A REPORT COVID 19 PROJECTION

A Case on Non-pharmaceutical and Vaccine Interventions

Produced By: National Data Management Center for Health

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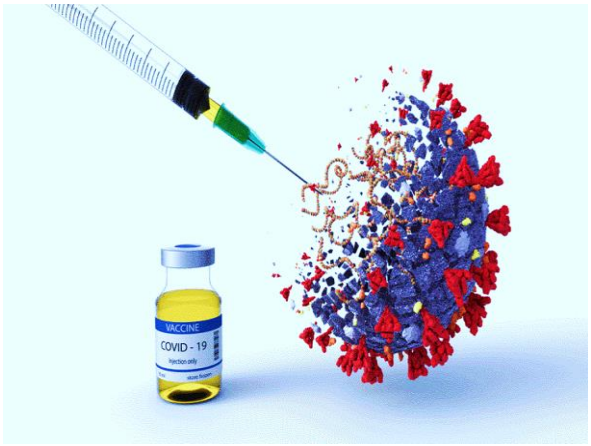

1. Introduction

The World Health Organization (WHO) declared the outbreak of COVID-19 as a global pandemic during March 11, 2020. By June 11, 2021, there were 174.4Million confirmed cases across the globe. In Ethiopia, on June 11, 2021, there were 273,678 total number of confirmed cases, and there were 4,231 total reported deaths. This evidence shows that the pandemic is still a national and global threat. Preventing and controlling the spread of COVDI 19, reducing disease severity and mortality require strict implementation of Non-Pharmaceutical Interventions (NPIs) and vaccination until proven treatment is made available.

Vaccination against SARS-CoV-2 has the potential to significantly reduce transmission and morbidity and mortality due to COVID-19. However, the efficacy of vaccination depends on demographic factors (age), level (prevalence) of the infection in the community, the compliance and efficacy of NPIs, the most prevalent variants of COVID-19 in the community, and the vaccine administration rate. Considering the complexities of large-scale vaccine production, distribution, storage, and uptake, achieving high coverage will be challenging. Therefore, critical questions remain regarding the need to continue non-pharmaceutical interventions (NPIs), such as physical distancing and face mask usage, as the public is vaccinated over time. The infection rate can be reduced by various non-pharmaceutical interventions (NPIs) while a vaccine is targeted to sections of the population where it will have the greatest impact. Therefore, any proposed model must provide comparative simulations for different age groups and joint impact simulations for NPIs and vaccine intervention by considering different levels of compliances, efficacy, and rates of vaccine coverages.

This study aimed to provide long-term and short-term predictions on the total number of cases, severe (hospitalized) cases, critical (ICU) cases, and the number of deaths considering different vaccination coverage and its effectiveness across age groups and for COVID-19 variants and, compliances and effectiveness of the NPIs.

2. Methodology

Age stratified Hybrid model was used to forecast the total number of cases, hospitalization and ICU requirements, and the total number of deaths at national level.

The Hybrid model is implemented in two major steps:

1. The mathematical and statistical models were used to rapidly characterize and estimate the key parameters of the compartmental model from surveillance and case management data.

2. The compartmental S-E-Ic-Ih-I(icu) - R - D for the non-vaccinated portion of the population. This structure is connected to V-E_v-$I(c)_v$-$I(h)_v$-$I(icu)_v$ - R_v for the vaccinated portion of the population.

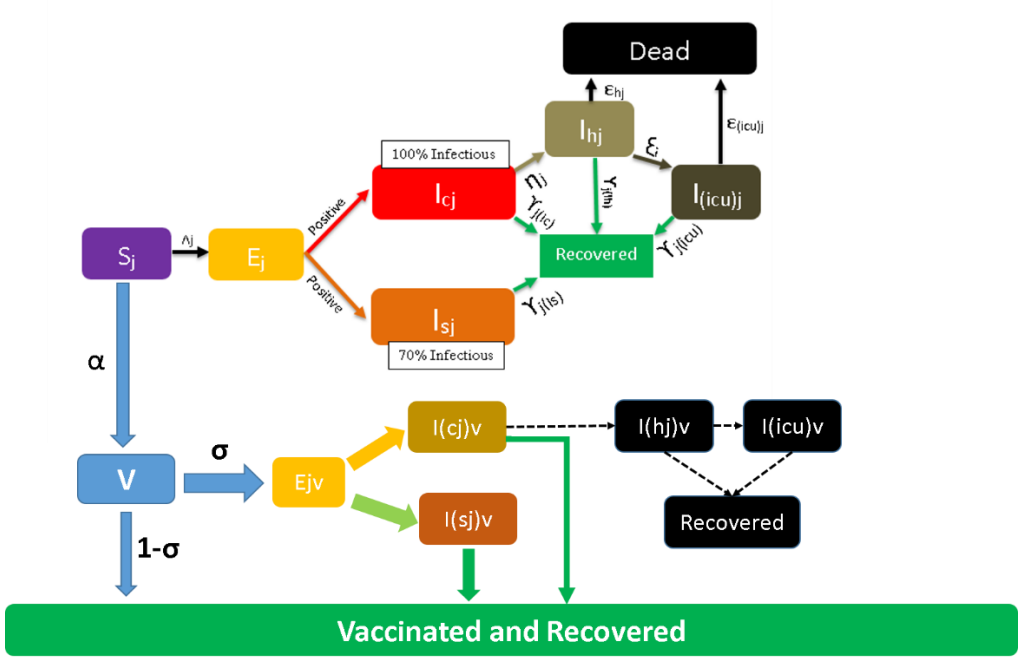

Fig 1. Compartmental model structure

1.1 Model Values and Assumptions

In this model the transmission rate is statistically fitted, on adjusted number of cases reported by the Ministry of Health.

The model has been dis-aggregated into 16 age groups to effectively capture differences in the level of compliance and efficacy of interventions, transmission dynamics, case severity and fatality among across the age groups.

The model simulation started on May 10, 2020, when community transmission was reported for the first time in Ethiopia. The model assumes vaccines doses were being administered as of March 25, 2021 targeting older age groups (55+). While, intervention tightening scenarios were introduced starting from June 05, 2021.

Two projection target (time) were identified.

1. **Shorter-term projection (STP)**: For this condition, different scenarios were simulated to forecast total number of cases, clinical cases, severe and critical cases, and number of deaths by July 10, 2021, starting from June 10, 2021. Only slight increment in the values of the interventions were considered.

2. Longer-term projection (LTP): For this condition, different scenarios were simulated to forecast total number of cases, clinical cases, severe and critical cases, and number of deaths by December 31, 2021, starting from June 10, 2021.

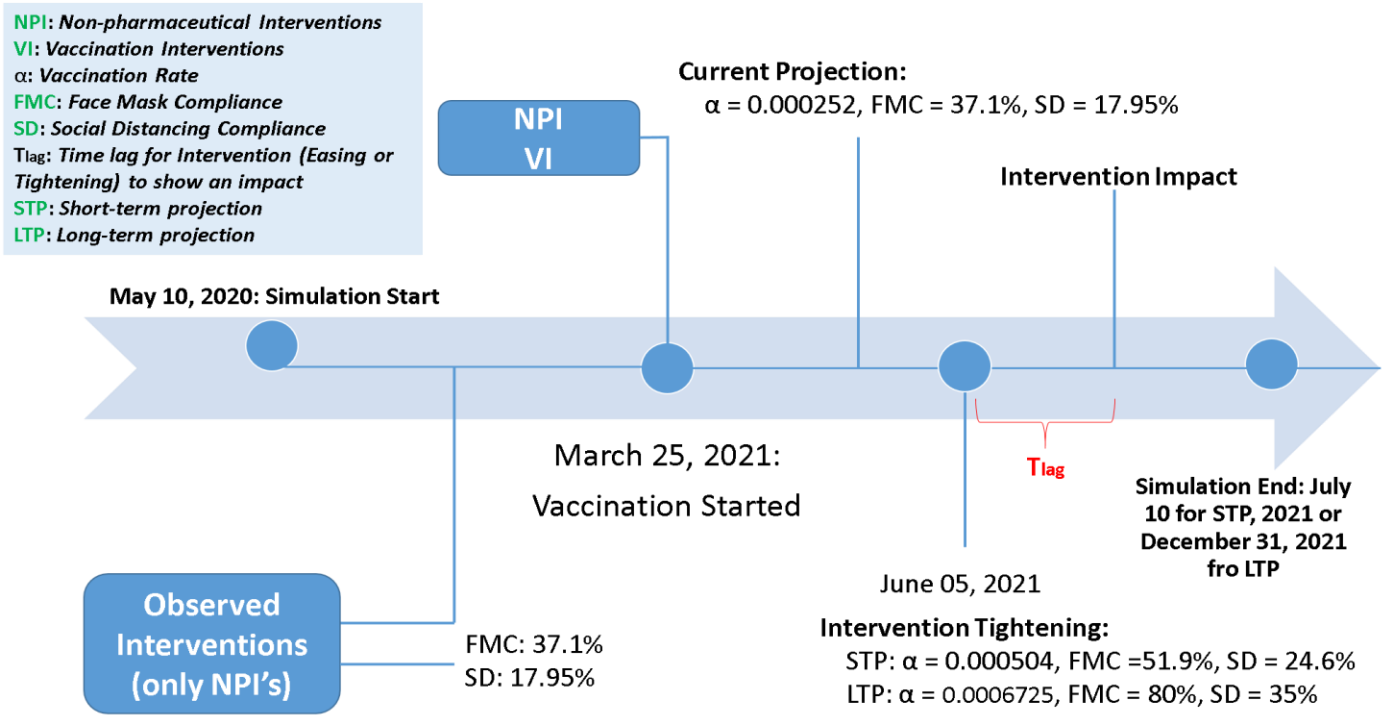

Fig 2. Model simulation time-line

In this model two interventions were considered for this report

1. **Non-Pharmaceutical Interventions (NPIs)**
2. **Vaccine Intervention(VI)**

1.2 Non-pharmaceutical Interventions (NPIs)

Weekly observed facemask and social distancing compliances at a national level were used in the model. NPI compliance weekly survey is conducted by Addis Ababa University in major Ethiopian cities. NPIs are useful intervention in preventing and reducing the transmission rate as well as burden on the health system.

1.3 Vaccine Intervention (VI)

The rate of vaccination is calculated from reports on currently administered vaccines. The impact of the vaccines is quantified in the model, in the following three areas.

1. Prevention of infection
2. Prevention of symptomatic diseases
3. Prevention of severe or critical cases (Hospitalization and ICU)

The efficacy of the vaccine is also dependent on vaccine type and COVID-19 variant(s) in Ethiopia, which are taken into account in this modeling exercises.

1.4 Intervention Package

Currently, in Ethiopia the intervention package include NPI and Vaccines for the prevention and control of the disease. Thus, the model incorporates this as one intervention package.

Table 1: Intervention parameter values

Intervention		Current Projection	Intervention Tightening – shorter term projection (July 10, 2021)	Intervention Tightening – longer term projection (December 31, 2021)
NPIs	Face Mask Efficacy	25%	25%	25%
	Face Mask Compliance*	37.1%	51.88%	80%
	Social Distancing*	17.95%	24.59%	35%
VI for D614G & B.1.1.7 variants (Group 1)	Coverage Proportion	65%	65%	65%
	Prevention of Infection**	52%	52%	52%
	Prevention of diseases**	74%, but 85% for age group above 85.	74%, but 85% for age group above 85.	74%, but 85% for age group above 85.

	Prevention of severity**	100%	100%	100%
	Vaccination rate	0.000252	0.000504	0.0006725
	Target Population group	Above 55 age group	Above 45 age group	All age groups
VI for B.1.351 & P.1 variants (Group 2)	Prevention of Infection**	31%	31%	31%
	Prevention of diseases**	35%	35%	35%
	Prevention of severity** (Assumed, no study was found)	100%	100%	100%
	Vaccination rate	0.000252	0.000504	0.0006725
	Target Population group	Above 55 age group	Above 45 age group	All age groups
*** Average values from the observed/forecasted NPI compliances.**				
**** The values are for AstraZeneca vaccine type.**				

Using this model, different realistic scenarios depending on the above projection targets, were generated and simulated for the different COVID-19 variants. The following scenarios were developed.

1. **Current Projection:** The observed NPI trends will continue into the future. In addition, vaccination rate will also continue with current coverage rate. For the shorter-term projection, current projection the observed NPI trends and vaccination rate with the defined target population group will continue until July 10, 2021. Similarly, for the longer-term projection the

observed NPI trends and vaccination rate will continue, but this tame the target group for the vaccine is the entire population as the simulation will continue until December 31, 2021.

2. **Intervention Tightening:** For the shorter-term projection, from the observed NPI compliance trends, we forecasted the most likely achievable compliances. In case of vaccination, we have assumed the vaccination rate will double over this period and the target group will increase subsequently. The time lag for the NPIs to increase to the targeted value over this period is assumed to be 14 days.

   Intervention tightening scenarios for the longer-term projection, are defined as follow:

   a. Face Mask Compliance will increase from 37.10% to 80%
   b. Social Distancing will increase from 17.95% to 35%
   c. Vaccination coverage will reach 30M (27% of the population)

   We have assumed the interventions are targeted to be achieved one year from now. The major point to consider here is that, first: we cannot assume these interventions will increase over-night. Second: we cannot assume these interventions will increase gradually (slowly) to the targeted values over the period of one year. Since this, might under-estimate the impacts of NPIs. Accordingly, we have considered:

   a. The NPIs will be strictly implemented in the coming two months, and will reach the targeted values. In addition, we have assumed after the targets are achieved with in these two months, the mandate will be held in place throughout the year.
   b. The vaccination rate will continue with the observed trend up to June 05, 2021, and will gradually change to the new vaccination rate. This new vaccination rate is calculated so that the target vaccine coverage will be achieved after one year.

Table 2. Intervention scenarios and parameter values, for Longer-term projection

Interventions	Current Projection	Intervention Tightening	Period of attainment
Face Mask Compliances	37.10%	80%	Over two months, and will be maintained afterward.
Social	17.95%	35%	Over two months,

Distancing			and will be maintained afterward.
Vaccination rate	0.000252 (10M will be vaccinated after one year)	0.000697 (30M will be vaccinated after one year)	Over the period of one year.

In the subsequent section, we provide results for the short-term and long-term projections the above two scenarios. Only AstraZeneca was considered for vaccine intervention scenarios.

3. Results: Shorter-term Projection

3.1 Total COVID-19 Cases Forecast

The total number of cases is the sum of all COVID-19 cases regardless of the clinical stages. The total number of cases includes detected and undetected cases, symptomatic and asymptomatic cases, including all severe or critical cases in hospitalization or ICU. (see fig 3 and 4)

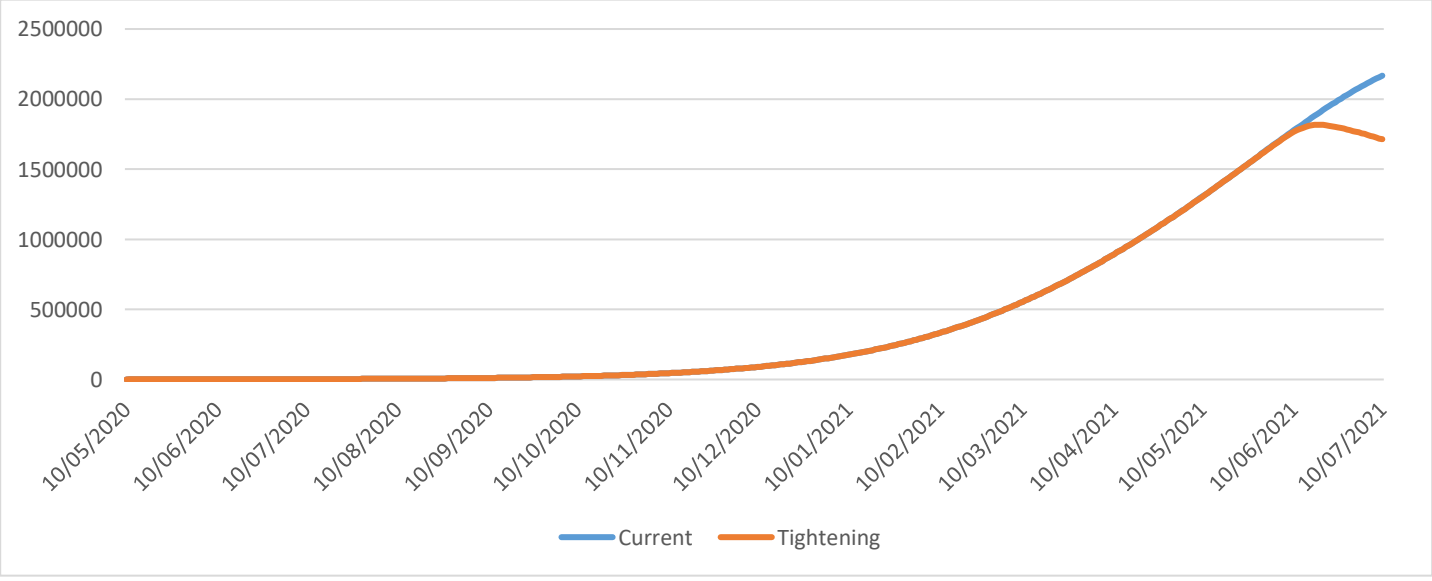

Fig 3. Total cases for D614G & B.1.1.7 variants

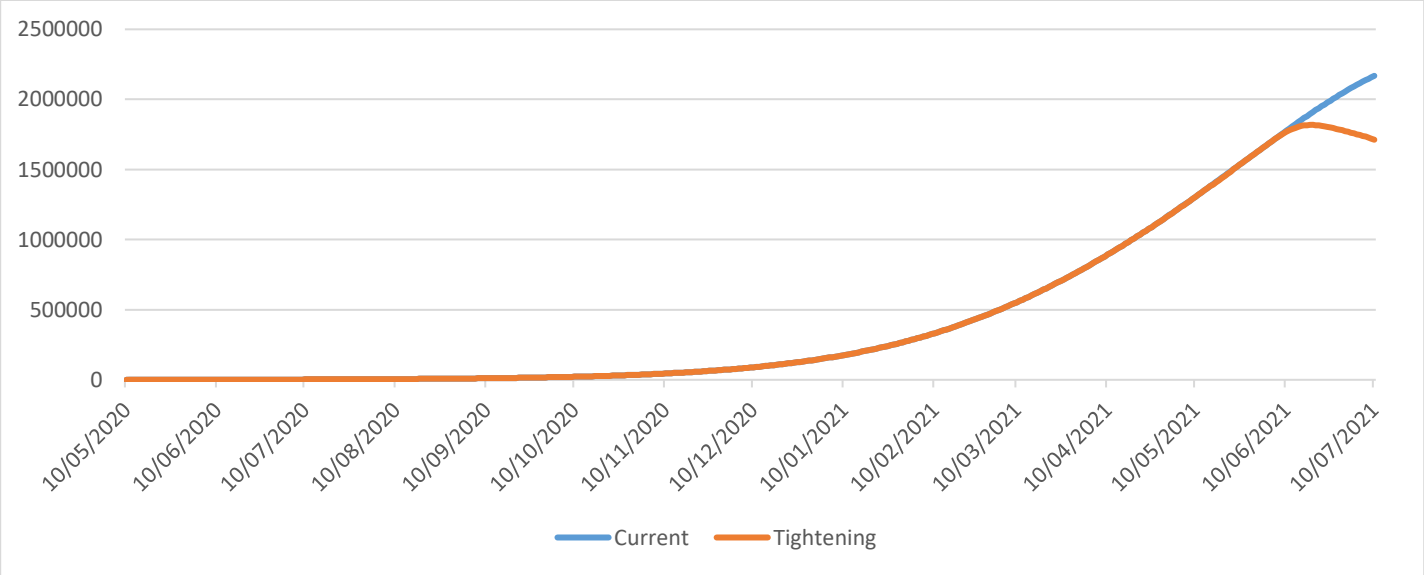

Fig 4. Total cases for B.1.351 & P.1 variants

Table 3. COVID 19 cases with current projection and intervention tightening for the two different variants

Scenarios	Date of projection	For group I variants (D614G & B.1.1.7)	For group II variants (B.1.351 & P.1)	Percentage Change
Current Projection	July – 10, 2021	2,167,031	2,168,263	0.056%
Intervention Tightening	July – 10, 2021	1,712,114	1,713,989	0.11%
Percentage Reduction		21%	21%	

As shown in table 3, Even though AstraZeneca vaccine type is less effective on group two variants (B.1.351 & P.1), the change in total cases is very small. This is mainly because in both scenarios, the model only targets older age group and highly susceptible population groups. Thus, the vaccine will be more or less effective only for small portion of the population. As it is shown on Fig 3 and Fig 4, the current tightening scenario is capable of flattening the curve.

3.2 Clinical COVID-19 Cases Forecast

In our model, the number of clinical cases are captured using Clinical compartment. Individuals in these compartments are characterized as individuals having mild/moderate COVID 19 symptoms (Table 4).

Table 4. COVID 19 Clinical cases with current projection and intervention tightening for the two different variants

Scenarios	Date of projection	For group I variants (D614G & B.1.1.7)	For group II variants (B.1.351 & P.1)	Percentage Change
Current Projection	July – 10, 2021	61,570	61,690	0.19%
Intervention Tightening	July – 10, 2021	48,906	49,055	0.30%
Percentage Reduction		21%	20%	

3.3 Severe COVID 19 Cases Forecast

As shown in table 5 below, our model captured the number of severe cases within the Hospitalized compartment. Individuals in these compartments are characterized as individuals having severe COVID 19 symptoms. Thus, they likely require hospital beds and oxygen cylinder.

Table 5. Sever COVID 19 cases with current projection and intervention tightening for the two different variants

Scenarios	Date of projection	For group I variants (D614G & B.1.1.7)	For group II variants (B.1.351 & P.1)	Percentage Change
Current Projection	July – 10, 2021	8,195	8,209	0.17%
Intervention Tightening	July – 10, 2021	7,045	7,064	0.27%

Percentage Reduction		14%	14%	

3.4 Critical COVID 19 Cases Forecast

In our model, the number of critical cases are captured using ICU compartment. Individuals in these compartments are characterized as individuals having critical COVID 19 symptoms. Thus, they might require ICU beds and/or Mechanical Ventilators. (Table 6)

Table 6. Critical COVID 19 cases with current projection and intervention tightening for the two different variants

Scenarios	Date of projection	For group I variants (D614G & B.1.1.7)	For group II variants (B.1.351 & P.1)	Percentage Change
Current Projection	July – 10, 2021	822	823	0.12%
Intervention Tightening	July – 10, 2021	767	769	0.26%
Percentage Reduction		7%	7%	

3.5 COVID 19 Deaths Forecast

As shown in table 7, in addition to the registered/reported deaths due to COVID-19, this model takes into account deaths from undetected cases as well.

Table 7. COVID 19 death with current projection and intervention tightening for the two different variants

Scenarios	Date of projection	For group I variants (D614G & B.1.1.7)	For group II variants (B.1.351 & P.1)	Percentage Change

Current Projection	July – 10, 2021	10,954	10,962	0.073%
Intervention Tightening	July – 10, 2021	10,874	10,884	0.09%
Percentage Reduction		0.73%	0.71%	

4. Results: Longer-term Projection

4.1 Total Cases Forecast

Table 8. Total number of cases

Scenarios	Peak date	For group I variants (D614G & B.1.1.7)	For group II variants (B.1.351 & P.1)	Percentage Change
Current Projection	August – 04, 2021	2,214,418	2,255,207	1.81%
Intervention Tightening	June – 23, 2021	1,826,501	1,845,238	1.01%
Percentage Reduction		18%	18%	

As shown in table 8, after the peak, the rate of infection decreases exponentially. Thus, predicting for longer time after the peak is less informative. The longest period we could predict before the infection dies-out, is until December 31, 2021. By this time, for group I variant the total infection will decrease to 410,808 and 33, 011 for the current projection and the intervention tightening scenarios respectively. As

it is shown in the table 8, intervention-tightening scenario is capable of breaking the transmission cycle and driving the infection down.

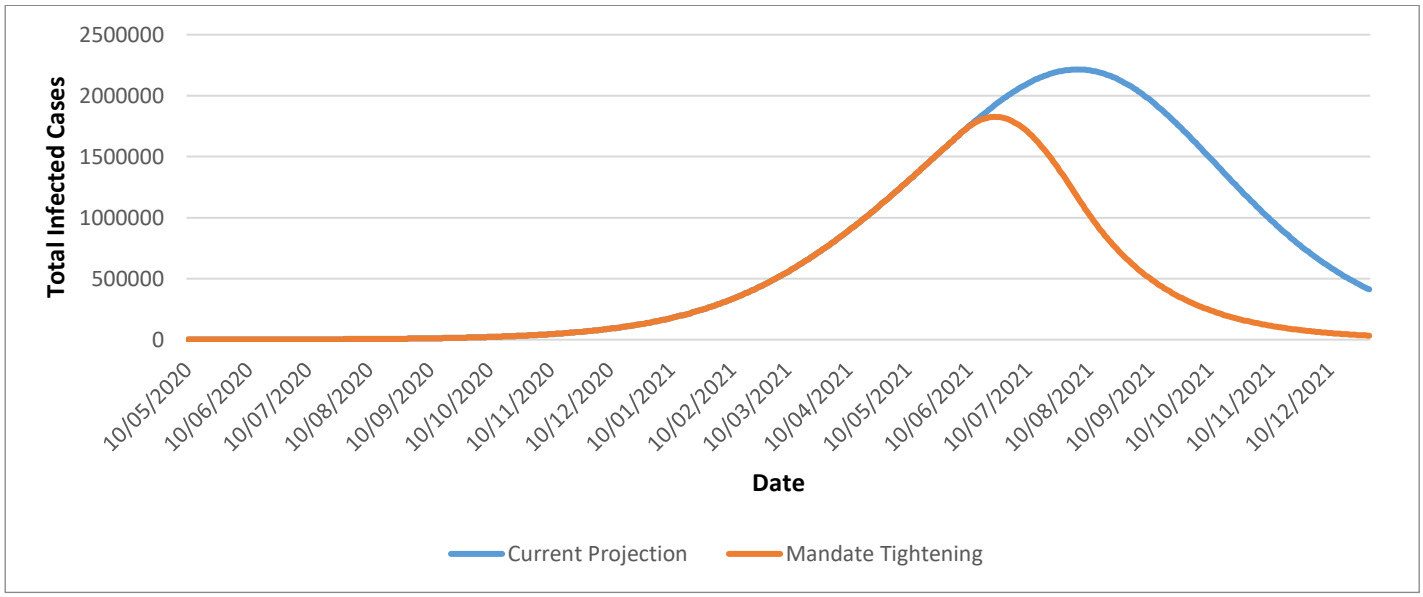

Fig 5. Total number of cases projection for the first variant groups

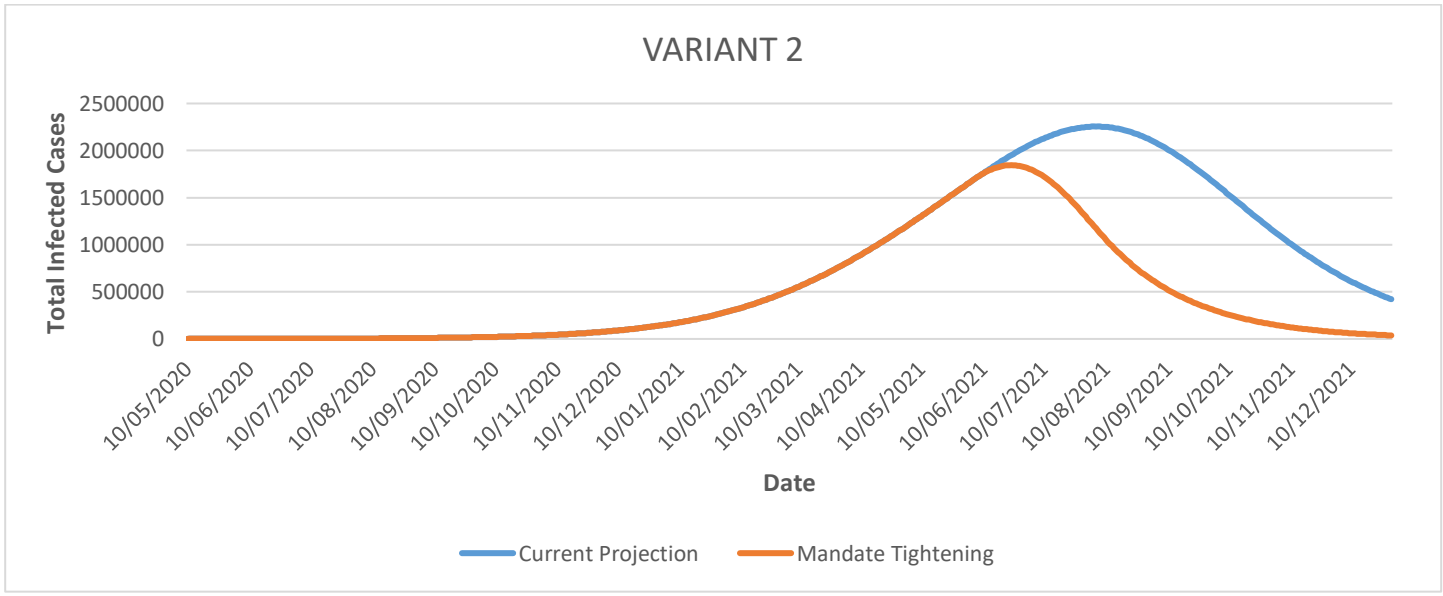

Fig 6. Total number of cases projection for the second variant groups

4.2 Clinical Cases Forecast

Table 9. Total number of projected cases

Scenarios	For group I variants (D614G & B.1.1.7)	For group II variants (B.1.351 & P.1)	Percentage Change
Current Projection	59,658	60,617	1.61%
Intervention Tightening	56,641	57,164	0.91%
Percentage Reduction	5%	6%	

The projection for the number of clinical cases by December 31, 2021 for group I variants are 9,436 and 737 for current projection and for the intervention tightening scenarios respectively (Table 9).

4.3 Severe Cases Forecast

Table 10. Total number of projected severe cases

Scenarios	For group I variants (D614G & B.1.1.7)	For group II variants (B.1.351 & P.1)	Percentage Change
Current Progression	8,363	8,392	0.34%
Intervention Tightening	8,362	8,390	0.33%
Percentage Reduction			

As shown in table 10, the projection for number of clinical cases on December 31, 2021 for group I of variants are 1,016 and 83 for the current projection and for intervention tightening respectively. Even though the peak values are almost similar, there is considerable difference in the numbers between these scenarios after the peak time as shown in figure 7 below.

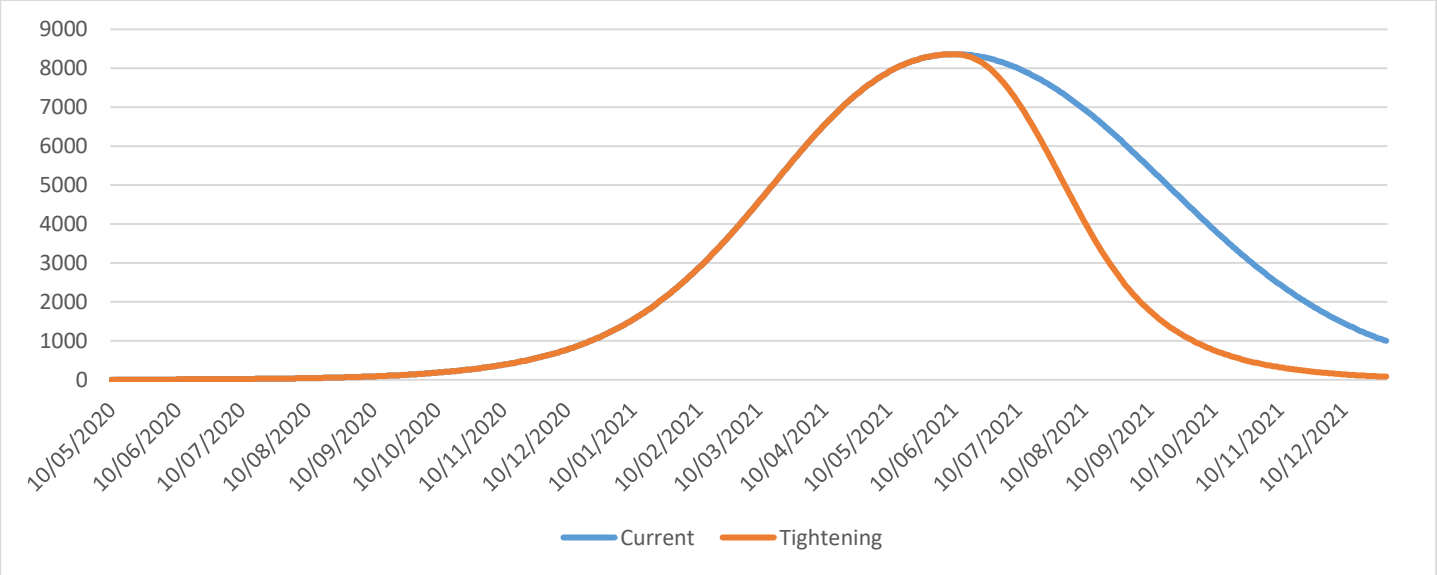

Fig 7. Hospitalized cases for variant group one, considering current intervention and mandate tightening scenarios

4.4 Critical Cases Forecast

Table 11. Total number of projected severe cases

Scenarios	Date of projection	For group I variants (D614G & B.1.1.7)	For group II variants (B.1.351 & P.1)	Percentage Change
Current Progression	December 31 - 2021	997	1,018	2.06%
Intervention Tightening	December 31 - 2021	80	89	10%
Percentage Reduction		92%	91%	

Since the peak values are almost similar, we have provided a projection for December 31, 2021.

4.5 Forecasting the Deaths

The starting date for projecting the cumulative deaths for both scenarios were the data the cumulative death curve started to flatten. Therefore, the number of deaths shown in the table below is cumulative deaths. In the case of current projection and intervention tightening scenarios, the cumulative deaths for group I variant by December 31, 2021 would be 15,241 and 13,150 respectively. This could avert 14% of the deaths. (Table 12)

Table 12. Total number of projected severe cases

Scenarios	Date of projection	For group I variants (D614G & B.1.1.7)	For group II variants (B.1.351 & P.1)	Percentage Change
Current Progression	June 01 - 2022	15,465	15,543	0.5%
Intervention Tightening	April 02 - 2022	13,164	13,211	0.40%
Percentage Reduction		15%	15%	

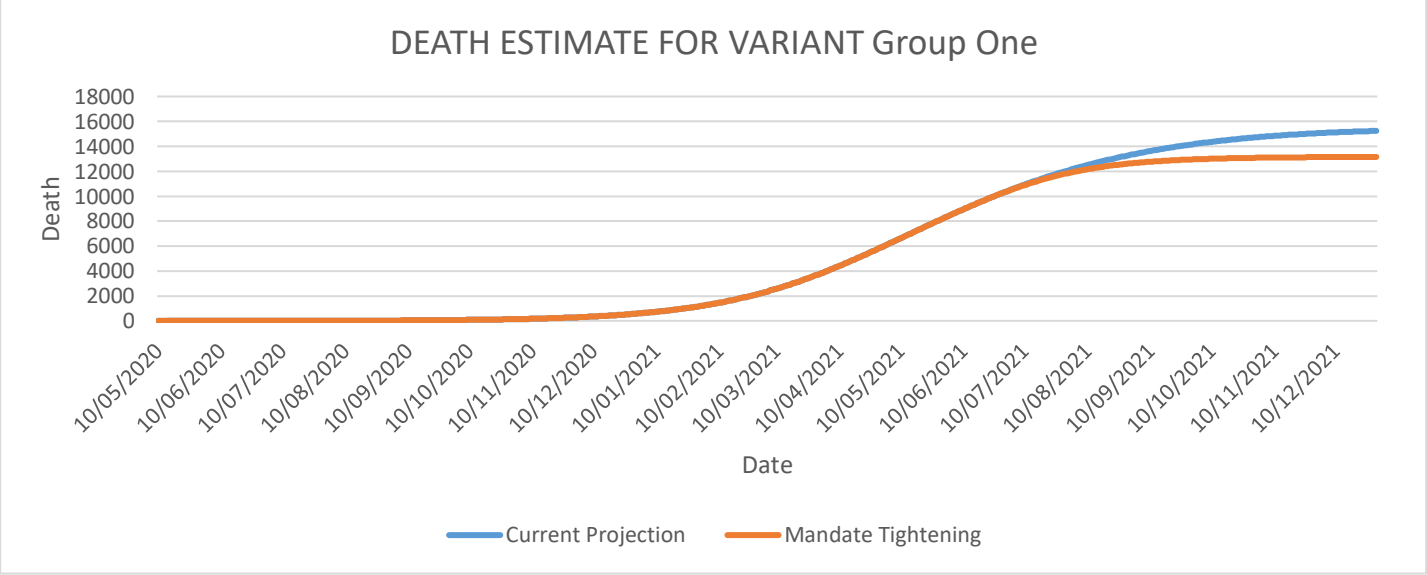

Fig 8. Number of deaths for group one variant group

5. Discussions

The percentage of hospitalization, critical cases and deaths aversions in this model is very small in some simulations due to the following reasons:

> The model introduces the intervention tightening conditions exactly on the time the interventions are introduced/enforced. In most cases, these periods are already after the cases and deaths are built-up in the community (i.e almost at the end of the transmission dynamics). Moreover, in Ethiopia the vaccine started quite late with a slow roll out. In addition, the trends in NPI largely showed a decreasing trend yet slight increment following some enforcement measures.

Our study suggests that, at national level by July 10, 2021, about 454,917 total cases, 55 critical cases and 80 deaths could averted with increment of the observed facemask and social distancing compliances by 15% and 7% respectively, in addition to the observed vaccination rate. Moreover, after applying these interventions the curve for total infection started to decrease starting from the end of June 2021. Under conditions with low vaccination coverage rate, tightening of NPI mandates are highly essential. As it is shown above, AstraZeneca is less efficacious on variants B.1.351 & P.1 compared to that of D614G & B.1.1.7. However, since the vaccination coverage rate is very small the over-all case or death change when considering the two variant groups is minimal. This is consistent with prior studies, suggesting that higher vaccine efficacy could lead to comparatively lesser reduction to infections than that of higher vaccine coverage rate. There are 0.26% and 0.09% differences between the number of critical cases and deaths, for the two virus variants considering mandate-tightening scenario. In order for the vaccine to be highly efficacious one need to identify the most prevalent variant(s) as the efficacy of AstraZeneca depends on the type of the variant(s).

For the longer-term projection, the peak time of total infection is on August 04, 2021, for both variant groups. However, for both variants increasing the vaccination rate and strictly implementing the NPI mandates halts the increment in total number of cases after June 23, 2021. For this scenario, at national level by August 04, 2021, about 1,043,436 total cases could averted with increment of the observed facemask and social distancing compliances by 43% and 17% respectively, in addition to the increment of vaccination rate. On December 31, 2021, about 92% and 14% total cases and deaths could be averted. This clearly highlights the importance of continued adherence to NPIs while the population is being vaccinated. The increment in total number of cases and deaths, which is because of vaccine inefficacy, is somehow large in the larger-term projections compared to that of shorter-term projections.

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