**Health and economic burden of Long COVID in Kenya**

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**Abstract**

**Objectives:** To estimate the quality-adjusted life-years (QALYs) loss, disability-adjusted life years (DALYs), and productivity loss due to Long COVID in Kenya.

**Methods:** A Markov model was developed with 9 health states, a 12-week cycle, and a 10-year time horizon. The target population included adults ≥18 years with COVID-19 infection with no symptoms, mild/moderate, severe, and critical symptoms. Individuals with COVID-19 can either die or survive. If individuals survive, they can evolve to mild, moderate, and severe Long COVID or recover. Transition probabilities between health states, health-related quality of life, and absenteeism days of each health state were collected from the Kenya population databases and the Kenyan prospective cohort of Long COVID. Disability weights were extracted from the literature. Life expectancy and mortality tables were extracted from Kenya databases.

**Results:**

**Conclusions:**

1. **Introduction**

Worldwide, the COVID-19 pandemic has increased mortality considerably and overstretched healthcare systems’ capacity to provide care1. At the start of the pandemic, people who needed hospitalisation and intensive care were those who had priority of care1. Over the second year, as vaccination rates increased greatly, which in turn reduced the prevalence of serious illness and deaths, the demand for care started to come from those with post-infection complications, also referred to as Long COVID2. Evidence is still limited but suggests that approximately 1 in 10 adults experience ongoing symptoms 3 months after being infected, including those who are asymptomatic at the time of diagnosis3–8. The fact that symptoms are heterogeneous and may be different in different populations makes it difficult to accurately identify individuals who are suffering from Long COVID, and thus to assess its burden9.

In this context, information on the impact of long-term disease-related disabilities on populations’ well-being and productivity losses is deemed necessary to not underestimate the pandemic’s societal aftermath10. This is relevant especially in low- and middle-income countries (LMICs) as they usually rely on the productivity of people of working age for economic development9. Information on the long-term consequences of the COVID-19 pandemic can be obtained by using metrics such as Quality-Adjusted Life Year (QALY) losses and Disability-Adjusted Life Years (DALYs). These metrics capture the impact of illness on a person’s life course by combining the years lived while suffering from a health condition and years of life lost due to premature death9,10. It is also relevant to know how QALY losses and DALYs due to Long COVID translates into productivity losses. As an added value, these metrics can provide inputs to models estimating the population-wide impact on health and economic consequences of COVID-19 under different epidemic scenarios, and, therefore, help decision-makers to decide how to allocate already limited resources in such a way that benefits society the most.

Kenya has not been spared from the COVID-19 scourge and has continued to experience waves of the pandemic11. The first COVID-19 case in Kenya was reported on 12th March 2020 in Nairobi (Kenya’s capital) and since then Kenya has recorded 323,939 cases and 6,649 deaths (as of 13 May 2022). The COVID-19 pandemic reports have focused primarily on evaluating the number of cases, hospitalizations, and deaths. These statistics are important, yet insufficient to provide a better understanding of the long-term impact of Long COVID on health and its economic consequences from a societal perspective. Therefore, this study aims to provide information on the burden of Long COVID by estimating the QALY losses, DALYs, and productivity loss due to Long COVID in Kenya.

1. **Methods**
   1. **Target population**

The target population of the model included data on adults ≥18 years who tested positive for COVID-19 infection with no symptoms (i.e., asymptomatic), mild/moderate, and severe symptoms between January 2021 and January 2022 followed for a period of 10 years. Between January 2021 and January 2022, 3 waves of COVID-19 variants occurred, namely Alpha variant (B.1.1.7 wave in March 2021), Delta variant (B.1.617.2 wave in August 2021), and Omicron (B1.1.529 wave in December 2021)12.

* 1. **Setting**

The Kenyan Health Care System is provided by public and private healthcare facilities, and it is structured in six levels (i.e., community, dispensaries, health centres, primary referral facilities, secondary referral facilities, and provincial and national hospital)13. To expand health coverage and reduce out-of-pocket payments a health insurance coverage is being implemented by the National Hospital Insurance Fund (NHIF)14. Despite the efforts, the NHIF covers roughly 16% of the Kenyan population15, meaning that most of population rely on ou-of-pocket payments to get access to healthcare and, therefore, they avoid going to hospital unless their health state is critical16,17. Costs of COVID-19 testing has not been included in the NHIF which may also lead to an underestimation of cases.

* 1. **Model structure**

A Markov model was developed with 9 health states, a 12-week cycle, and a 10-year time horizon. This model was built on the published model developed by the European Burden of Disease Network18 and Angeles et al.19. The model includes two components, namely the *acute* and the *Long COVID* components (**Figure 1**).

The *acute component* represents the acute COVID-19 infection and starts with the COVID-19 diagnosis by the Polymerase Chain Reaction (CPR). Given a positive PCR, individuals may remain asymptomatic or evolve to having mild/moderate signs and symptoms. Subsequently, individuals in the mild/moderate health state may evolve to a severe state (i.e., hospitalization admission), and then evolve to a critical state (intensive care unit, ICU admission). Individuals can either survive or die. Those who survive can recover or present Long COVID symptoms. In the *acute component*, the COVID-19 health states are represented as tunnel states because individuals progress through them in a sequence that does not allow returning to the previous state (**Figure 1**). Acute signs and symptoms of COVID-19 can last up to 4 weeks20,21.

In the *Long COVID component*, individuals with asymptomatic COVID-19 infection or at any acute COVID-19 health state can either die or survive. If individuals survive, they can recover or evolve to mild, moderate, or severe Long COVID. Long COVID is defined as signs and symptoms that continue or develop after acute COVID‑19 infection and are not explained by an alternative diagnosis20. It includes both ongoing symptomatic COVID‑19 (from 4 to 12 weeks) and post‑COVID‑19 syndrome (12 weeks or more)20 (**Figure 1**). Categorization of Long-COVID according to severity levels was based on data collected from the prospective cohort of Long COVID in Kenya available in another publicationREF. Briefly, information on the presence and severity of fatigue, pain, cognitive impairment, and dyspnoea, age, sex, level of education, number of comorbidities, and healthcare utilization up to 12 weeks were used to estimate a weighted Long COVID severity score using a Principal Component Analysis.

The model was adjusted by vaccination coverage rate22, primary care coverage rate23, and health conditions that are prevalent in Kenya (i.e., HIV24, and obesity25) as well as life expectancy of Kenya population26. The implementation of these parameters in the model are detailed explained in section 2.4.5.

**2.4 Model parameters**

**2.4.1 Transition probabilities**

For the *acute component* of the model, transition probabilities in the acute COVID-19 infection were extracted from systematic reviews and metanalyses (**Table 1**). For the *Long COVID component* of the model, transition probabilities were based on the prospective cohort of Long COVID in Kenya (**Table 1**).

**2.4.2 Quality-adjusted life year losses**

QALYs will be calculated based on the EQ-5D-5L data collected from a prospective cohort of Long COVID in Kenya. The EQ-5D-5L is a generic preference-based measure of health-related quality of life including a descriptive system describing five different aspects of health (i.e., mobility, self-care, usual activities, pain/discomfort, and anxiety/depression) on a five-point ordered scale (i.e., no problems, slight problems, moderate problems, severe problems, unable to/ extreme problems)27. Participants are asked to indicate their health state by checking the box next to the most appropriate response level for each of the five dimensions. Health states were scored using tariffs or utility values from Uganda population29 since a value set for Kenya is not available. QALYs were calculated by multiplying the duration of life a participant spent in a health state by the utility value of this health state32.

**2.4.3 Disability-adjusted life years**

**2.4.4 Productivity Losses**

**2.4.5 Other parameters**

**2.5 Analysis**

**2.6 Sensitivity analysis**

**Results**

**Discussion**

**Main findings**

**Explanation of findings and comparison with the literature**

**Strengths and limitations**

**Implications to decision-making**

**Conclusion**

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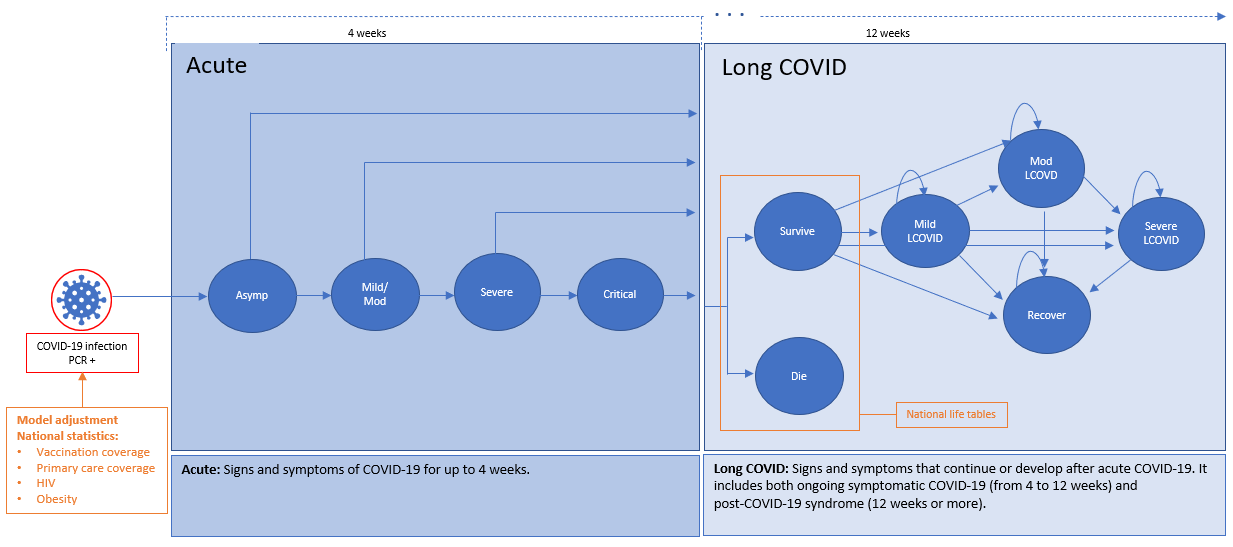
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**Figure 1.** Long COVID model. In the acute COVID-19 infection phase, individuals with asymptomatic infection or symptomatic can either die or survive. Health states in the acute phase are represented as tunnel states as individuals progress through them in a sequence that does not allow returning to the previous one. If individuals survive, they can evolve to mild, moderate, and severe Long COVID or recover. The model is adjusted by vaccination coverage rate, primary care coverage rate, and health conditions that are prevalent in Kenya (i.e., HIV, and obesity).

**Table 1. Model parameters**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Value** | **Sensitivity analysis** | **Reference** | **Year** |
| **Acute component – Omicron variant** | | | | |
| **Transition probabilities** | | | | |
| From asymp to mild/mod COVID-19 | 0.60 | 0.53 – 0.66 | 33,34 | 2021 |
| From mild/mod COVID-19 to severe | 0.10 |  |  |  |
| From severe COVID-19 to critical | 0.03 |  |  |  |
| **Utilities** |  |  |  |  |
| Asymp COVID-19 |  |  |  |  |
| Mild/mod COVID-19 |  |  |  |  |
| Severe COVID-19 |  |  |  |  |
| Critical COVID-19 |  |  |  |  |
| **Disability weights** | | | | |
| Asymp COVID-19 |  |  |  |  |
| Mild/mod COVID-19 |  |  |  |  |
| Severe COVID-19 |  |  |  |  |
| Critical COVID-19 |  |  |  |  |
| **Absenteeism days** |  |  |  |  |
| Asymp COVID-19 |  |  |  |  |
| Mild/mod COVID-19 |  |  |  |  |
| Severe COVID-19 |  |  |  |  |
| Critical COVID-19 |  |  |  |  |
| **Unit costs** | | | | |
| Asymp COVID-19 |  |  |  |  |
| Mild/mod COVID-19 |  |  |  |  |
| Severe COVID-19 |  |  |  |  |
| Critical COVID-19 |  |  |  |  |
| **Long COVID component – Omicron variant** | | | | |
| **Transition probabilities** | | | | |
| From asymp COVID-19 to mild LCOVID | 0.10 |  |  |  |
| From asymp COVID-19 to mod LCOVID | 0.01 |  |  |  |
| From asymp COVID-19 to severe LCOVID | 0.001 |  |  |  |
| From mild/mod COVID-19 to mild LCOVID | 0.15 |  |  |  |
| From mild/mod COVID-19 to mod LCOVID | 0.05 |  |  |  |
| From mild/mod COVID-19 to severe LCOVID | 0.001 |  |  |  |
| From severe COVID-19 to mild LCOVID | 0.10 |  |  |  |
| From severe COVID-19 to mod LCOVID | 0.20 |  |  |  |
| From severe COVID-19 to severe LCOVID | 0.15 |  |  |  |
| From critical COVID-19 to mild LCOVID | 0.05 |  |  |  |
| From critical COVID-19 to mod LCOVID | 0.20 |  |  |  |
| From critical COVID-19 to severe LCOVID | 0.25 |  |  |  |
| **Utilities** | | | | |
| Mild LCOVID |  |  |  |  |
| Mod LCOVID |  |  |  |  |
| Severe LCOVID |  |  |  |  |
| Recover |  |  |  |  |
| **Disability weights** |  |  |  |  |
| Mild LCOVID |  |  |  |  |
| Mod LCOVID |  |  |  |  |
| Severe LCOVID |  |  |  |  |
| Recover |  |  |  |  |
| **Absenteeism days** |  |  |  |  |
| Asymp COVID-19 |  |  |  |  |
| Mild/mod COVID-19 |  |  |  |  |
| Severe COVID-19 |  |  |  |  |
| Critical COVID-19 |  |  |  |  |
| **Unit costs** |  |  |  |  |
| Mild LCOVID |  |  |  |  |
| Mod LCOVID |  |  |  |  |
| Severe LCOVID |  |  |  |  |
| Recover |  |  |  |  |
| Average salary per day – males |  |  |  |  |
| Average salary per day – females |  |  |  |  |

**APPENDIX I**

**Data requirements**

*Demographic data from Kenya’s population in 2020*

|  |  |  |  |
| --- | --- | --- | --- |
| **Age** | **Male** | **Female** | **Source** |
| **0-14 years** | 10,412,321 | 10,310,908 | 35 |
| **15-24 years** | 5,486,641 | 5,460,372 | 35 |
| **25-54 years** | 9,046,946 | 9,021,207 | 35 |
| **55-64 years** | 1,053,202 | 1,093,305 | 35 |
| **65 years and over** | 750,988 | 892,046 | 35 |

*Data requirements for calculating years lived with disability (YLD)*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Type** | **Name** | **Description** | **Number of cases in 2020** | **Disability weight** | **Source** |
| **Acute COVID-19 infection**  Signs and symptoms of COVID‑19 for up to 4 weeks. | Asymptomatic | Has no symptoms up to 4 weeks |  |  | 21 |
| Mild/Moderate | *Mild*: Fever, cough, sore throat, malaise, headache, muscle pain BUT No dyspnoea (shortness of breath) and No abnormalities on chest imaging/  *Moderate*:  Clinical features of pneumonia (fever, cough, dyspnoea) AND/OR radiological features of pneumonia BUT Oxygen saturations (SPO2) greater than or equal to 94% on room air |  |  | 21 |
| Severe | Clinical and radiological features of pneumonia, tachypnea with RR>30 AND oxygen saturation (SPO2) less than 94% on room air |  |  | 21 |
| Critical illness | Features of severe illness AND Any of the following:  • respiratory failure  • sepsis/septic shock  • multiorgan dysfunction  • acute thrombosis |  |  | 21 |
|  | **Recovery** |  |  |  |  |
| **Long COVID**  Signs and symptoms that continue or develop after acute COVID‑19. It includes both ongoing symptomatic COVID‑19 (from 4 to 12 weeks) and post‑COVID‑19 syndrome (12 weeks or more). | Mild | Some difficulty daily activities |  |  | 20 |
|  | Moderate | Some difficulty daily activities |  |  |  |
|  | Severe |  |  |  |  |