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Cross-sectional Study

A cross-sectional study of COVID-19 outbreak in Indian population

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ABSTRACT

Background: Presently India is the second most populous country in the world with an estimated population of 1.4 billion people and has recently been affected by COVID-19 pandemic and subsequent mutant viral outbreak. To date, India has administered its population with over 1.30 billion cumulative doses of COVID-19 vaccine. The consequences of COVID-19 vaccination on the outbreak in India has not been reported until now. Therefore, we probed to assess the impact of COVID-19 outbreak in India from December 2019 to December 2021.

Methods: Indian COVID-19 related data were extracted from "ourworldindata.org" and "cowin.gov.in" databases. The incidence rate of COVID-19 per million people was calculated and other parameters such as new cases, positive rate, reproduction rate, new death and stringency index values were extracted from the database for statistical analysis.

Results: Data indicate that the COVID-19 positive rate declined as the number of vaccinations rose over time. The Pearson correlation values between new cases and the cumulative percentage of vaccination or the percentage of fully vaccinated population showed no correlation ($P < 0.01$). COVID-19 vaccination has significantly decreased the R-value and positive rate of SARS-CoV-2 in India ($P < 0.01$). Furthermore, containment measures showed no correlation with the incidence rate of SARS-CoV-2 in India which may be in contradictory to the global trends.

Conclusion: Vaccination against COVID-19 was efficacious in the control of the SARS-CoV-2 outbreak and the decrease in the positive rate. Further, the containment measures had no effect on the spread of COVID-19 infection in India, thus far.

1. Introduction

The novel coronavirus pandemic, currently referred to as COVID-19, is an infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1,2]. It is believed to have originated from the city of Wuhan in Hubei province in Southern China and caused an epidemic in many cities and rapidly spread across the world [3]. The emergence of this particular strain of the human coronavirus has resulted in a new global pandemic since December 2019 [4]. Major features of COVID-19 infection include shortness of breath, fever and pneumonia [2,5]. The World Health Organization (WHO) declared COVID-19 as a pandemic in March 2020 [6]. However, the spread of the infection was spreading vigorously around the world, even earlier [3].

Soon after the COVID-19 outbreak the world witnessed many fatalities since the treatment strategies were not clearly prescribed. Thus, physicians treated the patients with conventional medications that included steroid and antiviral medication with or without respiratory support [7,8]. Subsequently, certain medications, including hydroxychloroquine and remdesivir, were urgently approved by national regulatory authorities for the treatment of COVID-19 infection [9,10]. Meanwhile, many pharmaceutical companies across the globe had begun developing vaccines against COVID-19 infection [11]. Eventually, few vaccines were approved as an emergency tenacity and few countries began immunizing their populations against COVID-19 [12–14].

In India, the first COVID-19 positive case was reported in the state of Kerala in January 31, 2020 [15] and by early March 2020, there was a surge in COVID-19 incidence in rest of the country [16]. The first casualty due to COVID-19 in India was confirmed in the State of Karnataka on March 12, 2020 [17]. Subsequently, the Indian government imposed national containment on March 25, 2020 [18] and after numerous changes in relaxation policies, containment is still in place to certain extent. India has reported two waves of COVID-19 outbreaks to date, the former from March 2020 to September 2020 and the latter from March 2021 to May 2021. Rise in the number of cases in the second wave are

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estimated at over 400,000 positive cases per day [19]. In comparison to the first wave the positive rate was commensurate with significantly high incidence and casualty rates in the second wave [20].

Unfortunately, few studies reported that the SARS CoV-2 virus has a rapidly evolving genomic structure due to mutations over time [21,22]. The transformation of the genomic structure of the virus has had a significant impact on the number of new cases and subsequent outbreaks over time [23]. Several viral mutations have been reported worldwide, including alpha, beta, gamma and delta variants of SARS CoV-2 [23,24]. In India, the delta variant has spread and propagated most rapidly and may be suspected to have caused a marked rise in the number of positive cases during the second wave [24,25]. The novel mutant has a high rate of spread of SARS-CoV-2 G-clad infection ranging from 46% to 82.34% in India [19].

Given the seriousness of the COVID-19 outbreak and subsequent losses, the Government of India started the vaccination program on January 16, 2021. With nearly 3000 active vaccination centers across the country, India has administered 1 billion cumulative doses of the COVID-19 vaccine by October 21, 2021 [26]. However, the impact of COVID-19 vaccination on the outbreak in India has not been reported until now. Therefore, we investigated the impact of vaccination on COVID-19 outbreak in India using a publicly accessible database.

2. Vaccination programme in India

India is a federal union with 29 states and 8 union territories, of a total of 37 entities. The COVID-19 vaccination program in India started in mid-January 2021 and by December 2021, India had the most vaccinated country in the world. The vaccination program was divided into three categories, the first being towards front-line healthcare workers, followed by people 40 years or above and people in 18–40 years age range throughout the country. The COVID-19 vaccine distribution was done based on the areas of spread and population density of any given territory. The heat generation graph of India shows that the highest number of vaccine doses were provided in the state of Uttarakhand (Fig. 1). Furthermore, the vaccination program began just before the beginning of the second wave in the country. A total of three vaccines against SARS-CoV-2 approved by Drugs Controller General of India (DCGI) to date are Covishield, Covaxin and Sputnik-V (Table 1).

2.1. Covishield

Covishield contains the attenuated adenovirus SARS-CoV-2 strain and when given intramuscularly leads to generation of antibodies against the novel COVID-19 strain (Fig. 2). Preliminary data indicates 70% of efficacy of this vaccine against SARS-CoV-2 infection [27].

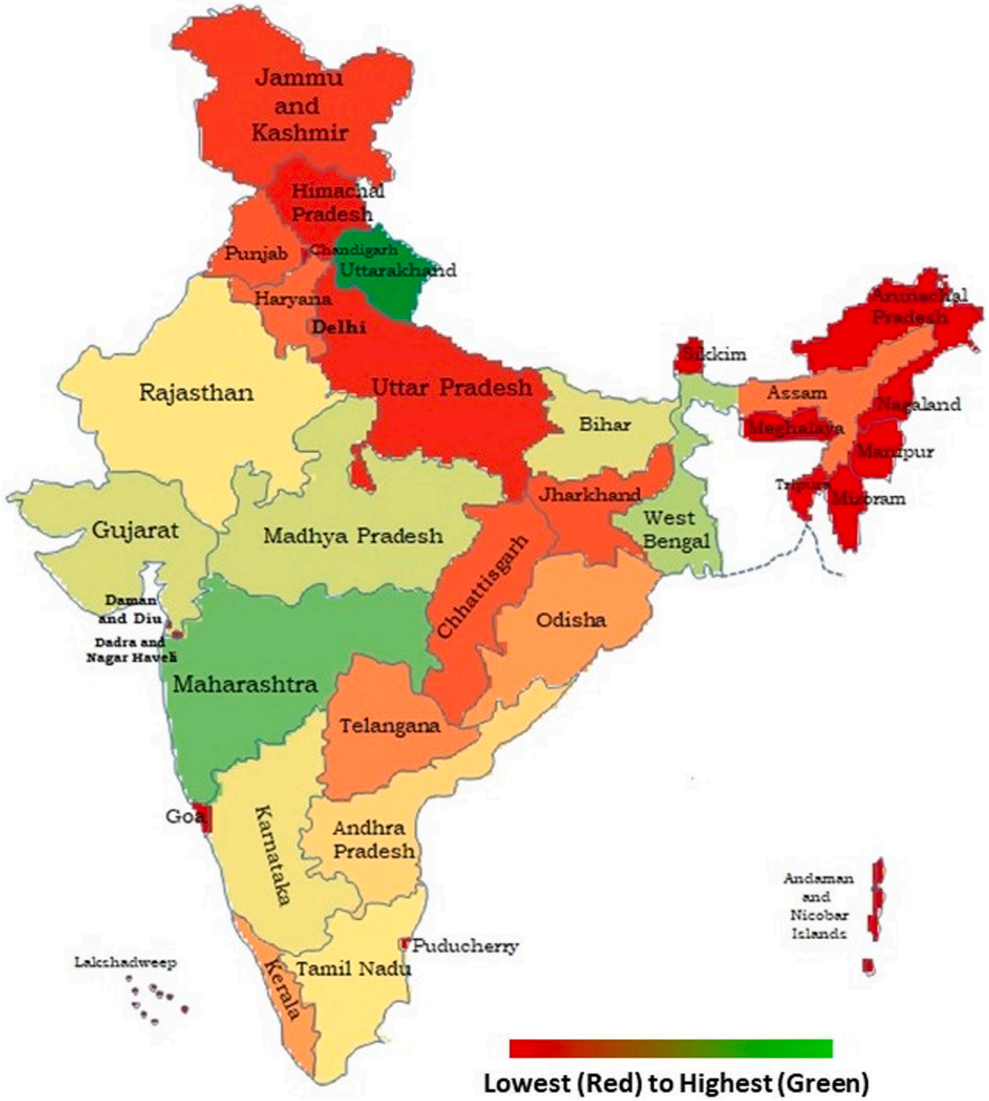

Fig. 1. The image depicting the mechanisms by which vaccines act against COVID-19 currently approved in India.

Table 1
Overview of the vaccination programme in India.

Vaccine	Approval	Deployment	Developed	Vaccine nature	Dosing period	Total vaccine doses administrated as of December 20, 2021
Covishield	January 1, 2021	January 16, 2021	Oxford University and AstraZeneca	Inactivated coronavirus strain	2nd dose to be taken 84 days after the 1st dose	1.23 billion
Covaxin	January 3, 2021	January 16, 2021	Bharat Biotech	Weakened strain of adenoviruses	2nd dose to be taken 21 days after the 1st dose	0.150 billion
Sputnik V	April 12, 2021	May 14, 2021	Moscow's Gamaleya Institute	Adenovirus vaccine	2nd dose to be taken 21 days after the 1st dose	0.0012 billion

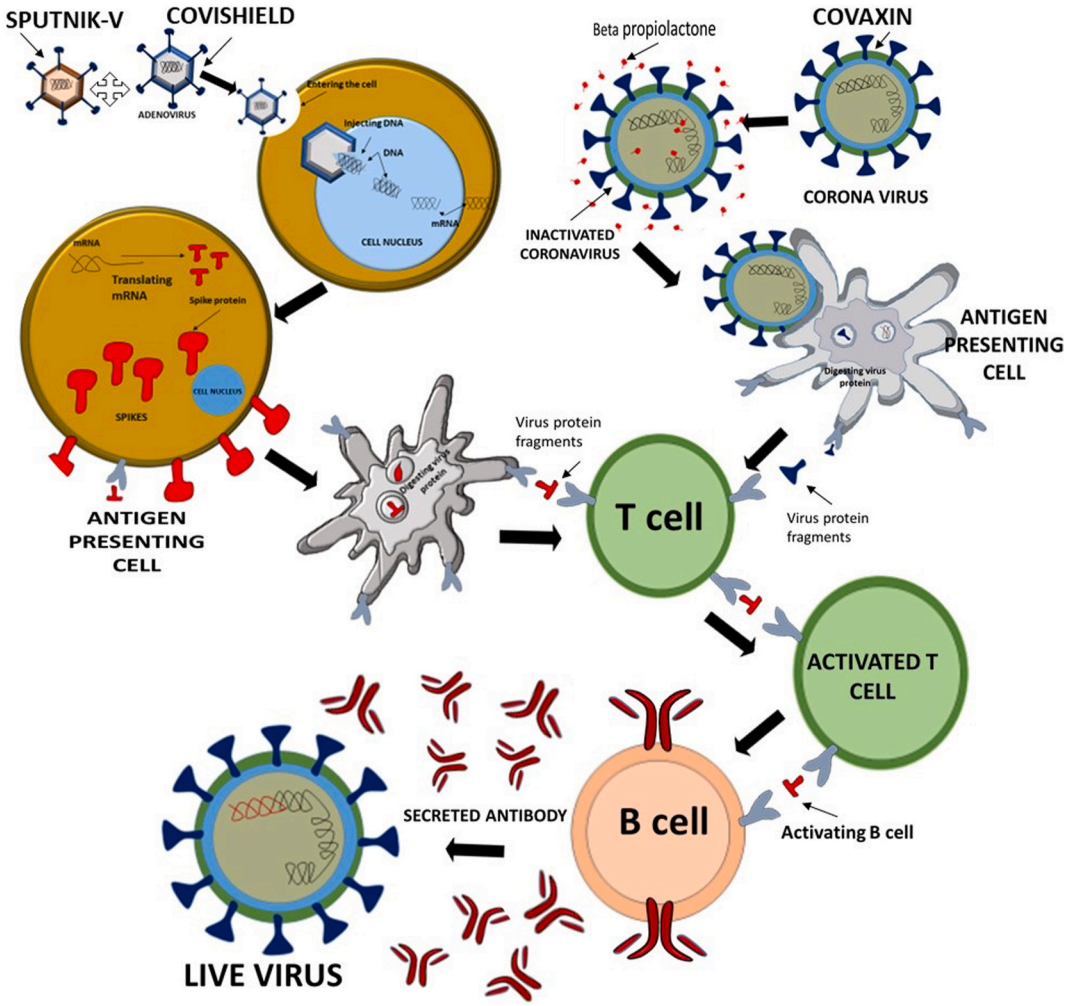

Fig. 2. The distribution of the COVID-19 vaccine across India. Total number of vaccinations administered Lowest (red) in total number of vaccinations administered Highest (green). Data were accessed from "cowin.gov.in" database from January 16, 2021 to December 20, 2021. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

2.2. Covaxin

Covaxin contains an inactivated coronavirus strain in a pathogenically reduced form of SARS-CoV-2 and its administration leads to production of complementary antibodies (Fig. 2). Based on the preliminary results of a Phase 3 trial, Covaxin has shown an efficiency rate of 81% [28].

2.3. Sputnik-V

Sputnik-V is an adenovirus-based vector vaccine and uses a cold-type virus as a vector to administer a small piece of COVID-19 gene to the recipient triggering production of anti- SARS- CoV-2 antibodies (Fig. 2) with 92% effectiveness [29].

3. Material and methods

Data for Indian COVID-19 cases were extracted from "ourworldindata.org" and "cowin.gov.in" databases and work has been reported in line with the STROCSS criteria [30]. The incidence rate of COVID-19 per million was calculated using the following formula: Incidence rate = (New cases/Estimated population) x 10,00,000 [31]. Whereas, other parameters such as positive rate, reproduction rate and stringency index values were extracted from the "ourworldindata.org" database for

statistical analyses. New cases, positive rate, reproduction and new death variables were correlated with vaccination. The stringency index was correlated with incidence rate while the number of new tests were correlated with number of new cases. In addition to this, variable such as new cases, positive rate, reproduction rate and new deaths were also correlated with date of events as described previously [32]. Further, to understand the impact of vaccination on positive rates and reproduction rates the data have been divided into two categories, namely, before vaccination (data from January 30, 2020 to January 15, 2021) and after vaccination (data from January 16, 2021 to December 20, 2021), since the inception of the vaccination programme in the country. The difference between pre- and post-vaccination was determined using an unpaired *t*-test and the P-value was calculated. The SPSS and Graph Pad prism software's were used for all statistical analyses.

4. Results

The information required for the correlation was assessed and a statistical analysis was carried out.

4.1. Impact of vaccinations on new cases, incidence rate and positive rate

In India the first COVID-19 incident was reported in the last week of January 2021. The impact of the vaccination on the positive rate ever since till December 2021 was assessed (Fig. 3). The data indicate that the initial positive and incidence rate showed decreasing trends as the number of vaccination doses increased over time (Fig. 4). The Pearson correlation between new cases and the cumulative percentage of vaccination (CPV) or the percentage of fully vaccinated (PFV) population did not correlate ($P < 0.01$) (Table 2).

4.2. Impact of vaccinations on reproduction rate

The reproduction rate (R value) of SARS-CoV-2 virus is the average ability of an infected person to spread a virus to others. Fortunately, COVID-19 vaccination has significantly decreased the R-value of SARS-CoV-2 virus in India (Fig. 5). The Pearson correlation between reproduction rate and the CPV or PFV shows a significant moderate negative correlation ($P < 0.01$) (Table 2).

4.3. Impact of vaccinations on new death

Vaccination against COVID-19 led to slight reduction in the number of new deaths. The CPV and PFV ($P < 0.05$) showed no correlation with new deaths (Table 2).

4.4. Impact of stringency index on incidence rate

The stringency index data were captured from "ourworldindata.org" database and was calculated based on "containment measures" and other policies towards restricting people to gather in groups or clusters. The containment measures had no effect on incidence rate of SARS- CoV-2 in India (Table 2).

4.5. Impact of increased new tests

The increase in the number of new tests shows a significantly moderate positive correlation with the increase in the number of new SARS-CoV-2 cases, with a correlation value of 0.450 ($P < 0.01$) (Table 2).

5. Discussion

The aggregated data are accessible in the "ourworldindata.org" database for each country and are updated daily. A total of 690 datasets were available for Indian populations between January 30, 2020 and December 20, 2021, with a median of 27,018 new cases. These data sets have values of 690 days of information throughout the country and the 'N' in Table 2 corresponds to the cumulative per-day information for the country. Presently India is the second most populous country in the world with an estimated population of 1.4 billion people and has recently been affected by COVID-19 pandemic and subsequent mutant viral outbreak. To date, India has administered its population with over 1.3 billion cumulative doses of COVID-19 vaccine. The impact of COVID-19 vaccination on the outbreak in India has not been reported until now. Therefore, we probed to assess the incidence of COVID-19 outbreak in India from December 2019 to December 2021 so as to enable scientists to predict the impact of vaccination on the global COVID-19 related clinical events. To address this concern, we accessed publicly available database and analyzed trends related to positive rate, incidence rate, reproduction rate and new death and the effect of stringency index on incidence rate. The data indicate that there is no reduction in new cases,

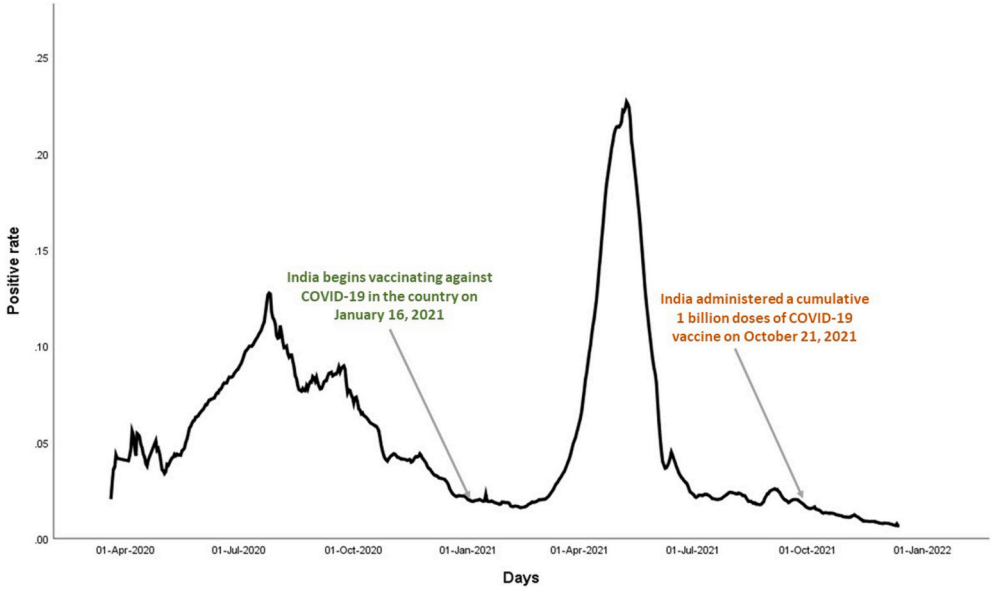

Fig. 3. The image shows the positive rate of SARS-CoV-2 in India over time.

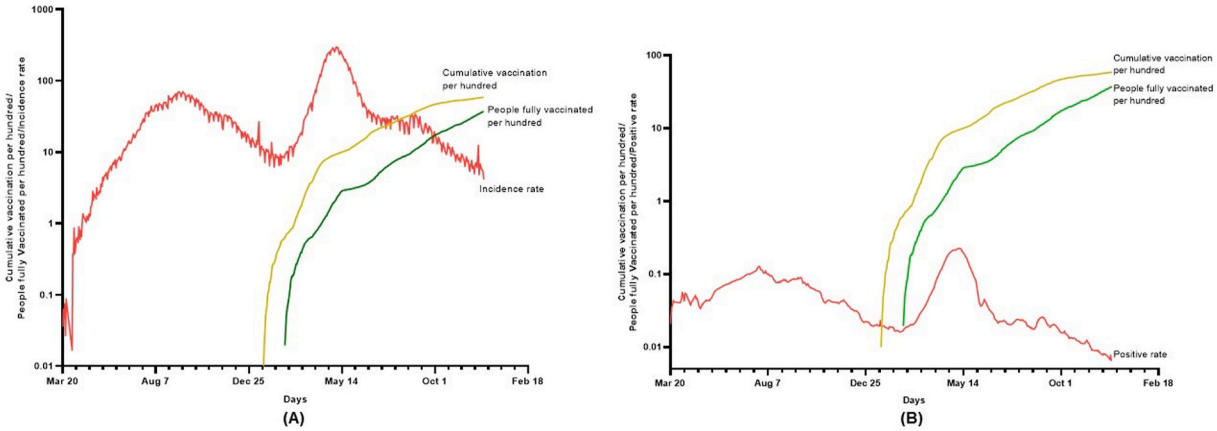

Fig. 4. The image shows comparisons between the incident rate (A) and the positive rate (B) of SARS-CoV-2 in India over time.

Table 2
Statistical correlation of the impact of vaccination on COVID-19 outbreak in India from January 16, 2021 to December 20, 2021.

S. No	Parameters	Pearson correlation coefficient (*r*) value		N	P value
1	Date Vs new cases per million	0.128	No correlation	598	<0.01
2	New cases Vs cumulative vaccination per hundred	−0.121	No correlation	598	<0.01
3	New cases Vs fully vaccinated per hundred	−0.175	No correlation	598	<0.01
4	Date Vs positive rate	−0.325	Low negative	598	<0.01
5	Positive rate Vs cumulative vaccination per hundred	−0.404	Moderate negative	598	<0.01
6	Positive rate Vs fully vaccinated per hundred	−0.403	Moderate negative	598	<0.01
7	Date Vs reproduction rate	−0.577	Moderate negative	598	<0.01
8	Reproduction rate Vs cumulative vaccination per hundred	−0.383	Moderate negative	598	<0.01
9	Reproduction rate Vs fully vaccinated per hundred	−0.336	Moderate negative	598	<0.01
10	Date Vs New death	0.169	Very low positive	598	<0.01
11	New death Vs cumulative vaccination per hundred	−0.046	No correlation	598	Non-significant
12	New death Vs fully vaccinated per hundred	−0.099	No correlation	598	<0.05
13	Stringency index Vs Incidence rate	0.128	No correlation	598	<0.01
14	New tests vs new cases	0.450	Moderate positive	598	<0.01

mortality, whereas vaccinations had a negative impact on positivity rate of COVID-19 (Fig. 5).

It is noteworthy that the second wave started shortly after the start of the vaccination program in the country and COVID-19 positivity and fatality was significantly high in the second wave in comparison to the first wave phase (Fig. 3). Interestingly, the second wave was suspected as a result of delta mutations in SARS-CoV-2 virus in India [25,33,34]. Although, there is no conclusive explanation for the link between the evolution of the mutated virus and the subsequent outbreak. The immediate spike observed in the number of cases in India after starting vaccination program is consistent with the theory of Luc Montagnier, a Nobel Prize winner from France, on mass vaccination and viral mutation [35]. Thus, the abrupt spike in the second wave in India after the initial immunization program could have been due to a higher ratio of unvaccinated individuals than partially vaccinated people. However, the existing data are not adequate to conclude the exact cause for this effect. Therefore, as an ongoing effort our team is actively monitoring the clinical data to understand the dynamics of the infection spread and the impact of vaccination on the Indian population.

Comparison of positivity rate and vaccination shows a moderate negative correlation indicating significant reduction in positive rates due to vaccination or its efficacy in the control of the COVID-19 spread. The effect of vaccination on reproduction rate of SARS-CoV-2 virus infection showed moderate negative correlation. In contrast, comparison between date and reproduction rate yielded better r value than comparison of reproduction rate and vaccination. These findings are supportive the theory of attenuation of SARS-CoV-2 by propagation, as postulated by one Italian physician [36]. However, further investigations are warranted to conclusively determine SARS-CoV-2 attenuation due to its spread. The comparison between new death and vaccination did not correlate suggesting that vaccination did not bring about any reduction in mortality due to COVID-19 complications, in contrast to earlier findings [37].

The stringency index has no correlation with the incidence rate, indicating that the containment measures did not have any effect on spread of COVID-19 infection. The lack of correlation between stringency index and new cases could be due to the household incidence of infection within the family members. Furthermore, comparison of the number of new tests with the number of new cases shows moderate positive correlation. In India tests are mostly conducted on persons developing clinical symptoms of COVID-19 infection or those closely associated with the COVID-19 positive patients. Hence, positive correlation between the new test and the new cases has defied the notion that increase in the number of tests will yield greater number of positive cases. Furthermore, India is not yet receiving booster doses of vaccination against SRAS-CoV-2 infection. Therefore, with adequate sample size taken for the current analyses, the booster dose may not be necessary for complete vaccination.

Of the total population of about 1.4 billion people in India, more than 1.3 billion vaccine doses have been administered to date and approximately 66.77% of the population has been fully vaccinated. However, as discussed above the sample size considered for the current analyses is adequate to assess the impact of mass vaccination on COVID-19 outbreak in India and may be extrapolated to rest of the world. The current study does not cover the adverse drug reaction profiling for the vaccines administered to Indian population.

6. Conclusion

We have analyzed various aspects of COVID-19 outbreak on India population through publicly accessible data. The data from the current

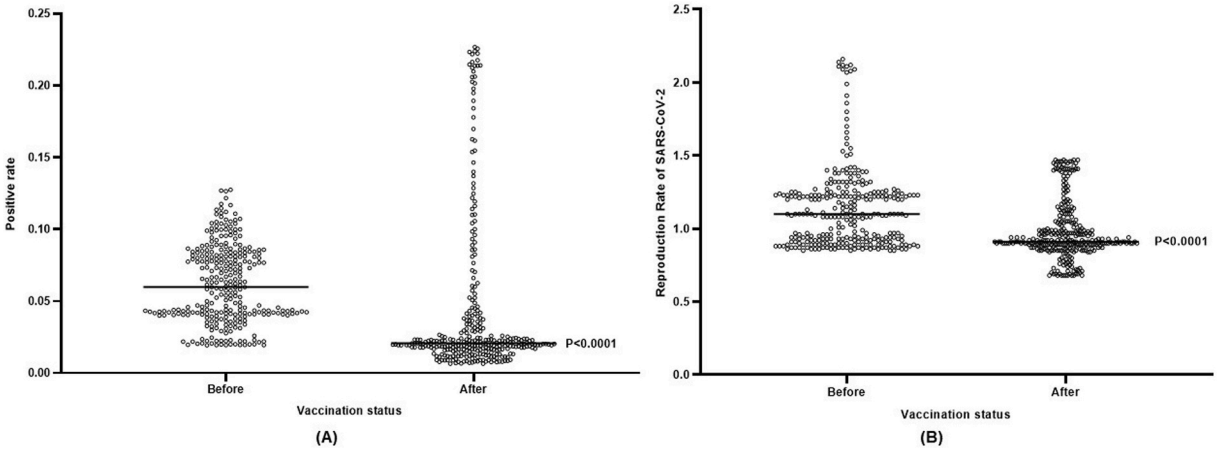

Fig. 5. The image compares the impact of vaccination on the difference between the positive (A) and reproductive (B) rates of SARS-CoV-2 in India. The difference between pre- and post-vaccination was determined using an unpaired *t*-test.

study indicate that the vaccination had negative impact on COVID-19 positivity rate, while had no effect on incidence rate and mortality. COVID-19 vaccination significantly decreased the reproduction rate of SARS-CoV-2 virus in India. The stringency index has no correlation with the incidence rate, indicating that the containment measures did not have any effect on spread of COVID-19 infection in India. Overall, vaccination against COVID-19 shows beneficial impact on outbreak. Furthermore, India is not yet receiving booster doses of vaccination against SRAS-CoV-2 infection. Therefore, with adequate sample size taken for the current analyses, the data suggests that booster dose may not be necessary for complete vaccination.

Provenance and peer review

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Please state any conflicts of interest

None.

Please state any sources of funding for your research

None.

Please state whether Ethical Approval was given, by whom and the relevant Judgement's reference number.

The data are acquired from publicly available database so the no ethical approval is sought. As per the "National Ethical Guidelines for Biomedical and Health – India" the current study is not required ethical committee approval.

Please find following link Page No 68 under the subdivision of "The EC may grant consent waiver in the following situations" for more details.

Research registration Unique Identifying Number (UIN)

1. Name of the registry: Researchregistry.

2. Unique Identifying number or registration ID: researchregistry7480.

3. Hyperlink to your specific registration (must be publicly accessible and will be checked):HYPERLINK "https://www.researchregistry.com/browse-the-registry" \l "home/registrationdetails/61c441ef73443e001fcf81d5/" \o "https://www.researchregistry.com/browse-the-registry"https://www.researchregistry.com/browse-the-registry#home/registrationdetails/61c441ef73443e001fcf81d5/

Author contribution

All authors have equally contributed to the data analysis and preparation of manuscript.

Guarantor

Murugesan Arumugam & Prashant S Patole.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2022.103554.

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