Proceeding of the Public Health and Well-being Conference, Vol. 1, 2022, pp. 31-41

ISSN 2659-2096
DOI: https://doi.org/10.32789/publichealth.2022.1003

Analyzing the Effectiveness of Vaccination as a Preventive Measure in Combating COVID-19 and Recommendations for Future Health Emergencies in India

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ANALYZING THE EFFECTIVENESS OF VACCINATION AS A PREVENTIVE MEASURE IN COMBATING COVID-19 AND RECOMMENDATIONS FOR FUTURE HEALTH EMERGENCIES IN INDIA

Abstract: In order to mitigate the impact of the COVID-19 pandemic, India launched the world's most extensive vaccination drive. Almost 1.9 billion vaccination doses were given till 13th May 2022 since the beginning of the drive, with 1 billion people vaccinated for 1st dose and 0.87 billion people for 2nd dose. The objective of the study is to analyze the impact of vaccination on the control of SARS-CoV-2 infection. The secondary data was obtained by the World Health Organization for COVID-19 cases and the Ministry of Health and Family Welfare for vaccination from 22 Jan 2022 to 13th May 2022. Exponential regression was performed for total cumulative vaccinations (18 years & above received at least one dose) as independent variable and rate of covid infection/0.1million/week, as dependent variable. The p-value is 0.001 with a negative slope emphasizing that the correlation is significant for the selected time period. Further, the predictive model with $R^2 = 0.96$ shows the model is best fitted. The mathematical model supports the role of vaccination in decreasing cases of COVID-19. Predicting the rate of occurrence of infection in the backdrop of vaccination drive can be a valuable tool for assessing vaccine effectiveness and planning for future actions.

Keywords: COVID-19, vaccination, health emergencies, preventive measures

Introduction

The novel coronavirus, first detected in Wuhan of Hubei Province in China, spreading rapidly throughout the world had led to a major global health emergency. The virus identified as the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was the cause of the coronavirus disease 2019 (COVID-19) pandemic (*WHO*, 2022). The pandemic brought unprecedented challenges jolting even the advanced health systems of the developed countries in the world.

In India, the first case of COVID-19 disease was reported on 30th January 2020 (Andrews *et al*., 2020). Since then, the cases have increased rapidly leading to three major pandemic waves in the country. With lockdown, isolation and other restrictions, the progression of the disease was slow initially but increased eventually after the relaxation of certain infection control measures for the revival of economic activities. The nationwide lockdown that started on 25th March 2020 lasted till 31st May 2020 (68 days) (Tewary, 2020). Subsequently, unlock phase was initiated in a phase-wise manner from 1st June 2020 (Singh, 2020). As of 13th May 2022, India recorded 43.11 million COVID-19 cases and a death count of 0.5 million (India News, 2022). The daily positivity rate was at 0.61% and weekly positivity rate at 0.62% (Indian Express, 2022).

As a preventive strategy against COVID-19, non-pharmaceutical interventions (NPIs) such as masks, hand sanitation, social distancing, isolation and quarantine, etc. (*CDC*, 2020) was implemented and mandated. These interventions are crucial together in building layers of barrier between infected and susceptible individuals (Panda *et al*., 2021). However, the willingness to adhere to NPIs varied among individuals based on the availability of resources, socioeconomic status, perceived consequences, and their perceived level of personal and local community risk (Seale *et al*., 2020). Although studies show that in the initial period NPIs were instrumental in the control of disease transmission in the

community (Huy *et al*., 2022), it can also be interpreted as these interventions decelerated the disease progression and delayed the onset of the peak. Thus, the graph of disease transmission was spread over the period of time while the risk of infection still persists.

The recurring waves, newer strains and daily incidences of COVID-19 infection made it evident that we need a stronger preventive strategy against the pandemic. Vaccination is one of the important preventive measures in the control of infectious diseases and hence, countries across the world begin mass vaccination for their citizens. India is the second-largest country in the world in terms of population with more than 1.3 billion people. Thus, control of infection and reviving the economy was major challenge with the ongoing pandemic. To mitigate the impact of the COVID-19 pandemic in India, the government launched the world's most extensive vaccination drive on 16th January 2021(Vaghela *et al*., 2021). Vaccination was initiated phase-wise with the Indian-origin Covaxin produced by Bharat Biotech International Ltd. and Covisheild developed by Oxford/AstraZeneca and manufactured by Serum Institute of India Pvt Ltd. vaccines approved for emergency use for health workers, frontline workers (e.g. police, soldiers, sanitary workers), elderly people and people with co-morbidities (Bagcchi, 2021). One more vaccine Sputnik-V developed by the Gamaleya Research Institute of Epidemiology and Microbiology was also approved for emergency use in India (Mukim *et al.*, 2022). Almost 1.9 billion vaccination doses were given till 13th May 2022 since the beginning of the drive, with 1 billion people vaccinated for the 1st dose and 0.87 billion people for the 2nd dose (*COWIN*, 2022).

With such a massive vaccination drive the participation of the citizens is a matter of concern. There are high speculations over the safety and efficacy of COVID-19 vaccines specifically due to their fast-track development (Islam *et al.*, 2021; Moola *et al*., 2021). A number of studies conducted to assess vaccine hesitancy among people in India showed varied results. Furthermore, poor knowledge and vaccine hesitancy among the low-income and rural population is a major barriers to the success of the vaccination drive (Kumari *et al.*, 2021). These hesitancies are because of the perceived disease severity, infection risk, and vaccine safety and effectiveness. With widespread cultural and regional diversity in India misinformation, culture, customs, beliefs and fear are other major influencers in vaccine utilization (Jacob *et al*., 2021).

It is necessary to ensure every individual is vaccinated against the SARS-CoV-2 virus. Traditionally vaccination is associated with achieving a level of herd immunity among the population. But in the case of the current pandemic with newer strains appearing at such short intervals, it is questionable to believe that a certain level of immunization will ensure complete eradication of the COVID-19 infection. Thus, it is essential to understand the effectiveness of the vaccine to control the spread of COVID-19 disease and plan strategies based on this evidence to efficiently tackle current and future health emergencies.

Methodology

This study is quantitative research that uses regression analysis to understand the relationship between vaccination and infection rate. In this study exponential regression model is used to analyze the relationship between cumulative vaccination and rate of COVID-19 infection in the population of India. The secondary data for this study was obtained from the database available in public domain which is the actual population data for vaccination and COVID-19 cases in the country. The data on COVID-19 cases was obtained from World Health Organization website https://covid19.who.int/region/searo/country/in and for vaccination, the data was obtained from the

COWIN dashboard of the Ministry of Health and Family Welfare https://dashboard.cowin.gov.in/. The data available for COVID-19 infection on the WHO dashboard provided the number of confirmed cases of COVID-19 infection per day all over the country whereas in COWIN Dashboard, data available was per week number of vaccination done. As 2nd dose is considered completion of vaccination, the data for the number of individuals vaccinated for 2nd dose was used in the study. The vaccination in the analysis refers to the cumulative sum of individuals vaccinated for 2nd dose. The rate of COVID-19 infection measures the frequency of occurrence of new cases of infection within the population during a week. All variables were converted into weekly data of the number of COVID-19 cases and vaccination.

Exponential regression analysis was done on the rate of COVID-19 infection and cumulative vaccination from 22nd January 2022 to 13th May 2022. The rate of COVID-19 infection was calculated by the following formula,

Rate of COVID-19 infection = (Number of new cases in a week/ Total population of India)*100000

In case of vaccination data, the variable was taken as cumulative vaccination per week starting from the first week of 22nd January 2022 till the week of 13th May 2022. During this time period, more than 50% of the population was vaccinated for 2nd dose all over the country. Thus this will provide a better picture in order to understanding the association of vaccination with the rate of COVID-19 infection.

The scatter plot was plotted between the Rate of COVID-19 cases (y-axis) and cumulative vaccination (x-axis), where x is an independent variable and y is a dependent variable. The trend line was obtained of an exponential regression giving the equation of the line and value of R square. The p-value was also obtained by using the regression tool present in the data analysis. The analysis was conducted using Microsoft excel. A predictive model was made by using the regression equation and the data present, giving the value of the rate of COVID-19 infections per 0.1 million per week in the country by putting the value of vaccination done per week.

Results

The result shows the exponential regression line with a negative slope having the equation,

$y = 258.72e^{-2E-08x}$

having an intercept of 258.72. The p-value obtained by applying regression from the data analysis tool is 0.001, indicating that the exponential decrease in the rate of COVID-19 infection per 0.1 million per week with cumulative vaccination is significant. The R^2 value is 0.96 emphasizing the model is significantly fit and it is reliable.

Table 1 The indicators of exponential regression analysis for the rate of COVID-19 infection and cumulative vaccination in India

Indicator	Value
P-value	0.001
Slope	-0.00000002
Intercept	258.72

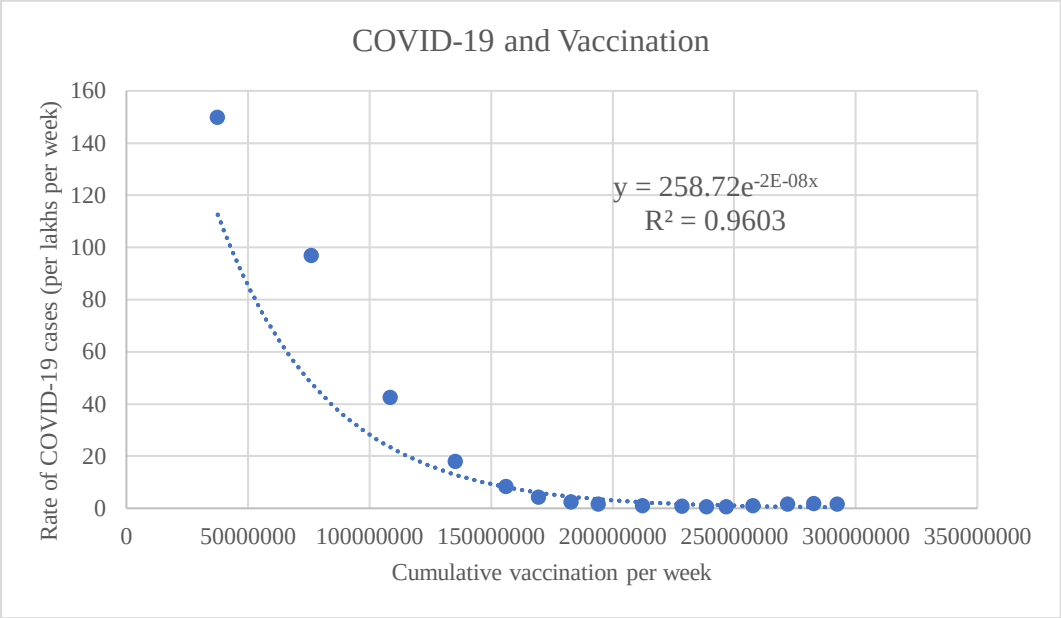

Figure 1: Exponential Regression plot for rate of COVID-19 infection and cumulative vaccination

The equation of exponential regression gives the number of individuals infected with COVID-19 considering the effect of the second dose of vaccine (x), where 258.72 is the intercept and the slope is -0.00000002. The Figure 1 represents the exponential regression model for the cumulative sum of people vaccinated and the rate of COVID-19 infection. In the case of COVID-19 infection rate, the exponential regression curve is more reliable as it considers the complexities of variables which is reflected in the value of R^2 (0.96). From the regression curve plotted, we can conclude that with the increase in total number of vaccinations done, there is a sharp decrease in COVID-19 cases indicating the effectiveness of the vaccination.

The prediction model is used to calculate the increase in vaccination needed to decrease the number of cases of COVID-19 in India. By putting the values in the model we can deduce that the increase in vaccination at a constant value of 0.8 million per week the rate of COVID-19 infection will reduce to 0.83 cases per 0.1 million per week. Thus this concludes the increase in vaccination the rate will further reduce the rate of COVID-19 infection.

Table 2 Predictive modelling of the analysis for cumulative vaccination and rate of COVID-19 infection

Duration (in weeks) – 2022	Total Vaccination (n)	Cumulative Vaccination	Actual Rate of COVID-19 infections (per lakhs per week)	Prediction of Rate of COVID-19 Infection
22 Jan - 28 Jan	37566496	37566496	149.712	121.944
29 Jan - 04 Feb	38524960	76091456	96.815	73.899
05 Feb - 11 Feb	32456109	108547565	42.469	38.612
12 Feb - 18 Feb	26792508	135340073	17.769	22.595

19 Feb - 25 Feb	20797971	156138044	8.306	14.906
26 Feb - 04 Mar	13550032	169688076	4.165	11.368
05 Mar - 11 Mar	13329018	183017094	2.381	8.707
12 Mar -18 Mar	11113167	194130261	1.437	6.972
19 Mar - 25 Mar	18230333	212360594	0.900	4.842
26 Mar - 01 Apr	16210006	228570600	0.684	3.501
02 Apr - 08 Apr	10186006	238756606	0.531	2.856
09 Apr - 15 Apr	8165080	246921686	0.503	2.426
16 Apr - 22 Apr	10918798	257840484	0.906	1.950
23 Apr - 29 Apr	14191483	272031967	1.438	1.468
30 Apr - 06 May	10865441	282897408	1.657	1.181
06 May- 13 May	9596688	292494096	1.551	0.975

In Figure 2 the actual rate of infection is compared with the infection rate predicted with the modelling. Both the lines are close and indicate that the predicted data and actual data is comparable. Thus, this again confirms that the predictive model can be very well used for obtaining information of the further course of infection among the population and the necessary levels of vaccination required.

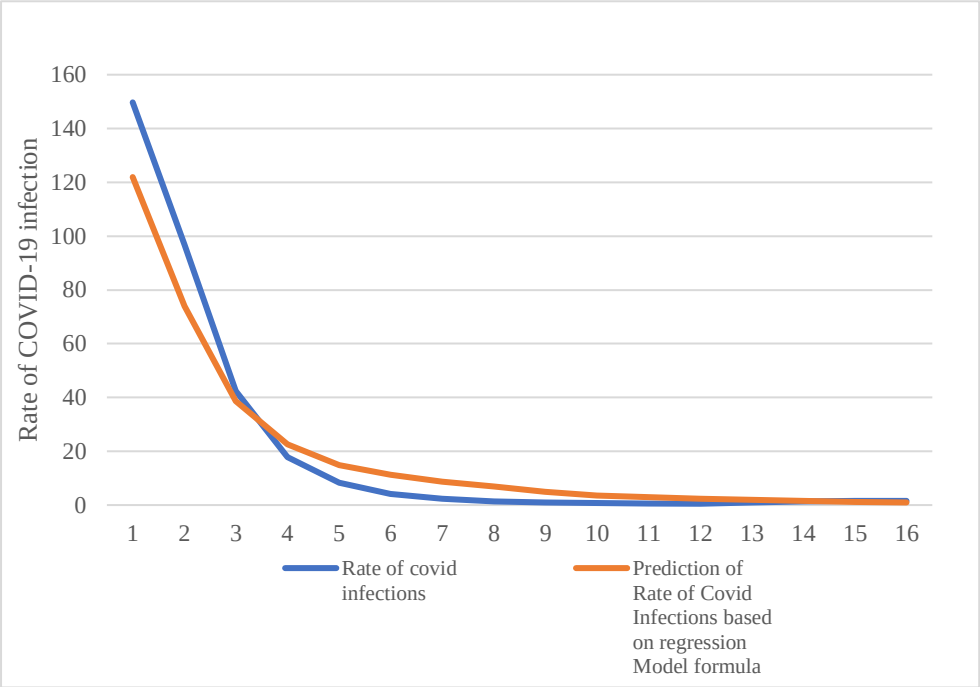

Figure 2 Comparing rate of COVID-19 infection through Regression Predictive Model with Actual Rate of infection

Discussion

Vaccination is an important strategy given the inadequacy of other resources and strategies to reduce morbidity and mortality in case of infectious diseases. It not only prevents the loss of health but also the financial burdens that arise due to episodes of illness for individuals and families. At national and international levels, preventive strategies are critical to contain situations such as pandemics that bring a larger scale of social and economic disruption pushing families into poverty and hunger. The implications are huge with nations and economies coming to a standstill. Thus, evidence of these preventive vaccination strategies to contain the infection is critical.

A year after the vaccination, the course of the pandemic changed drastically. However, it cannot be measured directly and we need to understand this association. In order to understand the dynamics of the epidemic tools like mathematical models are valuable for quantifying the impact of vaccination strategies(Li *et al.*, 2021). The above analysis through modelling has shown that vaccination has played an important role in the control of COVID-19 infection in India. The vaccination drive in India which started on 16th January 2021 had mixed responses initially, with some hesitancy reflected in the population. As the vaccination began during the second wave, the impact was not visible due to low vaccination among the people. However, as the vaccination increased the positive effect was more visible during the third wave with a decrease in the duration of the wave and the number of cases. Similarly, another mathematical modelling study on the global impact of the vaccination on pandemic estimated that vaccinations prevented 14.4 million deaths from COVID-19 in countries across the world. Thus, the vaccination strategy has been proven effective in both prevention of infection and death for millions of lives across the world (Watson *et al.*, 2022). The

results of a study in US on the impact of vaccination on COVID-19 outbreak indicates that vaccination can substantially mitigate the impact of COVID-19 outbreak (Moghadas *et al*., 2021).

Thus, improving vaccination in the population is critical. In pandemic situation like COVID-19, active vaccination delivery specifically targeting high-risk individuals and densely populated zone where the infection risk is high can prove effective in control infection and deaths to a large extent. Along with this, understanding its effectiveness in various age groups and appropriate intervals for a precautionary dose of vaccine in the population is important to reduce or stop the recurring waves of infection. However, many people hesitate to be vaccinated (Kumari *et al*., 2021). The delivery of appropriate precautionary information and the right practice of vaccination is critical to minimize adverse reactions. As such episodes of adverse events are major factors in building vaccine hesitancy. In order to reduce vaccine hesitancy among the people, providing them with the right knowledge that builds their trust and acceptance of the preventive strategy is very essential. Thus, mass dissemination of evidence-based information is critical to reducing vaccine hesitancy. Mathematical modelling can provide information on the nature and pattern of the spread of disease in the population even when epidemiological information about the infection is not available. Thus, these techniques can be leveraged during the initial period in estimating risks and developing combating strategies.

This study tries to emphasize the importance and effectiveness of vaccination in combating COVID-19 statistically, hence can work as a reliable source to inform individuals regarding the benefits of vaccination more so for the population. One of the major concerns regarding vaccination leading to hesitancy among individuals is the effectiveness of vaccination to provide protection against infection. The exponential regression model shows stronger relation between the decrease in cases of COVID-19 with increased weekly vaccination. It predicts that the increase in vaccination in the community will show a significant decrease in the rate of COVID-19 infection, which is very helpful in creating awareness in decreasing vaccine hesitancy. This also suggests the idea of active vaccination in the country regarding COVID-19 for further control of infection. Thus, the vaccination drive is a reassuring strategy for combating the current pandemic and stopping the recurring chain of disease wave and lockdowns.

Limitations of the study

The current study has certain limitations. It considers the overall scenario of vaccination and the rate of COVID-19 infection in the country and does not account for the interstate variability in both these aspects. The role of behavioural factors in the community and adherence to Non-pharmaceutical Intervention in influencing the rate of infection was also not factored in the study due to the non-availability of such data in the Indian context. The study does not take into consideration of age or morbidity in the population.

Data Sharing

This study does not involve any patient data or participant data. The data collection was population data from the publicly available website of WHO and the Ministry of Health and Family Welfare, India which are freely accessible.

Acknowledgements

We express our gratitude towards Maj. Gen. (Prof) Dr Atul Kotwal, SM, VSM Executive Director, National Health Systems Resource Centre, India, for supporting, motivating and providing us with valuable inputs that enriched our work. We also thank the guidance and support from Dr J. N. Srivastava, Advisor Quality and Patient Safety, National Health Systems Resource Centre, India and Dr Sandeep Sharma, Lead Consultant Healthcare Financing, National Health Systems Resource Centre, India. The views expressed in the article are those of the author and not necessarily of the National Health Systems Resource Centre.

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