COMPARATIVE STUDY AND SIMULATION OF COVID-19 MODELS

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Abstract. The COVID-19 pandemic has caused a tremendous setback in health care and other associated environmental systems, as well as global economic stability. As a result, poorer developing nations and some developed nations have taken the hardest hits. Although the response strategies to COVID-19 during the initial phase of the pandemic vary considerably across countries, the recovery rate was somewhat commendable all over the world. In this paper, the author(s) gleaned two existing Covid-19 models and carryout some modifications on them. The author(s) employed a simulation case study methodology to conduct an in-depth analysis of the models in a bid to determine the dynamics of the disease, how fast it can be controlled, which model among them performs better, and what key policy lessons can be drawn from the behavioral dynamics of all the models.

Keywords: *Covid-19, vaccination, simulation, dynamics, pandemic*

Introduction

Corona virus disease (COVID -19) is a novel disease that has taken the life of many people, crippled economy and placed restriction on social gathering all over the world. It is caused by a severe acute respiratory syndrome corona virus 2 (SARS-CoV-2) (WHO, 2019). SARS-COV2 is a highly virulent virus that has caused COVID-19 to be a fatal disease. Corona virus disease (COVID-19) outbreak was noticed in December 2019. The first outbreak started in Hubei province, Wuhan, China on 30 January, 2020). The World Health Organization (WHO) described it as a public health emergency and identified it as a pandemic on 11 March, 2020 and it is transmitted from human-to-human via direct contact with contaminated surfaces and through the inhalation of respiratory droplets from infected individuals (Bai et al., 2020). The possible modes of transmission for SARS-CoV-2, including contact, droplet, airborne, fomite, faeces of some patients, blood borne, mother-to-child, and animal-to-human transmission (WHO, 2023). It spreads more easily in Crowded places; Close-contact settings, especially where people have conversations very near each other; Confined and enclosed spaces with poor ventilation (WHO, 2021).

Several mathematical models have already been formulated for the population dynamics of COVID-19 in several countries (Aslan et al., 2022; Atangana, 2020; Ferguson et al., 2020; Hellewell et al., 2020; Ivorra et al., 2020; Khan and Atangana, 2020; Mizumoto and Chowell, 2020; Shim et al., 2020). David et al. (2021) developed a novel deterministic susceptible-exposed-infected-removed-virus-death compartmental model to study the impact of indirect transmission. They discovered that indirect transmission of SARS-CoV-2 has a significant effect on the dynamics of COVID-19. Madubueze et al. (2020) studied the effect of different control strategies as time-dependent interventions using mathematical modeling and optimal control approach to ascertain their contributions in the dynamic transmission of COVID19. Their findings revealed that the optimal control analysis and numerical simulations showed that time-dependent interventions reduced the number of exposed and infected individuals compared to time-independent interventions. Iboi et al. (2020), developed a mathematical model which they used to study the transmission dynamics and control of COVID-19 in Nigeria. Their study centered on the Population of susceptible individuals, Population of exposed individuals, Population of symptomatically-infectious individuals, Population of asymptomatically-infectious individuals, Population of hospitalized individuals and. Their Numerical simulations of the model showed that COVID-19 can be effectively controlled in Nigeria using moderate levels of social-distancing strategy in the jurisdictions and in the entire nation. Okuonghae and Omame (2020) formulated a mathematical model, which they used to estimate the basic reproduction number of the disease outbreak in Lagos State, Nigeria. They used numerical simulations to show the effect of control measures such as social distancing, use of face mask and case detection (via contact tracing and subsequent testing) on the dynamics of COVID-19. They also provided forecasts for the cumulative number of reported cases and active cases for different levels of the control measures being implemented.

Moedel formulation

The mathematical models proposed by David et al. (2021) and Madubueze et al. (2020) on C0VID-19 epidemic were compartmental models in which they presented the disease into susceptible, exposed, infected, asymptomatic, symptomatic, hospitalized, quarantine, self-isolated, recovery, virus shed and death. In their model, the author pointed out that vaccination and partial immunity were not considered. The author proposed a model which is governed by a set of differential equations. The differential equations are formulated by adding two compartments on the models by David et al. (2021) and Madubueze et al. (2020) on C0VID-19. The two compartments are vaccination and partial immunity compartments.

Parameters and variables of model used by David et al. (2021)

Table 1 indicates parameters and the descriptions used by David et al. (2021).

***Table 1**. Variables and parameters descriptions.*

Parameter	Descriptions
N	Total population
S	Population of susceptible individuals
E	Population of Exposed individuals
I_A	Population of infected individuals who are asymptomatic
I_S	Population of infected individuals who are symptomatic
I_H	Population infected individuals who are hospitalized
I_w	Population of infected individuals who are isolated
R	Population of recovered individuals
V	Virus shed by infected individuals
D	Population of deceased individuals
βD_S	Transmission rate between S and I_S

βD_A	Transmission rate between S and I_A
β_I	Transmission rate for indirect (Environmental transmission) between S and V
P_1	Proportion of susceptible individuals effectively using mask (mask usage)
P_2	Proportion of individuals protected from environmental transmission
μ_S	Disease induced death rates for symptomatic individuals in the compartments I_S
γ_A	Testing rate of I_A individuals
γ_S	Testing rate of I_S individuals
α_A	Proportion of asymptomatic individuals who became hospitalized after testing
α_S	Proportion of symptomatic individuals who became hospitalized after testing
ω_2	Virus shedding rate for infectious individuals in the compartment I_S (The rate of viral release into the environment by symptomatic individuals
ω_1	Virus shedding rate for infectious individuals in the compartment I_A (The rate of viral release into the environment by asymptomatic individuals
μ_w	Disease induced death rate for isolated individuals in the compartment I_w
μ_H	Disease induced death rate for hospitalized individuals in the compartments I_H
δ	Progression rate from the exposed compartment to the infectious compartments ($1/\delta$ denotes the incubation
R	Proportion of exposed individuals showing symptoms at the end of incubation
ρ_A	Recovery rate of asymptomatic I_A individuals
ρ_s	Recovery rate of symptomatic l_S individuals
ρ_H	Recovery rate of hospitalized I_H individuals
ρ_w	Recovery rate of isolated I_w individuals
T_1	Time when the stay-at home policy (SAHP) is implemented
T_2	Time when the reopening of stage 1 begins
φ	Virus infectivity loss rate (Natural decay rate of virus from the environment

David et al. (2021) model equation

This section indicates formulations used by David et al. (2021).

$$\frac{dS}{dt} = -(1-P_1)S\beta_{DA}l_A - (1-P_1)S\beta_{DS}l_S - (1-P_2)S\beta_1 V \quad \text{Eq. (1)}$$

$$\frac{dE}{dt} = (1-p_1)S\beta_{DA}l_A + (1-p_1)\beta_{DS}l_S + (1-p_2)\beta_1 V - \delta E \quad \text{Eq. (2)}$$

$$\frac{dl_A}{dt} = (1-r)\delta E - (\rho_A + \gamma_A)l_A \quad \text{Eq. (3)}$$

$$\frac{dl_S}{dt} = r\delta E - (\rho_S + \mu_S + \gamma_S)l_S \quad \text{Eq. (4)}$$

$$\frac{dl_H}{dt} = \alpha_A\gamma_A l_A + \alpha_S\gamma_S l_S + \nu l_W - (\rho_H + \mu_H)l_H \quad \text{Eq. (5)}$$

$$\frac{dl_W}{dt}=(1-\alpha_A)\gamma_A l_{Al}+(1-\alpha_S)\gamma_S l_S-(\nu+\rho_W+\mu_W)l_W \qquad \text{Eq. (6)}$$

$$\frac{dR}{dt}=\rho_A l_A+\rho_S l_S+\rho_H l_H+\rho_W l_W \qquad \text{Eq. (7)}$$

$$\frac{dV}{dt}=\omega_1 l_A+\omega_2 l_S-\varphi V \qquad \text{Eq. (8)}$$

$$\frac{dD}{dt}=\mu_H l_H+\mu_S l_S+\mu_W l_W \qquad \text{Eq. (9)}$$

Variables and parameters of modified model used by David et al. (2021)

Table 2 indicates parameters and the descriptions used by David et al. (2021).

***Table 2**. Variables and parameters descriptions.*

Parameter	Descriptions
N	Total population
S	Population of susceptible individuals
E	Population of Exposed individuals
I_A	Population of infected individuals who are asymptomatic
I_S	Population of infected individuals who are symptomatic
I_H	Population infected individuals who are hospitalized
I_w	Population of infected individuals who are isolated
R	Population of recovered individuals
V	Virus shed by infected individuals
D	Population of deceased individuals
V_c	Population of vaccinated individuals
P_M	Population of individuals with partial immunity
βD_S	Transmission rate between S and I_S
βD_A	Transmission rate between S and I_A
β_I	Transmission rate for indirect (Environmental transmission) between S and V
P_1	Proportion of susceptible individuals effectively using mask (mask usage)
P_2	Proportion of individuals protected from environmental transmission
μ_S	Disease induced death rates for symptomatic individuals in the compartments I_S
ρ_S	Recovery rate of symptomatic I_S individuals
γ_A	Testing rate of I_A individuals
γ_S	Testing rate of I_S individuals
α_A	Proportion of asymptomatic individuals who became hospitalized after testing
α_S	Proportion of symptomatic individuals who became hospitalized after testing
ω_2	Virus shedding rate for infectious individuals in the compartment I_S (The rate of viral release into the environment by symptomatic individuals
ω_1	Virus shedding rate for infectious individuals in the compartment I_A (The rate of viral release into the environment by asymptomatic individuals
μ_W	Disease induced death rate for isolated individuals in the compartment I_W
μ_H	Disease induced death rate for hospitalized individuals in the compartments I_H
δ	Progression rate from the exposed compartment to the infectious compartments ($1/\delta$ denotes the incubation
R	Proportion of exposed individuals showing symptoms at the end of incubation

ρ_A	Recovery rate of asymptomatic individuals I_A
ρ_H	Recovery rate of hospitalized individuals I_H
ρ_w	Recovery rate of isolated individuals I_w
T_1	Time when the stay-at home policy (SAHP) is implemented
T_2	Time when the reopening of stage 1 begins
φ	Virus infectivity loss rate (Natural decay rate of virus from the environment
Γ	Rate at which the susceptible individuals are vaccinated
ϖ_1	Rate of loss of immunity (partial recovery due to pressure in the hospital facilities)
ϖ_2	Rate of loss of immunity due to incomplete doses of vaccines
Z	Rate of loss of immunity (partial due to depression from the patient)

Modified David et al. (2021) model equation

This section indicates formulations used by David et al. (2021).

$$\frac{ds}{dt} = -(1-\rho_1)S\beta_{DA}I_A - (1-\rho_1)S\beta_{DS}I_S - (1-\rho_1)S\beta_1 + ZP_M - \Gamma S \quad \text{Eq. (10)}$$

$$\frac{dE}{dt} = (1-p_1)S\beta_{DA}l_A + (1-p_1)S\beta_{DS}l_S + (1-p_2)S\beta_1 V - \delta E \quad \text{Eq. (11)}$$

$$\frac{dl_A}{dt} = (1-r)\delta E - (\rho_A + \gamma_A)l_A \quad \text{Eq. (12)}$$

$$\frac{\mathrm{d}l_S}{\mathrm{dt}} = r\delta E - (\rho_S + \mu_S + \gamma_S)l_S \quad \text{Eq. (13)}$$

$$\frac{dl_H}{dt} = \alpha_A\gamma_A l_A + \alpha_S\gamma_S l_S + \nu l_W - (\rho_H + \mu_H)l_H \quad \text{Eq. (14)}$$

$$\frac{dl_W}{dt} = (1-\alpha_A)\gamma_A l_{AI} + (1-\alpha_S)\gamma_S l_S - (\nu + \rho_W + \mu_W)l_W \quad \text{Eq. (15)}$$

$$\frac{dR}{dt} = \rho_A l_A + \rho_S l_S + \rho_H l_H + \rho_W l_W - \varpi_1 R \quad \text{Eq. (16)}$$

$$\frac{dV}{dt} = \omega_1 l_A + \omega_2 l_S - \varphi V \quad \text{Eq. (17)}$$

$$\frac{dD}{dt} = \mu_H l_H + \mu_S l_S + \mu_W l_W \quad \text{Eq. (18)}$$

$$\frac{dV_C}{dt} = \Gamma S - \varpi_2 V_C \quad \text{Eq. (19)}$$

$$\frac{dP_M}{dt} = \varpi_2 V_C - Z P_M + \varpi_1 R$$

Eq. (20)

Parameters and variables of model used by Madubueze et al. (2020)

Table 3 indicates parameters and the descriptions used by Madubueze et al. (2020).

***Table 3**. Variables and parameters descriptions.*

Parameter	Descriptions
$N(t)$	Total population at time t
$S(t)$	Susceptible individuals at time t
$E(t)$	Exposed individuals
$Q(t)$	Quarantine individuals
$I(t)$	Infectious individuals
$J(t)$	Hospitalized/Isolated individuals
$R(t)$	Recovered individuals
$\alpha(t)$	Public health education rate at time, t
$\tau(t)$	Quarantine rate at time, t
$\eta(t)$	The isolation rate for infectious not hospitalized individuals at time, t
β	Transmission rate
γ_1	The recovery rate for infectious not hospitalized individuals
γ_2	Recovery rate of hospitalized/isolated individuals
P	Proportion of exposed individuals quarantined
d_1	The death-induced rate for infectious not hospitalized individuals
d_2	The death-induced rate for hospitalized/isolated individuals
σ_1	Progression rate from quarantine to susceptible compartment after the incubation period
ρ	Progression rate for exposed individuals that missed quarantine to infectious not hospitalized compartment
σ_2	The isolation rate of those that developed symptoms during the quarantine period
π	The proportion of persons coming from a high-risk area of COVID-19
Λ	Immigration rate
Ψ	The force of infection

Madubueze et al. (2020) model equation

This section indicates formulations used by Madubueze et al. (2020).

$$\frac{dS}{dt} = \Lambda(1-\Pi) + q\sigma_1 Q - (1-\alpha(t))\psi S - \mu S$$

Eq. (21)

$$\frac{dE}{dt} = (1 - \alpha(t)\Psi S + \Lambda\pi - p\tau(t)\mathrm{E} - (1-p)\rho\mathrm{E} - \mu E$$

Eq. (22)

$$\frac{dQ}{dt} = p\tau(t)E - q\sigma_1 Q - (1-q)\sigma_2 Q - \mu Q$$

Eq. (23)

$$\frac{dI}{dt} = (1-p)\rho E - \gamma_1 I - \eta(t)I - d_1 I - \mu I$$

Eq. (24)

$$\frac{dJ}{dt} = (1-q)\sigma_2 Q + \eta(t)I - \gamma_2 J - d_2 J - \mu J \frac{dR}{dt} = \gamma_2 J + \gamma_1 I - \mu R$$

Eq. (25)

$$\frac{dR}{dt} = \gamma_2 J + \gamma_1 I - \mu R$$

Eq. (26)

Variables and parameters of modified model used by Madubueze et al. (2020)

Table 4 indicates parameters and the descriptions used by Madubueze et al. (2020).

***Table 4**. Variables and parameters descriptions.*

Parameter	Descriptions
$N(t)$	Total population at time t
$S(t)$	Susceptible individuals at time t
$E(t)$	Exposed individuals
$Q(t)$	Quarantine individuals
$I(t)$	Infectious individuals
$J(t)$	Hospitalized/Isolated individuals
$R(t)$	Recovered individuals
$V_c(t)$	Population of vaccinated individuals at time t
$P_M(t)$	Population of individuals with partial immunity at time t
$\alpha(t)$	Public health education rate at time, t
$\tau(t)$	Quarantine rate at time, t
$\eta(t)$	The isolation rate for infectious not hospitalized individuals at time, t
β	Transmission rate
γ_1	The recovery rate for infectious not hospitalized individuals
γ_2	Recovery rate of hospitalized/isolated individuals
ρ	Proportion of exposed individuals quarantined
d_1	The death-induced rate for infectious not hospitalized individuals
d_2	The death-induced rate for hospitalized/isolated individuals
σ_1	Progression rate from quarantine to susceptible compartment after the incubation period
P	Progression rate for exposed individuals that missed quarantine to infectious not hospitalized compartment
σ_2	The isolation rate of those that developed symptoms during the quarantine period
π	The proportion of persons coming from a high-risk area of COVID-19
Λ	Immigration rate
Ψ	The force of infection
Γ	Rate at which the susceptible individuals are vaccinated
ϖ_1	Rate of loss of immunity (partial recovery due to pressure in the hospital facilities)
ϖ_2	Rate of loss of immunity due to incomplete doses of the vaccines
Z	Rate of loss of immunity (partial due to depression from the patient)

Modified Madubueze et al. (2020) model equation

This section indicates formulations used by Madubueze et al. (2020).

$$\frac{dS}{dt} = \Lambda(1-\Pi) + q\sigma_1 Q - (1-\alpha(t)\psi S - \mu S + \mathrm{Z} P_M - \Gamma S$$

Eq. (27)

$$\frac{dE}{dt} = (1-\alpha(t)\Psi S + \Lambda\Pi - p\tau(t)\mathrm{E} - (1-p)\rho\mathrm{E} - \mu E$$

Eq. (28)

$$\frac{dQ}{dt} = p\tau(t)E - q\sigma_1 Q - (1-q)\sigma_2 Q - \mu Q$$

Eq. (29)

$$\frac{dI}{dt} = (1-p)pE - \gamma_1 I - \eta(t)I - d_1 I - \mu I$$

Eq. (30)

$$\frac{dJ}{dt} = (1-q)\sigma_2 Q + \eta(t)I - \gamma_2 J - d_2 J - \mu J \frac{dR}{dt} = \gamma_2 J + \gamma_1 I - \mu R$$

Eq. (31)

$$\frac{dR}{dt} = \gamma_2 J + \gamma_1 I - \mu R - \varpi_1 R$$

Eq. (32)

$$\frac{dV_C}{dt} = S\Gamma - V_C \varpi_2 - \mu V_C$$

Eq. (33)

$$\frac{dP_M}{dt} = R\varpi_1 - P_M Z - \mu P_M + V_C \varpi_2$$

Eq. (34)

Case 1: David et al. (2021) and Madubueze et al. (2020) (Where there is no vaccination and partial immunity)

There are four (4) criteria that take into consideration: (1) the author assume that the infected and treated COVID-19 patient who recovered and vaccinated have partial immunity which can be lost and as such makes the patient to become susceptible for possible reinfection. Of COVID-19; (2) all human beings are susceptible to infections; (3) the author also assume that recovered human acquires immunity for some period of time which wanes over time and so become susceptible again; and (4) the author also assume that natural death can cause decrease in every class of human population, except for the infectious class which has an additional per capital disease-induced death.

Limitation of the existing David et al. (2021) and Madubueze et al. (2020) models

David et al. (2021) developed a deterministic susceptible-exposed-infected-removed-virus-death compartmental model to study the impact of indirect transmission pathway on the spread of COVID-19. Madubueze et al. (2020) also developed a deterministic model which they used to determine the effects of different control strategies as time-dependent interventions to ascertain their contributions in the dynamic transmission of COVID-19. In these models, they did not consider vaccination and partial immunity as part of the control measures to the study of the spread of COVID-19.

Case 2: David et al. (2021) and Madubueze et al. (2020) (Where there is vaccination and partial immunity)

The author introduced two new compartments which are vaccination and partial immunity compartments to account for waning immunity among human population and the author also incorporate loss of immunity parameters, which include; loss as a result of depression, loss of immunity due to incomplete doses of the vaccines and loss as a result of pressure in hospital facilities. The author assumes that all human beings, irrespective of age are susceptible to COVID-19. Recovered and vaccinated individuals can loss immunity and then move to the susceptible individual who have the chance of being infected and re-infection. These interactions can be represented schematically with the flow and Eq. (10) to Eq. (20) and Eq. (27) to Eq. (34) respectively (*Table 5*).

The author assumed that infected individuals who recover naturally acquire a lesser degree of immunity and are thus moved to the partial immunity compartment.

***Table 5**. Parameter values.*

Parameters	David et al. (2021)	Modified David et al. (2021)	Madubueze et al. (2020)	Modified Madubueze et al. (2020)
$\alpha(A)$	0.74087	0.74087	-	-
δ_s	0.01	0.01	-	-
$\gamma(S)$	0.012972	0.012972	-	-
$\mu(S)$	0.30844	0.30844	-	-
$\mu(h)$	0.007	0.007	-	-
$\alpha(S)$	0.82189	0.82189	-	-
$\rho(S)$	0.00019475	0.00019475	-	-
$\rho(A)$	0.0007	0.0007	-	-
$\tau(t)$	-	-	1/18	1/18
$\eta(t)$	-	-	0.2	0.2
β_1	0.0000016462	0.0000016462	-	-
p_1	0.24701	0.24701	-	-
p_2	0.30844	0.30844	-	-
γ_1	-	-	0.03521	0.03521
γ_2	-	-	0.04255	0.04255
P	-	-	1/15	1/15
d_1	-	-	0.0079	0.0079
d_2	-	-	0.0068	0.0068
$\beta[DS]$	0.0000004306	0.0000004306	-	-
$\beta[DA]$	0.000000622	0.000000622	-	-
σ_1	-	-	0.07143	0.07143
P	-	-	0.07	0.07
σ_2	-	-	0.1259	0.1259
π	-	-	0.1	0.1
Λ	-	-	0.07	0.07
Ψ	-	-	0.5	0.5
Γ	-	0.04	-	0.04
ϖ_1	-	1/35	-	1/35
ϖ_2	-	0.2	-	0.2
Z	-	0.09	-	0.09

Cpomparative study on the performance of the modified models with the existing one

In order to compare the performance of the two modified models, the author carry out the first numerical simulation and plotted the graph of their recovery rate. The reason for considering the recovery rate is because, that is our major point of concern. The author observed that both modified models were improvement of the existing models. The modified Madubueze et al. (2020) performs better than the existing Madubueze et al. (2020). This is as a result of the vaccination parameters incorporated which reduces the inflow of susceptible individuals to the infected individuals thereby increases the rate of recovery of already infected individuals. However, the modified David et al. (2021) performs better than all. The graphs and values obtained using parameter values and initial conditions compatible with COVID-19 as given in *Table 5* is shown in *Table 6* (*Figure 1*).

***Table 6**. Comparative result values of the different COVID 19 models.*

S/n	Day	With initial conditionR(O)=6 and a constant recovery parameters: $\rho_A = 0.07, \rho_S = 0.1, \rho_H = 0.5$		With initial conditionR(O)=6 and a constant recovery parameters: $\gamma_1 = 0.03521, \gamma_2 = 0.04255$	
		Madubueze et al. (2020)	Modified Madubueze et al. (2020)	David et al. (2021)	Modified David et al. (2021)
1	0	6.0000000000000	6.0000000000000	6.0000000000000	6.0000000000000
2	50	26.7309371733761	42.1021392025720	50.2502066474431	55.5551326988947
3	100	33.8858093049148	46.5366590513660	51.5311565005882	57.3511715255752

4	150	36.6765705278749	47.0440497235604	52.0491640253561	57.8539626938257
5	200	37.8047232969908	47.2059615970758	52.5429573618277	58.2391499802510
6	250	38.2990981961421	47.3381105655986	53.0358910732264	58.6082853394678
7	300	38.5517350839196	47.4673287899774	53.5287935640860	58.9725773790536
8	350	38.7120287083224	47.5958868844436	54.0216948918655	59.3334932703553
9	370	38.7645556315168	47.6471776735456	54.2188554198500	59.4769794191463

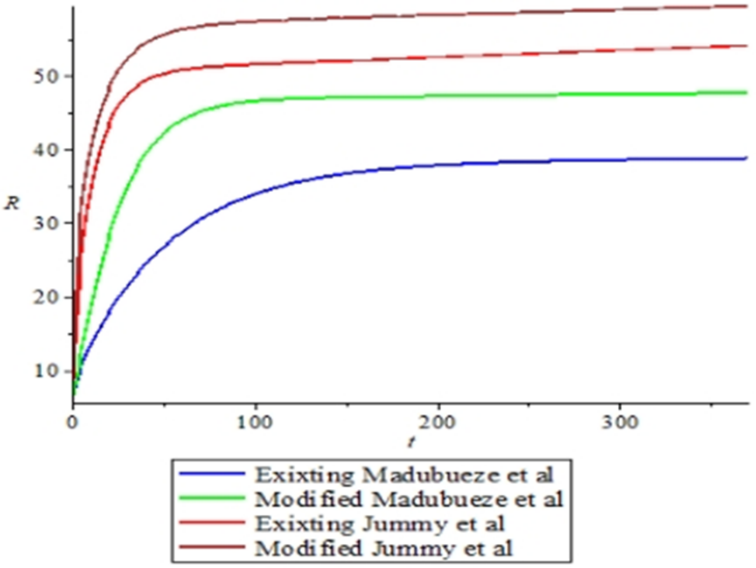

Figure 1. *Graphs of the two existing models and the two modified models.*

Looking at the graphs of the four models, the author discovered that the two modified models perform better than the two existing models. The author found that the recovery level of pandemic increases over time as a result of the timely and comprehensive response of the control measures. However, our simulation further revealed that the modified David et al. (2021) model performs better than modified Madubueze et al. (2020) model as it shows the highest rate of recovery individual compared to the other models. The result, as illustrated in the studies and figure shows that with proper health policy framework, resource constrained countries can channel their resources efficiently and innovatively to confront the public health emergency using vaccination as a key control strategy in the fight for COVID-19.

Conclusion

In this research work, the author compared two existing COVID-19 models with two modified COVID-19 models. In the two modified models, the author incorporated the vaccination as a control measure to curb the spread of COVID-19. The author also incorporated partial immunity compartment which serves as an indicator of possible re-infection of COVID-19 even after recovery, if attention is not paid to it. Numerical simulation was carried out and the result shows that the modified David et al. (2021) performed better than the other three models. This shows that with proper health policy framework, resource constrained countries can channel their resources efficiently and innovatively to confront the public health emergency using vaccination as a key control strategy in the fight for COVID-19.

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Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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