The impact of climate temperature on counts, recovery, and death rates due to SARS-CoV-2 in South Africa.

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ABSTRACT
The impact of climate temperature on the counts (number of positive COVID-19 cases reported), recovery, and death rates of COVID-19 cases in all of South Africa's 9 provinces was investigated. The data for confirmed cases of COVID-19 were collected for March 25 and June 30, 2020 (14 weeks) from South Africa's Government COVID-19 online resource, while the daily provincial climate temperatures were collected from the website of the South African Weather Service. Our result indicates that a higher or lower climate temperature does not prevent or delay the spread and death rates but shows significant positive impacts on the recovery rates of COVID-19 patients. Thus, it indicates that the climate temperature is unlikely to impose a strict limit on the spread of COVID-19. There is no correlation between the cases and death rates, an indicator that no particular temperature range is closely associated with a faster or slower death rate of COVID-19 patients. As evidence from our study, a warm climate temperature can only increase the recovery rate of COVID-19 patients, ultimately impacting the death and active case rates and freeing up resources quicker to enable health facilities to deal with the climbing rates of those patients who need treatment.

Keywords: climate temperature, COVID-19, rates, SARS-CoV-2, South Africa.

Introduction
The roles of climate temperature on transmitting the novel Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV-2) and patients' recovery and death rates seemed to have generated significant worldwide debates. Several kinds of research indicated the spreads of other seasonal flu virus outbreaks by reporting a substantial number of cases with colder climate conditions similar to the spreads of SARS-CoV-2 [1, 2]. In contrast, others found an inverse or no correlation between climate temperature variations and the Coronavirus [3–5].

SARS-CoV-2, popularly called Coronavirus (COVID-19), envelopes positive-stranded RNA viruses with a characteristic surface [6, 7]. It has been reported that the infection of the virus in humans causes severe gastroenteritis and respiratory tract diseases [6, 8]. The persistence of these viruses was officially lost at around 56°C but somewhat differed depending on the infection [9]. In their study of SARS-CoV-2 aerosol and surface stability, Doremalen et al. [10] revealed that the virus could survive on hard surfaces for up to 72 hours at temperatures between 21°C and 23°C. Similarly, Zhou et al. [11] found the coronavirus to be most active between 9°C and 24°C, decreasing with higher temperatures. The fact that
the virus causing the SARS-CoV-2 is new still limits information about how it impacted by variations in climatic temperature conditions. Peng et al. [2] studied the impacts of temperature and absolute humidity on COVID-19 in 31 provincial regions of mainland China. They observed a decline in the transmission rate of the COVID-19 as temperature increases. A recent study examining the impact of temperature variation and humidity on COVID-19 mortality in Wuhan China found that mortality rates were lower for days with higher temperatures and humidity. The study also indicates high death rates on days with a broader maximum and minimum temperature range [12].

Therefore, this study aims to investigate the impact of climate temperature variation on the counts, recovery, and death rates of COVID-19 cases in all South Africa’s provinces. The findings were compared with those of countries with comparable climate temperature values.

Results and Discussion

The average climate temperature within the study period for Eastern Cape Province ranges from 10.2 to 29.6 °C with 0.0295 (2.95 %) death-to-count ratio and 0.0207 (2.07 %) recovery-to-count ratio for the lockdown periods and average climate temperature of 6.8 to 29.4 °C with 0.0204 (2.04 %) death-to-count ratio and 0.0683 (6.83 %) recovery-to-count ratio for the eased-lockdown periods, respectively. The average climate temperature within the study period for Northern Cape Province ranges from 9.2 to 33.8 °C with 0.1000 (10 %) death-to-count ratio and 1.400 (140 %) recovery-to-count ratio for the lockdown periods and average climate temperature of 1.7 to 28.3 °C with 0.0000 (0 %) death-to-count ratio and 0.5732 (57.32 %) recovery-to-count ratio for the eased-lockdown periods, respectively. The average climate temperature within the study period for Limpopo Province ranges from 10.8 to 29.8 °C with 0.1833 (18.33 %) death-to-count ratio and 1.1667 (116.67 %) recovery-to-count ratio for the lockdown periods and average climate temperature of 4.4 to 25.2 °C with 0.0095 (0.95 %) death-to-count ratio and 0.4794 (47.94 %) recovery-to-count ratio for the eased-lockdown periods, respectively. The average climate temperature within the study period for Northwest Province ranges from 9.4 to 30 °C with 0.000 (0 %) death-to-count ratio and 0.8412 (84.12 %) recovery-to-count ratio for the lockdown periods and average climate temperature of 0.5 to 25.1 °C with 0.0073 (0.73 %) death-to-count ratio and 0.1889 (18.89 %) recovery-to-count ratio for the eased-lockdown periods, respectively. The average climate temperature within the study period for Mpumalanga Province ranges from 10.4 to 30 °C with 0.000 (0

Fig 1: Map of South Africa showing the provinces [13].
(a) Eastern Cape

Table 1 (a – i): COVID-19 counts, death, recovery rates along with the death-to-count, recovery-to-count ratios, and average weekly climate temperature.

| Date       | Counts | Death | Recovery | D/C  | R/C  | Temp. (°C) |
|------------|--------|-------|----------|------|------|------------|
| WK 1       | March 25-31 | 12    | 0        | 0    | 0.0000 | 0.0000 | 12 – 30   |
| WK 2       | April 1-7    | 20    | 0        | 0    | 0.0000 | 0.0000 | 12 – 36   |
| WK 3       | April 8-14   | 161   | 5        | 12   | 0.0292 | 0.0702 | 9 – 34    |
| WK 4       | April 15-21  | 171   | 3        | 0    | 0.0000 | 0.0186 | 8 – 25    |
| WK 5       | April 22-28  | 271   | 32       | 4    | 0.1181 | 0.0148 | 8 – 23    |
| Total      | March 25-31  | 635   | 37       | 19   | 0.0295 | 0.0207 | 10.2 – 29.6 |
| Average    | 127        | 7.4   | 3.8      | 6.8  | 0.0204 | 0.6083 | 6.8 – 29.4 |

(b) Northern Cape
| Date       | Counts (C) | Death (D) | Recovery (R) | D/C      | R/C      | Temp. (°C) |
|------------|------------|-----------|--------------|----------|----------|------------|
| WK 1       | March 25-31| 9         | 0            | 0.0000   | 0.0000   | 11 – 37    |
| WK 2       | April 1-7 | 2         | 0            | 0.0000   | 0.0000   | 10 – 33    |
| WK 3       | April 8-14| 8         | 0            | 0.0000   | 0.0000   | 9 – 33     |
| WK 4       | April 15-21| 2        | 1            | 6.0000   | 3.0000   | 8 – 35     |
| WK 5       | April 22-28| 1        | 0            | 0.0000   | 4.0000   | 8 – 31     |
| **Total**  | 22         | 1         | 10           |          |          |            |
| **Average**| 4.4        | 0.2       | 2            | 0.1000   | 1.4000   | 9.2 – 33.8 |
| WK 6       | April 29-30/May, 1-5 | 9      | 0            | 3.0000   | 0.0000   | 10 – 30    |
| WK 7       | May 6-12  | 4         | 0            | 3.0000   | 0.7500   | 7 – 30     |
| WK 8       | May 13-19 | 7         | 0            | 14.0000  | 2.0000   | 4 – 31     |
| WK 9       | June 20-26, May | 9      | 0            | 2.0000   | 0.0000   | 3 – 29     |
| WK 10      | May 27-31/June, 1-2 | 46     | 0            | 4.0000   | 0.0870   | 1 – 30     |
| WK 11      | June 3-9 | 29        | 0            | 8.0000   | 0.2759   | 0 – 32     |
| WK 12      | June 10-16| 85        | 0            | 8.0000   | 0.0941   | 8 – 24     |
| WK 13      | June 17-23| 59        | 0            | 60.0000  | 1.0169   | 3 – 25     |
| WK 14      | June 24-30| 195       | 0            | 74.0000  | 0.3795   | 0 – 24     |
| **Total**  | 32         | 3         | 25           |          |          |            |
| **Average**| 6.4        | 0.6       | 5            | 0.1833   | 1.1667   | 9.8 – 29.8 |

### (c) Limpopo

| Date       | Counts (C) | Death (D) | Recovery (R) | D/C      | R/C      | Temp. (°C) |
|------------|------------|-----------|--------------|----------|----------|------------|
| WK 1       | March 25-31| 14        | 0            | 0.0000   | 0.0000   | 14 – 32    |
| WK 2       | April 1-7 | 5         | 0            | 0.0000   | 0.0000   | 12 – 31    |
| WK 3       | April 8-14| 6         | 0            | 13.0000  | 2.1667   | 10 – 31    |
| WK 4       | April 15-21| 3        | 2            | 8.0000   | 2.6667   | 9 – 28     |
| WK 5       | April 22-28| 4        | 1            | 4.0000   | 1.0000   | 9 – 27     |
| **Total**  | 32         | 3         | 25           |          |          |            |
| **Average**| 6.4        | 0.6       | 5            | 0.1833   | 1.1667   | 9.8 – 29.8 |

### (d) North West

| Date       | Counts (C) | Death (D) | Recovery (R) | D/C      | R/C      | Temp. (°C) |
|------------|------------|-----------|--------------|----------|----------|------------|
| WK 1       | March 25-31| 8         | 0            | 0.0000   | 0.0000   | 12 – 32    |
| WK 2       | April 1-7 | 3         | 0            | 0.0000   | 0.0000   | 9 – 29     |
| WK 3       | April 8-14| 11        | 0            | 3.0000   | 0.2727   | 8 – 32     |
| WK 4       | April 15-21| 3        | 0            | 10.0000  | 3.3333   | 8 – 29     |
| WK 5       | April 22-28| 5        | 0            | 3.0000   | 0.6000   | 10 – 28    |
### Mpumalanga

| Date             | Counts (C) | Death (D) | Recovery (R) | D/C   | R/C   | Temp. (°C) |
|------------------|------------|-----------|--------------|-------|-------|------------|
| WK 1 March 25-31 | 12         | 0         | 0            | 0.0000| 0.0000| 13 – 35    |
| WK 2 April 1-7   | 6          | 0         | 0            | 0.0000| 0.0000| 0 – 33     |
| WK 3 April 8-14  | 5          | 0         | 6            | 0.0000| 1.2000| 14 – 32    |
| WK 4 April 15-21 | 4          | 0         | 8            | 0.0000| 2.0000| 12 – 24    |
| WK 5 April 22-28 | 4          | 0         | 4            | 0.0000| 1.0000| 13 – 26    |
| Total            | 31         | 0         | 18           | 3.6   | 0.0000| 10.4 – 30  |
| Average          | 6.2        | 0.78      | 50           | 0.0033| 0.5681| 7.1 – 25.9 |

### Free State

| Date             | Counts (C) | Death (D) | Recovery (R) | D/C   | R/C   | Temp. (°C) |
|------------------|------------|-----------|--------------|-------|-------|------------|
| WK 1 March 25-31 | 74         | 1         | 0            | 0.0135| 0.0000| 6 – 30     |
| WK 2 April 1-7   | 15         | 0         | 0            | 0.0000| 0.0000| 5 – 27     |
| WK 3 April 8-14  | 10         | 3         | 61           | 0.3000| 6.1000| 2 – 28     |
| WK 4 April 15-21 | 9          | 2         | 13           | 0.2222| 1.4444| 4 – 29     |
| WK 5 April 22-28 | 7          | 0         | 18           | 0.0000| 2.5714| 7 – 28     |
| Total            | 115        | 6         | 92           | 18.4  | 0.1071| 4.8 – 28.4|
| Average          | 23         | 1.2       | 18.4         | 0.1071| 2.0232| 4.8 – 28.4 |
## KwaZulu-Natal

| Date           | Counts (C) | Death (D) | Recovery (R) | D/C     | R/C     | Temp. (°C) |
|----------------|------------|-----------|--------------|---------|---------|------------|
| WK 1 March 25-31 | 179        | 2         | 0            | 0.0112  | 0.0000  | 16 – 31    |
| WK 2 April 1-7  | 78         | 6         | 0            | 0.0769  | 0.0000  | 15 – 29    |
| WK 3 April 8-14 | 232        | 4         | 15           | 0.0172  | 0.0647  | 16 – 33    |
| WK 4 April 15-21 | 182       | 11        | 136          | 0.0604  | 0.7473  | 15 – 28    |
| WK 5 April 22-28 | 248       | 7         | 213          | 0.0282  | 0.8589  | 16 – 27    |
| Total           | 919        | 30        | 364          | 0.0388  | 0.3342  | 15.6 – 29.6 |
| Average         | 184        | 6         | 72.8         | 0.0146  | 0.2933  | 7.6 – 25   |

## Western Cape

| Date           | Counts (C) | Death (D) | Recovery (R) | D/C     | R/C     | Temp. (°C) |
|----------------|------------|-----------|--------------|---------|---------|------------|
| WK 1 March 25-31 | 325        | 1         | 0            | 0.0031  | 0.0000  | 8 – 24     |
| WK 2 April 1-7  | 137        | 2         | 0            | 0.0146  | 0.0000  | 9 – 30     |
| WK 3 April 8-14 | 181        | 5         | 152          | 0.0276  | 0.8398  | 4 – 30     |
| WK 4 April 15-21 | 367       | 9         | 64           | 0.0245  | 0.1744  | 7 – 32     |
| WK 5 April 22-28 | 860       | 21        | 389          | 0.0244  | 0.4523  | 10 – 27    |
| Total           | 1870       | 38        | 605          | 0.0188  | 0.2933  | 7.6 – 28.6 |
| Average         | 374        | 7.6       | 121          | 0.0190  | 0.1311  | 8 – 27     |
### Gauteng

|       | Date              | Counts (C) | Death (D) | Recovery (R) | D/C   | R/C    | Temp. (°C) |
|-------|-------------------|------------|-----------|--------------|-------|--------|------------|
| WK 1  | March 25-31       | 633        | 1         | 0            | 0.0016| 0.0000 | 11 – 27    |
| WK 2  | April 1-7         | 80         | 0         | 0            | 0.0000| 0.0000 | 9 – 24     |
| WK 3  | April 8-14        | 196        | 3         | 157          | 0.0153| 0.8010 | 8 – 25     |
| WK 4  | April 15-21       | 290        | 3         | 388          | 0.0103| 1.3379 | 7 – 24     |
| WK 5  | April 22-28       | 178        | 1         | 352          | 0.0056| 1.9775 | 9 – 23     |
|       | **Total**         | **1377**   | **8**     | **897**      | **0.0066**| **0.8233**| **8.8 – 24.6**|
|       | **Average**       | **275.4**  | **1.6**   | **179.4**    | **0.0066**| **0.8233**| **8.8 – 24.6**|
| WK 6  | April 29-30/May, 1-5 | 320      | 7         | 82           | 0.0219| 0.2563 | 7 – 23     |
| WK 7  | May 6-12          | 317        | 7         | 268          | 0.0221| 0.8454 | 5 – 22     |
| WK 8  | May 13-19         | 347        | 5         | 420          | 0.0144| 1.2104 | 4 – 21     |
| WK 9  | 20-26, May        | 682        | 4         | 293          | 0.0059| 0.4296 | 1 – 21     |
| WK 10 | May 27-31/June, 1-2 | 1233    | 2         | 141          | 0.0016| 0.1144 | 0 – 23     |
| WK 11 | June 3-9          | 2270       | 24        | 515          | 0.0106| 0.2269 | 3 – 23     |
| WK 12 | June 10-16        | 6477       | 30        | 826          | 0.0046| 0.1275 | -4 – 17    |
| WK 13 | June 17-23        | 11018      | 35        | 2178         | 0.0032| 0.1977 | -2 – 17    |
| WK 14 | June 24-30        | 18840      | 94        | 4914         | 0.0050| 0.2608 | 0 – 18     |
|       | **Total**         | **41504**  | **208**   | **9637**     | **0.0099**| **0.4077**| **1.6 – 20.6**|
|       | **Average**       | **4611.6** | **23.1**  | **1071**     | **0.0099**| **0.4077**| **1.6 – 20.6**|

As shown from the results in Table 1 (a – i), higher or lower climate temperatures cannot be reported to prevent or delay the transmissions and death rates of patients of COVID-19. Nonetheless, it can be concluded that a higher temperature of the climate raises recovery rates for COVID-19 patients. Figure 2 shows the average minimum and maximum climate temperatures and the death-to-count ratio for the lockdown period. In contrast, Figure 3 shows the average minimum and maximum climate temperatures and the COVID-19 recovery-to-count ratio for the lockdown period.

![Fig. 2: Average minimum and maximum climate temperatures and death-to-count (D/C) ratio for the lockdown period.](image-url)
Figure 3 shows the average minimum and maximum climate temperatures, as well as the death-to-count ratio for the eased-lockdown period. In contrast, Figure 4 shows the average minimum and maximum climate temperatures and the COVID-19 recovery-to-count ratio for the eased-lockdown period.

The results showed that higher climate temperatures aren’t essential to avoid the COVID-19 from being spread. The present results conform to the reports that suggested that COVID-19 is unlike the seasonal flu, which does dissipate as the climate temperature rises [14]. Accordingly, the ratio of counts and death-to-count cannot be concluded to be influenced by variations in the climate temperatures within the study areas.
Table 2: Comparison of COVID-19 counts, death, recovery rates, and death-to-count, recovery-to-count ratios from the study provinces with values from other countries (as of June 30, 2020).

| Country              | Count (C) | Death (D) | Recovery (R) | D/C  | R/C  | References              |
|----------------------|-----------|-----------|--------------|------|------|-------------------------|
| Eastern Cape         | 27,686    | 422       | 14,081       | 0.0152 | 0.5086 | Present Study (South Africa) |
| Northern Cape        | 465       | 1         | 186          | 0.0022 | 0.4000 |                          |
| Limpopo              | 1,131     | 10        | 520          | 0.0088 | 0.4598 |                          |
| North West           | 4,187     | 7         | 651          | 0.0017 | 0.1555 |                          |
| Mpumalanga           | 1,190     | 7         | 464          | 0.0059 | 0.3899 |                          |
| Free State           | 1,514     | 9         | 385          | 0.0059 | 0.2543 |                          |
| KwaZulu-Natal        | 9,674     | 126       | 3,602        | 0.0130 | 0.3723 |                          |
| Western Cape         | 62,481    | 1,859     | 43,120       | 0.0298 | 0.6901 |                          |
| Gauteng              | 42,881    | 216       | 10,534       | 0.0050 | 0.2457 |                          |
| Total                |           |           |              | 0.0212 | 0.5510 |                          |
| Australia*           | 7,834     | 104       | 7,037        | 0.0133 | 0.8983 | [15]                    |
| USA*                 | 2,618,480 | 126,645   | 705,203      | 0.0484 | 0.2693 | [16]                    |
| Argentina*           | 64,517    | 1,307     | 22,015       | 0.0203 | 0.3412 | [17]                    |
| Russia**             | 647,849   | 9,320     | 412,650      | 0.0144 | 0.6370 | [18]                    |
| Nigeria**            | 25,694    | 590       | 9,746        | 0.0230 | 0.3793 | [19]                    |
| India**              | 566,840   | 16,893    | 334,822      | 0.0298 | 0.5907 | [20]                    |

*similar climate temperature as South Africa **higher climate temperature than South Africa.

The results show no significant difference in counts, death, and death-to-count rates for different climate temperatures compared with values from other countries with similar and higher climate temperatures, just like South Africa’s. Higher recovery rates for countries with higher climate temperatures (Table 2) have also been reported. This study concludes that the virus can be spread at every climate temperature, with no significant difference in the count and death rates. However, higher recovery rates were recorded for countries with higher climate temperatures than South Africa, which coincides with the results from provinces with higher climate temperatures from the study areas having higher recovery rates of patients infected with COVID-19.

Conclusion

The study investigates the impact of climate temperature on the counts, recovery, and death rates of COVID-19 cases in all South Africa’s provinces. The findings were compared with those of countries with comparable climate temperatures as South Africa. Our result indicates that a higher or lower climate temperature does not prevent or delay the spread and death rates but shows significant positive impacts on the recovery rates of COVID-19 patients. Warm climate temperatures seem not to restrict the spread of the COVID-19 as the count rate was substantial at every climate temperatures. It thus indicates that the climate temperature is unlikely to impose a strict limit on the spread of COVID-19. There is no correlation between the cases and death rates, an indicator that there is no particular temperature range of the climatic conditions that are closely associated with a faster or slower death rate of COVID-19 patients. As evidence from our study, a warm climate temperature can only help COVID-19 patients recover more quickly, thereby having huge impacts on the death and active case rates.

Methods
The data for confirmed cases of COVID-19 were collected for March 25 and June 30 (14 weeks) for South African provinces, including daily counts, death, and recovery rates. The dates were grouped into two, wherein weeks 1-5 represents the period of total lockdown to contain the spread of COVID-19 in South Africa. Weeks 6-14 are periods where the lockdown was eased to various levels 4 and 3. The daily information of COVID-19 count, death, and recovery was obtained from South Africa's Government COVID-19 online resource (https://sacoronavirus.co.za). Daily provincial climate temperatures were collected from the website of the South African Weather Service (https://www.weathersa.co.za). The provinces of South Africa are Eastern Cape, Western Cape, Northern Cape, Limpopo, Northwest, Mpumalanga, Free State, KwaZulu-Natal, Western Cape, and Gauteng. Weekly consideration was given to the daily climate temperature (average minimum and maximum). The recorded values were considered, respectively, to be in the ratio of death-to-count (D/C) and recovery-to-count (R/C).

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Author contributions statement
NC conceived the study, and then he supervised and guided the process of the research. BA and AOI performed the data collection/analysis, designed the layouts, and wrote the manuscript. All authors reviewed the manuscript.

Competing Interests
The authors declare no competing interests.