VACCINATION STATUS, ANTI-SARS-COV-2 IGM AND IGG SEROPREVALENCE, AND FACTORS INFLUENCING VACCINATION INTENTIONS OF PARTICIPANTS FROM KENYATTA UNIVERSITY COMMUNITY IN NAIROBI CITY COUNTY, KENYA

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DECLARATION

This thesis is my original work and has not been presented for a degree or any other award in any other university.

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TABLE OF CONTENTS

DECLARATION ii
TABLE OF CONTENTS iii
LIST OF TABLES vi
LIST OF FIGURES vii
ABBREVIATIONS AND ACRONYMS viii
OPERATIONAL DEFINITION OF TERMS ix
ABSTRACT xi
CHAPTER ONE: INTRODUCTION 1
1.1 Background of the Study 1
1.2 Statement of the Problem 5
1.3 Justification 6
1.4 Research Questions 7
1.5 Research Objectives 8
1.5.1 General Objective 8
1.5.2 Specific Objectives 8
1.6 Significance and Output of the Research 9
CHAPTER TWO: LITERATURE REVIEW 10
2.1 Epidemiology and History of SARS-CoV 2 12
2.1.1 Global 12
2.1.2 Africa 13
2.1.3 Kenya 13
2.2 SARS-CoV-2 Disease Pathogenesis, Symptoms, and Treatment 14
2.3 SARS-CoV-2 Immunology and Serology 17
2.4 SARS-CoV-2 Vaccines and Coverage 20
2.5 Natural and Vaccine-induced Responses to SARS-CoV-2: Antibody Kinetics and their Utility 23
2.6 Summary of Gaps Identified in the Literature 26
CHAPTER THREE: MATERIALS AND METHODS 28
3.1 Study Area 28
3.2 Study Design 28
3.3 Study Variables 28
3.3.1 Independent Variables 28

3.3.2 Dependent Variable 29
3.4 Study Population 29
3.4.1 Inclusion Criteria 29
3.4.2 Exclusion Criteria 29
3.5 Sample Size Determination 29
3.6 Sampling Technique 31
3.7 Research Questionnaire 31
3.7.1 Pre-testing of Questionnaire 31
3.7.2 Validity of Research Questionnaire 32
3.7.3 Reliability of Research Questionnaire 32
3.8 Laboratory procedures 32
3.8.1 Sample Collection, Preparation, and Storage 32
3.8.2 Sample Testing; ELISA testing for Anti-SARS-CoV-2 IgM and IgG 33
3.9 Data Analysis 33
3.10 Ethical Considerations 35
CHAPTER FOUR: RESULTS 36
4.1 Demographic Characteristics of the Study Participants 36
4.2 Anti-SARS-CoV-2 IgM Seroprevalence 37
4.2.1 SARS-CoV-2 Positivity Rates Among Participants by Gender 39
4.3 Anti-SARS-CoV-2 IgG Seroprevalence 40
4.4 Comparison of Anti-SARS-Cov-2 IgM Titers among Study Participants at Kenyatta University 42
4.5 Anti-SARS-Cov-2 IgM Variations among Vaccinated Study Participants at Kenyatta University 43
4.6 Comparison of Anti-SARS-Cov-2 IgG Titers in a Study Cohort Drawn from Kenyatta University 44
4.7 Variations in Anti-SARS-Cov-2 IgG Titers among Vaccinated Study Participants from Kenyatta University 45
4.8 Vaccination Status of Study Participants 46
4.8.1 Comparative Analysis of Anti-SARS-Cov-2 IgM and IgG Titers among Vaccinated Participants Based on Vaccine Type 47
4.8.2 Persistence of Anti-SARS-Cov-2 (Immunoglobin G) among study participants post Vaccination 48
4.8.3 Factors Contributing to SARS-CoV-2 Vaccine Hesitancy Among Study Participants 49

CHAPTER FIVE: DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS52

5.1 Discussion 52

5.1.1 The prevalence of anti-SARS-CoV-2 IgM and IgG levels.....52

5.1.2 Comparative Analysis of Anti-SARS-CoV-2 Antibody Levels: Vaccination vs. Natural Infection.....54

5.1.3 Participants' Vaccination Status and Factors Influencing Vaccination Decisions 56

5.2 Study Limitations 59

5.3 Conclusions 60

5.4 Recommendations 61

5.4.1 Recommendation for further research 62

REFERENCES.....64

APPENDICES.....75

Appendix I: Informed Consent Form 75

Appendix II: Time Schedule of the Proposed Masters Project.....77

Appendix III: Budget 78

Appendix IV: Questionnaire.....79

Appendix V: NACOSTI (National Commission for Science Technology and Innovation) Research Permit 84

Appendix VI: Ethical Approval (Kenyatta University Ethics Review Committee).....86

Appendix VII: Renewal of Ethical Approval (Kenyatta University Ethics Review Committee).....88

LIST OF TABLES

Table 4.1: Socio-demographic Attributes of Study Participants from Kenyatta University (Gender, Age Group, Vaccination Status, Level of Education, and Current Occupation) 37
Table 4.2: Anti-SARS-CoV-2 IgM Seroprevalence in A Study Population Drawn from Kenyatta University Categorized by Gender, Age Group, Vaccination Status, Level of Education, and Current Occupation 38
Table 4.3: Anti-SARS-CoV-2 IgG Seroprevalence in a Study Cohort Drawn from Kenyatta University, Categorized by Gender, Age Group, Vaccination Status, Level of Education, and Current Occupation 41
Table 4.4: Comparison of Anti-SARS-CoV-2 IgM Seroprevalence in a Study Cohort Drawn from Kenyatta University by Gender, Age Group, Vaccination Status, Level of Education, and Current Occupation 42
Table 4.5: Variations in Anti-SARS-CoV-2 IgM Titers Among Vaccinated Study Participants from Kenyatta University, Analyzed By Gender, Age Group, Booster Dose Receipt, and Occupation 43
Table 4.6: Comparative Analysis of Anti-SARS-CoV-2 IgG Seroprevalence in a Study Cohort Drawn from Kenyatta University by Gender, Age Group, Vaccination Status, Level of Education, and Current Occupation 44
Table 4.5: Comparison of Anti-SARS-CoV-2 IgG Seroprevalence Among Vaccinated Study Participants from Kenyatta University Based on Gender, Age Group, Booster Dose Receipt, and Occupation 45
Table 4.6: Summary of Vaccination Status, Vaccine Type Administered, Booster Dose Receipt, and Incidence of Breakthrough Infections in a Study Population Drawn from Kenyatta University 46
Table 4.7: Comparative Analysis of IgM Seroprevalence in a Study Population from Kenyatta University by Vaccine Type Administered (Moderna, AstraZeneca, Pfizer, Johnson & Johnson) 47
Table 4.8: Post-Vaccination Persistence of Anti-SARS-CoV-2 IgG Among Study Participants Drawn from Kenyatta University, Analyzed by Time Since Vaccination (0 to 6 Months, 7 to 12 Months, 13 Months and Over)....48
Table 4.9: Summary of Study Participants' Reasons for Opting Out of Vaccination, Analyzed According to the 3Cs Model: Themes of Confidence, Convenience, and Complacency....51

LIST OF FIGURES

Figure 4.1: SARS-CoV-2 Antigen Positivity Among the 65 of 189 Study Participants from Kenyatta University Who Agreed to Undergo COVID-19 Testing 39
Figure 4.2: COVID-19 Positivity Rates in a Study Population Drawn from Kenyatta University Based on Self-Reported Questionnaire Data 40
Figure 4.3: A box plot illustrating temporal changes in IgG levels following vaccination in a study population Drawn from Kenyatta University, with levels peaking within 0-6 months post-vaccination and showing a gradual decline over time thereafter.....49

ABBREVIATIONS AND ACRONYMS

ACE2	Angiotensin-Converting Enzyme 2
ARDS	Acute Respiratory Distress Syndrome
CI:	Cardiac index
CLIA	Chemiluminescent Immunoassays
COVID-19:	Corona Virus Disease
ELISA:	Enzyme-Linked Immunosorbent Assay
IDVI	Infectious Disease Vulnerability Index
IgA:	Immunoglobulin A
IgG:	Immunoglobulin G
IgM:	Immunoglobulin M
LFIA	Lateral Flow Immunoassays
N:	Nucleocapsid
NACOSTI:	National Commission for Science Technology and Innovation
RBD:	Receptor-Binding Domain
RNA	Ribonucleic Acid
SPSS:	Statistical Package for Social Sciences
TMPRSS2	Transmembrane Protease Serine 2
US:	United States
WHO:	World Health Organization

OPERATIONAL DEFINITION OF TERMS

Anti-sars-cov-2 antibody: These are virus-specific immunoglobulins produced by the body's immune system when it encounters the SARS-CoV-2 virus, the etiological agent of COVID-19. Secreted by B-cells, these antibodies have high neutralizing capacity and are, therefore, key players in the immune system's response toward COVID-19. Their presence indicates prior infection or a response to vaccination, making them critical to understanding individual and population-level immunity.

COVID-19: COVID-19, shorthand for Coronavirus Disease 2019, is a respiratory illness triggered by the SARS-CoV-2 virus. It is characterized by high transmissibility and variability in clinical severity, ranging from asymptomatic cases to severe pneumonia and death. The disease rapidly escalated to a global pandemic following its discovery in 2019, reshaping public health priorities and significantly disrupting economies and societies worldwide.

Prevalence: Prevalence quantifies the proportion of persons in a specific population or location who have a particular disease at a given time. In the context of this research, it denotes the extent of SARS-CoV-2 exposure or immunity, as indicated by SARS-CoV-2 antibody titers, within the study population. Prevalence is a key epidemiological metric, usually presented as a percentage or ratio, and is crucial for gauging the spread and public health impact of COVID-19.

Vaccine: A biological preparation designed to stimulate an immune response against a particular infectious agent, allowing the immune system to recognize and response to the agent upon future exposure. It typically contains antigens derived from a pathogen—such as a live attenuated, inactivated, or

subunit form of the virus or bacterium—or a synthetic construct such as mRNA. Vaccine administration primes the immune system to recognize and combat the pathogen upon future exposure.

Vaccination: Vaccination refers to the clinical process of administering a vaccine to induce immunity. Vaccination in the case of COVID-19 refers to administration of SARS-CoV-2 vaccines, which trigger immune protective mechanisms against COVID-19, slowing disease progression upon reinfection and curbing transmission within communities.

ABSTRACT

The Coronavirus Disease 2019 (COVID-19) pandemic catalyzed unprecedented global public-health action and vaccine innovation to control the spread of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). Despite broad vaccine availability, inequities in distribution and variable immune responses continue to impede global containment, particularly in developing countries such as Kenya. This cross-sectional study employed a purposive sampling approach to examine the relationship between vaccination status and the seroprevalence of anti-SARS-CoV-2 IgM and IgG antibodies among 189 participants aged ≥ 18 years within the Kenyatta University community. Demographic, clinical, and vaccination data were obtained using a structured questionnaire, and serum antibody levels were quantified through Sandwich ELISA. Statistical analyses included the Mann–Whitney U, Kruskal–Wallis H tests at a 95 % confidence level. Vaccinated participants demonstrated significantly higher median IgG titers than unvaccinated individuals ($U = 2817.5$, $p < 0.001$, 95 % CI [1580–3020]), confirming more robust vaccine-induced humoral responses. Conversely, IgG levels declined progressively with increasing time since the last vaccination ($H = 12.359$, $p = 0.002$), indicating antibody waning. IgM titers showed no significant variation by vaccination status ($U = 4172$, $p = 0.564$). Vaccine uptake remained suboptimal, with 43.4 % (82/189) unvaccinated. Among these, 22.4 % cited mistrust in vaccine efficacy under the World Health Organization's (WHO) 3C Model "confidence" domain as the main driver of hesitancy. The findings affirm that vaccination elicits markedly higher and more durable antibody response than natural infection but highlight the need for booster programs to sustain immunity. To bridge hesitancy-related gaps, the study recommends targeted community engagement, transparent risk-communication strategies, and integration of routine serosurveillance to inform adaptive immunization policies. These data provide critical empirical evidence for optimizing Kenya's post-pandemic vaccination strategies and enhancing population-level protection against SARS-CoV-2.

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

The COVID-19 pandemic has presented unique challenges to public health infrastructures around the world (World Health Organization, 2020). SARS-CoV-2, the etiological agent responsible for COVID-19, is characterized by exceptional transmissibility and pathogenicity (Hu *et al.*, 2021), and rapidly proliferated around the globe following its discovery in late 2019, leading the World Health Organization to formally declare COVID-19 a pandemic barely a year later (World Health Organization, 2020b). The virus has since led to widespread morbidity and mortality (World Health Organization, 2023), in addition to precipitating profound socioeconomic and public health disruptions (World Bank, 2022).

In response to recurrent infection waves and the emergence of viral variants, national governments have prioritized the enhancement of population-level immunity through comprehensive vaccination initiatives, as the WHO advocates. As of August 6, 2021, nearly 296 vaccine candidates were under development, with 63% (184) still in preclinical stages (Kantarcioglu *et al.*, 2022). Of these, approximately 112 had advanced to clinical trials, with six receiving emergency use authorization: Pfizer-BioNTech, Moderna, Johnson & Johnson, AstraZeneca, Novavax, and Sinovac. As of early 2024, an estimated 70.6% of the world's population had obtained at least one dose of a COVID-19 vaccine, contributing to a global administration of 13.5 billion doses. (Khatiwada *et al*. 2024). This was a considerable feat despite the challenges of misinformation, logistical hurdles in different regions, and vaccine hesitancy.

Despite robust vaccine development and distribution efforts, spatial disparities in vaccine uptake have emerged, posing a formidable barrier to comprehensive vaccine coverage across the globe. A comprehensive analysis of COVID-19 vaccination data from 237 countries and territories up to March 5, 2022, revealed glaring regional disparities in vaccination coverage (Kim & Ahmad, 2022). The Eastern Mediterranean region exhibited the highest coverage rates, followed by Europe, the Americas, the Western Pacific, South-East Asia, and Africa, in descending order.

Contemporary research indicates that income level functions as a critical mediator in the observed spatial disparities in vaccine coverage, with high-income nations progressively approaching vaccine equity at a significantly faster rate than their low-income counterparts. For instance, according Centres for Disease Control (CDC), approximately 270 million Americans, representing about 81% of the population, had obtained at least one dose of a COVID-19 vaccine, with 70% achieving full vaccination status by May 2023. Moreover, A study by Jones *et al.* (2021) revealed that 68.4% of U.S. residents aged 16 and older exhibited detectable levels of SARS-CoV-2 antibodies, attributable to either vaccination, prior infection, or both. Specifically, 47.5% were vaccinated without prior infection, 12.0% had contracted the virus without vaccination, and 8.9% exhibited antibodies from both vaccination and natural infection.

Per the WHO, China had administered approximately 3.5 billion doses of COVID-19 vaccines by March 2023, constituting one of the most expansive immunisation campaigns globally. This initiative achieved near-universal coverage, with 91% of the national

population receiving at least one dose and roughly 85% completing the full vaccination regimen. Additionally, booster dose administration became a focal point of China's vaccination strategy, with over 1.2 billion booster doses administered and 57% of the national population obtaining at least one booster by March 2023.

In contrast, vaccination rates in Africa remain considerably lower, with only 16% of eligible persons fully vaccinated and a mere 1.3% having been administered a booster dose. Contributing factors to lower vaccination rates in Africa include limited vaccine supply, logistical challenges, and vaccine hesitancy (Adedeji-Adenola *et al.* 2022). Nevertheless, actual vaccination coverage varies by country, with some making significant progress while others face challenges in distribution and administration.

Kenya, in particular, has faced substantial challenges since the inception of its COVID-19 vaccination campaign in March 2021. The initial phase of this program targeted frontline healthcare workers, essential service providers, and security personnel (World Health Organization [WHO], 2022). The vaccination effort was subsequently expanded to a nationwide campaign in November 2021, aiming to reach 35.5 million individuals aged 15 years and older (Ministry of Health [MOH], 2021). By March 2022, significant progress had been made in increasing vaccine availability, with more than 18 million individuals receiving at least one dose of a COVID-19 vaccine. (Ministry of Health [MOH], 2022). However, despite improved vaccine accessibility, only 21% of the population had completed their vaccination regimen by December 2023, per the WHO.

Vaccine hesitancy has posed a formidable barrier to achieving widespread vaccination coverage in Kenya. A systematic review by Azanaw *et al.* (2023), encompassing 13 African nations, including Kenya, reported an average vaccine acceptance rate of 55.04%. Similarly, a study conducted in February 2021 across four Kenyan counties found that vaccine hesitancy was prevalent, with 36.5% of respondents expressing reluctance. Hesitancy was linked to factors such as rural residence, scepticism regarding vaccine safety and efficacy, challenges in adhering to governmental COVID-19 prevention measures, and entrenched religious and cultural beliefs (Orangi *et al*., 2021). Vaccine hesitancy within close-knit communities poses a significant challenge to COVID-19 control and prevention. As such, assessing the determinants of vaccine hesitancy at the community level is critical to mitigating spatial disparities in vaccine uptake.

Vaccination remains integral to curbing SARS-CoV-2 transmission and mitigating COVID-19-related morbidity and mortality. Early research following the initial outbreak of SARS-CoV-2 in November 2020 indicated that over 34% of the global population had developed immunity within eight months, suggesting that herd immunity could potentially be achieved by the end of 2021 (Ngere *et al.,* 2022). However, there exists a significant gap in the literature regarding SARS-CoV-2 antibody seroprevalence, particularly at the granular, community level. This deficit hinders accurate assessment of whether herd immunity thresholds have been attained, thereby complicating the evaluation of the overall immunity status within specific populations.

Population-based serosurveillance is critical to comprehensively understanding the formation and distribution of immunity to COVID-19 within a community. Serosurveillance studies can aid in evaluating the effectiveness of vaccine-induced immunity, monitoring the temporal persistence of antibodies, and assessing the impact of viral variants on immune protection. While several studies have investigated anti-SARS-CoV-2 seroprevalence in Kenya, many have relied on convenience sampling from specific demographic groups—such as truck drivers, blood donors, healthcare workers, and antenatal clinic attendees—rather than employing population-based methodologies (Etyang *et al.*, 2022; Kagucia et al., 2023; Uyoga *et al*., 2020). Furthermore, research into the post-vaccination persistence of SARS-CoV-2 antibodies and comparative analyses of antibody titers between vaccinated and unvaccinated individuals remain scarce. To fully elucidate SARS-CoV-2 antibody seroprevalence and the long-term impact of vaccination efforts in Kenya, rigorous, population-based serosurveillance studies are imperative.

1.2 Statement of the Problem

Vaccination remains the cornerstone of the Coronavirus Disease 2019 (COVID-19) mitigation strategy, offering both individual and population-level protection against Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). However, recent studies have revealed significant variability in vaccine-induced antibody responses and their temporal persistence across populations (Uyoga *et al.*, 2022; Kagucia *et al.*, 2023). In Kenya, while vaccination campaigns have expanded since 2021, evidence on the seroprevalence and durability of anti-SARS-CoV-2 IgM and IgG antibodies in the general population remains limited. Most serological studies to date have focused on

specific groups such as healthcare workers, blood donors, or antenatal clinic attendees (Etyang *et al.*, 2022; Uyoga *et al.*, 2020), leaving a critical gap in understanding immunity dynamics within diverse community populations.

Moreover, despite ongoing national vaccination efforts, Kenya continues to experience suboptimal vaccine uptake, with only 21% of the population fully vaccinated by December 2023 (World Health Organization, 2023), partly due to vaccine hesitancy driven by mistrust, misinformation, and cultural perceptions (Orangi *et al.*, 2021; Azanaw *et al.*, 2023). These challenges underscore the need for context-specific evidence to guide responsive health communication and policy interventions.

The Kenyatta University community, characterised by socio-demographic diversity and high interpersonal interaction, provides a representative microcosm for assessing both serological responses and behavioural determinants of vaccine uptake. Investigating these parameters will bridge a crucial knowledge gap in Kenya's post-vaccination landscape, informing targeted strategies to strengthen population immunity and mitigate future COVID-19 waves.

1.3 Justification

Understanding the seroprevalence and persistence of anti-SARS-CoV-2 antibodies is vital for guiding Kenya's evolving COVID-19 control strategies. While vaccination remains the cornerstone of pandemic mitigation, the magnitude and durability of immune protection vary widely between individuals and across populations. Generating localized

serological evidence will therefore help determine the effectiveness of current vaccination programs and inform the need for booster campaigns.

This study responds to a clear knowledge gap: the absence of population-based serological data within Kenyan university settings, where individuals of diverse backgrounds interact closely and can influence wider community transmission dynamics. By examining IgM and IgG antibody profiles in relation to vaccination status and sociodemographic variables, the research will provide empirical evidence on both vaccine-induced and infection-acquired immunity among young adults and staff.

Furthermore, by exploring the socio-behavioural determinants of vaccine hesitancy, the study addresses a major impediment to achieving optimal coverage. Insights from the Kenyatta University community will support the design of targeted communication and engagement strategies that strengthen public trust and enhance uptake.

Ultimately, this work contributes to Kenya's public-health evidence base by linking immunological data with behavioral dynamics, thereby supporting evidence-driven policy formulation, equitable vaccine delivery, and sustained population-level protection against future SARS-CoV-2 outbreaks.

1.4 Research Questions

1. What is the prevalence of anti-SARS-CoV-2 IgM and IgG among participants within the Kenyatta University community?

2. How do the levels of anti-SARS-CoV-2 IgG and IgM titers differ between vaccinated, unvaccinated, and previously infected individuals within the Kenyatta University community?
3. What is the current vaccination status within the Kenyatta University community and what factors influence their vaccination intentions?

1.5 Research Objectives

This section delineates the general and specific objectives that guided the conduct of this study.

1.5.1 General Objective

To assess vaccination status, anti-SARS-CoV-2 seroprevalence and factors influencing vaccination intentions among individuals within the Kenyatta University community located in Nairobi City County, Kenya.

1.5.2 Specific Objectives

1. To evaluate the prevalence of anti-SARS-CoV-2 IgM and IgG seroprevalence among participants from the Kenyatta University community.
2. To analyze the differences in anti-SARS-CoV-2 antibody responses between vaccinated, unvaccinated, and previously infected individuals within the Kenyatta University community.
3. To determine the vaccination status and identify factors influencing vaccination intentions among individuals within the Kenyatta University community.

1.6 Significance and Output of the Research

This research delivers critical, community-level insights directly applicable to public health strategy in Kenya. By mapping the immune landscape within the Kenyatta University community, the findings provide a data-driven blueprint for action. They directly inform decisions on the necessity and timing of booster vaccinations and the design of targeted campaigns to curb COVID-19 transmission.

A core contribution of this study is its direct comparison of immunity from vaccination versus natural infection, offering an evidence-based assessment of vaccine efficacy within a real-world population. Furthermore, by tracking how antibody levels change over time, the research sheds light on the durability of vaccine-induced protection, a crucial factor for sustainable long-term public health planning.

Crucially, this study moves beyond immunology to confront the human factor behind low vaccine coverage: hesitancy. By identifying the specific reasons for vaccine refusal, from mistrust and misinformation to access issues, the findings enable the development of culturally sensitive and targeted public health communication. This empowers health officials to craft messages that resonate, thereby increasing vaccine uptake not just within the university, but as a model for similar communities across Kenya and beyond. Ultimately, this work strengthens the overall resilience of public health systems against future pandemic threats.

CHAPTER TWO: LITERATURE REVIEW

A member of the Coronaviridae family, SARS-CoV-2, derives its nomenclature from the Latin term "corona," owing to its distinct morphology. The spike glycoproteins embedded in its lipid envelope form a crown-like structure, a hallmark of coronaviruses. Since its emergence in late 2019, the virus has undergone significant genomic evolution, driven by the accumulation of mutations during viral replication.

These genetic changes, often arising from replication errors or recombination events, have led to the formation of distinct viral lineages and variants (CDC, 2023). Among these, variants such as Alpha, Beta, Gamma, Delta, and Omicron have garnered global attention due to their heightened transmissibility, immune evasion capabilities, and variable pathogenicity. The SARS-CoV-2 Interagency Group (SIG) has established a systematic classification of these variants, organizing them into categories including variants being monitored (VBM), variants of concern (VOC), variants of high consequence (VOHC), and variants of interest (VOI). This taxonomical framework underpins the global effort to rapidly identify and characterize novel variants, particularly with regard to their potential impact on the efficacy of vaccines, therapeutic agents, and diagnostic tools.

The Alpha variant (B.1.1.7), first identified in the United Kingdom, exhibited exceptional transmissibility, enabling it to rapidly become the dominant strain across several geographic regions (Krause *et al*., 2021). Similarly, the Gamma variant (P.1), initially detected in Brazil, was associated with more severe clinical outcomes, even in individuals

previously infected with other strains. The Delta variant (B.1.617.2) further intensified global concerns due to its enhanced transmissibility and partial evasion of neutralizing antibodies generated by both natural infection and vaccination (Wintersdorff *et al.*, 2022). A thorough characterization of the virological, immunological, and epidemiological features of these variants is imperative for the formulation of effective public health strategies, as well as for the refinement of vaccination and therapeutic protocols.

Accurate laboratory detection of SARS-CoV-2 remains foundational to the containment and management of COVID-19. Diagnostic methodologies for SARS-CoV-2 can be broadly categorized into molecular and serological assays. The gold standard for molecular detection is real-time reverse transcriptase-polymerase chain reaction (RT-PCR), which facilitates the amplification and quantification of viral RNA from clinical specimens such as nasopharyngeal or oropharyngeal swabs. RT-PCR offers unparalleled sensitivity and specificity, making it indispensable for early diagnosis and effective containment of SARS-CoV-2 (Zhang et al., 2021). In addition, serological assays such as enzyme-linked immunosorbent assays (ELISA) are employed to detect SARS-CoV-2-specific antibodies, including immunoglobulin M (IgM) and immunoglobulin G (IgG). These serological tests have proven indispensable in assessing individual immune status and conducting population-level seroprevalence studies. However, they remain suboptimal for early-stage diagnosis due to the temporal delay in antibody production post-infection (Alpdagtas *et al.*, 2020; Zhang *et al.*, 2021). A comprehensive understanding of available diagnostic tools, including their respective strengths and

limitations, is essential for the effective management of the pandemic and the surveillance of emerging variants.

2.1 Epidemiology and History of SARS-CoV 2

This section delineates the epidemiology of SARS-CoV-2 globally as well as in Africa and Kenya

2.1.1 Global

In late 2019, a cluster of pneumonia cases with an unidentified cause emerged in Wuhan, located in China's Hubei Province. an outbreak of atypical pneumonia of unknown etiology was reported in Wuhan, Hubei Province, China. Initial epidemiological investigations linked the outbreak to the Huanan Seafood Wholesale Market, a site known for the trade of live wild animals and aquatic species (Chowdhury & Oommen, 2020). Subsequent investigation revealed the presence of a previously unidentified betacoronavirus in the respiratory tract samples of these patients, detected through unbiased next-generation sequencing. This virus, provisionally named 2019 novel Coronavirus (2019-nCoV) by the World Health Organization (WHO), was subsequently renamed SARS-CoV-2 after phylogenetic analysis revealed its close relation to the SARS coronavirus identified in 2003.

SARS-CoV-2 has since catalyzed a global pandemic of COVID-19, resulting in over 770,085,713 individual infections and 6,956,173 deaths worldwide by August 2023, per the World Health Organization (WHO). The geographic distribution of cases has been

highly heterogeneous, with Europe reporting 275,912,918 cases, followed by the Western Pacific (206,823,836), the Americas (193,210,684), South-East Asia (61,201,773), the Eastern Mediterranean (23,388,656), and Africa (9,547,082) (WHO,2023).

2.1.2 Africa

Africa's experience with the COVID-19 pandemic has been markedly different from other regions, characterized by relatively lower reported case numbers and mortality rates. The Africa Centres for Disease Control and Prevention reported 12,216,748 COVID-19 cases and 256,542 fatalities across the continent as of August 2023(Africa CDC, 2023). The epidemiological dynamics of COVID-19 in Africa have been shaped by several factors, including the limited capacity for large-scale testing, disparities in healthcare infrastructure, and varying public health responses across countries. A systematic review and meta-analysis conducted by Tadesse *et al*. (2020) underscored the dearth of robust data on the burden of COVID-19 in Africa, particularly with regard to hospitalization rates and clinical outcomes, highlighting the need for enhanced surveillance and research to inform targeted public health interventions.

2.1.3 Kenya

COVID-19 has had overwhelming impacts on the Kenyan public health system. Between January 3, 2020, and August 30, 2023, the WHO reported 343,955 confirmed cases and 5,689 deaths in Kenya. The country had administered 23,750,431 vaccine doses by April 1, 2023 (WHO, 2023).

Early in the pandemic, Kenya was identified as a high-risk country for COVID-19 importation due to its low Infectious Disease Vulnerability Index (IDVI) and fragile healthcare infrastructure (Macharia *et al,* 2020). A study by Ojal *et al*. (2020) revealed that the true prevalence of COVID-19 in Kenya might have been vastly underestimated, citing limitations in PCR testing availability and reporting accuracy. He approximated that as of September 30th, the real prevalence of SARS-CoV-2 among the population was 43.3% (CI 35.3%-49.5%) in Nairobi and 37.6% (CI 29.2%-45.7%) in Mombasa. These findings highlight the need for improved testing and data collection to accurately assess the burden of COVID-19 in Kenya and guide public health responses. These findings underscore the necessity for strengthening diagnostic and epidemiological surveillance systems to more accurately gauge the pandemic's impact and to guide appropriate public health responses.

2.2 SARS-CoV-2 Disease Pathogenesis, Symptoms, and Treatment

SARS-CoV-2, like other members of the *Coronaviridae* family, is an enveloped virus with a positive-sense, single-stranded RNA genome. The spike (S) protein is central to the virus's pathogenicity, facilitating host cell entry through binding to the angiotensin-converting enzyme 2 (ACE2) receptor, which is widely expressed in epithelial cells of the respiratory tract. The main types of cells infected include type II alveolar epithelial cells and ciliated epithelial cells (Shuai *et al*., 2020; Nardacci *et al*., 2020). The infection process begins with the virus binding to specific receptors on the surface of cells, predominantly the angiotensin-converting enzyme 2 (ACE2) receptor, which serves as the primary entry point for the virus (Hui *et al.*, 2020; Cao *et al*., 2021). Additionally, the

transmembrane protease serine 2 (TMPRSS2) is essential for helping SARS-CoV-2 enter host cells by preparing the spike glycoprotein, which allows it to fuse with the host cell membrane (Chu et al., 2020; Katzman *et al*., 2021). The process of cell entry for SARS-CoV-2 involves both receptor-mediated endocytosis and direct membrane fusion. Research has indicated that the virus can enter cells through clathrin-mediated endocytosis, which is a common pathway for viral entry (Bayati *et al*., 2021; Shang *et al*., 2020). Once inside the cell, SARS-CoV-2 can avoid the innate immune response, leading to a higher degree of viral replication compared to its predecessor, SARS-CoV (Chu *et al.*, 2020; Lokugamage *et al.*, 2020). This evasion is partly due to the virus's ability to suppress the production of type I and III interferons, which are crucial components of the host's antiviral response (Yin *et al.,* 2021; Loske *et al*., 2021). The immune response to SARS-CoV-2 infection creates localized immunological memory in the lungs and associated lymph nodes, essential for long-term protection against reinfection. SARS-CoV-2 primarily infects respiratory tract epithelial cells through the ACE2 receptor and TMPRSS2 protease, evading the innate immune response and leading to significant viral replication. (Poon *et al*., 2021).

SARS-CoV-2 is primarily transmitted via respiratory droplets and aerosols, although fomite transmission has also been documented. Animal models, particularly Syrian hamsters, have demonstrated efficient viral transmission through respiratory routes, providing critical insights into the mechanisms of viral spread (Boon et al., 2022). Bats are widely considered the natural reservoir for SARS-CoV-2, given their unique immune

systems that allow them to harbor a wide range of coronaviruses without succumbing to disease, thus serving as a potential source for zoonotic spillover events (Li *et al*., 2005).

The clinical manifestations of COVID-19 are heterogeneous, ranging from asymptomatic infections to severe pneumonia, acute respiratory distress syndrome (ARDS), multi-organ failure, and death (Carignan *et al*., 2020). Mild cases often present with symptoms such as fever, cough, fatigue, myalgia, anosmia, and dysgeusia. Loss of taste and smell, in particular, present early in the course of infection and are hallmark diagnostic features of SARS-CoV-2 infection, even in the absence of other respiratory symptoms, making them valuable for identifying and isolating asymptomatic carriers who may unknowingly spread the virus (Keck et al., 2022).

Severe cases are more likely to occur in older adults and those with underlying comorbidities such as cardiovascular disease, diabetes, or obesity. The post-acute sequelae of SARS-CoV-2 infection, colloquially referred to as "long COVID," has been observed in some cases, with persistent symptoms including cognitive dysfunction, fatigue, and pulmonary complications lasting for months after recovery, particularly in patients who required intensive care (Heesakkers et al., 2022). Children, although less likely to develop severe disease, can still act as carriers and may suffer from long-term symptoms (Milani et al., 2021).

The control of SARS-CoV-2 transmission has relied heavily on a combination of non-pharmaceutical interventions (NPIs) in addition to vaccination efforts. These NPIs have

included measures such as social distancing, mask mandates, travel restrictions, and lockdowns, which have been crucial in mitigating the spread of the virus, particularly during the early stages of the pandemic when vaccines were not yet available (Zhang, 2023; Moore et al., 2021; Wambua et al., 2022; Perra, 2021). The effectiveness of these interventions has been demonstrated through various modeling studies, which indicate that stringent NPIs can significantly reduce the reproductive number of the virus, thereby lowering transmission rates and preventing healthcare system overload (Chowdhury et al., 2020; Kaslow, 2021).

The therapeutic landscape for COVID-19 has rapidly evolved, with several antiviral agents repurposed for SARS-CoV-2 management. Remdesivir, an RNA polymerase inhibitor initially developed for Ebola, has shown efficacy in reducing recovery time in hospitalized patients with severe disease. Similarly, Lopinavir/Ritonavir, antiretroviral drugs used in the management of HIV, and other agents such as chloroquine, hydroxychloroquine, and favipiravir have demonstrated varying levels of antiviral activity against SARS-CoV-2, though their clinical utility remains contentious due to concerns over efficacy and safety (Costanzo et al., 2020). Ongoing clinical trials continue to investigate the potential of these and other therapeutic agents, including monoclonal antibodies and novel antiviral drugs.

2.3 SARS-CoV-2 Immunology and Serology

The immunological response to SARS-CoV-2 involves a highly complex and coordinated interplay between innate and adaptive immunity, both of which are crucial in

orchestrating a multifaceted defense against viral invasion. A central component of this defense mechanism is the production of virus-specific antibodies, primarily IgM and IgG, which play pivotal roles in viral neutralization and long-term immune protection (Vabret et al., 2020). Upon SARS-CoV-2 infection, the immune system responds with an initial production of IgM, detectable within approximately 5-10 days post-infection. This transient IgM response is subsequently replaced by IgG, which can persist for several weeks or months, providing immunological memory (Gudbjartsson et al., 2020; Liu et al., 2021). IgA antibodies play a significant role in mucosal immunity and are often the first line of defense against respiratory pathogens. Padoan et al. highlighted the kinetics of IgA responses to the spike glycoprotein of SARS-CoV-2, noting that IgA levels can persist for extended periods following infection. This persistence is crucial for maintaining mucosal immunity, particularly in the respiratory tract, where SARS-CoV-2 primarily enters the body (Padoan et al., 2020). The study emphasized that monitoring IgA levels could provide additional insights into the immune status of individuals post-infection.

Serological assays, particularly enzyme-linked immunosorbent assays (ELISA), have proven indispensable in detecting these antibodies. Notably, assays targeting both the nucleocapsid (N) and spike (S) proteins of the virus tend to deliver superior sensitivity compared to tests focusing on a single antigen (Wang et al., 2020). The inclusion of multiple antigens in serological testing allows for a more robust detection of immune responses, which is particularly valuable in detecting subclinical or asymptomatic infections, where viral RNA may have gone undetected by molecular methods such as

RT-PCR. Moreover, chemiluminescent immunoassays (CLIA) have demonstrated higher sensitivity than lateral flow immunoassays (LFIA), highlighting the importance of selecting the appropriate diagnostic modality (Wang *et al*., 2020).

Interestingly, studies have revealed significant inter-individual variability in both the magnitude and duration of antibody responses. Research by Zeng *et al.* (2021) highlights sex-specific differences, with females generally exhibiting higher antibody titers than males, which may reflect underlying hormonal or genetic influences on immune function. Additionally, prior exposure to endemic human coronaviruses, such as those responsible for the common cold, has been hypothesized to induce cross-reactive immune responses, effectively priming the immune system for SARS-CoV-2. This pre-existing immunity may present as a rapid IgG response, akin to a secondary immune response, thereby bypassing the IgM phase, as noted in several case studies (Lin *et al.*, 2022).

Another crucial dimension of SARS-CoV-2 immunology pertains to the impact of vaccination, particularly in individuals with prior exposure to related coronaviruses. Liang et al. (2022) explored the immunogenicity of inactivated SARS-CoV-2 vaccines in individuals previously infected with SARS-CoV. Their findings revealed a notable elevation in neutralizing antibodies against both SARS-CoV-2 and the original SARS-CoV, illustrating the potential for cross-protection between related coronaviruses. Similarly, Xu *et al.* (2022) reported a sustained IgG response following a three-dose vaccination regimen with an inactivated SARS-CoV-2 vaccine, with IgG levels correlating strongly with neutralizing antibody titers over time. Their findings underscore

the pivotal role of IgG in providing durable immunity, while the transient nature of IgM suggests its limited role beyond the early stages of infection or vaccination.

The intricacies of the immune response to SARS-CoV-2, particularly the differential roles of IgM and IgG, have significant implications for both diagnostic accuracy and long-term immunity. The persistence of IgG antibodies, often lasting for months or even years, offers a valuable biomarker for assessing prior infection and immune protection, though it is not without limitations. The variability in antibody kinetics across individuals, influenced by factors such as age, sex, prior coronavirus exposure, and vaccine history, highlights the need for personalized approaches to serological testing and immunological research. Despite the wealth of data on antibody dynamics, many aspects of the humoral response remain poorly understood, including the role of other immunoglobulins like IgA in mucosal immunity and the precise correlates of protection against reinfection or severe disease. Further research is needed to elucidate these complexities, particularly in the context of emerging viral variants and evolving vaccine strategies.

2.4 SARS-CoV-2 Vaccines and Coverage

The global rollout of vaccines against SARS-CoV-2 has been instrumental in mitigating the catastrophic consequences of the COVID-19 pandemic. The advent of various vaccine platforms, including mRNA-based vaccines (Pfizer-BioNTech BNT162b2 and Moderna mRNA-1273), viral vector-based vaccines (Oxford-AstraZeneca AZD1222 and Johnson & Johnson Janssen), and inactivated viral vaccines (Sinopharm and Sinovac),

has played a pivotal role in mitigating the incidence of severe disease, hospitalizations, and mortality.

These vaccines, underpinned by distinct immunological mechanisms, were developed with unprecedented speed, receiving emergency use authorization or full regulatory approval across different regions (Zhi-Rong *et al.*2022). However, variations in efficacy have been observed across vaccine types. The mRNA vaccines, which work by encoding the SARS-CoV-2 spike protein using a lipid nanoparticle delivery system, initiating host cell translation and provoking a potent adaptive immune response, demonstrate approximately 94-95% efficacy in preventing symptomatic COVID-19.

Viral vector vaccines, in contrast, utilize adenoviruses to deliver the spike protein gene into host cells, eliciting a similar immune reaction with efficacy rates ranging between 70% and 90% depending on the population and viral variant (Mazzoni *et al*., 2022). This response encompasses the production of neutralizing antibodies and the activation of memory B and T cells (Al-Sadeq *et al*., 2021). Both platforms have proven their capacity not only to reduce disease severity but also to offer varying degrees of cross-protection against emerging variants, albeit with waning efficacy over time.

Kenya’s vaccine rollout, emblematic of global challenges, faced significant initial hurdles, notably due to global vaccine shortages and logistical constraints. The early phases of the campaign, constrained by limited doses, prioritized healthcare workers and essential personnel. Private sector initiatives facilitated access to vaccines such as

Sputnik V, Pfizer, and Moderna, though these channels were fraught with challenges, including inconsistent government messaging and pricing disparities that exacerbated socio-economic inequalities (MOH, 2022).

In particular, the distribution of Sputnik V, approved in March 2021, was undermined by governmental indecision regarding its emergency use status, which led to significant public distrust. The high cost of vaccines available through private entities further entrenched access disparities, limiting vaccine availability predominantly to wealthier demographics, and thereby intensifying existing inequities in vaccine distribution.

However, vaccine procurement strategies diversified over time, particularly through bilateral agreements and international consortia such as the COVAX Facility. Notably, the arrival of the AstraZeneca-Oxford vaccine through COVAX in March 2021 marked a turning point, enabling broader and more equitable vaccine rollout.

Since then, Kenya has received over 20 million doses from five major manufacturers, AstraZeneca, Moderna, Johnson & Johnson, Pfizer, and Sinopharm, enabling broader vaccine distribution and improved coverage (MOH, 2022). By March 2022, over 18 million doses had been administered, with more than 8 million individuals fully vaccinated and an additional 2 million partially vaccinated (MOH, 2022). These efforts were supported by strategic initiatives such as increasing the number of vaccination centers and conducting outreach campaigns in densely populated regions to enhance public access and uptake.

Despite these successes, the country's vaccination campaign has been plagued by multifaceted challenges. Vaccine hesitancy, driven by socio-cultural factors, misinformation, and concerns over vaccine safety and efficacy, remains a significant barrier. An investigation by Osur et al. (2022) revealed that hesitancy rates among community health volunteers (CHVs) reached 19%, with hesitancy rates varying significantly across different regions. Moreover, religious and cultural beliefs, as highlighted in a study by Limaye *et al*. (2022), play a considerable role in shaping public attitudes towards vaccination, further complicating efforts to achieve herd immunity. These challenges underscore the importance of addressing public concerns and improving vaccine accessibility to enhance uptake and ensure the success of future vaccination campaigns in Kenya.

Epidemiological assessments have highlighted the importance of strategic vaccine rollout, particularly in prioritizing vulnerable populations. A study by Orangi et al. (2021), which modelled different vaccine distribution scenarios, underscored the importance of adopting a strategic, data-driven approach to vaccine rollout and optimizing resource allocation to enhance the cost-effectiveness of vaccination campaigns and maximize public health outcomes.

2.5 Natural and Vaccine-induced Responses to SARS-CoV-2: Antibody Kinetics and their Utility

SARS-CoV-2, whether arising from natural infection or vaccination, elicits a multifaceted immune response involving both humoral and cellular mechanisms (Al-

Tamimi *et al.* 2023). Central to this defense is the production of neutralizing antibodies that specifically target the viral spike (S) protein, specifically its receptor-binding domain (RBD), which facilitates viral entry into host cells. Neutralizing antibodies serve as a frontline defense by binding to the RBD, thereby preventing viral attachment and subsequent infection (Al-Tamimi *et al*., 2023).

Research has established that the kinetics of the antibody response following SARS-CoV-2 infection or vaccination follow a biphasic pattern. The production of immunoglobulins IgM and IgG, specific to SARS-CoV-2 antigens, typically occurs within 6 to 15 days post-symptom onset or vaccination. This rapid surge in antibody levels, driven by short-lived antibody-secreting plasma cells, peaks during the acute phase of infection or shortly after vaccination. However, these levels decline considerably within the first 3 to 6 months, entering a protracted decay phase where antibody titers gradually diminish (Xu *et al*., 2022). A more sustained immune response is maintained by long-lived plasma cells that migrate to the bone marrow, where they continue to secrete antibodies over extended periods. Memory B cells also play a pivotal role, as they can quickly re-engage in antibody production upon re-exposure to the virus or a viral antigen (Xu *et al.,* 2022).

Longitudinal studies of other coronaviruses, particularly SARS-CoV-1, have demonstrated that antibodies can persist for years, albeit with a gradual decline in titers. Although such patterns are similarly observed in SARS-CoV-2, studies have indicated that long-term antibody persistence is highly variable among individuals, influenced by

factors such as the severity of initial infection, vaccination status, and the presence of comorbidities (Tang *et al.*, 2023; Amellal *et al.,* 2023). The ability of SARS-CoV-2 vaccines, particularly mRNA-based platforms such as mRNA-1273, to elicit an immune response comparable to that observed following natural infection has been well documented. These vaccines generate a robust antibody response, not only against the ancestral strain but also against several variants of concern (Vaquero *et al.,* 2021). Importantly, mRNA vaccines have demonstrated flexibility in responding to emerging viral variants through booster immunizations, highlighting their utility in providing broad-spectrum protection (Al-Sadeq *et al*., 2021).

Of particular interest is the growing body of research on hybrid immunity, wherein individuals who have recovered from natural SARS-CoV-2 infection receive subsequent vaccination. Studies, such as those by Bagno *et al*. (2022), suggest that a single dose of an inactivated vaccine can elicit a pronounced antibody response in previously infected individuals, comparable to the response observed after a full vaccine regimen in uninfected individuals. This finding has important implications for vaccine deployment strategies in populations with high seroprevalence, as it may reduce the number of doses required to achieve effective immunity, thus optimizing vaccine allocation and distribution.

While the role of serology in individual clinical decision-making remains limited, seroprevalence studies at the population level provide critical insights into the scope and durability of immunity within communities (Bailey *et al.,* 2020). Such studies offer

invaluable data on the proportion of individuals with detectable antibodies, serving as proxies for exposure or vaccination rates.

2.6 Summary of Gaps Identified in the Literature

The existing body of literature reveals significant gaps in understanding the specific dynamics of SARS-CoV-2 antibody responses and vaccine hesitancy within localized populations, such as the Kenyatta University community. Prior research, often limited by small sample sizes and geographic constraints, may not adequately reflect broader seroprevalence trends or the long-term persistence of antibodies across diverse demographic groups. Despite the significant body of literature addressing vaccine hesitancy, there remains a lack of comprehensive understanding regarding the specific factors influencing hesitancy among different demographic groups, particularly in close-knit populations such as universities. Future studies should aim to explore the qualitative aspects of hesitancy, the impact of misinformation, the role of social determinants such as education, income, and access to healthcare services in influencing vaccine hesitancy which remain inadequately addressed, and the need for targeted policy interventions to enhance vaccine uptake among diverse populations. This study aims to bridge these gaps by providing a comprehensive analysis of IgM and IgG antibody levels within the Kenyatta University community and an in-depth analysis of vaccine refusal.

An investigation into the kinetics of antibody response to SARS-CoV-2 can facilitate a more nuanced understanding of vaccine-induced and naturally-acquired immunity. By examining both naturally acquired and vaccine-induced immune responses, this research

will offer valuable insights into the efficacy the longevity of immunity conferred by natural infection and vaccination. Such data will be instrumental in optimizing vaccination strategies, improving coverage, and assessing the potential need for booster vaccinations. This study's findings may also serve as a benchmark for other sub-Saharan African regions, where similar studies are sparse, thereby contributing to the global understanding of SARS-CoV-2 immune responses in diverse population groups.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study Area

All study participants were recruited from Kenyatta University located along one of Kenya's major Highways, the Thika Superhighway approximately 20 km from Nairobi City.The university holds a heterogenous population of students, staff and other members of the university community representing a broad spectrum of age, gender, ethnicity,cultural background socioeconomic statuses and geographic origins, thereby providing a representative cross-section of the institution. Kenyatta's student body has over 70,000 students enrolled in undergraduate and postgraduate courses and taught by approximately 1,500 academic staff thus providing a balanced pool across multiple displines and year levels.

3.2 Study Design

A cross-sectional research design, was appropriate for assessing the prevalence of specific characteristics such as antibody presence within a defined population at a single point in time was deployed to fulfill this study’s objectives.

3.3 Study Variables

3.3.1 Independent Variables

This study’s independent variable is the participants’ vaccination status, analyzed in relation to the presence of antibodies to assess vaccine efficacy and seroprevalence within the study cohort.

3.3.2 Dependent Variable

This study's dependent variable is anti-SARS-CoV-2 antibody titers, specifically IgM and IgG, which function as biomarkers of prior infection or immune activation following vaccination.

3.4 Study Population

Recruitment activities targeted members of the Kenyatta University community, including students, staff, and other associated members.

3.4.1 Inclusion Criteria

Volunteers were considered eligible if they were 1) students or employees of Kenyatta University, 2) 18 years of age and above, 3) consented to provide nasopharyngeal swabs and blood specimens, and 4) consented to complete the structured questionnaire.

3.4.2 Exclusion Criteria

Volunteers were considered ineligible for participation if they were under 18 years of age and did not provide consent to participate.

3.5 Sample Size Determination

The calculation of the sample size was informed by the seroprevalence data reported by Etyang et al. (2022), who identified a crude anti-SARS-CoV-2 seroprevalence rate of 19.7% within a population sample comprising 684 individuals. After adjusting for assay performance, the seroprevalence was revised to 20.8%, with a 95% credible interval of

17.5% to 24.4%. The sample size was calculated using the standard formula for estimating a single population proportion (Cochran, 1977; Fisher et al., 1998), as shown below: ensuring adequate statistical power to detect significant associations between variables.

$$n_0 = \frac{z^2 Pq}{e^2}$$

Where n_0= Sample size

Z^2 = confidence interval at 95% (standard value set at 1.96)

p = The estimated prevalence of a specific attribute within the population (0.208)

q = 1 – p

e = Absolute maximum statistical error

$$n_0 = \frac{1.96^2 X\ 0.485\ X\ (1 - 0.208)}{0.05^2}$$

$$n_0 = \frac{3.8416\ X\ 0.208 X\ 0.792}{0.05^2}$$

n_0 =253

n_0=253

Despite calculations indicating that a sample size of 253 was necessary to achieve adequate statistical power, only 189 participants were ultimately recruited. This shortfall in recruitment is partly attributable to the study's timing, which coincided with a prolonged academic recess at Kenyatta University, impacting participant availability and enrollment rates. The failure to reach the calculated sample size of 253, culminating in a final cohort of 189 participants, may have reduced the statistical power of the study. This increases the probability of a Type II error, meaning that some true associations, particularly those with smaller effect sizes, may not have been detected as statistically significant.

3.6 Sampling Technique

A purposive sampling strategy was deployed for participant recruitment. Announcements were disseminated through class representatives and staff meetings to encourage voluntary participation from both students and staff within the Kenyatta University community. Sampling continued for as long as participants continued to come and until we approached the targeted sample size, ensuring comprehensive coverage of the university population.

3.7 Research Questionnaire

Structured English questionnaires were deployed to gather detailed information on participants' demographics, clinical history, and vaccination intentions. Demographic variables included age, gender, educational level, and occupation. Clinical data covered a range of factors, including COVID-19 diagnosis history, vaccination status, type of vaccine received, booster dose receipt, and incidence of breakthrough infection.

3.7.1 Pre-testing of Questionnaire

The structured questionnaire employed in this study was pre-tested at the Health unit of Kenyatta University. The pre-test was done by health unit staff and aimed to evaluate the relevance, comprehensiveness, and simplicity of the data collection tool. The feedback obtained facilitated the refinement of the final questionnaire, enhancing its content, structure, and overall clarity, thus optimizing the response rate. The research assistants were responsible for administering the pre-test.

3.7.2 Validity of Research Questionnaire

To ensure validity, well-constructed research tools were employed. The construct validity of the questionnaire items and the appropriateness of the language used were rigorously evaluated through expert review. The research tool's accuracy was further validated through pre-testing. Face validity was achieved by having the questionnaire reviewed by university supervisors.

3.7.3 Reliability of Research Questionnaire

Reliability, which reflects the consistency and dependability of the research tool, was assessed during the pre-testing phase. Enumerators were carefully selected and received a one-day training session to ensure they fully understood the questionnaire content and the questions posed. A test-retest method was employed with 42 participants, where the questionnaire was administered twice to the same respondents, one week apart. The degree of association between the two sets of responses was determined, yielding a Cronbach's Alpha score of 0.81, indicating good reliability.

3.8 Laboratory procedures

The following laboratory procedures were adhered to in the study:

3.8.1 Sample Collection, Preparation, and Storage

Nasopharyngeal swabs were collected from each participant, ensuring that each specimen was assigned a unique identifier for accurate tracking. These swabs were promptly tested on-site for the presence of SARS-CoV-2 using the Panbio™ COVID-19 Ag Rapid Test

Device (Abbott, Jena, Germany). Simultaneously, 5 ml of venous blood was drawn from each participant and labeled with corresponding identifiers. These samples then underwent centrifugation at 1000 x g for 5 minutes to isolate the serum, which was then preserved at -20°C until additional testing.

3.8.2 Sample Testing; ELISA testing for Anti-SARS-CoV-2 IgM and IgG

Quantification of anti-SARS-CoV-2 IgM and IgG in the collected serum samples was achieved through enzyme-linked immunosorbent assays (ELISA), specifically designed for human SARS-CoV-2 Spike (Trimer) IgM and IgG detection (Thermo Fisher Invitrogen, Waltham, MA, USA). The assay deployed a sandwich ELISA methodology, wherein wells were pre-coated with trimerized spike protein to serve as the antigen for antibody binding. Serum samples were diluted in a 1:1000 ratio, and 10 µL of the diluted serum was introduced into each well for incubation. Detection was achieved using biotin-conjugated secondary antibodies specific to human IgM and IgG. The final complex was visualized using a streptavidin-HRP system, and absorbance readings were obtained at 450 nm using a high-precision spectrophotometer (RT-2100C, Rayto Life and Analytical Sciences, Guangdong, China).

3.9 Data Analysis

Absorbance data for standards, controls, and test samples were obtained directly from the spectrophotometer and analyzed to determine antibody levels. Qualitative interpretation was based on the ratio of the optical density (OD) of the test sample to the OD of the plate medium control. A ratio exceeding 1.3 was classified as positive for the presence of

SARS-CoV-2-specific IgG or IgM antibodies, while ratios below 1 indicated a negative result (Manufacturer's instructions; Thermo Fisher Invitrogen, Waltham, MA, USA). For quantitative analysis, a standard curve was generated by fitting the standard absorbance values to a four-parameter logistic (4PL) curve-fitting model using Excel Curve Fitting tools. The unknown antibody concentrations in the test samples were extrapolated from this standard curve, allowing for precise quantification.

Antibody concentration data were tested for normality using the Kolmogorov–Smirnov test, revealing a non-normal distribution. Consequently, the data were expressed as medians and interquartile ranges (IQR). Categorical variables, such as demographic information and vaccination status, were expressed as frequencies and percentages. To assess statistical differences between groups, the Mann–Whitney U test was employed for pairwise comparisons, while the Kruskal–Wallis test was utilized for multi-group comparisons. A significance threshold of $p < 0.05$ was applied across all analyses. Data processing and statistical analysis were conducted using SPSS software (version 18, IBM Corp, Armonk, NY).

Qualitative data on vaccine hesitancy were classified based on the 3C model—confidence, complacency, and convenience—proposed by the WHO's Strategic Advisory Group of Experts on Immunization (SAGE). Participant responses were subjected to thematic analysis, identifying key trends and underlying motivations for vaccine hesitancy within each of these domains.

3.10 Ethical Considerations

This study was conducted in full accordance with ethical standards and was approved by the Kenyatta University Ethics Review Committee (refer to Appendices VI and VII for detailed approval documents). Additional authorization was secured from the National Commission for Science, Technology, and Innovation (NACOSTI) (refer to Appendix V for detailed NACOSTI approval details). Strict adherence to confidentiality and participant anonymity was maintained throughout the study to protect individual privacy.

Participants were comprehensively apprised of the study's aims and methodologies. Informed consent was obtained through a written agreement prior to participation. Informed consent documentation explicitly delineated the potential benefits of participating in the study. These benefits included gaining personalized insights into their COVID-19 antibody status and free COVID-19 status testing via nasopharyngeal swabs. Additionally, their participation would contribute to a broader understanding of vaccine effectiveness and hesitancy, aiding public health efforts to improve vaccination strategies within the community.

The informed consent documentation also outlined the risks associated with participation, including discomfort or mild pain from blood draws for serum sampling and the potential for irritation or minor bleeding from the nasopharyngeal swab. Participants were also made aware of the psychological discomfort that might arise from self-reporting vaccine hesitancy or discussing personal health decisions.

CHAPTER FOUR: RESULTS

4.1 Demographic Characteristics of the Study Participants

189 members of the Kenyatta University community were recruited for this study. The sample comprised slightly more female participants (n = 96, 50.8%) than male participants (n = 93, 49.2%). The participants had a median age of 21 years, with the majority (n = 135, 71.4%) belonging to the 20-29-year age group. The 50 year and above age group had the least representation, with a frequency of five participants (2.6%).

Regarding COVID-19 vaccination status, the majority of participants had been vaccinated (n = 107, 56.6%), with only n = 82, 43.4% unvaccinated. In terms of educational attainment, a significant proportion of participants had completed higher education (College/University) (n = 186, 98.4%), while only a small fraction had attained basic education (Primary/Secondary) (n = 3, 1.6%). The majority of participants were students (n = 170, 89.9%), with the remainder comprising teaching staff, health unit staff, and non-teaching staff, as detailed in Table 4.1.

Table 4.1: Socio-demographic Attributes of Study Participants from Kenyatta University (Gender, Age Group, Vaccination Status, Level of Education, and Current Occupation)

	Variables	Frequency (N)	Percentages (%)
Gender	Male	93	49.2%
	Female	96	50.8%
Age group	<19	30	15.9%
	20-29	135	71.4%
	30-39	10	5.3%
	40-49	9	4.8%
	>50	5	2.6%
Vaccination status	Vaccinated	107	56.6%
	Not vaccinated	82	43.4%
Level of education	Primary	1	0.5%
	Secondary	2	1.1%
	College/ University	186	98.4%
Current occupation	Teaching staff	10	5.3%
	Non-teaching staff	4	2.4%
	Students	170	89.9%
	Health unit staff	.8 5	2.6%

Key: % = Percentage, < = Below, > = Above

4.2 Anti-SARS-CoV-2 IgM Seroprevalence

Among the 189 participants enrolled in the study, 24 (12.7%) had detectable levels of anti-SARS-CoV-2 IgM. Of these, 15 were female and 9 were male. All positive cases were observed within the student population, specifically in the 20-29 years age group.

Anti-SARS-CoV-2 IgM was detected in both vaccinated and non-vaccinated individuals, as delineated in Table 4.2.

Table 4.2: Anti-SARS-CoV-2 IgM Seroprevalence in A Study Population Drawn from Kenyatta University Categorized by Gender, Age Group, Vaccination Status, Level of Education, and Current Occupation

	Variable	Frequency (N)	No. of positive	Prevalence
Overall	All participants	189	24	12.7%
Gender	Male	93	9	9.7%
	Female	96	15	15.6%
Age group	<19	30	0	0.0%
	20-29	135	24	17.8%
	30-39	10	0	0.0%
	40-49	9	0	0.0%
	>50	5	0	0.0%
Vaccination status	Vaccinated	107	18	16.8%
	Not vaccinated	82	6	7.3%
Current occupation	Teaching staff	10	0	0.0%
	Non-teaching staff	4	0	0.0%
	Students	170	24	14.1%
	Health unit staff	5	0	0.0%

Key: N= Number, % = Percentage. 4.2.1 COVID-19 Testing Outcomes

Of the 189 participants enrolled in the study, only 65 (34.4%) consented to undergo COVID-19 testing via nasopharyngeal swabs, with three (4.6%) testing positive, as depicted in Figure 4.1.

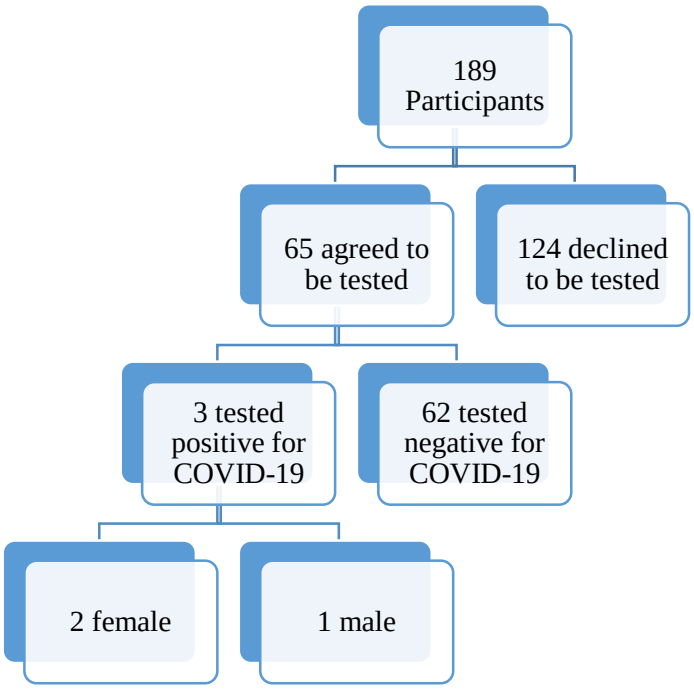

Figure 4.1: SARS-CoV-2 Antigen Positivity Among the 65 of 189 Study Participants from Kenyatta University Who Agreed to Undergo COVID-19 Testing

4.2.1 SARS-CoV-2 Positivity Rates Among Participants by Gender

Out of the eligible participants, 40(21.2%) reported testing positive SARS-CoV-2. Of these 22 (23.7%) were male and 18 (18.8%) were female, as depicted on figure 4.2 below.

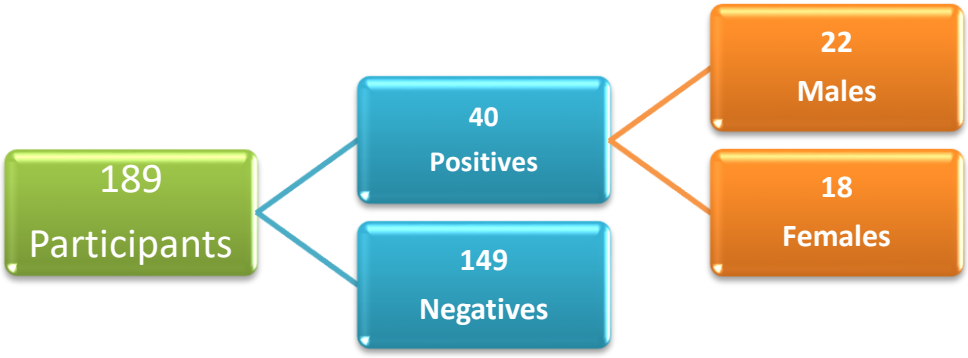

Figure 4.2: COVID-19 Positivity Rates in a Study Population Drawn from Kenyatta University Based on Self-Reported Questionnaire Data

4.3 Anti-SARS-CoV-2 IgG Seroprevalence

Of the 189 participants, 166 (87.8%) had detectable levels of anti-SARS-CoV-2 IgG. T anti-SARS-CoV-2 IgG seroprevalence was slightly higher in female participants (n = 89, 92.7%) compared to male participants (n = 77, 83.8%). Notably, all participants aged above 30 years tested positive for IgG antibodies. Anti-SARS-CoV-2 IgG seroprevalence was also significantly elevated among vaccinated individuals (n = 105, 98.1%) compared to non-vaccinated individuals (n = 61, 74.4%), as shown in Table 4.3.

Table 4.3: Anti-SARS-CoV-2 IgG Seroprevalence in a Study Cohort Drawn from Kenyatta University, Categorized by Gender, Age Group, Vaccination Status, Level of Education, and Current Occupation

	Variable	Frequency (N)	No. of positive	Prevalence
Overall	All participants	189	166	87.8%
Gender	Male	93	77	83.8%
	Female	96	89	92.7%
Age group	<19	30	24	80.0%
	20-29	135	120	88.9%
	30-39	10	10	100%
	40-49	9	9	100%
	>50	5	5	100%
Vaccination status	Vaccinated	107	105	98.1%
	Not vaccinated	82	61	74.4%
Current occupation	Teaching staff	10	10	100%
	Non-teaching staff	4	4	100%
	Students	170	147	86.5%
	Health unit staff	5	5	100%

Key: N= Number, % = Percentage.

4.4 Comparison of Anti-SARS-Cov-2 IgM Titers among Study Participants at Kenyatta University

Comparative analysis, accomplished via a Mann-Whitney U test, revealed no statistically significant variation in anti-SARS-CoV-2 IgM titers based on gender (male vs. female, $U = 398.5$, $p = 0.199$) or vaccination statuses (vaccinated vs. non-vaccinated, $U = 417.2$, $p = 0.564$). Furthermore, a Kruskal-Wallis H test indicated no significant differences in IgM levels across various age groups, as delineated in Table 4.4.

Table 4.4: Comparison of Anti-SARS-CoV-2 IgM Seroprevalence in a Study Cohort Drawn from Kenyatta University by Gender, Age Group, Vaccination Status, Level of Education, and Current Occupation

	Variables	Number (N)	Median x 10^3 (Units/mL)	IQR x 10^3 (Units/mL)	P -Value
Gender	Male	93	1595.00	3600.33	0.199
	Female	96	2147.70	4383.28	U=3981.5
Age group	<19	30	1675.40	9070.61	0.566
	20-29	135	1395.00	30185.71	H=2.952
	30-39	10	2186.67	2052.64	
	40-49	9	2345.00	3533.33	
	>50	5	2386.67	2124.36	
Vaccination status	Vaccinated	107	1828.33	4449.55	0.564
	Not vaccinated	82	1345.00	3666.51	U=4172
Occupation	Teaching staff	10	2145.00	1777.048	-
	Non-teaching staff	4	3028.33	775.00	
	Students	170	15616.66	4265.22	
	Health unit staff	5	1028.33	3285.36	

Key: N= Number, IQR = interquartile range, U= Man Whitney statistic, H= Kruskal Wallis Statistic.

4.5 Anti-SARS-Cov-2 IgM Variations among Vaccinated Study Participants at Kenyatta University

107 study participants had undergone SARS-Cov-2 vaccination, albeit with significant variations in vaccine brand. There were no statistically significant variations in anti-SARS-Cov-2 IgM titers based on gender (males vs. females) P=0.276, or age (P=0.876). In addition, our analyses showed no significant variations in anti-SARS-CoV-2 IgM titers between participants that received booster & those that did not as delineated in Table 4.5 below.

Table 4.5: Variations in Anti-SARS-CoV-2 IgM Titers Among Vaccinated Study Participants from Kenyatta University, Analyzed By Gender, Age Group, Booster Dose Receipt, and Occupation

	Variables	Number (N)	Median $x10^3$ (Units/mL)	IQR $x10^3$ (Units/mL)	P - Value
Gender	Male	46	1528333.33	3999151.70	0.276 U=1230
	Female	61	2311666.67	29928871.4	
Age group	<19	13	287833.330	5763640.70	0.876 H=1.213
	20-29	75	1747626.00	4804308.00	
	30-39	7	207833.30	1919500.00	
	40-49	9	2395000.00	1483333.33	
	>50	5	1122621.00	983533.44	
Occupation	Teaching staff	10	2145.00	1777.048	-
	Non-teaching staff	4	3028.33	775.00	
	Students	170	15616.66	4265.22	
	Health unit staff	5	1028.33	3285.36	
Booster	Received	29	1747.63	4338.70	0.758 H=1087
	Did not Receive	78	2020.00	30185.71	

Key: N= Number, % = Percentage, IQR = interquartile range, U= Man Whitney statistic, H= Kruskal Wallis Statistic.

4.6 Comparison of Anti-SARS-Cov-2 IgG Titers in a Study Cohort Drawn from Kenyatta University

Comparative analysis revealed a statistically significant variation in anti-SARS-Cov-2 IgG titers based on gender (males vs. females) and vaccination status (vaccinated vs. non vaccinated) (P= 0.024 U= 3616, P= 0.000, U= 2817.5; respectively). Analysis based on participant age groups showed insignificant differences as delineated in Table 4.6 below.

Table 4.6: Comparative Analysis of Anti-SARS-CoV-2 IgG Seroprevalence in a Study Cohort Drawn from Kenyatta University by Gender, Age Group, Vaccination Status, Level of Education, and Current Occupation

	Variables	Number (N)	Median $x10^3$ Units/mL	IQR $x10^3$ Units/mL	P -Value
Gender	Male	93	145245.00	139330.00	0.024*
	Female	96	180350.00	132730.00	U=3616
Age group	<19	30	160422.64	149457.50	0.123
	20-29	135	146147.50	136992.50	H=7.260
	30-39	10	184650.00	100855.00	
	40-49	9	266950.00	70400.00	
	>50	5	201200.00	6546.55	
Vaccination status	Vaccinated	107	189050.00	137355.00	0.000*
	Not vaccinated	82	133120.00	139817.50	U=2817.5*
Occupation	Teaching staff	10	239600.00	119950.00	-
	Non-teaching staff	4	269850.00	42425.00	
	Students	170	146147.50	135455.00	
	Health unit staff	5	183750.00	827775.50	

Key: N= Number, % = Percentage, IQR = interquartile range, U= Man Whitney statistic, H= Kruskal Wallis Statistic.

4.7 Variations in Anti-SARS-Cov-2 IgG Titers among Vaccinated Study Participants from Kenyatta University

Comparative analyses of anti-SARS-CoV-2 IgG titers among vaccinated participants revealed no statistically significant differences based on gender or age group ($p > 0.05$), as presented in Table 4.7. Additionally, a Mann-Whitney U test indicated no significant variation in IgG titers between individuals who reported receiving booster shots and those who went without ($p = 0.340$).

Table 4.7: Comparison of Anti-SARS-CoV-2 IgG Seroprevalence Among Vaccinated Study Participants from Kenyatta University Based on Gender, Age Group, Booster Dose Receipt, and Occupation

	Variables	Number (N)	Median $x10^3$ Units/mL	IQR $x10^3$ Units/mL	P -Value
Gender	Male	46	196200.00	136420.00	0.813
	Female	61	183750.00	139280.00	U=1365
Age group	<19	13	218320.00	152015.00	0.377
	20-29	75	181750.00	138855.00	
	30-39	7	183750.00	68655.00	H=4.221
	40-49	9	266950.00	70400.00	
	>50	5	157330.00	56893.45	
Occupation	Teaching staff	7	234150.00	119500.00	-
	Non-teaching staff	4	269850.00	45425.00	
	Students	92	176600.00	138020.00	
	Health unit staff	5	193950.00	87300.00	
Booster	Received	29	204150.00	128430.00	0.340
	Did not Receive	78	183850.00	137610.00	H=995

Key: N= Number, IQR = interquartile range, U= Man Whitney statistic, H= Kruskal Wallis Statistic.

4.8 Vaccination Status of Study Participants

A significant proportion of study participants were vaccinated against COVID-19, with 56.6% reporting vaccination and 43.4% unvaccinated. Among the vaccines administered, AstraZeneca and Johnson & Johnson had the highest uptake, at 38.3% and 22.4%, respectively. Notably, no participants reported receiving the Sinopharm vaccine, and four participants (3.7%) were unaware of which vaccine they had received. Of the 107 vaccinated participants, 29 (27.1%) had received a COVID-19 booster dose, as detailed in Table 4.6. The study also found that 8.2% of males and 10.9% of females had reported breakthrough infections following vaccination, as detailed in Table 4.8.

Table 4.8: Summary of Vaccination Status, Vaccine Type Administered, Booster Dose Receipt, and Incidence of Breakthrough Infections in a Study Population Drawn from Kenyatta University

	Variable	Frequency (N)	Percentage
Vaccination	Vaccinated	107	56.6%
Status	Non-vaccinated	82	43.4%
Type of Vaccine	Moderna	21	19.6%
	AstraZeneca	41	38.3%
	Pfizer	16	15.9%
	Johnson & Johnson	24	22.4%
	Sinopharm	0	0%
	Sputnik	1	0.9%
	Do not know	4	3.7%
Booster	Received booster	29	27.1%
	Did not receive booster	78	72.9%
Breakthrough Infection	Female	5	10.9%
	Male	5	8.2%

Key: N=number, % = Percentage.

4.8.1 Comparative Analysis of Anti-SARS-Cov-2 IgM and IgG Titers among Vaccinated Participants Based on Vaccine Type

This study evaluated variations in anti-SARS-CoV-2 antibody titers (IgM and IgG) among participants vaccinated with Moderna, AstraZeneca, Pfizer, and Johnson & Johnson. Statistical analysis revealed no significant variations in both IgM ($p = 0.571$) and IgG ($p = 0.170$) levels across these vaccines, as delineated in Table 4.8.

Table 4.8: Comparative Analysis of IgM Seroprevalence in a Study Population from Kenyatta University by Vaccine Type Administered (Moderna, AstraZeneca, Pfizer, Johnson & Johnson)

Anti-SARS-Cov-2 (Immunoglobin M) levels					
	Variables	**Number (N)**	**Median $x10^3$ (Units/mL)**	**IQR $x10^3$ (Units/mL)**	**P - Value**
Type of Vaccine	Moderna	21	1747.63	4952.72	0.571
	AstraZeneca	41	2061.67	3188.33	H=2.007
	Pfizer	16	1320.00	4808.28	
	Johnson & Johnson	24	1428.33	4808.28	
Anti-SARS-Cov-2 (Immunoglobin G) levels					
	Variables	**Number (N)**	**Median x103 (Units/mL)**	**IQR x103(Units/mL)**	**P - Value**
Type of Vaccine	Moderna	21	137295.00	117290.00	0.170
	AstraZeneca	41	232150.00	110650.00	H=5.027
	Pfizer	16	144145.00	149617.50	
	Johnson & Johnson	24	175772.50	139305.00	

Key: N= Number, IQR = interquartile range, H= Kruskal Wallis Statistic.

4.8.2 Persistence of Anti-SARS-Cov-2 (Immunoglobin G) among study participants post Vaccination

This study observed statistically significant variations anti-SARS-CoV-2 IgG levels, based on time-lapsed since vaccination (p = 0.002, H = 12.359), as detailed in Table 4.9.

Table 4.9: Post-Vaccination Persistence of Anti-SARS-CoV-2 IgG Among Study Participants Drawn from Kenyatta University, Analyzed by Time Since Vaccination (0 to 6 Months, 7 to 12 Months, 13 Months and Over)

	Variables	Number (N)	Median $x10^3$ Units/mL	IQR $x10^3$ Units/mL	P -Value
Persistence	0 – 6 Months	31	264950.00	138155.00	0.002
	7 – 12 Months	21	196450.00	149805.00	H=12.359
	13 Months & Above	55	147095.00	122555.00	

Key: **N= Number, IQR = interquartile range, H= Kruskal Wallis Statistic.**

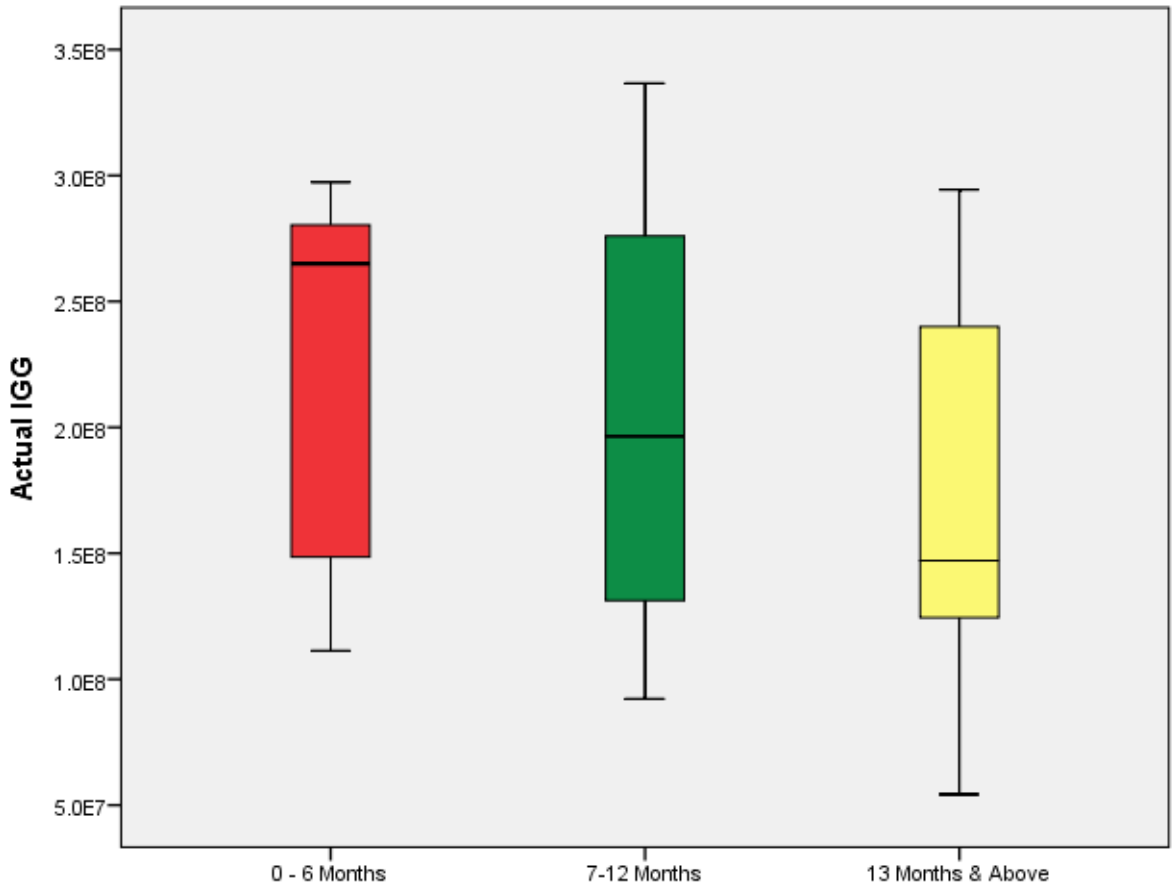

Figure 4.3: A box plot illustrating temporal changes in IgG levels following vaccination in a study population Drawn from Kenyatta University, with levels peaking within 0-6 months post-vaccination and showing a gradual decline over time thereafter

4.8.3 Factors Contributing to SARS-CoV-2 Vaccine Hesitancy Among Study Participants

Out of the 189 participants, 82 (43.4%) were not vaccinated against COVID-19. Among these, 10 participants did not specify their reasons for non-vaccination. Vaccine hesitancy was more pronounced in male participants compared to females (50.5% vs. 36.5%, p = 0.05).

An analysis of the reasons for non-vaccination was conducted for the remaining 72 participants. Within the 'confidence' category, key themes included mistrust in vaccine effectiveness and production processes (22.4%), concerns about health and side effects (19.7%), lack of information about vaccines (18.4%), and religious or cultural reasons (3.9%). The 'complacency' category included no specific reason (14.5%), lack of interest (11.8%), and procrastination (2.6%). The 'convenience' category identified vaccine unavailability (2.6%) and lack of time (3.9%), as shown in Table 4.10.

Table 4.10: Summary of Study Participants' Reasons for Opting Out of Vaccination, Analyzed According to the 3Cs Model: Themes of Confidence, Convenience, and Complacency

3Cs model	Theme	Frequency* (%)	Examples of Participants' Responses
Confidence	Health concerns/side effects	15 (19.7%)	"Fear of adverse reactions (blood clotting)" "I had health concerns/suspicions about the vaccines side effect"
	Lack of Information	14 (18.4%)	"I have not been infected" "I had never experienced any COVID-related signs, so I thought my immune system is strong enough hence there was no need to introduce any vaccines or drugs"
	Mistrust	17 (22.4%)	"I doubted the effectiveness of the vaccine" "I thought the vaccine was approved too fast" "I see no point in getting vaccinated, especially with something that is experimental (has not gone through the proper testing process)"
	Religious and cultural reasons	3 (3.9%)	"religious and cultural reasons"
Convenience	Vaccine unavailability	2 (2.6%)	"Just missed out" "Had no access to the vaccine"
	Lack of time	3 (3.9%)	"I couldn't spare time to obtain the vaccine"
Complacency	No reason	11 (14.5%)	"No any specific reason"
	Lack of interest	9 (11.8%)	"I didn't feel the need to"
	Procrastination	2 (2.6%)	"I just kept on postponing"

* Of the 82 non-vaccinated participants, only 72 provided reasons remaining unvaccinated against COVID-19. Since some participants gave multiple reasons, the total number of responses exceeds 72. Key: % = Percentage.

CHAPTER FIVE: DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Discussion

This section provides a detailed analysis of the study's results, contextualizing them within the broader body of research on immune mobilization consequent to COVID-19 vaccination and natural infection, as well as on vaccine hesitancy within Kenyan communities.

5.1.1 The prevalence of anti-SARS-CoV-2 IgM and IgG levels

Conducted nearly four years post the initial outbreak of COVID-19 and two and a half years following the commencement of global vaccination campaigns, this study reported an overall seroprevalence of 12.7% for anti-SARS-CoV-2 IgM and 87.8% for IgG. These results are in line with similar research conducted in Kenya. For example, Kagucia et al. (2023) reported a comparable IgG seroprevalence of 92.2% among Nairobi residents, while Kilifi County demonstrated a lower seroprevalence of 77.4%. The elevated seroprevalence in urban populations and closely-knit communities, such as universities, may stem from frequent interpersonal interactions, leading to increased viral transmission and a corresponding boost in immunity levels within these communities.

The demographic profile of this study's participants was unique, with the 20-29 age group comprising the majority (71.4%) and also showing the highest IgM seroprevalence and second-highest IgG seroprevalence (88.9%). Notably, all participants over 30 years tested positive for IgG, indicating widespread exposure and likely herd immunity within the population. These findings align with previous research, such as Awandu et al. (2022),

which noted a similarly elevated seropositivity in older populations. This finding aligns with global trends where cumulative exposure to the virus and vaccination efforts have significantly boosted immunity. A comprehensive meta-analysis by Bergeri et al. (2022) further corroborates the rapid rise in seroprevalence across different regions, largely driven by infection and vaccination.

Of the 189 participants, only 65 consented to undergo testing for COVID-19 using rapid test kits, resulting in five positive cases—three females and two males—all of whom also tested positive for both IgM and IgG, suggesting robust immune responses. Despite the relatively low vaccination uptake, these results suggest that significant immunity had developed within this community, likely due to the combined effects of vaccination and infection.

The study also explored vaccine hesitancy, noting that 43.4% of participants were not vaccinated. Vaccine hesitancy was more pronounced in males (50.5%) than females (36.5%), a trend seen in other studies within sub-Saharan Africa. Reasons cited for non-vaccination included distrust in the efficacy of vaccines (22.4%), concerns over potential health risks (19.7%), and a lack of adequate information (18.4%). These findings echo broader regional patterns where misinformation, health concerns, and logistical challenges have impacted vaccine uptake (Al-Hanawi et al. 2020).

5.1.2 Comparative Analysis of Anti-SARS-CoV-2 Antibody Levels: Vaccination vs. Natural Infection

This study revealed a statistically significant variation in anti-SARS-CoV-2 IgG levels between females and males ($p = 0.024$), between vaccinated and non-vaccinated individuals ($p < 0.001$), and between participants vaccinated within six months of the study versus those vaccinated over a year prior ($p = 0.002$).

The observed elevation in antibody titers among vaccinated participants is in line with established immunological research, which indicates that SARS-CoV-2 vaccines are highly effective at inducing a robust humoral immune response. This immune activation is particularly pronounced in the period immediately following vaccination, with antibody levels peaking within a few weeks and then gradually declining over time.

The observed gender disparity in antibody mobilization aligns with the growing body of evidence indicating that females tend to exhibit stronger immune responses than males. This disparity may be attributable to both behavioral factors, such as greater health awareness and healthcare access among females, and biological differences, including the immunomodulatory effects of estrogen and the presence of two X chromosomes, which encode numerous immune-related genes (Ciarambino, Para, & Giordano, 2021; Fernandes et al., 2023). This phenomenon has been consistently observed in both vaccine-induced and infection-induced immune responses, suggesting that gender is a significant variable in understanding differential immune outcomes.

The significant variation in antibody titers between participants vaccinated within six months of the study those vaccinated over a year prior is consistent with research showing waning of SARS-CoV-2 antibody titers over time. Several studies have pinpointed the 6–8-month mark as a critical period during which antibody levels begin to decline significantly (Haq et al., 2024). However, this natural decline does not necessarily correlate with a loss of immunity, as memory B cells and T cells continue to provide immune protection even in the absence of high circulating antibody levels.

Notably, the study found no statistically significant increase in antibody levels following booster shot administration ($p = 0.340$). This finding contrasts with research indicating that booster doses can substantially reduce the risk of severe outcomes, such as hospitalization and death, particularly in vulnerable populations (Mattiuzzi et al., 2023). However, the low number of booster dose recipients in this study (29 out of 107) limits our ability to draw definitive conclusions about booster shot efficacy in this population.

Additionally, no significant differences in IgG titers were observed across the various vaccine brands administered ($p = 0.170$), suggesting that the vaccines available within this population cohort exhibited comparable efficacy. This finding is congruent with the large-scale clinical trials of vaccines such as Pfizer-BioNTech, Moderna, and AstraZeneca, which have reported similar efficacy rates across different demographic subgroups (Polack et al., 2020). Nevertheless, some studies have noted varying levels of vaccine effectiveness, indicating that further research is needed to fully understand these dynamics in different populations.

Lastly, no significant age-related variations in antibody mobilization were detected in this study. This finding aligns with a study by Li et al. (2021), which did not observe a clear correlation between age and the degree of antibody mobilization post-vaccination. However, this finding contrasts with other studies that have reported age-related differences in immune response. For instance, a study by Fonseca et al. (2022) found statistically significant differences in antibody mobilization across age groups, with participants in the 18–30 age group recording 92.5% IgG seropositivity, while those aged 50 and above recording 80.4%. Moreover, while our findings show no obvious correlation between age and IgG mobilization, there was limited age diversity in the study population, with only 2.6% exceeding 50 years, 4.8% within the 40-49 age range, and 5.3% within the 30-39 age range. This limitation hinders our ability to draw definitive conclusions on the modulating role of age on IgG mobilization, highlighting the need for studies involving larger and more diverse cohorts.

5.1.3 Participants' Vaccination Status and Factors Influencing Vaccination Decisions

56.6% of study participants reported obtaining at least one dose of a COVID-19 vaccine, while 43.4% remained unvaccinated. Notably, no participants reported receiving the Sinopharm vaccine, only one reported receiving Sputnik V, and 3.7% were uncertain about which vaccine they had received. These patterns of vaccine distribution are consistent with broader trends observed in Kenya and other parts of sub-Saharan Africa, where vaccine uptake has been shaped by both vaccine availability and public perception of efficacy (Orangi et al., 2021). The higher uptake of AstraZeneca and Johnson &

Johnson vaccines is reflective of their greater accessibility through public health campaigns. Conversely, the limited uptake of Sputnik V in this study may be attributed to its inconsistent global availability, compounded by mixed government messaging regarding its approval status and the high costs associated with accessing it through private channels.

Of the 107 vaccinated participants, 27.1% (n = 29) had received a booster dose, reflecting an awareness of the importance of booster shots in maintaining immunity. However, the relatively low booster uptake mirrors findings from other African contexts, where booster coverage has been hampered by vaccine fatigue, logistical challenges, and a diminishing perception of risk as infection rates decline (Ackah et al., 2022).

Notably, 8.2% of male and 10.9% of female participants reported contracting COVID-19 post-vaccination. This finding is attributable to an array of factors, most notably the advent of increasingly transmissible and immune-evasive variants, such as Omicron and Delta, which have significantly reduced the effectiveness of vaccine-induced immunity and heightened the probability of breakthrough infections. Moreover, the study's findings suggest waning immunity driven by temporal declines in antibody titers, which may increase susceptibility to breakthrough infections.

This study's investigation into the determinants of vaccine hesitancy within the Kenyatta University revealed that personal beliefs, health-related concerns, and other contextual factors played pivotal roles in vaccine refusal. Personal beliefs were the predominant

reason for vaccine refusal, cited by 81.7% of unvaccinated participants. These findings align with a study by Barasa et al. (2021), which noted that mistrust in the healthcare system, concerns over vaccine safety, and a preference for natural immunity were common deterrents to vaccination in Kenya.

Health Concerns accounted for 17.1% of vaccine refusals. These concerns may be related to underlying health conditions, fear of adverse outcomes, or skepticism regarding the long-term efficacy of vaccines., a pattern observed in other studies on vaccine hesitancy in Kenya. For instance, a study by Baye et al. (2022) documented a similarly low rate of vaccine uptake among individuals with chronic illnesses, attributable to analogous concerns.

The Other category, though representing a minor proportion (1.1%), could include a range of issues such as logistical challenges, access issues, or cultural and religious beliefs. This suggests that, while personal and health-related reasons dominate vaccine hesitancy, there are also unique, context-specific barriers that need to be addressed through targeted interventions.

Vaccine hesitancy in Kenya is further compounded by widespread misinformation, distrust in public health institutions, and inadequate communication regarding vaccine safety. A study by Adetifa et al. (2021) emphasized that despite concerted efforts to scale up vaccine coverage, deeply ingrained fears of vaccine side effects, coupled with

skepticism about the rapid development of COVID-19 vaccines, continue to undermine public confidence in the vaccination process.

5.2 Study Limitations

The study's findings should be interpreted in light of a few limitations. First, the cross-sectional design inherently limits our ability to capture the temporal evolution of immune responses post-vaccination. While the findings indicate a decrease in antibody levels six months post-vaccination, the snapshot provided by a cross-sectional design does not allow for a nuanced understanding of the dynamics of antibody fluctuations over time.

Additionally, the study's statistical power was limited by a smaller-than-expected sample size. Although the original power calculation recommended a sample size of 253 participants, only 189 participants were ultimately recruited because the majority of the students and staff were on long holidays. However, only 189 participants were ultimately recruited. The relatively small sample size limits the precision of our estimates and may impact the reliability of the conclusions regarding the overall immune response within the population studied.

The study also exhibited limited age diversity among participants, with only 2.6% exceeding 50 years, 4.8% within the 40-49 age range, and 5.3% within the 30-39 age range. This limited age diversity constrains the ability to make inferences regarding age-related differences in immune responses. Given that older adults often exhibit diminished immune responses due to immunosenescence, the restricted representation of this

demographic in the study population hinders our capacity to generalize findings regarding vaccine efficacy and antibody mobilization to older, more vulnerable groups. Another significant limitation pertains to the small number of participants who reported receiving booster doses. Although the study found no significant variations in IgG titers based on booster dose receipt, only 27 out of the 107 vaccinated study participants had received a booster shot. Consequently, we are unable to draw definitive conclusions regarding the efficacy of booster doses in enhancing immune responses against COVID-19.

5.3 Conclusions

1. IgM Seroprevalence, IgG Seroprevalence, Gender, and Age-Related Immunity: The findings demonstrate persistent SARS-CoV-2 exposure among university populations despite substantial serological immunity, underscoring the need for ongoing surveillance and preventive measures. Moreover, the observed gender and age-related variations in antibody prevalence highlight intrinsic differences in immune response dynamics within this population
2. Antibody Levels: IgG Levels, IgM levels, and booster doses: Here the findings indicate that while long-term antibody responses (IgG) vary by gender and vaccination status, booster doses did not significantly elevate IgG levels, suggesting either sufficient baseline immunity or waning booster effects over time. Comparable immune responses across vaccine types further reinforce their collective efficacy, though moderate booster uptake underscores the need for strengthened immunization reinforcement strategies.

3. Vaccination Rate and Vaccine Hesitancy: The recorded vaccination rate of 56.6%, the findings reflect national distribution patterns dominated by AstraZeneca and Johnson & Johnson, yet reveal persistent vaccine hesitancy driven by personal and health-related concerns. This underscores the ongoing need for targeted interventions addressing misinformation, trust, and access barriers to improve vaccine uptake in sub-Saharan Africa.

5.4 Recommendations

1. Maintain Robust Surveillance and Adaptive Vaccination Strategies
   Given the persistence of viral exposure, evidenced by persisting IgM seroprevalence, it is imperative to maintain a robust epidemiological surveillance system and adaptive vaccination strategies that can respond to shifting viral transmission patterns.
2. Tailored Immunization Strategies and Prioritization of Vaccination and Boosters
   Improve Vaccine Accessibility and Distribution, Intensify Public Health Education Campaigns, Evaluate and Optimize Immunization Strategies.
   Enhancing equitable vaccine coverage requires strengthening distribution systems, addressing access barriers, and delivering vaccines at no cost, while simultaneously intensifying culturally sensitive public health education to counter hesitancy. Continuous evaluation and optimization of immunization strategies will ensure sustained, inclusive, and effective vaccine uptake across all populations.

5.4.1 Recommendation for further research

1. Explore Vaccine Hesitancy and Refusal at Kenyatta University

   A deeper exploration of the socio-cultural, psychological, and economic determinants of vaccine hesitancy at Kenyatta University is required. This research should explore socio-cultural, economic, and psychological factors influencing vaccination decisions, providing valuable insights for designing targeted interventions and informing policy decisions.

2. Monitor Anti-SARS-CoV-2 Antibody Trajectories

   Future studies should track the longitudinal dynamics of IgM and IgG antibodies in both vaccinated and unvaccinated individuals to better understand the durability of immune responses. Such research could provide a more concise assessment of the relative contribution of natural infection versus vaccination to long-term immunity, which could foster strategic timing of booster shots for sustained immunity within populations.

3. Examine Booster Dose Efficacy and Necessity

   Investigate the efficacy and necessity of booster doses in enhancing immune responses, particularly IgG levels, among individuals with varying vaccination statuses and demographic characteristics. This research should inform public health planning and guide future vaccination strategies.

4. Study Long-Term Efficacy and Durability of Immune Responses

   Comprehensive studies are required to evaluate the long-term efficacy of COVID-19 vaccines across different populations. Such studies should pay

particular attention to the persistence of immune responses, breakthrough infection rates, and the long-term safety profile of vaccines.

5. Investigate the Need for Booster Doses Among Younger Demographics

   Given the high IgM seroprevalence among younger adults, there is an urgent need for studies assessing the need and potential impact of booster doses in this age demographic. Studies should focus on understanding the impact of booster doses on long-term immunity and virus containment.

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APPENDICES

Appendix I: Informed Consent Form

INFORMED CONSENT FORM

We are **Drs. Eric Ndombi and Peris Thamaini** (Lecturers of Kenyatta University). We are Co-investigators conducting a study titled "**Uptake of Preventive Measures, Sero-Surveillance and Complementary Management of Covid-19 in Kenya**" The information from the study will be used to get a better understanding of the immune responses produced in people who suffer and recover from infection with Covid-19 and how this might be helpful in mitigating future infections with the same virus. We are also seeking to understand the level of protection conferred by Covid-19 vaccines administered in Kenya. We will also seek to understand the short term and long term effects of infection with Covid-19 with a view to better help in managing this disease in patients.

Procedures to be followed

Participation in this study will require that I ask you some questions. I will record the information you provide in a questionnaire.

I will also require that you agree to take a Covid-19 test and provide about 10 ml of blood collected in 2 vials from your vein.

Voluntarism

You have the right to refuse participation in this study. You will get the same services and care whether you agree to join the study or not and your decision will not change the care you will receive. Please remember the participation in this study is voluntary. You may ask questions related to the study at any time.

You may refuse to respond to any questions and you may stop an interview at any time. You may also stop being in the study at any time without any consequences to the services you receive here or any other organization now or in the future.

Discomforts and Risks

Some of the questions you will be asked are of a personal nature and may be embarrassing or make you uncomfortable. If this happens, you may refuse to answer these questions if you so choose. You may also stop the interview at any time. The interview will take approximately fifteen (15) minutes of your time.

There will also be discomfort during sample collection from your nose. However, the technician involved is very experienced and will take utmost precaution to minimize discomfort.

There will be pain as well from piercing with the needle to collect blood. This will be done by an experienced technician who will take utmost care to minimize pain and chances of infection from the prick.

Benefits

If you participate in this study you will help us to learn the level of uptake and population behavioural attitudes towards the MoH preventive and control measures in the Kenyan population. This will inform the government of Kenya on Covid-19 preventive strategies that are sustainable and those that require reinforcement. The information collected will also help us better understand how Covid-19 disease affects the immune system's level of protection against reinfection, vaccine efficacy, symptoms of the disease and how long they last in patients.

Reward

There are no rewards or any payment to you if you participate in this study. However, should the researchers identify an immediate health need, a referral will be recommended to the patient.

Confidentiality

The interviews will be conducted at the health unit. Your name will not be recorded on the questionnaire. The questionnaires and data collected from the analyzing your blood sample will be kept in a locked cabinet for safe keeping at Kenyatta University. Everything will be kept private and only shared with the study team.

Contact Information

If you have questions about the study kindly call Dr. Eric Ndombi 0722250342 or Dr. Peris Thamaini 0722844673

However, if you have questions about your rights as a study participant: You may contact Kenyatta University Ethical Review Committee Secretariat on chairman.kuerc@ku.ac.ke, secretary.kuerc@ku.ac.ke,

Participant's statement

The above information regarding my participation in the study is clear to me. The study has been explained to me and I have been given a chance to ask questions and my questions have been answered to my satisfaction. My participation in this study is entirely voluntary. I understand that my records will be kept private and that I can leave the study at any time. I understand that I will not be victimized whether I decide to leave the study or not.

Name of Participant .....

Signature or Thumbprint Date

_____ _____

Appendix II: Time Schedule of the Proposed Masters Project

Time Period	**Activities/ Procedures**
July 2023-October 2023	Proposal development and presentation
October 2023- November 2023	Study ethical approval and logistics
December 2023-January 2024	Sample collection, processing and testing
January 2024- February 2024	Interpretation of data and analysis
March 2024- May 2024	Final write-up and publication
June 2023- July 2024	Defense and final submission of thesis

Appendix III: Budget

Item	**Estimated Costs (in Kshs)**	**Covered How/By Whom**
Human SARS-CoV-2 Spike IgM kit	3 @110,000	Purchase of ELISA Human SARS-CoV-2 Spike IgM kit
Human SARS-CoV-2 Spike IgG kit	3@110,000	Purchase of ELISA Human SARS-CoV-2 Spike IgG kit
Distilled H2O- 60L Pippettes tips(assorted)Gloves (3), Syringes, Eppendorf tubes	18,700	Purchase of consumables/referral laboratory costs
Printing, photocopying and other stationeries	20,000	Proposal, thesis, study questionnaires and consent forms
Publications	15,000	Publication fee (1 publication)
Local Travel costs	15,000	To the study sites and transport of research samples
Research Assistants	30,000	Collection of samples
Total	758,000	

Appendix IV: Questionnaire

Uptake of Preventive Measures, Sero-Surveillance and Complementary Management of Covid-19 in Kenya

Socio-Demographics

Instructions: Please select the best answer of your choice.

1. How old are you in years? _____
2. What is your gender?
   O Male
   O Female
3. What is your highest level of education?
   O Primary school
   O Secondary school
   O College and above
   O No formal education
4. What is your current occupation
   O Teaching staff
   O Non-teaching staff
   O Student
   O Health unit staff
   O Student
   O Other (Specify)_____
5. Do you have or have you had any of the illnesses listed below

	Yes	No
Diabetes	O	O
Hypertension	O	O
HIV	O	O
Asthma	O	O
Cancer	O	O
Autoimmune disease	O	O
Other Chronic illness (specify)	O	O

Specify other illness _____

6. Have you been sick with coronavirus (Covid-19)?

   O Yes, confirmed

   O Yes, but not yet confirmed

   O No

7. If yes, when was the last time you were confirmed sick with Covid-19? _____

8. If yes, how ill were you with Covid 19?

   O I did not have any symptoms

   O I had symptoms but recovered without medication

   O I had symptoms and was treated as an outpatient in hospital

   O I had symptoms and was admitted to hospital in the general wards

   O I had symptoms and was admitted to hospital in the ICU/HDU

9. When you had Covid-19 which symptoms did you have? Please select all that apply.

	Yes	No
Fever	O	O
Cough	O	O
Shortness of breath	O	O
Sore throat	O	O
Runny or stuffy nose	O	O
Muscle or body aches	O	O
Headaches	O	O
Fatigue (tiredness)	O	O
Diarrhea	O	O
Loss of taste and smell	O	O

10. How long did you take to recover from COVID-19 symptoms

	Yes	No
Less than 2 weeks	O	O
2 weeks – 4 weeks	O	O
1 month to 3 months	O	O

3 months to a year	O	O
More than a year	O	O
I still have symptoms	O	O

11. If you still have symptoms, please tick which of them still persist

	Yes	No
Fever	O	O
Cough	O	O
Shortness of breath	O	O
Sore throat	O	O
Runny or stuffy nose	O	O
Muscle or body aches	O	O
Headaches	O	O
Fatigue (tiredness)	O	O
Diarrhea	O	O
Loss of taste and smell	O	O

12. Did you develop any symptoms that were not there at your initial diagnosis later on in your illness?

    O Yes

    O No

13. If Yes please list the symptoms you experienced (tick all that apply)

	Yes	No
Extreme Tiredness	O	O
Shortness of breath	O	O
Loss of smell or taste	O	O
Muscle aches and pains	O	O
Heart palpitations	O	O
Dizziness	O	O
Pins and needles	O	O

Joint pain	O	O
Depression and anxiety	O	O
Earache and tinnitus	O	O
Loss of appetite and nauseas	O	O
Skin rash	O	O
Problems with memory	O	O
Alterations in menstrual flow or patterns	O	O
Other	O	O

Specify Other: _____

14. How long after your initial diagnosis with COVID-19 did you later symptoms develop?

	Yes	No
1 month to 3 months	O	O
3 months to a year	O	O
More than a year	O	O

15. Have you been vaccinated against coronavirus (Covid-19)?

    O Yes

    O No

16. If yes, what vaccine did you receive?

    O MODERNA

    O ASTRAZENECA

    O PFIZER

    O JOHNSON&JOHNSON

    O SINOPHARM

    O DON'T KNOW

17. If yes, have you received a booster dose?_

    O Yes

    O No

18. When last did you receive your vaccine? _____

19. Have you been infected with Covid-19 following vaccination?

    O Yes

    O No

20. If yes, how ill were you with Covid 19 after vaccination?

    O I did not have any symptoms

    O I had symptoms but recovered without medication

    O I had symptoms and was treated as an outpatient in hospital

    O I had symptoms and was admitted to hospital in the general wards

    O I had symptoms and was admitted to hospital in the ICU/HDU

21. When were you last diagnosed with Covid-19? _____

22. If you have not been vaccinated against Covid-19, please indicate why? _____

Appendix V: NACOSTI (National Commission for Science Technology and Innovation) Research Permit

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **262270**

Date of Issue: **08/November/2021**

RESEARCH LICENSE

This is to Certify that Kenyatta University, has been licensed to conduct research in Kisumu, Mombasa, Nairobi on the topic: UPTAKE OF PREVENTIVE MEASURES, SERO-SURVEILLANCE AND COMPLEMENTARY MANAGEMENT OF COVID-19 IN KENYA. for the period ending : 08/November/2022.

License No: **NACOSTI/P/21/14053**

262270

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

The Grant of Research Licenses is Guided by the Science, Technology and Innovation (Research Licensing) Regulations, 2014

CONDITIONS

1. The License is valid for the proposed research, location and specified period
2. The License any rights thereunder are non-transferable
3. The Licensee shall inform the relevant County Director of Education, County Commissioner and County Governor before commencement of the research
4. Excavation, filming and collection of specimens are subject to further necessary clearence from relevant Government Agencies
5. The License does not give authority to tranfer research materials
6. NACOSTI may monitor and evaluate the licensed research project
7. The Licensee shall submit one hard copy and upload a soft copy of their final report (thesis) within one of completion of the research
8. NACOSTI reserves the right to modify the conditions of the License including cancellation without prior notice

National Commission for Science, Technology and Innovation
off Waiyaki Way, Upper Kabete,
P. O. Box 30623, 00100 Nairobi, KENYA
Land line: 020 4007000, 020 2241349, 020 3310571, 020 8001077
Mobile: 0713 788 787 / 0735 404 245
E-mail: dg@nacosti.go.ke / registry@nacosti.go.ke
Website: www.nacosti.go.ke

Appendix VI: Ethical Approval (Kenyatta University Ethics Review Committee)

KENYATTA UNIVERSITY
CENTRE FOR RESEARCH ETHICS AND SAFETY

Fax: 8711242/8711575 **P. O. Box 43844,**
Email: chairman.kuerc@ku.ac.ke
Nairobi, 00100

Tel: 8710901/12

Website: www.ku.ac.ke
Our Ref: **KU/ERC/APPROVAL/VOL.1** Date: 28th /02/2022

Prof. Paul Okemo
P.O Box 43844-00100
Nairobi

Dear Sir,

APPLICATION NUMBER: PKU/2379/1I516 – UPTAKE OF PREVENTIVE MEASURES, SERO-SURVEILLANCE AND COMPLEMENTARY MANAGEMENT OF COVID-19 IN KENYA

This is to inform you that ***KENYATTA UNIVERSITY ETHICS REVIEW COMMITTEE*** has reviewed and approved your above research proposal. Your application approval number is **PKU/2379/1I516.** The approval period is **28th /02/2022 to 28th /02/2023**

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used
ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by ***KENYATTA UNIVERSITY ETHICS REVIEW COMMITTEE***
iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to ***KENYATTA UNIVERSITY ETHICS REVIEW COMMITTEE*** within 72 hours of notification
iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to ***KENYATTA UNIVERSITY ETHICS REVIEW COMMITTEE*** within 72 hours
v. Clearance for export of biological specimens must be obtained from relevant institutions.

vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.

vii. Submission of an executive summary report within 90 days upon completion of the study to ***KENYATTA UNIVERSITY ETHICS REVIEW COMMITTEE***

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://research-portal.nacosti.go.ke and also obtain other clearances needed.

To serve you better, researchers are kindly requested to access and complete a customer feedback form and sent it back online as you continue with research and upon completion of data collection found on the following website link; ;(https://docs.google.com/forms/d/1ytWefDwvyz5h1oz_VIn0xbxg3uGdlDzMXFWNDsMrRPQ/edit?usp=sharing

Yours sincerely

Prof. Judith Kimiywe

Director: Centre for Research Ethics and Safety

Appendix VII: Renewal of Ethical Approval (Kenyatta University Ethics Review Committee)

KENYATTA UNIVERSITY
ETHICS REVIEW COMMITTEE

Fax: 8711242/8711575
Email: kuerc.chairman@ku.ac.ke

P. O. Box 43844,
Nairobi, 00100
Tel: 8710901/12

Website: www.ku.ac.ke

Our Ref: **KU/ERC/EXTEN.APPR.1/VOL.1** (1) Date: 5TH /04/2024

Dear Prof. Paul O. Okemo,

APPLICATION NUMBER- PKU/2379/I1516 – UPTAKE OF PREVENTIVE MEASURES, SERO-SURVEILLANCE AND COMPLEMENTARY MANAGEMENT OF COVID – 19 IN KENYA.

1. IDENTIFICATION OF PROTOCOL

The application before the committee is with a research topic - **"Uptake of Preventive Measures, Sero-Surveillance and Complementary Management of Covid – 19 in Kenya."** received on 5th April 2024 and deliberated on 5th April 2024

2. DECISION

Kenyatta University Ethics Review Committee has **RENEWED THE APPROVAL, and that the research may proceed for one year from 5th April 2024 to 5th April 2025** as per the request and NACOSTI approval

3. ADVICE/CONDITIONS

i. Progress reports are submitted to the KU-ERC every six months and a full report is submitted at the end of the study.
ii. Serious and unexpected adverse events related to the conduct of the study are reported to this committee immediately they occur.
iii. Notify the Kenyatta University Ethics Committee of any amendments to the protocol.
iv. Submit an electronic copy of the protocol to KUERC.

When replying, kindly quote the application number above.

KENYATTA UNIVERSITY OFFICE OF THE CHAIRMAN 05 APR 2024 ETHICS REVIEW COMMITTEE NAIROBI

PROF. JUDITH KIMIYWE
CHAIRMAN ETHICS REVIEW COMMITTEE