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COVID-19 outbreak trends in South Africa: A comparison of Omicron (B.1.1.529), Delta (B.1.617.2), and Beta (B.1.351) variants outbreak periods

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Abstract

Objectives: We provided COVID-19 outbreak trends in South Africa during the Omicron (B.1.1.529), Delta (B.1.617.2), and Beta (B.1.351) variants outbreak periods from November 2020 to March 2022.

Methods: We used the time series summary data of the COVID-19 outbreak for South Africa available in the COVID-19 data repository created by the Center for System and Science and Engineering at Johns Hopkins University and the Our World in Data database by the University of Oxford from January 2020 to March 2022. We used the joinpoint regression model with a data-driven Bayesian information criterion method for analyzing the outbreak trends. In addition, we used density ellipses and partition modeling on the outbreak data.

Results: During the Omicron outbreak period, COVID-19 cases in South Africa significantly jumped by 4.7 times from December 01 to December 08, 2021. The average daily growth rate of incidence peaked at 23,000 cases/day until December 16, 2021, which was 18.6% higher than the peak growth during the Delta outbreak period. South Africa experienced peak growth in COVID-19 cases with 18,611 cases/day (January 04 to January 14, 2021) during the Delta outbreak period and with 19,395 cases/day (July 01 to July 11, 2021) during the Delta outbreak period. Density ellipsoid showed a significant correlation between daily cases and daily death count during the Beta and Delta outbreak periods which were not prominent in the Omicron outbreak period. Comparatively, higher daily death tolls were reported in days with a recovery rate of less than 89.1% and 91.9% in the Beta and Delta outbreak periods respectively. The backlog counts may be one of the reasons for the significant increase in daily death tolls during the Omicron period.

Conclusions: During the Omicron period, COVID-19 cases peaked growth was 18.6% higher than the peak growth during the Delta outbreak period. Despite that fact, growth in death trends in the Omicron outbreak period was found low which might be due to the low mortality rate and case fatality proportion. The emergence of the Omicron variant once again reminds us that “no one is safe until everyone is safe”.

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Introduction

The discovery of a new variant of concern of the severe acute respiratory syndrome coronavirus 2, SARS-CoV-2, (causative virus of the coronavirus disease, COVID-19) in South Africa has triggered a global scramble [1]. World Health Organization designated the new variant as a variant of concern and named it Omicron (B.1.1.529) on the 26th of November 2021 [2]. Omicron has numerous mutations similar to changes seen in previous variants of concern and some novel mutations which are associated with the potential to enhance transmissibility, confer resistance to therapeutics, or partially escape infection-acquired immunity and/or vaccine-administered immunity [3-7]. In the current situation, there are too many confounding factors that need to be compared in patients infected with...
the Omicron variant in South Africa with patients infected by other variants [8].

To date, little data and information is available on the Omicron variant to answer the uncertainties, and studies must be quickly carried out to better define the threat that this variant represents [8]. Obtaining and analyzing information about what has happened until now and what might happen in the future is essential for understanding and controlling the SARS-CoV-2 variants of concern outbreaks at the global level. Researchers in South Africa and around the world are conducting studies to better understand many aspects of Omicron [3]. Based on the real-time data, in this study, we attempted to provide the trends and significant changes in the COVID-19 outbreak in South Africa during the Omicron (B.1.1.529), Delta (B.1.617.2), and Beta (B.1.351) outbreak periods from November 2020 to March 2022. Moreover, through the ellipse and partition models, we tried to demonstrate comparatively how the daily cases, recovery rate, and percent positivity in South Africa were correlated to daily death tolls during the Omicron (B.1.1.529), Delta (B.1.617.2), and Beta (B.1.351) outbreak periods.

Methods

Sources of data and compilation

Data for this time-trend study were primarily retrieved and compiled from two global databases for providing public aggregated global information on the COVID-19 pandemic. In the first part, we used the time series summary data from January 2020 to March 2022 available in the COVID-19 data repository by the Johns Hopkins University Center for System and Science and Engineering which is also supported by ESRI living Atlas Team and Johns Hopkins University Applied Physic Lab [9]. From this database, COVID-19 total cases, total recoveries, and total deaths data for South Africa were sorted out from the master database file from November 2020 to March 2022 as three separate comma-separated values (.csv) files and combined as one excel file. We then calculated the daily COVID-19 cases, daily deaths, daily recoveries, daily recovery rate, and case fatality proportion from the total cases, total recoveries, and total deaths data. For additional data, we used the Our World in Data COVID-19 vaccination dataset [10] by the University of Oxford. This COVID-19 vaccination dataset covers the full period from the first vaccination published data (December 13, 2020) and has been updated regularly ever since. From this database, we filtered out the total tests, people vaccinated, people fully vaccinated, and population dataset for South Africa from February 2020 to March 2022 and compiled it into an excel file. The operational definition of people vaccinated is the number of people who had received at least one dose of the vaccination protocol whereas people fully vaccinated denotes those who completed the initial vaccination protocol. We calculated the daily tests, percent positivity, and percent of the total population partially and fully vaccinated in South Africa from the related variables in the dataset. Percent positivity was calculated from the proportion of people who tested positive for SARS-CoV-2 on a given day and the total number of tests conducted on that specific given day [11].

Study variables from both the excel files were combined into one excel file that matched the date and further filtered out from November 2020 to March 2022. We matched our calculated daily cases and deaths figures, especially during the Omicron outbreak period, with the figures provided in the official COVID-19 Online Resource and News Portal of the National Department of Health of the Republic of South Africa [12]. For missing data and repeated values on two consecutive days in the compiled dataset, we imputed the values also from the official COVID-19 Online Resource and News Portal of the National Department of Health of the Republic of South Africa. This compiled data set then was converted to the comma-separated values (.csv) file for trend analysis. In addition, since January 06, 2022, the Department of Health of the Republic of South Africa had recorded and reported the COVID-19 death backlog as an ongoing audit exercise conducted in each province across the country to address a backlog of COVID-19 mortality [12]. This audit exercise increased the daily death tolls on some specific days when the backlog death counts were added. We have provided the information on the backlog death counts together with the original death counts on the specific dates in a Supplementary table (Table S1).

Segregation of Beta, Delta, and Omicron outbreak period

Beta (B.1.351) outbreak period was considered from the prior month when the Beta variant of SARS-CoV-2 had discovered by scientists in South Africa on December 18, 2020, to March 2021. During this period, South Africa experienced the second wave of its COVID-19 pandemic. The tentative duration of the second wave (November, 2020–March, 2021) was determined from the line graph of the daily cases in South Africa. In the line graph, where the visible surge in new cases followed by a decline was considered a wave. Delta (B.1.617.2) outbreak period was considered from the prior month when the earliest documented sample with the Delta variant of SARS-CoV-2 was identified in South Africa (May 08, 2021) to the prior month of the earliest documented sample with the Omicron variant of SARS-CoV-2 reported (November 2021). The Delta outbreak probably resulted in the third pandemic wave in South Africa [2]. The tentative duration of the third wave (April 2021 to October 2021) was determined from the line graph of the daily cases when the visible surge in new cases was followed by a decline. Omicron (B.1.1.529) outbreak period was considered from the month when the earliest documented sample with the Omicron variant of SARS-CoV-2 was reported in South Africa (November 09, 2021) to the last reported date of this analysis (December 30, 2021). This is an ongoing wave during our analysis. The tentative duration of the fourth wave (November 2021 to continue) was determined from the line graph of the daily cases when the visible surge was followed by a decline.

Trends analysis, density ellipse, and partition models

To analyze the temporal trends and to identify significant changes in trends in the coronavirus disease (COVID-19) outbreak in South Africa from November 01, 2020, to March 31, 2022 (a total of 516 days), we performed a jointpoint regression analysis [13]. We have analyzed the trends segregated on each month from November 2020 to March 2022. We used Windows-based statistical software, the Joinpoint Regression Program (version 4.9.0.0, National Institute of Health, Bethesda, MD, United States) for performing the jointpoint regression by using the jointpoint models. With this analysis, it was possible to identify days when a significant change in the linear slope of the trend is detected over the study period. The best-fitting points, called ‘jointpoints’, are chosen when the rate changes significantly. The analysis starts with the minimum number of jointpoints and tests whether one or more jointpoints (in this study up to 3) are significant and must be added to the model. To describe linear trends by period, the estimated regression coefficients (β) are then computed for each of those trends [13–15]. The multiple jointpoints were used to reflect and provide a background for the changing epidemic patterns. In addition, we used density ellipses analysis to
assess the correlation between daily deaths and daily cases of the outbreak data segregated on Omicron, Delta, and Beta outbreak periods. We selected and represented the 50%, 90%, and 99% probability plots for the density ellipses around the data point. We used the partition model using the decision tree method to identify the possible important factors that split the continuous outcome (daily deaths) during the Omicron, Delta, and Beta outbreak periods with a cutting value of the factor variables. The daily cases, recovery rate, and percent positivity values during the Omicron, Delta, and Beta outbreak periods were divided into two groups based on the variability of the daily death and created a tree of partition on the factor variables’ responses. In the Omicron period, we used the backlog-reported days as an additional factor to predict the variability in the daily deaths. We used JMP (Version 16.1, SAS Institute Inc., Cary, NC, United States) software package for these analyses.

Results

As of March 31, 2022, about 6.2% of the South African have had COVID-19 and 97.0% of them have recovered. About 39.7% of the population has tested for SARS-CoV-2 and 34.9% of the total population received at least one dose of vaccine, and 29.8% were fully vaccinated. So far, South Africa has experienced four waves (surge in periods. We selected and represented the 50%, 90%, and 99% incidence growth rate reached almost 3000 cases/day during the last week of November and created a tree of partition on the factor variables’ responses. In the Omicron period, we used the backlog-reported days as an additional factor to predict the variability in the daily deaths. We used JMP (Version 16.1, SAS Institute Inc., Cary, NC, United States) software package for these analyses.

Discussion

Our analysis showed that during the Omicron outbreak period, COVID-19 cases in South Africa peaked within one month of the first infectious specimen collected on November 09, 2021. Since then, the growth rate of incidence slowed down to 1321 cases/day during the last three weeks of March 2022, and the total cases reached 3.72 million. Unlike the case trend, the death trend did not show any noticeable changes and continued to maintain the third wave’s decreasing trend till mid-December 2021. During the last few days of December 2021, the death rate jumped to 98 deaths/day. During January and February 2022, death trends showed lots of fluctuations as high as 344 deaths/day and as low as 75 deaths/day. These fluctuations in trends were mainly due to the ongoing audit exercise conducted by the Department of Health of the Republic of South Africa since January 06, 2022. COVID-19-related deaths reached 100,032 in South Africa as of March 31, 2022.

Partition models to assess the variability in daily deaths

During the Beta and Delta outbreak period, the ellipsoid collapsed diagonally (Fig. 1) which indicates a high correlation between daily cases and deaths whereas the ellipsoid was more circular during the Omicron outbreak period. Days with a recovery rate of less than 89.1% had comparatively higher daily death tolls compared to the days with a recovery rate of 89.1% and more (478 vs. 127 deaths) during the Beta outbreak period (Table 3). In the Delta outbreak period, days with a recovery rate of less than 91.6% had 312 deaths on an average compared to days with a recovery rate of 91.2% and more. During the Beta outbreak period, deaths were reported significantly higher when the number of daily cases was over 5297 cases mark (about 414 vs. 125 deaths). Death was counted markedly high when the daily cases were over 5574 cases in the Delta outbreak period (about 291 vs. 76 deaths). During the Omicron period, days with backlog counts had higher daily death tolls as opposed to the days with no backlog counts (173 vs. 57 deaths).
compared the peak growth of incidence (average cases/day) during the Omicron outbreak period with the Beta and delta outbreak period, we found that peak growth in COVID-19 cases during the Omicron outbreak period was 1.2 times higher than the peak growth during Delta outbreak period. Initially, during the Omicron outbreak period, much of this growth in cases occurred in the Gauteng province, South Africa, indicating an increase in hospitalization due to COVID-19. Compared to other variants outbreak period, in the Omicron outbreak period cases peaked at a much faster period which indicates its probable high transmissibility in South Africa. Another possible aspect of the high transmissibility in South Africa is their current vaccination level. South Africa had the highest growth in COVID-19 cases compared to other variants' outbreak period, death trends were found significantly lower during this period. During the Beta outbreak period, although South Africa had the highest growth in COVID-19 cases compared to other variants' outbreak period, death trends were found significantly lower during this period. During the Beta outbreak period, the death rate peaked between July 19 and July 31, 2021 at 400 deaths/day. During the Omicron outbreak period, data from the South African Health Department reported in studies. During the Omicron outbreak period, although South Africa had the highest growth in COVID-19 cases compared to other variants' outbreak period, death trends were found significantly lower during this period. During the Beta outbreak period, although South Africa had the highest growth in COVID-19 cases compared to other variants' outbreak period, death trends were found significantly lower during this period. During the Beta outbreak period, the death rate peaked between July 19 and July 31, 2021 at 400 deaths/day. During the Omicron outbreak period, data from the Gauteng province, South Africa, indicate an increase in hospitalization.

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**Table 1**

| Trend 1 | Trend 2 | Trend 3 | Trend 4 |
|---------|---------|---------|---------|
| Period  | Period  | Period  | Period  |
| Beta Outbreak Period  | Delta Outbreak Period  | Omicron Outbreak Period  | Fourth wave of the Pandemic  |
| Month    | Month    | Month    | Month    |
| November 2020 | Dec 01-Nov 29 | Nov 01-Nov 8 | Mar 01-Nov 8 |
| December 2020 | Dec 30-Dec 08 | Dec 02-Dec 18 | Nov 09-Nov 17 |
| January 2021  | Dec 29-Jan 04 | Jan 01-Jan 14 | Nov 10-Dec 31 |
| February 2021 | Jan 05-Feb 04 | Jan 05-Feb 13 | Feb 05-Mar 31 |
| March 2021  | Feb 04-Mar 31 | Feb 04-Mar 31 | Mar 01-Mar 31 |

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1. Trends analysis identified jointpoints, which are points where line segments of the COVID-19 cases trends are joined. Each jointpoint denotes a statistically significant (P < 0.05) change in the trends of the COVID-19 total cases in South Africa from November 2020 to March 2022.
2. $\beta$ is the estimated regression coefficient for a specific trend; $P$ was calculated from the data-driven Bayesian Information Criterion (BIC) method for the jointpoint model.
3. Beta outbreak period was considered from the prior month when the Beta variant of SARS-CoV-2 had been discovered by scientists in South Africa on December 18, 2020, to March 2021.
4. The tentative duration of the second wave (November 2020–March 2021) was determined from the line graph of the daily cases in South Africa and in the line graph, the visible surge in new cases followed by a decline was considered.
5. Delta outbreak period was considered from the prior month when the earliest documented sample with Delta variant of SARS-CoV-2 was identified in South Africa (May 08, 2021) to the prior month of the earliest documented sample with Omicron variant of SARS-CoV-2 reported in (November 2021).
6. The tentative duration of the third wave (April 2021–October 2021) was determined from the line graph of the daily cases in South Africa and in the line graph, the visible surge in new cases followed by a decline was considered.
7. Omicron outbreak period was considered from the month when the earliest documented sample with the Omicron variant of SARS-CoV-2 was reported in South Africa (November 09, 2021) to the last reported date of this analysis (March 31, 2022).
8. This is an ongoing wave during our analysis. The tentative duration of the fourth wave (November 2021 to continue) was determined from the line graph of the daily cases in South Africa and in the line graph, the visible surge in new cases expected to be followed by a decline was considered.

Denotes that the estimated regression coefficient ($\beta$) was significantly different from 0 for a specific trend (P < 0.05) in the COVID-19 cases trends in South Africa.
admissions of COVID-19 cases, from 153 cases in week 45–2201 cases in week 48, and in deaths, from 18 deaths in week 45–83 deaths in week 49 [20]. This increase was associated with the increasing prevalence of the Omicron variant among the reported COVID-19 cases [7]. According to an analysis of 211, 000 COVID-19-positive cases during the Omicron outbreak, adults were experiencing a 29 % lower admission risk, adjusted for vaccination status, relative to South Africa’s first wave of infection [21]. In a recent preprint, authors found that people diagnosed with Omicron in South Africa between October and November 2021 were 80 % less likely to be admitted to hospital than those diagnosed with another variant in the same period [22]. The proportion of patients requiring oxygen therapy (17.6 % vs. 74.0 %) and admission to intensive care (18.5 % vs. 29.9 %) reduced significantly during the Omicron outbreak compared to the Delta period [23]. Moreover, the median length of stay in the hospital decreased to 3 days in the Omicron outbreak period as opposed to 7–8 days during the other outbreak periods. There was a marked decrease in the death rate during the Omicron outbreak period (2.7 %) as compared to Delta (29.1 %) and the first wave of COVID-19 (19.7 %) in South Africa [23]. Before omicron hit South Africa, the population as a whole had built up a considerable amount of immunity against SARS-CoV-2. Maybe, a large proportion of people who were once at higher risk of severe disease during the earlier time of the pandemic, are now probably at lower risk [19,24].

The positive story of reduced severity of Omicron in South Africa may not be generalized to other countries. As what is unclear is whether the picture will be similar in countries where there were high levels of vaccination but low levels of previous infection [25]. However, panic and havoc started in the rest of the world in the late-November 2021. The number of countries reporting Omicron variant cases continued to increase globally. On December 01, 2021, a total of 352 confirmed cases were reported by 27 countries and 70 confirmed cases were reported by 13 European Union and European Economic Area (EU/EEA) countries [26] which jumped to a total of 4691 confirmed cases in the EU/EEA countries as of December 19, 2021 [27]. The majority of confirmed cases had a history of travel to southern African countries, with some having taken connecting flights at other destinations between Africa and Europe. Several European countries had reported subsequent household or community transmission [26]. An analytical report from the Imperial College of London COVID-19 response team estimated that Omicron had a 5.4 times greater risk of reinfection compared to the Delta variant in England [28]. This implies that past infection can provide only 19 % protection against reinfection by Omicron [29]. The Omicron variant of SARS-CoV-2 displays a significant growth advantage

Table 2
Trends in deaths due to the COVID-19 in South Africa from November, 2020 to March, 2022 1.

| Period                        | Trend 1 | Trend 2 | Trend 3 | Trend 4 |
|------------------------------|---------|---------|---------|---------|
| **Beta Outbreak Period**     |         |         |         |         |
| November 2020                | Nov 01–Nov 15 60.12* | Nov 15–Nov 27 93.90* | Nov 27–Nov 30 50.32* | Dec 28–Dec 31 451.63* |
| December 2020                | Dec 01–Dec 09 114.54* | Dec 09–Dec 20 194.43* | Dec 20–Dec 28 306.90* | Dec 28–Dec 31 451.63* |
| January 2021                 | Jan 01–Jan 31 532.46* | Feb 03–Feb 03 467.29* | Feb 03–Feb 12 249.86* | Feb 12–Feb 18 177.19* |
| February 2021                | Feb 01–Feb 03 467.29* | Feb 03–Feb 12 249.86* | Feb 12–Feb 18 177.19* | Feb 18–Feb 28 137.87* |
| March 2021                   | Mar 01–Mar 26 98.25* | Mar 26–Mar 31 50.29* | Mar 26–Mar 31 50.29* | Mar 26–Mar 31 50.29* |
| **Delta Outbreak Period**    |         |         |         |         |
| April 2021                   | Apr 01–Apr 06 24.42* | Apr 06–Apr 24 60.11* | Apr 24–Apr 30 41.58* | Apr 24–Apr 30 41.58* |
| May 2021                     | May 01–May 09 46.38* | May 09–May 17 69.02* | May 17–May 31 86.16* | May 17–May 31 86.16* |
| June 2021                    | Jun 01–Jun 07 71.85* | Jun 07–Jun 20 127.25* | Jun 20–Jun 28 171.67* | Jun 20–Jun 28 171.67* |
| July 2021                    | Jul 01–Jul 19 358.11* | Jul 19–Jul 31 399.03* | Jul 19–Jul 31 399.03* | Jul 19–Jul 31 399.03* |
| August 2021                  | Aug 01–Aug 18 352.56* | Aug 18–Aug 31 303.84* | Aug 18–Aug 31 303.84* | Aug 18–Aug 31 303.84* |
| September 2021               | Sep 01–Sep 17 203.65* | Sep 17–Sep 30 129.61* | Sep 17–Sep 30 129.61* | Sep 17–Sep 30 129.61* |
| October 2021                 | Oct 01–Oct 04 36.53* | Oct 04–Oct 09 94.69* | Oct 04–Oct 09 94.69* | Oct 04–Oct 09 94.69* |
| **Omicron Outbreak Period**  |         |         |         |         |
| November 2020                | Nov 01–Nov 17 27.87* | Nov 17–Nov 22 12.30* | Nov 22–Nov 25 55.42* | Nov 25–Nov 30 17.84* |
| December 2020                | Dec 01–Dec 18 25.10* | Dec 18–Dec 24 73.55* | Dec 24–Dec 28 29.84* | Dec 28–Dec 31 96.50* |
| January 2022                 | Jan 01–Jan 04 74.26* | Jan 04–Jan 07 274.88* | Jan 07–Jan 16 124.06* | Jan 16–Jan 31 118.16* |
| February 2022                | Feb 01–Feb 06 124.97* | Feb 06–Feb 16 164.79* | Feb 16–Feb 19 343.27* | Feb 19–Feb 28 83.10* |
| March 2022                   | Mar 01–Mar 11 27.70* | Mar 11–Mar 15 5.42 | Mar 15–Mar 18 42.36* | Mar 18–Mar 31 12.24* |

1 Trends analysis identified joinpoints, which are points where the line segment of the COVID-19-related deaths trends are joined. Each joinpoint denotes a statistically significant (P < 0.05) change in the trends of COVID-19-related deaths in South Africa from November 2020 to March 2022.

2 β is the estimated regression coefficient for a specific trend; it was calculated from the data-driven Bayesian Information Criterion (BIC) method for the joinpoint model.

3 Beta outbreak period was considered from the prior month when the Beta variant of SARS-CoV-2 was discovered by scientists in South Africa on December 18, 2020, to March 04, 2021.

4 The tentative duration of the second wave (November 2020–March 2021) was determined from the line graph of the daily cases in South Africa and in the line graph, the visible surges in new cases followed by a decline was considered.

5 Delta outbreak period was considered from the prior month when the earliest documented sample with Delta variant of SARS-CoV-2 was identified in South Africa (May 08, 2021) to the prior month of the earliest documented sample with Delta variant of SARS-CoV-2 reported in (November 2021).

6 The tentative duration of the third wave (April 2021–October 2021) was determined from the line graph of the daily cases in South Africa and in the line graph, the visible surge in new cases followed by a decline was considered.

7 Omicron outbreak period was considered from the prior month when the earliest documented sample with the Omicron variant of SARS-CoV-2 was reported in South Africa (November 09, 2021) to the last reported date of this analysis (March 31, 2022).

8 This is an ongoing wave during our analysis. The tentative duration of the fourth wave (November 2021 to continue) was determined from the line graph of the daily cases in South Africa and in the line graph, the visible surge in new cases expected to be followed by a decline was considered.

9 Denotes that the estimated regression coefficient (β) was significantly different from 0 for a specific trend (P < 0.05) in the COVID-19 related deaths in South Africa.
over the Delta variant. Data from South Africa and UK showed Omicron's rapid growth over the Delta variant [7]. Nonetheless, our study has several major limitations. One of the major analytical lackings we had was that we did not adopt and consider the methods to control for reporting and case-to-death distribution delays. We did not have any prior information about this in South Africa. The variations in the reporting and testing system capacity within a country in different periods made the identification of the true time more complicated. In this current analysis, we had not considered this delayed response. Another limitation is the interpretation of the results lacks the integration of post-infection and post-vaccine immunity as well as intrinsic virulence differences between variants. These limitations are due to the lack of sufficient data regarding these parameters and are out of our scope of analysis. Even though through the joinpoint regression analysis, we could detect the turning points of the outbreak but the causal relationship of this turning point with factors cannot be established and our results require further confirmation with individual-level data. Moreover, there is a possible overlap among the three outbreaks which cannot be detected through the joinpoint analysis. Our finding should not be generalized to other countries as COVID-19 severity and mortality vary enormously depending on the country, the prevalence of vaccination, the population's characteristics including age, socio-economic level or co-morbidities, medical management guidelines, or the number of simultaneous cases leading to the saturation of the health system [30]. In our analysis, we have not considered these vital issues while doing the trend analysis. We are unable to incorporate possible confounding factors in our trend analysis model due to the unavailability of incorporating options. Large-scale case-control studies, controlled for as many of these factors as possible, are essential to seriously investigate clinical severity [8]. In addition, we were highly deficient in explaining the possible drivers that might have acted to change the trends during this outbreak. Many factors together with their interplay might have affected the changes in the trends. For this research, we have extracted the data from the COVID-19 data repository by the Johns Hopkins University Center for System and Science and Engineering and matched it with the information provided on the official website of the National Department of Health of the Republic of South Africa. In the data compilation stage, we found a mismatch in the daily case report on November 23, 2021. The official COVID-19 statistics statement from the National Department of Health of the Republic of South Africa reported 868 new cases on November 23, 2021, but the actual value should be 18,586 new cases based on our calculation. This mismatch in the Government report we could not solve, and we did our trend analysis by considering the value based on our calculation.

Despite these limitations, this is the first-ever study in the scientific literature that provided the trends and significant changes in the COVID-19 outbreak in South Africa during the Omicron, Delta, and Beta outbreak period. We reported the recent ongoing trends of the outbreak caused by the Omicron variant of SARS-CoV-2 in South Africa and compared it with the Delta and Beta variants. In summary, during the Omicron outbreak period, COVID-19 cases in South Africa increased from October 24, 2021, which significantly jumped by 4.7 times since December 01, 2021. From December 08 to December 17, 2021, the Omicron variant induced growth rate of incidence peaked which was till now the highest in the COVID-19 pandemic in South Africa Comparatively higher daily death tolls were reported in the days with a recovery rate of less than 89.1 % and 91.9 % in the Beta and Delta outbreak period respectively. The emergence of the Omicron variant once again reminds us that- “no one is safe until everyone is safe”. Moreover, it’s an unavoidable actuality and an

Fig. 1. Density ellipses to assess the correlation between daily deaths and daily cases segregated on A. Beta (B.1.351), B. Delta (B.1.617.2), and C. Omicron (B.1.1.529) outbreak periods. Red line with red contour represents the 50 %, green line with the green contour represents the 90 %, and blue line with blue contour represents the 99 % probability plots around the data points.
Table 3
Partition models parameter using decision tree method on the daily cases and daily deaths data segregated on the Beta, Delta and Omicron outbreak periods in South Africa.

|                            | N  | Death/day | LogWorth  | R²   | AICs          |
|---------------------------|----|-----------|-----------|------|---------------|
| **Beta Outbreak Period**  |    |           |           |      |               |
| Recovery rate ≥ 89.11 %   | 103| 126.6 ± 90.4 | 5.924     | 0.533| 1907.7        |
| Recovery rate < 89.11 %   | 48 | 427.6 ± 194.1 | 2.128     |      |               |
| Case/day < 5297           | 100| 124.7 ± 90.0  | 3.531     | 0.507| 1915.9        |
| Case/day ≥ 5297           | 51 | 413.7 ± 197.3 | 1.765     |      |               |
| Percent positivity < 17.23 % | 119| 162.6 ± 138.5 | 2.868     | 0.359| 1955.3        |
| Percent positivity ≥ 17.23 % |32 | 444.3 ± 205.1 | 0.919     |      |               |
| **Delta Outbreak Period** |    |           |           |      |               |
| Recovery rate ≥ 91.92 %   | 133| 83.1 ± 63.9  | 10.126    | 0.565| 2573.5        |
| Recovery rate < 91.92 %   | 81 | 312.1 ± 136.6 | 0.211     |      |               |
| Case/day < 5574           | 120| 75.3 ± 57.4  | 10.189    | 0.521| 2594.1        |
| Case/day ≥ 5574           | 94 | 290.3 ± 140.9 | 2.185     |      |               |
| Percent positivity < 16.20 % | 133| 118.2 ± 122.9 | 0.899     | 0.200| 2703.8        |
| Percent positivity ≥ 16.20 % |81 | 254.5 ± 147.6 | 0.919     |      |               |
| **Omicron Outbreak Period** |    |           |           |      |               |
| Recovery rate ≥ 96.31 %   | 59 | 31.4 ± 38.9  | 0.903     | 0.152| 1744.9        |
| Recovery rate < 96.31 %   | 92 | 97.8 ± 93.7  | 1.913     |      |               |
| Case/day < 2111           | 66 | 38.2 ± 55.3  | 0.651     | 0.127| 1749.2        |
| Case/day ≥ 2111           | 85 | 98.1 ± 92.1  | 3.012     |      |               |
| Percent positivity < 15.94 % | 63 | 26.9 ± 27.2  | 0.411     |      |               |
| Percent positivity ≥ 15.94 % | 88 | 104.0 ± 94.7 | 5.304     |      |               |
| Backlog count’ = No       | 131| 56.5 ± 67.5  | –         | 0.223| 1731.7        |
| Backlog count’ = Yes      | 20 | 172.4 ± 107.6 | –         |      |               |

* Using the analysis platform, we conducted only one split over the dataset. We used decision tree method of the partition model to make a single pass through our dataset to produce a single portioned tree.
* COVID-19 related deaths per day were reported as mean ± SD values on the partitioned daily cases groups.
* LogWorth values reported after one split; node splitting is based on the LogWorth statistic; values gives an idea about further splitting on an arm will be done on which variable basis.
* AICs denote the corrected Akaike’s Information Criteria.
* Beta outbreak period was considered from the prior month when the Beta variant of SARS-CoV-2 was discovered by scientists in South Africa on December 18, 2020, to March 2021.
* Percent positivity denotes the percentage of people tested positive for SARS-CoV-2 on a given day.
* Delta outbreak period was considered from the prior month when the earliest documented sample with Delta variant of SARS-CoV-2 was identified in South Africa (May 08, 2021) to the prior month of the earliest documented sample with Omicron variant of SARS-CoV-2 reported in (November 2021).
* Omicron outbreak period was considered from the month when the earliest documented sample with Omicron variant was reported in South Africa (November 09, 2021) to the last reported date of this analysis (March 31, 2022).
* Since January 06, 2022, the Department of Health of the Republic of South Africa had been recorded and reported COVID-19 death backlog as an ongoing audit exercise across the country to address a backlog of COVID-19 mortality.
* Values are not available for this parameter.

almost iron-clad law: the pandemic will not come to an end while vaccine justice and equity are pushed to the margins [31].

Declaration of Competing Interest

The authors declare no conflict of interest.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jiph.2022.05.011.

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