratory infrastructures and services are required for the implementation of such a diverse range of techniques, both technological and operational (Gilbert, Pullano, Pinotti, Valdano, Poletto, Boëlle, D'Ortenzio, Yazdanpanah, Eholie, Altmann, Gutierrez, Kraemer & Colizza, 2020).

Contact tracing and isolation of confirmed COVID-19 cases and their contacts are standard interventions designed to monitor outbreaks of infectious diseases (He, Deng & Li, 2020). However, according to He, Deng and Li (2020), it is still not established whether case isolation and contact tracing interventions are appropriate to prevent a new outbreak of COVID-19 (Lipsitch, Swerdlow & Finelli, 2020). He et al. (2020) further suggest that contact tracing and case isolation alone in most modelled situations may not be sufficient to control a new outbreak of COVID-19 within three months, especially if the time between start of symptoms and isolation is significant. Furthermore, the delay in symptom onset might lead to fewer cases being identified through contact tracing, with the added risks associated with increased transmission before symptom onset and testing.

The short sequential period related to SARS-CoV-2 suggests that the methods of contact tracing will struggle against the accelerated duplication of incident generations, and the frequency of contacts quickly exceeding what is manageable by healthcare professionals and public health staff (Nishiura, Linton & Akhmetzhanov, 2020). Park et al. (2020) also affirm that a significant quantity of secondary disease spread may arise prior to the onset of infection. This suggests that certain transmissions might not be deterred entirely by isolation of symptomatic cases as, during the time contacts are traced, some could well have become somewhat infectious themselves and could have produced secondary cases.

2.3.3. Contact Tracing Methods, Measures and Models

Ferretti et al. (2020) recommend the application of key characteristics of disease transmission in order to determine the contribution of various transmission pathways. This is done through a renewal method application to analytically calculate the speed and scale of successful tracking of contacts to contain the epidemic. The same study further estimates that factors influencing the success of contact tracing required to reduce R0 to under one are a combination of two significant variables. These are the percentage of cases requiring isolation, as well as the total number of contacts that needed to be quarantined (Ferretti et al., 2020). However, the possible three-day delay in notification, as with manual contact tracing, and the nonparametric combination, leads to gaps in disease control (Erkhembayar, Dickinson, Badarch, Narula, Warburton, Thomas, Ochir & Manaseki-Holland, 2020).

Fiore, DeFelice, Glicksberg, Perl, Shuster, Kulkarni, O'Brien, Pisauro, Chung and Gu (2021) recommend that an application (app) based on existing technology should be used to reduce the gaps produced by manual contact tracing in the case of highly infectious diseases. This further enables that rate of general contact tracing to rapid notification of contracts via mobile phone. Moreover, the app may also have the potential to be adequate in responding to the outbreak if it is used by a significant percentage of the target population.

Burke's (2020) study on local health systems in the United States, in collaboration with the Centers for Disease Control and Prevention (CDC) teams, classifies and tracks all individuals deemed to have had close contact with reported COVID-19 patients. This procedure comprises determining the period of exposure during which each patient's symptoms occurred, in addition to the nature and length of exposures (Kretzschmar, Rozhnova & van Boven, 2020). This could furnish insight into possible transmission factors, including infection prevention and control initiatives by COVID-19 patients, their family members, and their healthcare professionals. Burke (2020) maintains that contact tracing initiatives are essential in reducing the spread of the infection. However, Burke's (2020) findings seem to be contradictory, as he concludes by stating that, despite massive follow-ups, no established person-to-person transmission of symptomatic SARS-CoV-2 was confirmed in direct connection with the first ten individuals diagnosed with commuting-related COVID-19 in the United States.

A stochastic transmission model, designed by Hellewell et al. (2020), was parametrised for the outbreak of COVID-19. The model was used to evaluate the potential efficacy of contact tracing and isolation of cases in the case of the acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pathogen. The model considers various scenarios, including:

a) The range in the number of initial events;
b) The simple replication amount (R*0*);
c) The duration from onset of symptoms to isolation;
d) The likelihood of communication being tracked;
e) The probability of transmission occurring before the onset of symptoms; and
f) The percentage of mild to moderate infections (Hellewell et al., 2020).

In the United Kingdom, public health specialists recommend that, for contact tracing to be effective, all parts of the population must be ready to be contacted by the National Health Services (NHS) or public health staff (Dropkin, 2020). Therefore, to combat this crisis and protect everyone's safety, all obstacles for access to care at the NHS, including charges and debt, and the risks of undocumented refugees and immigrants being reported to the Home Office, should be immediately removed.

2.3.4. Global COVID-19 Outbreak

During November 2002, severe acute respiratory syndrome coronavirus (SARS-CoV) originated in China, creating worldwide concern as the epidemic spread exponentially. By July 2003, more than 8 000 cases had occurred in 26 countries. What is striking is SARS-CoV-2, a new coronavirus first detected in Wuhan, China, in December 2019, causing COVID-19 to spread quickly (Wilder-Smith, Chiew & Lee, 2020). Zhou, Zhang and Qu (2020) concur that the sequences are nearly identical, SARS-CoV and SARS-CoV-2 are remarkably similar, having 79.6% compatibility.

The remarkable above-mentioned parallels between SARS-CoV and SARS-CoV-2 are significant, not just in the name (Wilder-Smith, Chiew & Lee, 2020). The similarities, however, stop here as the outbreaks' paths appear to be remarkably different. The SARS outbreak in 2003 recorded 8 098 cases and 774 deaths, and after eight months, the crisis was completely under control in July 2003; only 26 countries had reported cases. In comparison, by 28 February 2020, within two months of the COVID-19 outbreak, more than 82 000 confirmed cases of COVID-19 had been reported, with more than 2 800 deaths, mostly in China. Beyond China, over 3 600 infections were reported in 46 countries, including 700 passengers on cruise ships (Kinoshita, Anzai, Jung, Linton, Miyama, Kobayashi, Hayashi, Suzuki, Yang, Akhmetzhanov & Nishiura, 2020).

2.3.5. COVID-19 Outbreak in Africa

COVID-19 cases have been confirmed on every continent, with Africa reporting its first case in Egypt on 14 February 2020 (Gilbert et al., 2020). The major trading partner of Africa is China and the frequency of travel between China and the continent could lead to acute SARS-CoV-2 respiratory syndromes reaching the region through the importation of COVID-19 infections (Makoni, 2020).

In the earlier stages of the global COVID-19 outbreak, Africa was initially generally spared the kind of devastation that had engulfed China, the US, and Europe. On the African continent, approximately 14 000 confirmed cases had been reported as of 13 April 2020, compared to 160 000 in Italy and over 560 000 in the United States (El-Sadr & Justman, 2020). Africa has confronted its fair share of pandemics over the years, and the continent was more prepared due to the management of other significant endemic infectious diseases. Consequently, governments on the continent were more informed and prepared regarding responses to communicable diseases (Nachega, Ishoso, Otokoye, Hermans, Machekano, R.N., Sam-Agudu, Bongo-Pasi Nswe, Mbala-Kingebeni, Madinga, Mukendi, Kolié, Nkwembe, Mbuyi, Nsio, Mukeba Tshialala, Tshiasuma Pipo, Ahuka-Mundeke, Muyembe-Tamfum, J Mofenson & Smith, 2020).

In the early months of 2020, the spread of COVID-19 dominated North Africa; nevertheless, in comparison to Europe and even the United States, the infection's outbreak was delayed (Joffé, 2020). Joffé (2020) further states that, by this point, it could safely be assumed that the magnitude of the exponential change in the disease's trajectory would most likely be characterised by two parameters. These are, firstly, the countries' available resources and, secondly, the nature and application of the limitations each country imposed to curb infection spread. Egypt, Morocco and Algeria opted to implement control measures to minimize increased morbidity and, as a result, lessen the load on the healthcare system in order to counter the spread of COVID-19. These countries determined that the introduction of containment and confinement measures may aid in containing the spread of the epidemic and reducing the number of deaths (Ouchetto, Drissi Bourhanbour & Boumhamdi, 2020).

Gilbert et al. (2020) undertook data analysis of flights destined for Africa departing from airports in the affected Chinese provinces. The study considered the possibility of importation of COVID-19 cases from China to Africa. To do so, statistical data of origin to destination of air traffic flows from January 2019 was used. The findings of the analysis were that Egypt, Algeria, and South Africa were the most at-risk countries with highest import threat from China, a finding further confirmed by the report of moderate to high State Party Self-Assessment Annual Reporting (SPAR) levels (Gilbert et al., 2020).

COVID-19 pressures were lower in most of the African countries than in European countries. Early and strong political will and dedication, as well as the rigorous implementation of public health initiatives, have been attributed with this success (Nkonki & Fonn, 2020). National lockdowns, movement restrictions, face mask use, testing, contact tracing, and isolation, as well as community education, participation, and engagement, were among the measures used (Nachega et al., 2020).

The Africa Centres for Disease Control and Prevention (Africa CDC) assisted countries in the form of testing capacity and, in accordance with the WHO, technical guidelines for contact tracing and community surveillance were developed, including online materials. Governments in various countries played a critical role in mobilising and facilitating collaboration along with a diverse variety of stakeholders (MacIntyre, 2020). In South Africa, the government released contact tracing regulations on 2 April 2020 so as to create a new electronic COVID-19 tracing database (Nachega et al., 2021).

2.3.6. Mangaung Metro COVID-19 Response

Mangaung Metro is one of five health districts in the Free State province, with an estimated population of 850 000, and four local sub-districts (Bloemfontein, Naledi, Thaba Nchu, and Botshabelo). The district is mainly urban and based in Bloemfontein, the capital of the province (Profile: Mangaung Metro 2, n.d.).

The district already had an established District Outbreak Response Team to manage any possible outbreaks, with representation from the public health municipality, academics, and infectious disease specialists. This team is solely responsible for managing outbreaks and was designed to manage confirmed COVID-19 cases and their contacts for both private and public patients. The district has one academic, one tertiary, four district, and nine private hospitals, as well as five medical or clinical laboratories, four of which are private and one of which is public (COGTA, 2020).

The outbreak response teams are further organised around the main surveillance team, with different streams such as clinical, case management, contact tracing, monitoring, case investigation, admissions, emergency medical services, and forensic. The teams meet daily to discuss updates and the status of confirmed and reported cases (MMM, 2021).

2.3.7. The Outbreak and Response of COVID-19 in Mangaung Metro

On 16 March 2020, the Free State Department of Health received notification of its first coronavirus case, which involved a laboratory technician from one of Bloemfontein's private hospitals. On 19 March 2020, the first case was followed by five cases involving overseas visitors attending a local church conference, which resulted in a cluster (MMM, 2021). The number of incidents and prevalence of COVID-

19 remained low in comparison to other provinces with significant outbreaks due to aggressive prevention surveillance, contact tracing efforts, and systematic control monitoring. From the outbreak's inception, the provincial Centre for Disease Control and local health authorities carried out a response, including contact tracing (MMM, 2021). Best practice in Mangaung Metro's pivotal contact tracing included mobilisation of community health workers and intensive participation of a team of public health experts to handle different aspects of the response. Methods applied by the latter included active case finding, contact tracing, epidemiological tracking, surveillance, and the commissioning of public health and private quarantine sites for all confirmed cases and their contacts, regardless of socioeconomic status.

Confirmed laboratory cases from the Mangaung Metro outbreak that started on 16 March 2020, as well as their close contacts, were tracked down and tested for COVID-19 infection, regardless of symptoms, until 30 June 2020, by implementing and in accordance with the National Institute of Communicable Diseases COVID-19 guidelines of case definition, investigation, and contact tracing (NICD, 2020). Other subcategories were only tested if they were sick or had COVID-19 disease symptoms.

South African Minister of Health, Dr Zweli Mkhize, indicated that the Free State province managed the early phase of the outbreak superbly, as evidenced by the following quote:

> The Free State is one of the success stories of the early days of the pandemic; a cluster outbreak from a church gathering threatened to become a runaway bush fire but we quickly doused the flame by deploying mobile testing units and instituted an aggressive contact tracing strategy with immediate quarantine or isolation of persons under investigation (Grobler, 2020).

2.4. SUMMARY

Contact tracing appears to be the gold standard in preventing the spread of COVID-19 infections, according to several of the contact tracing research evaluated. However, timing, sourcing, as well as quarantining of contacts are critical, and any delays in tracing – more than four to five days – are ineffective, and might not significantly contribute to controlling the COVID-19 spread. Despite this, some studies reviewed seem to suggest that contact tracing and quarantining of close contacts seem to have no effect in reducing the risk of secondary cases of COVID-19. Lastly, the Mangaung Metropolitan Municipality contact tracing measures were also explored.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. INTRODUCTION

The research methodology chapter will show that the researcher conducted a retrospective descriptive quantitative study using the laboratory-confirmed COVID-19 index cases along with data from the contact line list records that were captured and recorded. It then compared the epidemiological changes from March 2020, when lockdown level 5 was in effect, to April and May 2020, when lockdown level 4 was in effect, and June 2020, when lockdown level 3 was in effect. The study further analysed the transmissibility of infections during these lockdown levels, including case load and COVID-19 tests conducted during this period. Both symptomatic and pre-symptomatic cases were included and identified from surveillance of contacts traced and approximated from the onset of symptoms to confirmation and isolation. Data of both confirmed cases and the contacts of those who were tested at post-mortem for COVID-19 were also included for analysis. Testing would be performed on the deceased with respiratory distress history. Tracing of their contacts was initiated in the instance of positive test results.

3.2. RESEARCH DESIGN

To determine the number of contacts detected from identified confirmed cases during the early stages of the COVID-19 outbreak, a retrospective descriptive analysis from the COVID-19 case line list was employed. The aforementioned analysis of data comprised data completed from contact line entered into a secure database, with a link to the index case and current status information. The data was from the period March 2020 to June 2020. Next, epidemiological COVID-19 data change as a result of contact tracing was investigated. Using this data, the transmission rate of COVID-19 contacts during the early phase of the outbreak was demonstrated. Finally, the possible effects of contact tracing control measures on the trajectory of the epidemic were investigated.

3.3. STUDY SETTING

The study setting was the Mangaung Metropolitan Municipality (Figure 3.1) in the Free State province. The economically productive population of Mangaung Metro is 36.25% of the total population, with 24.66% living in Bloemfontein, 8.71% in Botshabelo and

3.88% in Thaba Nchu. Due to the high rate of migration of people seeking better living conditions, the city has a high unemployment rate of 27.7% and is marked by a high level of poverty (MMM, 2016).

The proportion of dwellings of the district are as follows:

a) Formal dwellings (87.11%);
b) Informal dwellings (11.74%);
c) Traditional dwellings or villages (0.75%); and
d) Dwellings listed as "other" (0.39%).

The district's health facilities are well supplied, with some of the best private and public hospitals being in Bloemfontein. However, there have been reports of the huge backlog in terms of clinics, especially in new settlements in the south-eastern part of Bloemfontein, the western settlements of Botshabelo, and in the rural trusts of Thaba Nchu (MMM, 2016).

In the Free State province, Mangaung remains the epicentre of COVID-19. As of 2 June 2020, 5 248 COVID-19 tests had been performed in Mangaung, with 178 confirmed cases, 7 deaths, and 134 recoveries recorded. The highest number of cases (174) was registered within the capital, Bloemfontein, with two confirmed cases in Botshabelo, and two more in Thaba Nchu. Mangaung has 12 COVID-19 quarantine sites, with 11 of them situated in Bloemfontein. The Metro had commissioned access to 1 405 public and private beds. Seven of the quarantine sites were operational as of 29 May 2020 (COGTA, 2020).

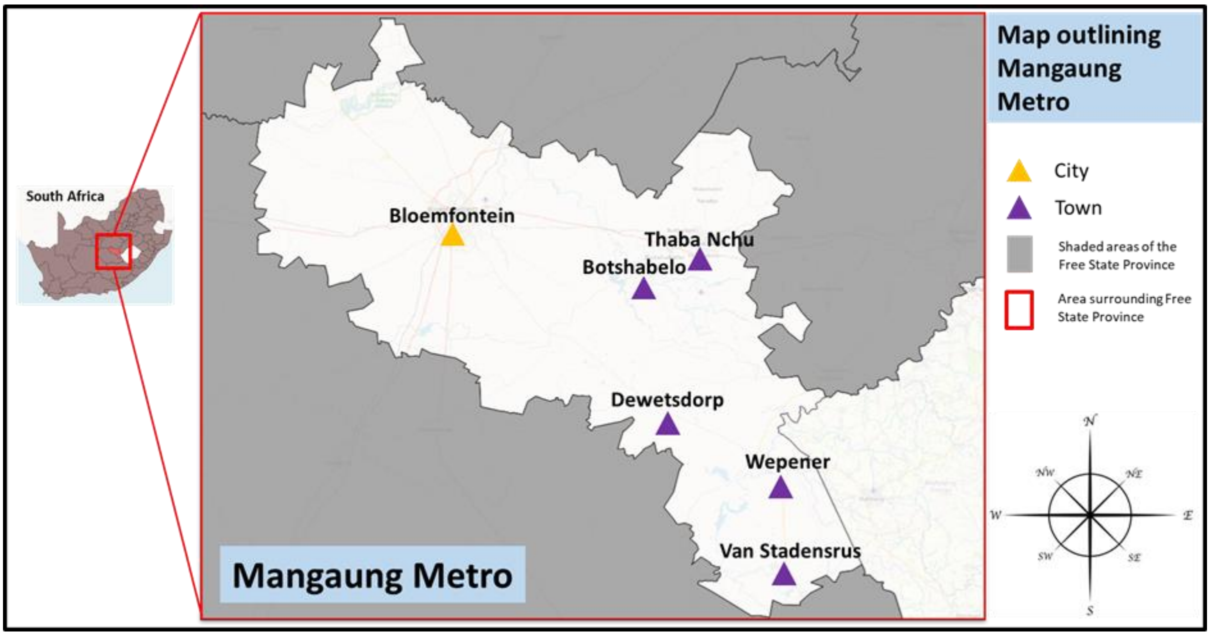

Figure 3.1: Map of Mangaung Metro (Combrink, 2020)

3.4. STUDY POPULATION

The study population in this investigation is specific to the early events that brought on the disease entering Mangaung Metro. The church conference attendees mentioned previously were the representative population size. This means that people who contracted the disease as a result of attending the conference, exposure to an attendee, or someone infected with the virus linked to people who contracted the virus, were the intended study population.

3.5. SAMPLING

A sampling of files of laboratory-confirmed COVID-19 index cases and their contacts in Mangaung Metro, specific to the church cluster, was undertaken. Files and records of laboratory COVID-19 cases included records of close contacts identified through contact tracing. Close contacts were defined as those who lived in the same apartment, work colleagues, who shared a meal, travelled, or socially interacted with an index case seven days before symptom onset or testing, and tests results were from both private and public laboratories. For sample size, ten cases per variable were chosen to achieve results that are both accurate and clinically relevant.

3.5.1. Inclusion Criteria

Only laboratory-confirmed index cases and their close contacts during the early outbreak phase in Mangaung Metro (18 March – 30 June 2020) were included. Close contacts included were anyone who had contact with confirmed cases through a range of circumstances or activities, including being family members, relatives, friends, colleagues, healthcare workers, and/or service employees.

3.5.2. Exclusion Criteria

Exclusions comprised all index cases and contacts residing outside of the Mangaung Metro district, including those defined as casual contacts and those who had limited activities and contact with the index cases, including contacts outside the 30 June 2020 period.

3.6. DATA INSTRUMENT

The researcher adopted the pre-existing instrument that was used to collect and measure the key variables of the study. The instrument adopted was proposed by the National Institute of Communicable Diseases (NICD), the COVID-19 Contact Line List, completed for all persons under investigation who would have been close contacts of confirmed cases and require to be tested for COVID-19.

The current details of the NICD contact line list are:

a) Details of the confirmed case followed by the following details of the contacts;
b) Demography indicators (such as age group, sex, and whether the contact was a healthcare worker);
c) Contact tracing indicators (root cause of exposure, relation to index case);
d) Basic symptomatology (symptomatic or asymptomatic during tracing); and
e) Date and details related to the laboratory of testing (place of test, COVID-19 positive or negative test etc.) (NICD, 2020).

The data was captured from the NICD line list in an Excel spreadsheet.

3.7. RELIABILITY

The researcher used the Bayesian hierarchical model (Albert & Hu, 2020) to improve the reliability of the small, estimated sample size. Furthermore, all the data obtained came from the verified NICD data line list for Mangaung Metro, which consisted of already validated and stored information related to the outbreak using the same Bayesian hierarchical model.

3.8. DATA COLLECTION PROCEDURE

The researcher extracted data files of confirmed index cases and their close contacts from the Free State Department of Health line list, data point and contact line lists; thereafter, only the Mangaung Metro district COVID-19 case line list was used. Data point and contact line were sorted from the master case line list. Demographic details from each contact line were extracted from the database list of each confirmed case. Daily surveillance and situation reports from the district were used to estimate incidence data, and deduplication was undertaken in the cases where files had duplication of cases. The process was conducted over three months. To maintain the confidentiality of the patients, the data collection process was conducted using a password-protected computer.

3.9. DATA ANALYSIS

To test the effectiveness of contact tracing and case isolation to monitor the outbreaks of COVID-19 for Mangaung Metro during the defined period, a parametric deterministic approach was undertaken based on the descriptive and inferential model (Köhler-Rieper, Röhl & De Micheli, 2020). A descriptive model was used as a means to illustrate the frequency and distribution of the study population so that general trends related to the disease spread in Mangaung Metro could be identified. The inferential statistics were based on a time-series analysis to measure the impact of contact tracing stratified according to the symptomatology and root cause of the cases against the overall cases in Mangaung Metro for the same period. The overall caseload in the Free State province can be found from a range of official governmental sources, that include peer-reviewed publications. This study uses the same data source as described by Combrink and Marivate (2020) for the publicly available data for the Free State province. A disease transmission characteristic and parameters specific to the COVID-19 pathogen were used to provide the best available evidence to determine whether contact tracing and isolation were able to control outbreaks.

The credibility and a branching process of the confirmed cases were ranked into laboratory-confirmed or probable, where all confirmed cases were paired with their contacts, dates of symptom onset, and testing. The concept of pre-symptomatic was clearly defined as per academic studies quoted from outbreak investigation reports (MacIntyre, 2020). The disease transmission metrics were calculated, and the elements that influence transmission risk were investigated further. R software (R Foundation for Statistical Computing) and RStan were used for data management and analysis.

3.10. ETHICAL CONSIDERATION

Ethical approval was obtained from the Faculty of Health Sciences ethics committee before data collection, with reference number Ref# 2020=12=03=MonyoboP. Permission was further obtained from the Free State Department of Health and all the health facilities before data collection commenced. Informed consent was obtained from the Mangaung Metro District Management Team after the nature and aim of the study had been explained to them. Management was made to understand that participation in the study was voluntary, and files were de-identified to remove names of the patients. There was no risk or harm to the participants seeing that patients were not directly involved. Since confidentiality, privacy, and anonymity are essential to uphold ethical standards and the research process's integrity, information from the records was kept on a password-protected computer.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1. INTRODUCTION

What follows are the analysis and interpretation of the findings, as well as key observations from the data.

4.2. DISCUSSION

The results of the data analysis show the number of cases in Mangaung Metro by lockdown level. To manage the gradual easing of the lockdown, the five-level COVID-19 alert system was implemented. The Mangaung Metro epidemiological curve depicts the progressive increase in cases from the initial outbreak in March 2020, from seven cases on 16 March 2020 to 1 001 cases in June 2020.

Fifty-two (52) cases were traced in March 2020, accounting for 73.2% of the total cases discovered through contact tracing, with a few cases discovered through self- and healthcare provider initiative. Cases tracked through contact tracing began to decline in April 2020, as did the number of incidents detected through contact tracing. In May 2020, contact tracing of new case identification decreased to 20 new cases (26.7%), and the caseload reached a specific capacity of 456 cases in June 2020, with daily new cases averaging 30. Despite having the highest case load in June (456), only eight cases (1.8%) were traced using contact tracing. From March to June 2020, 1 080 COVID-19 samples were collected, with 500 collected in April 2020, 202 in March, 170 in May, and 208 in June 2020. Lastly, the data shows that 79 healthcare workers were infected, based on the total of 1 001 cases, this represents 7.9% of all healthcare worker cases during this time period.

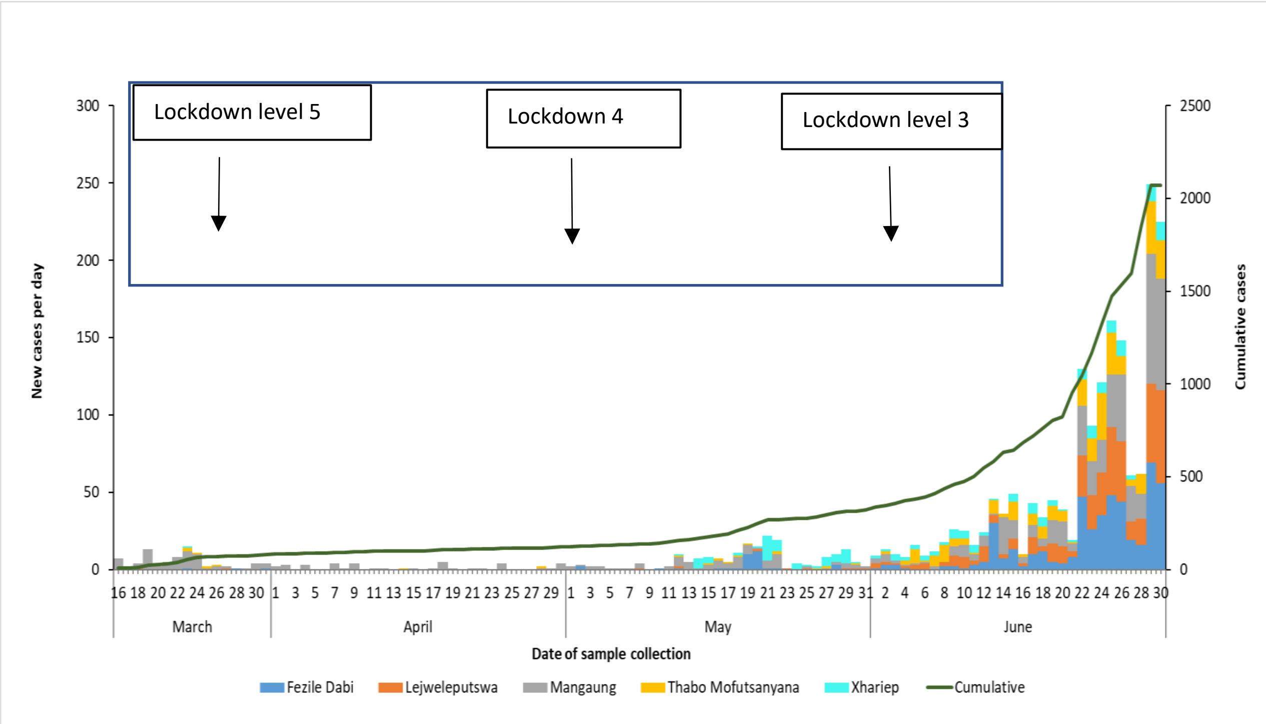

Figure 4.1: Total Caseload in the Free State (16 March – 30 June 2020)

Figure 4.1 shows the Free State's seven-day moving average and indicates the average of 151 reported cases per week from 16 March to 30 June 2020. Cumulatively, 2 072 cases were reported in the province during that period. This indicates that the Free State reported an average of 22 cases per day. Most of the cases (661 or 32%) were from Mangaung Metro, followed by Fezile Dabi at 509 (22%), Lejweleputswa with 412 (20%), Thabo Mofutsanyane had 295 cases which was 14%, and 194 cases in Xhariep which was 9.4%. The high number of cases seen in Mangaung Metro may be due to Mangaung Metro having the highest population compared to other districts, as it is the economic hub of the province (COGTA, 2020).

Figure 4.1 depicts the number of cases per lockdown levels in Mangaung Metro. To manage the gradual easing of the lockdown, the five-level COVID-19 alert system was implemented. Several criteria, including the level of infections and rate of transmission, the capacity of health facilities, the extent of implementation of public health interventions, and the economic and social impact of continued restrictions, guided these risk-adjusted approach. The number of confirmed cases was lowest during lockdown level 5 which was March to April 2022, due to movement restrictions, fewer contacts, and no gatherings were permitted; infections were still low during lockdown level 4, which was in May 2020, despite restrictions on mass gatherings remaining in place. However, infections began to rise as some level of movement was allowed, and during this time, there was more contact during funerals as they were seen as "super spreaders" of infections, and an increase in community transmissions contributed to the rise in infections. This period of lockdown level three marked the beginning of the country's first wave, which began to rise sharply in June. The 22 daily new cases were recorded as reported from all laboratories either public or private and reported on the data lake of the National Institute of Communicable Diseases daily situation report.

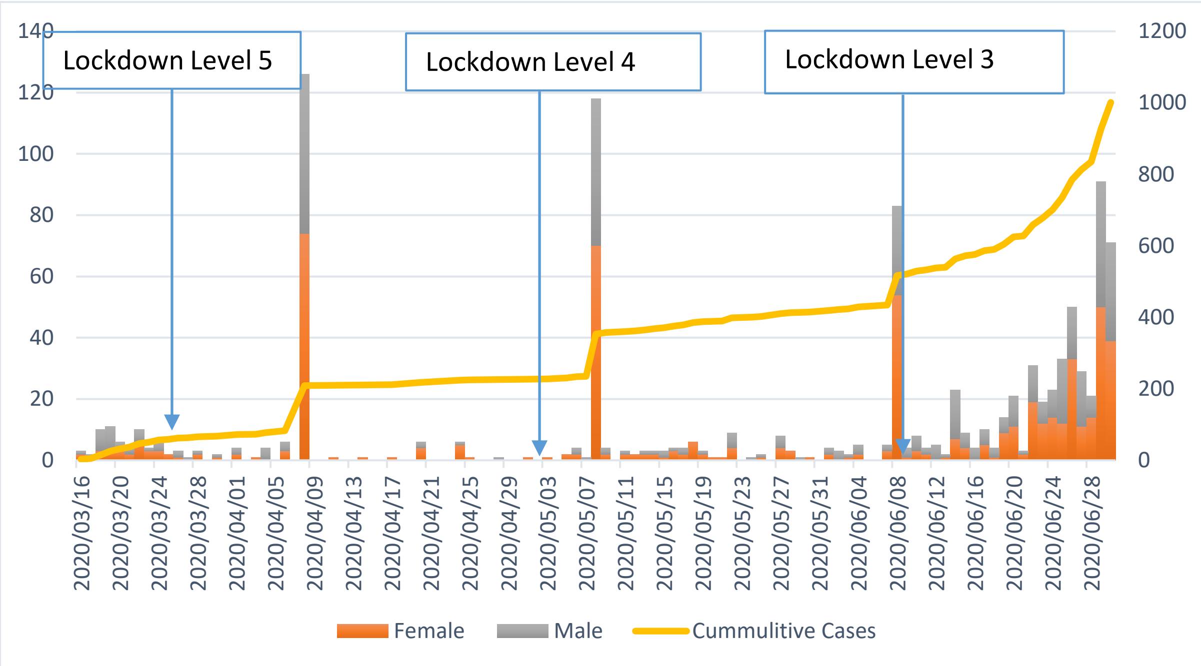

Figure 4.2: Total Caseload in Mangaung Metro (16 March – 30 June 2020)

In Figure 4.2, the epidemiological curve for Mangaung Metro shows the progressive increase in cases from the initial outbreak in March 2020, from seven cases on 16 March 2020 to 1 001 cases in June 2020. Female infections (35.4%) were higher than male infections (24.8%) as of 9 April 2020. On this date, female infections stood at 19.8%, compared to 13.5% on 7 May 2020 and 10.4% female and 5.6% male infections on 8 June 2020. The higher rate of female infections could be attributed to female health-seeking behaviour, and the fact that women are regarded as primary caregivers; as a result of the virus's transmissibility, women are thus more likely to be exposed and infected (Das, Angeli, Krumeich & van Schayck, 2018).

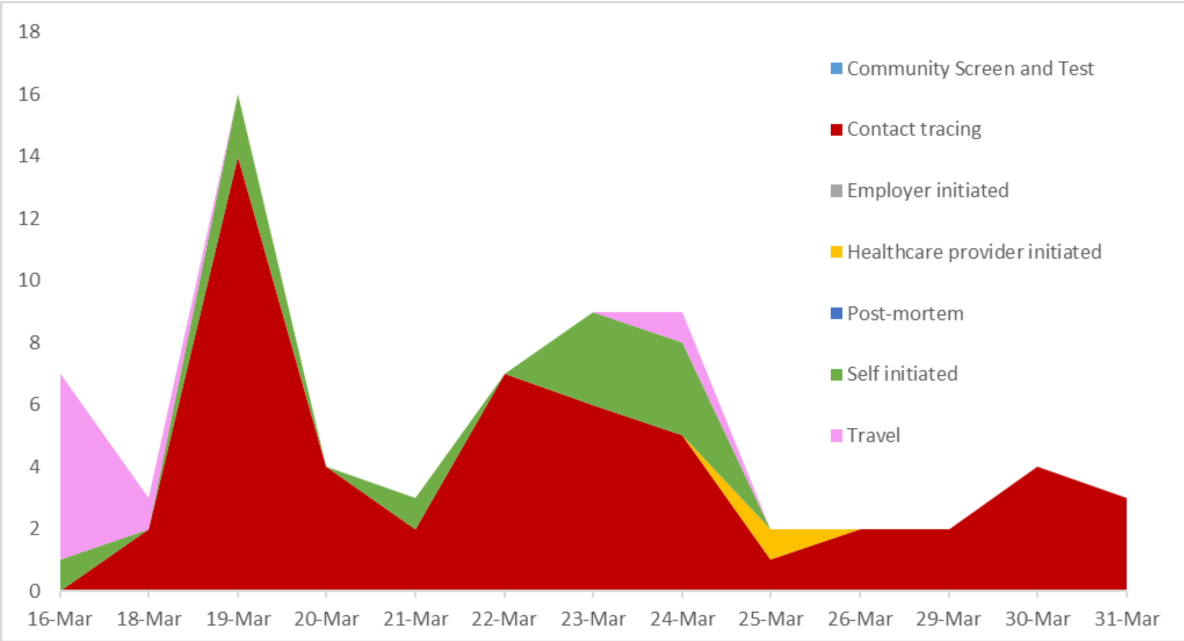

Figure 4.3: Identified Cases in Mangaung Metro (16 – 31 March 2020)

Figure 4.3 shows the majority of traced cases (N= 52). Statistically, 73.2% of the total cases were discovered as a result of contact tracing in March 2020, with a few cases discovered as a result of self and healthcare provider initiative. There were no cases discovered in March 2020 due to lockdown level 5, which prohibited any work other than essential health services, and there was no widespread community transmission in March 2020. The first seven cases were all imported.

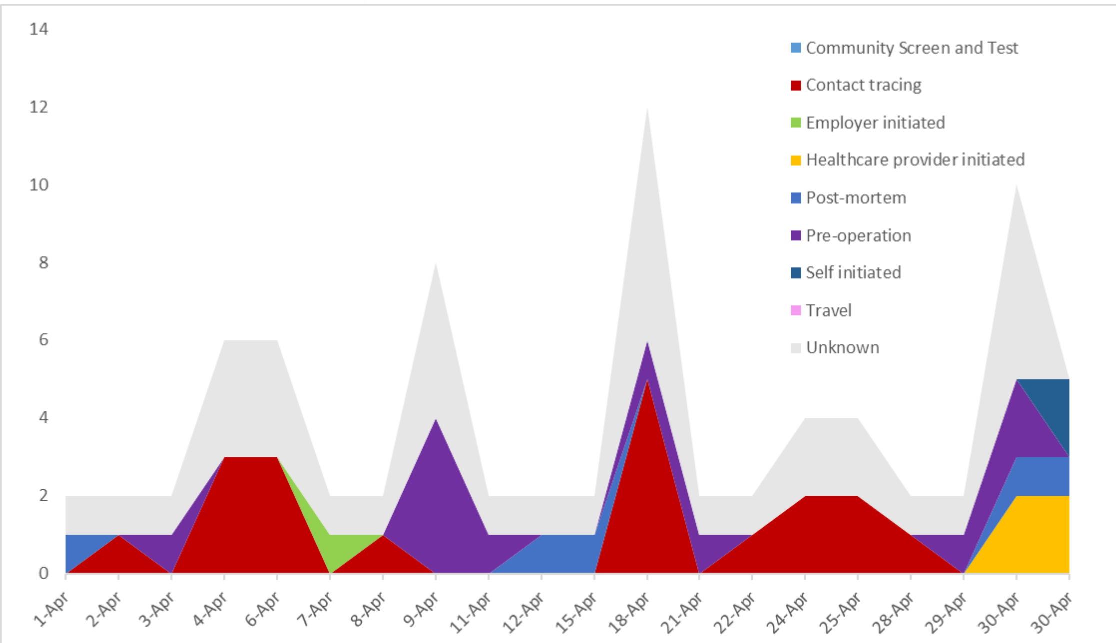

Figure 4.4: Identified Cases in Mangaung Metro (1 – 30 April 2020)

As seen in Figure 4.4, the 19 new cases tracked through contact tracing declined during April 2020, and the number of incidences detected as a result of contact tracing was lower. Case detection using other or unknown methods dominated case identification in April; however, contact tracing still allowed for the detection of an average of two cases daily. In mid-April 2020, post-mortem and pre-operative testing for case discovery became more prevalent.

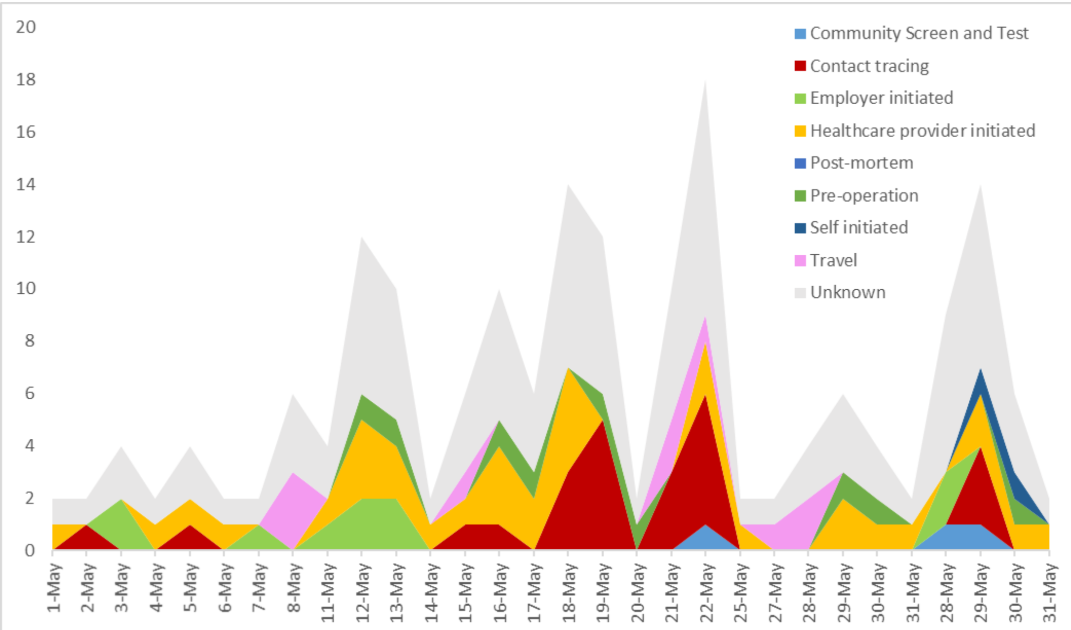

Figure 4.5: Identified Cases (1 – 31 May 2020)

Contact tracing of new case identification declined to 20 new cases (26.7%), as depicted in Figure 4.5. This serves to illustrate that, when the total number of new cases gradually increased to 75 in May 2020, the required capacity of contact tracers to manage the increased caseload was insufficient during early signs of community transmission. Although the principles underlying these strategies are not novel, the capacity and operational needs required to support disease investigation and contact tracing during the SARS-CoV-2 (COVID-19) pandemic were unprecedented, with the ratio of staff required to conduct contact tracing far outweighing district capacity. When the number of infections began to rise, the human resource capacity was insufficient; this shortfall was exacerbated by some of the contact tracers becoming infected and needing to isolate for 14 days, as per the initial guidelines. The proportion of people with an unclear mode of transmission began to rise. Consequently, new cases as a result of contact exposure were overlooked, with the unfortunate consequence that contact tracing had no effect during May.

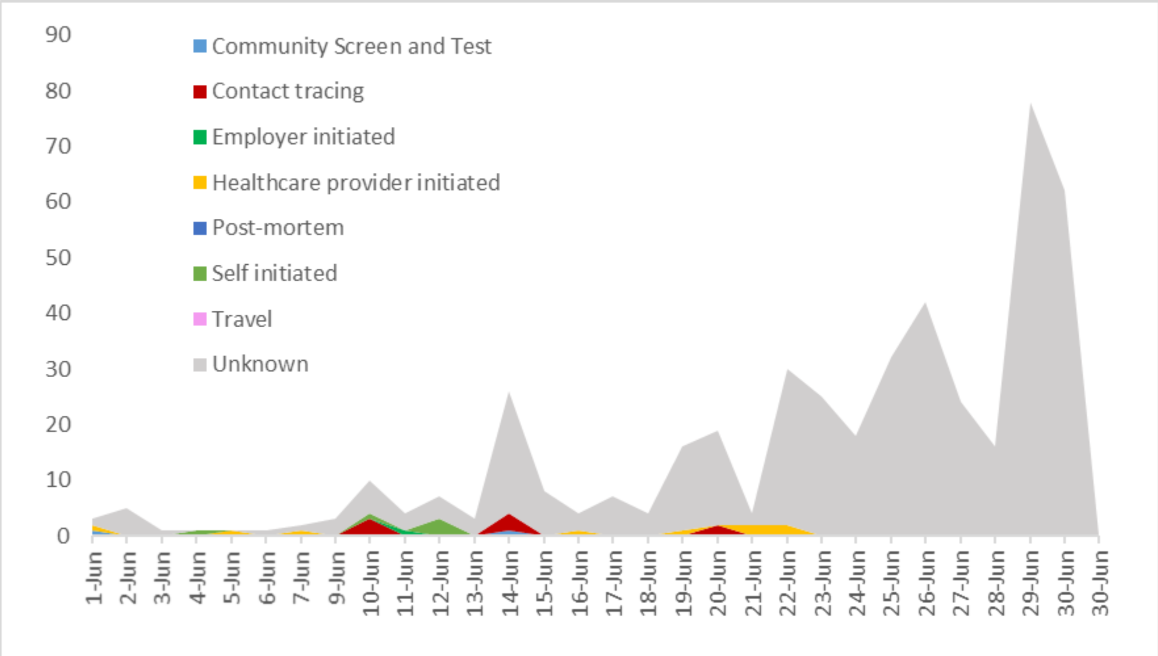

Figure 4.6: Total Number of Identified Cases Through Contact Tracing 2020 in Mangaung Metro (1 – 30 June 2020)

In Figure 4.6, it is shown that the caseload reached a specific capacity of 456 cases; daily new cases averaged 30. This was an early sign that contact tracing would become ineffective once a high daily case capacity was reached and that the capacity of contact tracers was insufficient. As opposed to the early-early phase in March 2020, there was already widespread community transmission in June 2020, referred to as the latent early phase.

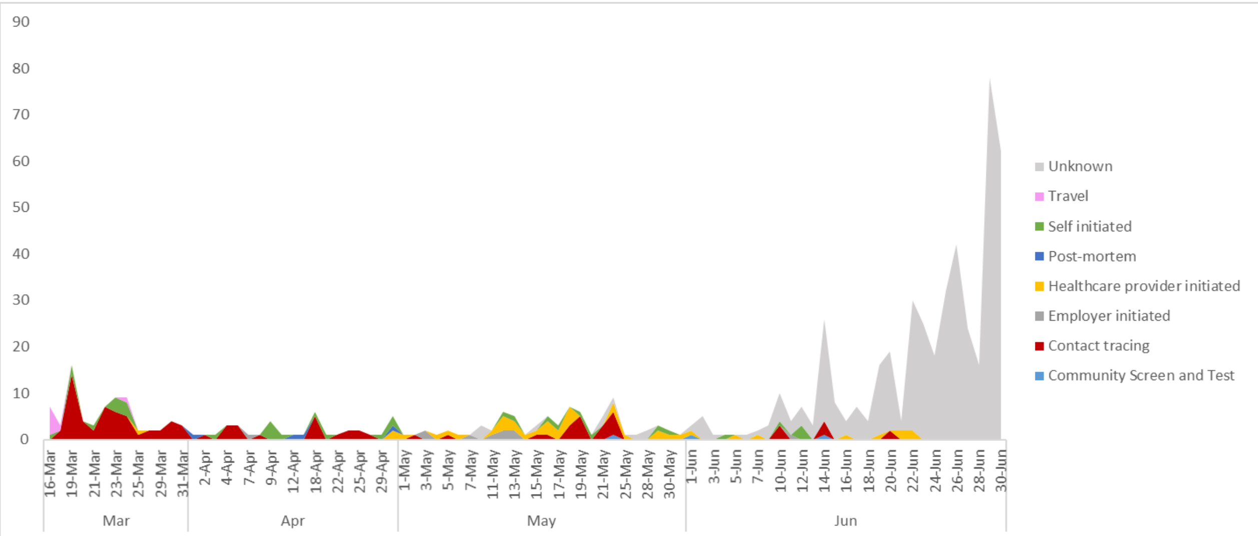

Figure 4.7: Caseload Detected Through Contact Tracing in Mangaung Metro (16 March – 30 June 2020)

Figure 4.7 indicates that 52 (73.2%) traced cases were found in Mangaung Metro. using contact tracing methods in March 2020. Case incidence started to decline, with 20 cases (26.7%) recorded towards the beginning of May 2020. However, the significant increase in new cases (456) shows that contact tracing began to decline in June 2020, with only eight (1.8%) cases identified in this way. Early contact tracing successes (73.2% of detected cases) could be attributed to better COVID-19 management during the outbreak's early stages in March 2020, where a dedicated team of healthcare practitioners was assigned to track contacts (Moonasar, Pillay, Leonard, Naidoo, Mngemane, Ramkrishna, Jamaloodien, Lebese, Chetty, Bamford, Tanna, Ntuli, Mlisana, Madikizela, Modisenyane, Engelbrecht, Maja, Bongweni, Furumele & Mayet, 2021). However, as the caseload escalated, the district's contact tracing efforts began to decline. The drop could be ascribed to insufficient contact tracer capacity required to trace (Gardner & Kilpatrick, 2021).

Table 4.1: Impact of Contact Tracing (16 March – 30 June 2020)

Month	**Cases**	**Identified Through Contact Tracing**	**Contact Tracing Rate (%)**
March	**71**	**52**	73.2%
April	**37**	**19**	51.4%
May	**75**	**20**	26.7%
June	**456**	**8**	1.8%
Total	639	**99**	15.5%

As evident in Table 4.1, despite the high caseload of 456 in June 2020, only eight cases (1.8%) were traced through contact tracing. The tracing rate was highest in March 2020, at 73.2%. This low tracing rate means that exposed and potentially infected contacts were possibly fuelling the increase in new cases (Althouse, Wenger, Miller, Scarpino, Allard, Hébert-Dufresne & Hu, 2020).

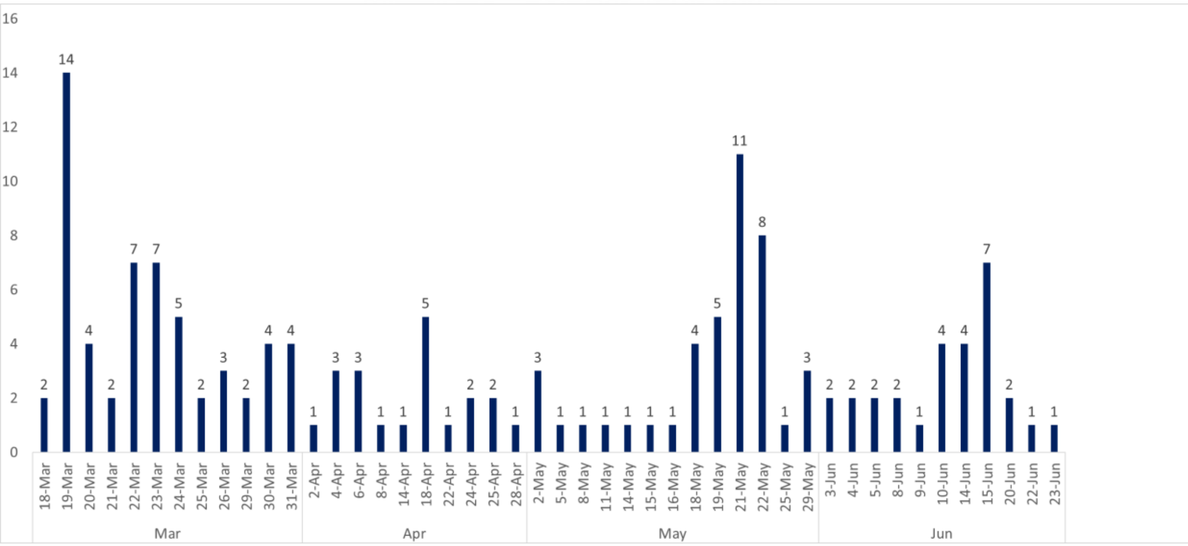

Figure 4.8: Caseload Identified Through Contact Tracing in Mangaung Metro

Most COVID-19 positive contacts were detected in March 2020, as seen in Figure 4.8. In March 2020, 92 cases (51.3%) were recorded, with 18 in April 2020 (10.5%), 41 in May 2020 (22.9%), and 28 in June 2020 (15.6%). Mangaung Metro's prompt activation of its rapid response team, that initiated screening and testing of all contacts of the church conference participants, which resulted in seven positive cases, is credited with the high case finding figure for March 2020.

The initial reproductive number (R_0) in Mangaung Metro, with an estimated period of 19 days from introduction, was 2.07 (95 % CI: 1.69-2.50), with transmission primarily from the seven imported church conference cases. During this period of flight restrictions and school closures, the daily R_0 dropped significantly and remained around 1.5 during stage five lockdown. During stage four lockdown in May 2020, there was a slight increase in R_0, but it quickly returned to around 1.5. Due to the large number of contacts traced in March 2020, screening and testing were expanded to other pastors' congregations to include secondary contacts who were conference attendees.

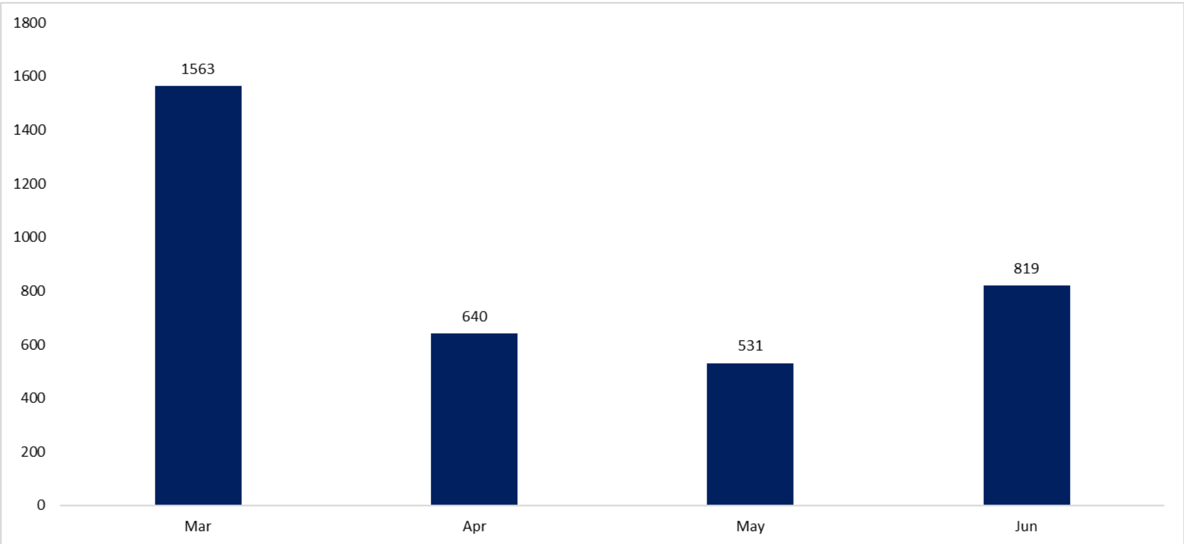

Figure 4.9: Number of Contacts Traced in Mangaung Metro (March 2020 – June 2020)

Figure 4.9 indicates that a total of 3 553 contacts were tracked from March to June 2020. In March 2020, 43% contacts (1 563) were traced, 18% in April, 14.9% in May, and 23% in June of the same year. The high contact tracing figure for March can be attributed to Mangaung Metro's massive expansion aligned to the World Health Organization’s 2020 interim guideline on contact tracing in the context of COVID-19, with the involvement of specialised (professional nurses only) contact tracers, potentially exposed contact lists, and the willingness, cooperation, and details of the contacts offered by the initial index cases (World Health Organization, 2020). As a result of manual contact tracing procedures being used in the early stages of the outbreak, there was an earlier acknowledgement of the number of skilled contact tracers that ought to conduct a detailed case investigation to source complete contacts as more cases were discovered (Braithwaite, Callender, Bullock & Aldridge, 2020).

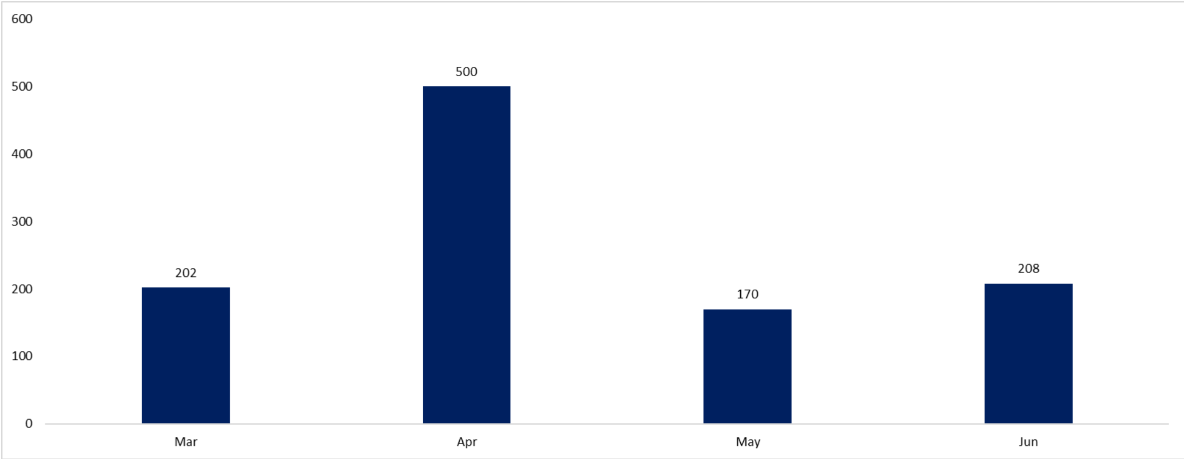

Figure 4.10: Number of Samples Collected from Contacts in Mangaung Metro (March 2020 – June 2020)

Figure 4.10 shows that, from March to June 2020, a total of 1 080 samples were collected. In April 2020, 500 samples were collected, 202 in March, 170 in May, and 208 in June 2020. The increase in samples collected in April coincided with South Africa's strategic response to COVID-19, which included a 10-day large-scale active mass community screening and testing case identification activity across the country from 8 to 18 April 2020. The 10-day active case detection activities were used by Mangaung Metro as part of the integrated contact tracing and surveillance effort for both new case identification and testing of all contacts, including testing of asymptomatic contacts (Baxter, Karim & Abdool Karim, 2020). Given that the outbreak was in its early stages and the country was in lockdown level five, termed "hard lockdown", the 18.7% sample collection in March was compelling (Moonasar et al., 2021).

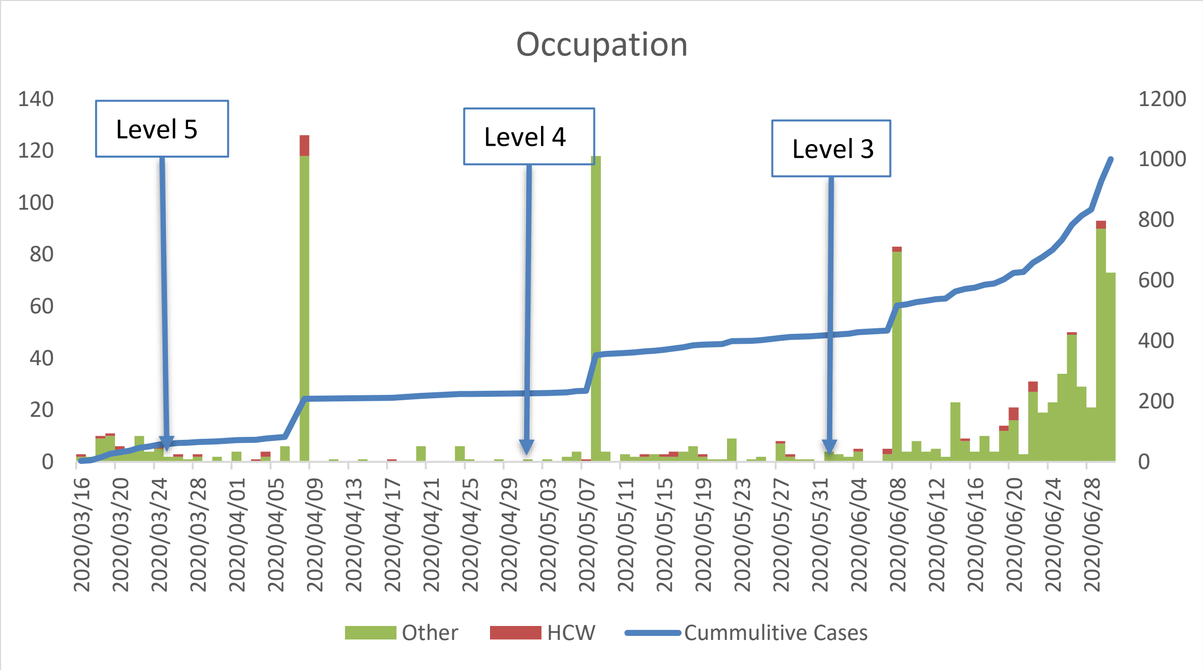

Figure 4.11: Number of Healthcare Workers with Covid-19 in Mangaung Metro (March 2020 – June 2020)

Figure 4.11 indicates a total of 79 healthcare workers infected from March to June 2020. Out of a total of 1 001 observations, this amounts to 7.9% of healthcare worker cases during that period.

CHAPTER FIVE: SUMMARY OF THE STUDY

This chapter discusses the research findings. It includes a summary of the study's findings, limitations, and conclusions.

5.1. INTRODUCTION

The study's summary, as well as key findings and study limitations, are discussed here. The chapter ends with a conclusion and some reflections on the current state of contact tracing on the African continent, as well as on a local level in South Africa, including the impact on Mangaung Metro's contact tracing efforts.

5.2. KEY FINDINGS FROM THE STUDY

Before the COVID-19 pandemic, contact tracing had never been done on such a large scale. Out of an initial seven imported cases in Mangaung Metro in March 2020, 1 563 contacts were traced, and 202 samples were collected in the first two weeks of the COVID-19 outbreak in the area (MMM, 2021). According to evidence from this study related to Mangaung Metro's early outbreak data, contact tracing, when used systematically, can help break infection chains. In addition, more contacts were traced in March 2020 as compared to June 2020; of those traced, more tested positive. It must be noted, however, that the increase in the June caseload could be as a consequence of the inability of Mangaung Metro to timeously track and test the contacts of the index cases when the caseload increased.

Even though the researcher acknowledges that tracking of contacts is an important public health tool in combating COVID-19 in the early phase, data analysis from when the caseload increased in the latent early phase in June 2020 shows that it was difficult for Mangaung Metro to sustain the early gains of tracing 73.2% of cases in March 2020. Another important observation is that March 2020 constituted the largest proportion of contacts who were traced and tested positive for COVID-19, all of which took place during the early phase as compared to 1.8% in June.

The initial reproductive number (R_0) in Mangaung Metro (an estimated period of 19 days from introduction) was 2.07 (95 % CI: 1.69-2.50), with transmission primarily from seven cases that were imported from a group attending a church conference in Bloemfontein.

Mangaung Metro faced challenges in adequately sustaining an established, well-functioning contact-tracing mechanism that could cope with widespread community transmission, specifically due to the insufficient contact tracing capacity. The manual contact-tracing methods implemented in Mangaung Metro proved to be difficult and time-consuming when the caseload reached a certain threshold. When performed appropriately, the investment is worthwhile when compared to the potential costs of full or partial lockdowns that the country experienced in the last 18 months, minimising the implication of productivity loss due to illness, and lessening the burden on the healthcare system.

Contact tracing has been one of the key strategies used by global health authorities to try to disrupt transmission chains and reduce mortality, as prescribed by the World Health Organization (WHO, 2021). Mangaung Metro's COVID-19 contact-tracing infrastructure was constructed on existing healthcare expertise and experience with other infectious diseases; however, as case numbers increased rapidly, additional personnel, who needed to be trained, were required to increase the contact tracing manpower and to ramp up operation.

The currently employed contact tracing methods are being reviewed in South Africa and Africa CDC and other countries in the WHO European Region to broaden the breadth of contact tracing and share the experiences further to develop this important public health response.

5.3. LIMITATIONS OF THE STUDY

The study is not representative of the entire Free State population, it is only focused in Mangaung Metro, and the findings cannot be generalised to other districts in the province. The period under consideration pertains to the early stages of the outbreak when the caseload was still low. The Mangaung Metro data were gathered early in the epidemic and are primarily based on church conference contacts of the international visitors, which might also introduce bias. The study was limited by the fact that it was conducted during lockdown levels three, four, and five, when contact between index cases was limited. In the analysis and estimation of R0, uncertainty was not fully quantified.

5.4. CONCLUSION

The data gathered and analysed through tracing during the early stages of the Mangaung Metro outbreak via contact was critical in comprehending the epidemiology of COVID-19. In the current phase of the epidemic, testing and tracing initiatives have yielded equally important information. Mangaung Metro could have reviewed and determined the required contact tracing ratio and tracer capacity earlier on in the outbreak.

Reviewing and strengthening of contact tracing as a COVID-19 control measure are required, as the virus has mutated. New variants have emerged over the subsequent 18 months of the pandemic, and some have more transmissible variants of concern. For example, the current dominant Omicron variant, which is dominant in 57 countries as of 17 December 2021, has multiple mutations and is more transmissible than previous variants, with the highest reproductive number of 2.5 as compared to the past three resurgences in South Africa. Furthermore, the reduction of lockdown levels from five to three may have contributed to the higher reproductive number.

The study objectives as stated in the first chapter were fully explored. This includes the number of contacts detected from identified confirmed cases during the early stage COVID-19 outbreak in Mangaung Metro, which totalled 3 553, as well as the epidemiological COVID-19 change as a result of contact tracing, where the epidemiological curve of Mangaung Metro grew exponentially as a result of contacts testing positive. The study demonstrated the transmission rate of COVID-19 of contacts during the outbreak. The epidemic's trajectory was investigated, and the findings revealed that more contacts were tracked, tested, and isolated in March 2020 than in June 2020.

Africa CDC advocates for rapid case identification during low case incidences, which appears to have yielded better results in Mangaung Metro during the early stages of the outbreak when incidences were low. South Africa's revised contact tracing guidelines have not abandoned contact tracing entirely, opting instead for a risk-adjusted approach that prioritises those in congregate settings.

The World Health Organization (WHO) has advocated for the development and adoption of digital contact tracing and quarantine in an effort to mitigate the current shortage of and insufficient contact tracer capacity during rapid caseload increases. Mangaung Metro also experienced a surge of cases from May 2020 that resulted in fewer contacts being traced. The digital contact tracing guideline proposed by WHO recommends steps for reviewing, developing, and monitoring legal requirements to ensure their ethically acceptable application. Contact tracing is a critical component of WHO guidelines developed to control COVID-19 spread by interrupting the chains of human-to-human transmission. The key is to successfully incorporate risk communication and community engagement (RCCE) guidelines into contact tracing activities in the context of COVID-19, and to ensure that compliance with contact tracing initiatives is strengthened and effectively implemented. COVID-19 transmission will eventually be halted or stopped, in turn reducing COVID-19-related mortalities, and minimising the significant impact on health systems and the economy (WHO, 2021).

Dr Richard Pebody, the World Health Organization's High-Threat European Pathogen team leader, stated on 10 November 2021 that, as the second year of the COVID-19 pandemic response was being deescalated (ReliefWeb, n.d.). WHO/Europe had been gathering and improving efficiency in contact tracing from countries across the WHO European Region. It intends to document several different approaches based on different factors, such as capabilities, methodology, techniques, community engagement, and culture (WHO, 2021).

The Africa CDC has also revised the continent's strategy on the management of COVID-19 and the strategy for Enhanced COVID-19 Surveillance at the community level in Africa to assist member states with:

a) Rapid detection and isolation of cases during low to moderate incidence phases;
b) Identification of sub-national hotspots where interventions can be targeted; and
c) Reduction of the general spread of SARS-CoV-2 and the implications of COVID-19 on the African continent (Africa CDC, 2021).

Except in cluster outbreaks, self-contained or congregate settings, all contact tracing must be halted immediately, according to the National Department of Health's revised contact tracing, quarantine, and isolation guidelines published in December 2021. The rationale behind this is that the yield of contact case findings was low due to skewed testing and symptomatic people not testing (National Department of Health, 2021). Mangaung Metro will therefore have to align its contact tracing methods with the revised National Department of Health revised protocol on contact tracing, quarantine, and isolation, as the South African Health Ministry provides the framework, response, and strategies for COVID-19 management.

All of these different and recent developments point to the importance of retaining contact tracing as an essential control and mitigation effort in the disruption of the COVID-19 transmission chain, albeit in different ways. Mangaung Metro, as the epicentre of COVID-19 in the province, continued contact tracing efforts, staff was repurposed to determine job functions and to increase the pool of contact tracers across the metro's four local areas, collaboration with other departments was strengthened, risk communication was strengthened, and community engagement was encouraged to increase community acceptance and participation in case investigation and contact tracing despite the changes in guidelines. An intraactive review activity was conducted in Mangaung Metro to evaluate the effectiveness of response actions during the containment and mitigation phases of an outbreak response, and the findings were used to sustain these best practices and the success of these contact tracing in controlling outbreaks that were still occurring.

Europe will conduct case studies on the effectiveness of contact tracing in European countries, as well as expounding on lessons learned over the last two years from contact implementation in those countries.

Finally, the researcher recommends that the clinical guidelines are updated factoring in the gains of early outbreak contact tracing. As it became evident that with this very specific outbreak, public healthcare teams, the healthcare system, and all the required staff must have workable knowledge of contact tracing and its impact, especially when the caseload is low. It is for this reason that a review from a provincial perspective is recommended. The review should include all healthcare systems impacted by the early use of contact tracing so that outbreak management and early outbreak guidelines can be adjusted for this context.

COVID-19 has changed the epidemiology and has altered the path of the pandemic; what scholars knew about epidemiology has been challenged during this pandemic, and questions of how and why diseases spread have loomed large in the struggle to understand, contain, and respond to COVID-19 (Nature, 2021). More research is therefore needed to assess COVID-19 case investigation and contact tracing program models and innovations, as well as strategies for implementing these activities during the containment and mitigation phases.

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ANNEXURE A: DATA COLLECTION INSTRUMENT

NATIONAL INSTITUTE FOR COMMUNICABLE DISEASES
Division of the National Health Laboratory Service

COVID-19 CONTACT LINE LIST

Complete a contact line list for every person under investigation for Coronavirus disease 2019 (COVID-19).

health
Department: Health
REPUBLIC OF SOUTH AFRICA

Details of person under investigation/confirmed COVID-19 case

Details of contacts (*With contact[1] from the date of symptom onset, or during symptomatic illness.)*

	Surname	First name(s)	Sex (M/F)	Age (Y)	Relation to case[2]	Date of last contact with case	Place of last contact with case (Provide name and address)	Residential address (for next month)	Phone number(s), separate by semicolon	HCW[3] or school-going/teacher? (Y/N) *If Yes, facility/school name*
9						DD/MM/YYYY				
10						DD/MM/YYYY				
11						DD/MM/YYYY				
12						DD/MM/YYYY				
13						DD/MM/YYYY				
14						DD/MM/YYYY				
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18						DD/MM/YYYY				
19						DD/MM/YYYY				
20						DD/MM/YYYY				
21						DD/MM/YYYY				

[1] Close contact: A person having had face-to-face contact (≤1 metre) or was in a closed environment with a COVID-19 case; this includes, amongst others, all persons living in the same household as a COVID-19 case and, people working closely in the same environment as a case. A healthcare worker or other person providing direct care for a COVID-19 case, while not wearing recommended personal protective equipment or PPE (e.g., gowns, gloves, NIOSH-certified disposable N95 respirator, eye protection). A contact in an aircraft sitting within two seats (in any direction) of the COVID-19 case, travel companions or persons providing care, and crew members serving in the section of the aircraft where the index case was seated. [2] Chose from: Spouse, Aunt, Child, Class mate, Colleague, Cousin, Father, Friend, Grandfather, Grandmother, Healthcare worker taking care of, Mother, Nephew, Niece, Other relative, Uncle. [3] Healthcare worker.

Page **2** of **2** **Please refer to www.nicd.ac.za for most recent version of this document before use.** Version 9, 18 August 2020

If more space required, continue on second form. Please complete header and staple to first form.

ANNEXURE B: LETTER OF APPROVAL FROM THE UNIVERSITY OF FORT HARE ETHICS COMMITTEE

University of Fort Hare
Together in Excellence

HEALTH RESEARCH ETHICS COMMITTEE

P.O Box 1054
East London 5200
Tel: +27 (0) 43 704 7368
E-mail: dgoon@ufh.ac.za

ETHICAL CLEARANCE CERTIFICATE
REC-100118-054

Certificate Reference Number:	**Ref # 2020=12=03=MonyoboP**
Project title:	**Analysis of early-phase contact tracing during the Coronavirus disease 2019 outbreak in Mangaung Metro, Free State**
Nature of Project	Masters of Public Health
Principal Researcher:	Monyobo P
Student Number:	201928128
Supervisor:	Prof DT Goon

On behalf of the University of Fort Hare Health Research Ethics Committee (HREC), I hereby give ethical approval in respect of the undertakings contained in the above-mentioned project and research instruments(s). Should any other instruments be used, these require separate authorization. The Researcher may therefore commence with the research as from the date of this certificate, using the reference number indicated above.

Please note that the HREC must be informed immediately of

- Any material change in the conditions or undertakings mentioned in the document
- Any material breaches of ethical undertakings or events that impact upon the ethical conduct of the research

The Principal Researcher must report to the HREC in the prescribed format, where applicable, annually, and at the end of the project, in respect of ethical compliance.

@ufh1916 ufh1916 www.ufh.ac.za

University of Fort Hare

HEALTH RESEARCH ETHICS COMMITTEE

P.O Box 1054
East London 5200
Tel: +27 (0) 43 704 7368
E-mail: dgoon@ufh.ac.za

The HREC retains the right to

- Withdraw or amend this Ethical Clearance Certificate if
    - Any unethical principles or practices are revealed or suspected
    - relevant information has been withheld or misrepresented
    - regulatory changes of whatsoever nature so require
    - the conditions contained in the Certificate have not been adhered to

- Request access to any information or data at any time during the course or after completion of the project.
- In addition to the need to comply with the highest level of ethical conduct principal investigators must report back annually as an evaluation and monitoring mechanism on the progress being made by the research. Such a report must be sent to HREC monitoring@ufh.ac.za.

The Ethics Committee wishes you well in your research endeavours.

Yours sincerely

Professor DT Goon
Chairperson: HREC
15 December 2020

ANNEXURE C: LETTER OF APPROVAL FROM FREE STATE DEPARTMENT OF HEALTH

health
Department of Health
FREE STATE PROVINCE

15 February 2021

Ms P Monyobo
Dept. of Public Health
UFH

Dear Ms P Monyobo

Subject: Analysis of early-phase contact tracing during the Coronavirus disease 2019 outbreak in Mangaung Metro, Free State.

- Please ensure that you read the whole document. Permission is hereby granted for the above – mentioned research on the following conditions:
- Participation in the study must be voluntary
- A written consent by each participant must be obtained.
- Serious Adverse events to be reported to the Free State department of health and/ or termination of the study
- Ascertain that your data collection exercise neither interferes with the day to day running of **Motheo District Municipal Offices** nor the performance of duties by the respondents or health care workers.
- Confidentiality of information will be ensured and please do not obtain information regarding the identity of the participants.
- **Research results and a complete report should be made available to the Free State Department of Health on completion of the study (a hard copy plus a soft copy).**
- Progress report must be presented not later than one year after approval of the project to the Ethics Committee of the University of Fort Hare and to Free State Department of Health.
- Any amendments, extension or other modifications to the protocol or investigators must be submitted to the Ethics Committee of the University of Fort Hare and to Free State Department of Health.
- **Conditions stated in your Ethical Approval letter should be adhered to and a final copy of the Ethics Clearance Certificate should be submitted to** sebeelats@fshealth.gov.za / makenamr@fshealth.gov.za **before you commence with the study**
- No financial liability will be placed on the Free State Department of Health
- **Please discuss your study with Institution Manager on commencement for logistical arrangements see 2nd page for contact details.**
- Department of Health to be fully indemnified from any harm that participants and staff experiences in the study
- **As part of feedback you will be required to present your study findings/results at the Free State Provincial health research day**

Trust you find the above in order.

Kind Regards

Dr D Motau
HEAD: HEALTH
Date: 16/02/2021

ANNEXURE D: COPY OF PLAGIARISM DEDICATION

University of Fort Hare
Together in Excellence

I **Priscilla Kesaletseng Monyobo** student number **201928128**
hereby declare that I am fully aware of the University of Fort Hare's policy
on plagiarism and I have taken every precaution to comply with the regulations

Signature:...

ANNEXURE E: EDITING DECLARATION

Proofreading • Proeflees
Text Editing • Teksredigering
Text Layout • Teksuitleg
Translation • Vertaling

HANTA HENNING
0824482726
HENNINGJG@UFS.AC.ZA

DECLARATION: 16 SEPTEMBER 2022

Hereby I, Johanna Gertruida (Hanta) Henning, declare that I completed editing of the research dissertation titled *Analysis Of Early-Phase Contact Tracing During The Coronavirus Disease 2019 Outbreak In Mangaung Metro, Free State* by Monyobo Priscilla Kesaletseng.

Based on the nature of the services performed, the editor cannot be held liable for any of the following:

i. The accuracy of the material contained in the thesis;
ii. The accuracy of material as gathered from sources contained in the thesis;
iii. Any plagiarism that may be present in the thesis;
iv. Any factual errors that may occur in the thesis; and/or
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A full report of the edited document can be provided upon request.

Henning

henningjg@ufs.ac.za
082 448 2726

ANNEXURE F: TURNITIN RECEIPT AND SIMILARITY REPORT

turnitin

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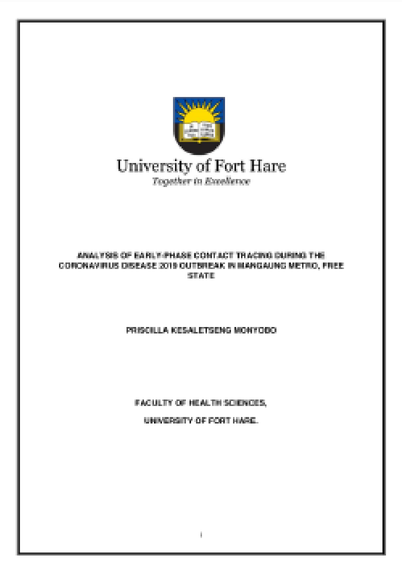

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ANALYSIS OF EARLY-PHASE CONTACT TRACING DURING THE CORONAVIRUS DISEASE 2019 OUTBREAK IN MANGAUNG METRO, FREE STATE

PRISCILLA KESALETSENG MONYOBO

FACULTY OF HEALTH SCIENCES,
UNIVERSITY OF FORT HARE.

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