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Detection of Change Patterns in COVID-19 Deaths and the Implementation of Public Health Policies in Botswana

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ABSTRACT

Background: At the earlier stages of COVID-19 disease, there were no pharmaceutical measures such as vaccines and medications available that could be used to either treat or reduce the spread of the virus. Countries worldwide reverted to implementing several non-pharmaceutical measures to end or at least reduce the spread of the COVID-19 pandemic. These included maintaining the physical distance of 1-2 meters in all gatherings, washing hands with soap and clean water, sanitizing hands, and wearing face masks especially when physical distancing cannot be certain. In this study, we aim to determine the change patterns or turning points in COVID-19 deaths, particularly those that occurred in Botswana.

Subjects and Method: The study used a retrospective cohort study conducted in Botswana for a period ranging from the 14th May 2020 up to the 3rd March 2022. The population covered for this study comprised of all persons who were susceptible to COVID-19 in Botswana. The researcher used secondary data sourced from Botswana's Ministry of Health and Wellness. Data for this study were statistically analysed using R software version 4.1.3 to apply the simulation methods.

Results: High numbers of COVID-19 deaths in Botswana were recorded starting from week 59 to week 69 and the numbers declined from week 70 to week 75. Altogether, COVID-19 deaths in Botswana have been rising since 14th May 2020 until 3rd March 2022.

Conclusion: It is important for the Government of Botswana through Ministry of Health and Wellness to ensure that COVID-19 restrictions are slowly relaxed to avoid the recurrence of the disease. COVID-19 adherence protocols should be strictly enforced by the Ministry more especially during winter seasons as well as public holidays.

Keywords: COVID-19, measures, turning points, change patterns

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BACKGROUND

The Coronavirus disease-2019 is shortened to COVID-19 and it is caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SAR-CoV-2). It is the respiratory illness that caused the COVID-19 pandemic (Ramphul and Mejias, 2020; Zhu et al., 2020; Rehman et al., 2021). The virus was first discovered in 2019 in the City of Wuhan, China and reported to World Health Organization (WHO) on the 31st December 2019 (Corman et al., 2020; Li et al., 2020;

Torales et al., 2020). Since the outbreak of COVID-19 in China, the virus affected all the continents leaving behind overwhelming social and economic impacts (Gondwe, 2020).

Studies by (Douglas et al., 2020; Kontis et al., 2020) found that the posterior probability that the observed change in deaths reflects an increase or decrease in deaths as compared to what would have been expected if COVID-19 pandemic had not occurred. Moreover, the authors indicated that the posterior probability reflects an inherent uncertainty in how many COVID-19 deaths would have occurred in the absence of the COVID-19 pandemic.

Just like other Sub-Saharan African (SSA) governments, Botswana quickly enforced some non-pharmaceutical COVID-19 measures to control the spread of the virus and mitigate the impact of the disease on the population (Reuben et al., 2021; Siamisang, Kebadiretse and Masupe, 2021). After the first confirmed case on 30th March 2020, the Government of Botswana took a step to declare a state of emergency and afterwards imposed the first lockdown which lasted 28 days.

The lockdown and state of emergency led to further restrictions on movement, which included localized lockdowns (Bedford et al., 2020), closing of schools, COVID-19 awareness campaign, debunking myths surrounding COVID-19, cancelling flight travels, restrictions on gathering, washing hands as well as good hygiene promotion (Amon, 2020; Freckelton QC, 2020).

Across SSA, different governments came up with an idea to form presidential task forces for public health and millions of money directed towards the pandemic was pledged (Osseni, 2020). A study by (Bolaane et al., 2022) states that the estimates of deaths in Botswana in the next 28 days may be inaccurate because of working assumptions for mortality, particularly in individuals who do not receive suitable treatment.

COVID-19 was a public health concern and deaths have a devastating impact on the entire globe (Gondwe, 2020). A study by (Porcheddu et al., 2020) states that shortage of adequate medical facilities, inadequate education on preventative measure, cultural barriers, as well as political interference on how to fight COVID-19 are challenging factors that facilitate an increase in the number of COVID-19 deaths.

Authors emphasised that families lost their members to the pandemic and possibly leaving both children and elderly persons with no means of support (Yanez et al., 2020). The authors also noted that the cost of the pandemic caused havoc in different countries, where already fragile public health facilities were unable to absorb those who were critically affected by the COVID-19 pandemic. When COVID-19 took place, it was challenging to predict its development, especially in the long-run (Martínez, 2021). Therefore, to the best of the researchers' knowledge, no research work of this kind has been conducted in Botswana, hence the present study seeks to fill this gap. This study aims to determine the change patterns or turning points in COVID-19 deaths, particularly those that occurred in Botswana.

SUBJECTS AND METHOD

1. Study Design

This study made use of an observational research design, specifically a retrospective cohort study conducted in Botswana from 14th May 2020 to 3rd March 2022.

2. Population and Sample

The study comprised of all persons who were vulnerable to COVID-19 in Botswana. All those who got infected and later on succumbed to COVID-19, as well as those who recovered and were reported to WHO by Botswana regardless of any demographic

features. The sample size for this study was 2,397,270.

3. Study Variables

There were a total of four important variables for this study, namely susceptible, infected, recovered, and deaths.

4. Operational Definition of Variables

Susceptible: These are individuals who are not infected by COVID-19 but are at risk of being infected.

Infected: These individuals have COVID-19 infection.

Recovered: These are individuals who have been confirmed recovered after being infected with COVID-19.

Deaths: These are individuals who succumbed to COVID-19 infection.

5. Study Instrument

The secondary data for individuals who were susciptible, infected, recovered and those who succumbed to COVID-19 virus were taken from the WHO website.

6. Data Analysis

Data for this study were analyzed using charts, tables, including the simulation method where coefficients were estimated. R software version 4.1.3 was used mainly to generate the outputs.

7. Research Ethics

The authors retrieved the readily available COVID-19 statistics on the WHO website for Botswana. The authors were under any circumstances unable to know the identities of individuals who were infected, recovered, or succumbed to COVID-19 disease. This anonymous information helped protect the privacy of individuals who were affected by COVID-19.

RESULTS

1. Sample characteristics

Generally, there has been an increase in the number of deaths in Botswana from the 14th May 2020 to the 3rd March 2022 as depicted by a straight blue line as shown in Figure 1.

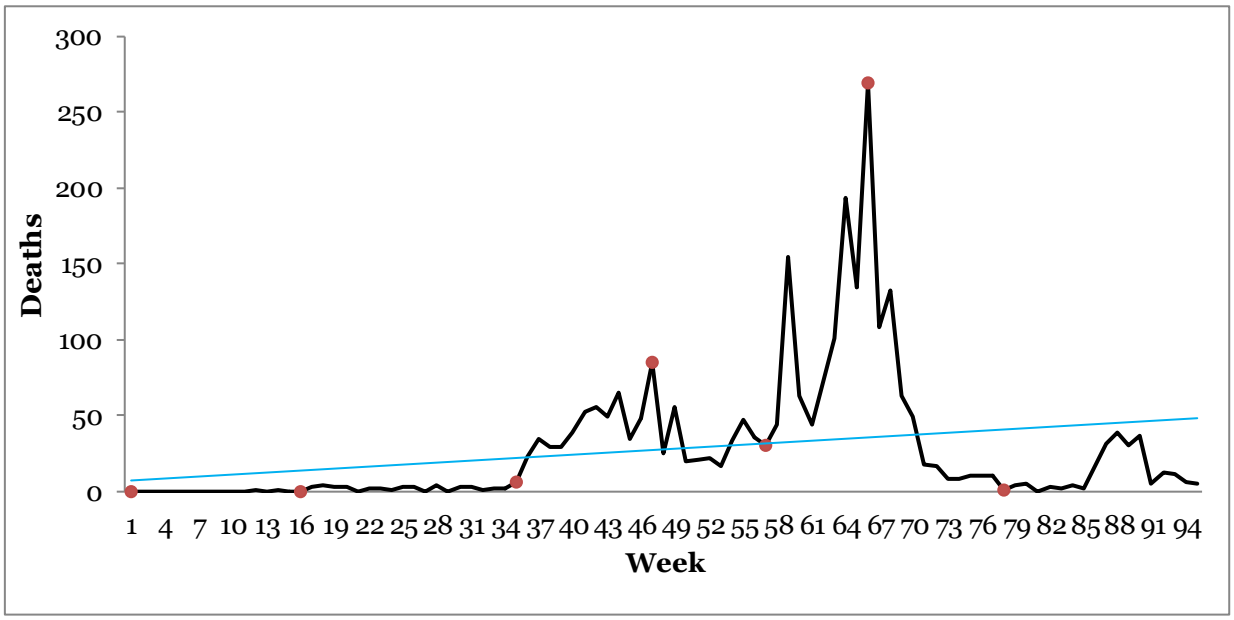

Figure 1. Weekly COVID-19 deaths in Botswana from 14th May 2020 to 3rd March 2022

A total of 259,664, 259,304, and 2,613 for patients who got infected, recovered, and succumbed to COVID-19 respectively from 14th May 2020 to 3rd March 2022 (Table 1).

The highest numbers recorded in a week for patients who got infected, recovered, and succumbed to COVID-19 are 15,884, 15,186, and 269 respectively. On average 2762, 2759 and 28 patients got infected, recovered and succumbed to COVID-19 respectively.

Table 1. COVID-19 descriptive statistics for 14th May 2020 to 3rd March 2022 data

Persons	Lowest	Highest	Sum	Mean
Susceptible	2,366,774	2,397,240	224,818,979	2,391,691
Infected	0	15,884	259,664	2,762
Recovered	0	15,186	259,304	2,759
Deaths	0	269	2,613	28

Figure 2 depicts actual numbers of the COVID-19 infected, recoveries, and deaths which occurred in Botswana for a period 14th May 2020 to 3rd March 2022. The deaths remained constant from the first week up to the 11th week. There was a slight increase from week 12 to week 34 and the number of deaths further increased from week 36 to week 48. A high number of deaths were recorded from week 59 to week 69 and the numbers decreased from week 70 to week 75. It is clear that a pattern displayed on deaths, approximately similar patterns were depicted on both infected persons and those who recovered.

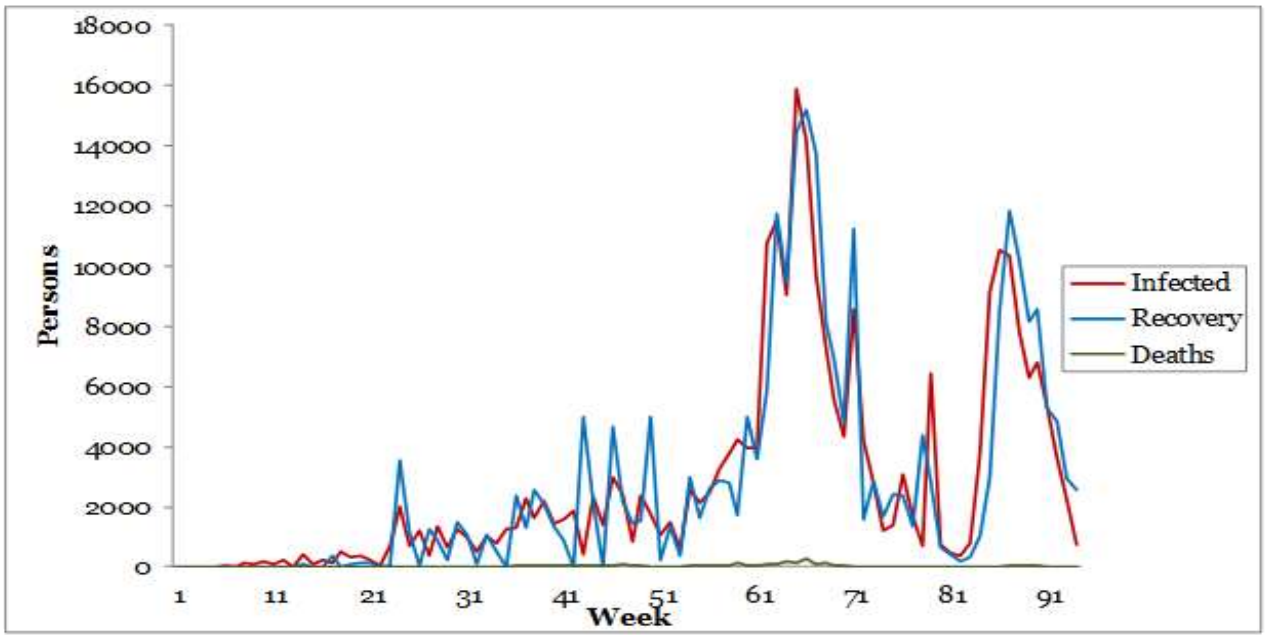

Figure 2. COVID-19 infected, recoveries and deaths from 14th May 2020 to 3rd March 2022

2. Inferential Analysis

a. Detection of change points

Now that the assumption of normality must be satisfied, the recorded numbers of deaths were transformed to a normally distributed number of deaths. The probability distribution of COVID-19 deaths is assumed to follow a Poisson distribution while the transformed numbers of deaths are approximately normal (Figure 3).

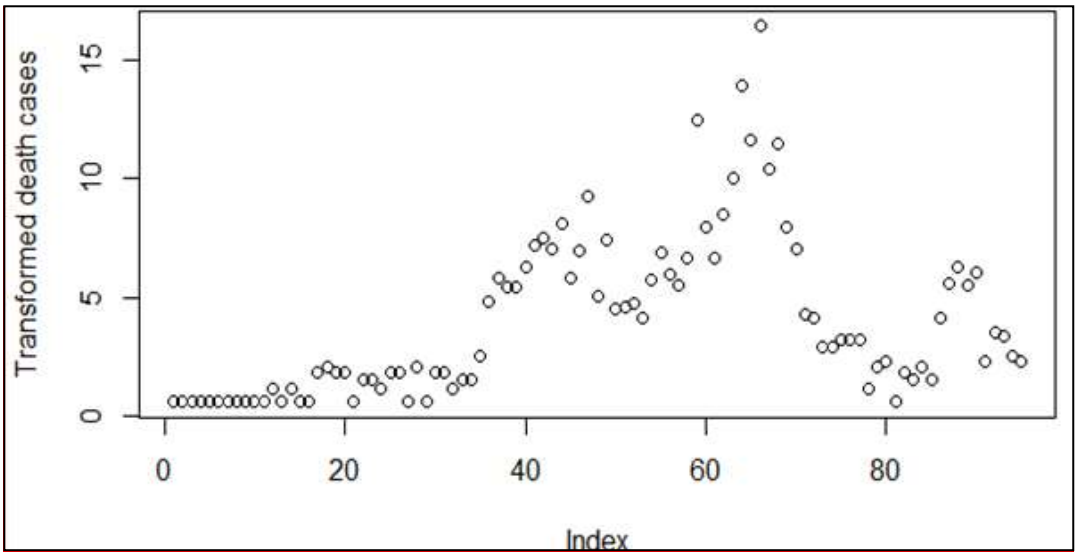

Figure 3. Transformed number of deaths from 14th May 2020 to 3rd March 2022

Kolmogorov–Smirnov (K-S) test was performed mainly to check and validate if the normality assumption was met for each change point in the death cases. The results are determined by the report of the normality p-values as shown in Table 2. Since the normality p-value is the p-value for the K-S normality test for the segment, the normality assumption is rejected if K-S p-value is less than 0.05/12 (if K-S p< 0.0417). According to the results, the normality test p-value shows that ten (10) out of the twelve (12) segments can be observed as normally distributed because they have large p-values.

A total of two are not normal as viewed having corresponding normality p-values which are less than the corrected p-value of the K-S normality test. This because there are more change points in the first and second segment with posterior probability values lower than the threshold of 0.7. The other reason is that the segments could be too short or that the segment of data could be too noisy to pass the normality test.

Table 2. Kolmogorov–Smirnov normality test results

Changepoint	Begind	End	Normality p-value
[1,]	1	5	<0.001
[2,]	6	9	0.000
[3,]	10	15	0.272
[4,]	16	21	0.373
[5,]	22	28	0.846
[6,]	29	35	0.961
[7,]	36	58	0.881
[8,]	59	70	0.942
[9,]	71	77	0.370
[10,]	78	81	0.901
[11,]	82	85	0.896
[12,]	86	94	0.801

The results in Table 3 show a total of eleven (11) change points or breakpoints, which are detected corresponding to their locations. It is clear that the eleven (11) change points cut the transformed data into 12 different seg-

ments and all the segments can be considered to be from normal distributions.

Table 3. Change points and locations of deaths

Change point	Location
[1,]	5
[2,]	9
[3,]	15
[4,]	21
[5,]	28
[6,]	35
[7,]	58
[8,]	70
[9,]	77
[10,]	81
[11,]	85

Figure 4 depicts the transformed death cases indicating where the change points are detected in the data. The results show the plot with a total of twelve (12) segments indicated by the red horizontal lines. The plot indicates that the probability of both the first and the second change point were the lowest, whereas the probability of the eighth change point had a sharp peak close to 16.

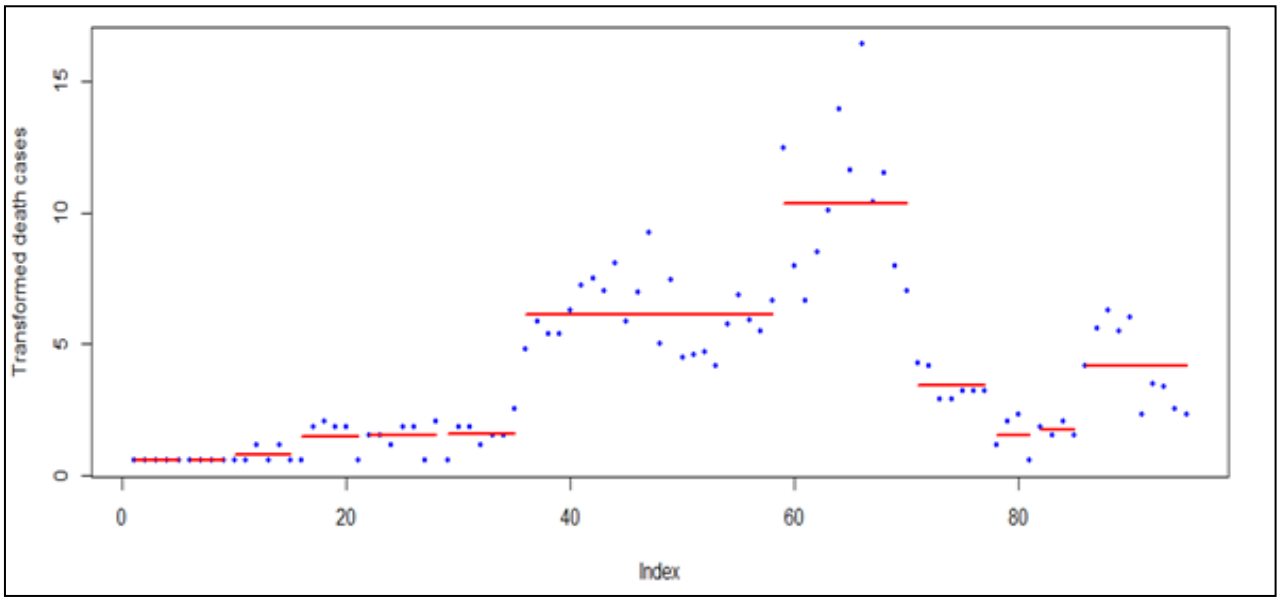

Figure 4. Detected change points of weekly deaths in Botswana from 14th May 2020 to 3rd March 2022

b. Change point 1 and 2

Just after the 11th March 2020, when WHO declared that COVID-19 is a pandemic, Botswana acted quickly by closing its borders on the 24th March 2020 so as to stop the spread of COVID-19. By 20th March 2020, gatherings of more than 10 people were not allowed in one place, either for religious, schools, social functions, or sporting events. Soon after closing the borders, Botswana further declared a state of emergency on the 30th March 2020. The first confirmed case was reported on the same date.

On 2nd April 2020, the Government of Botswana imposed a lockdown period of 28 days in the entire country and 6 months State of Public Emergency was also imposed. The decision was taken mainly to ensure extreme social distancing. Only essential movements were allowed during lockdown and State of Public Emergency. This period was important as it allowed the government to prepare sufficient quarantine and isolation services that could be used in case of an increase in COVID-19 cases.

WHO procured test kits and reagents, and these allowed the Government to decentralise the testing capacity throughout the country. The efforts also enabled the Government to reduce test processing times. The National Health Laboratory opened satellite testing centres in certain districts with large population size as well as in key ports of entry. Other important supplies like personal protective equipment and thermosmeters were acquired by WHO. Still on the same change point, by 4th May 2020 Botswana had recorded the lowest confirmed cases among other neighboring countries which stood at 23, 8 recoveries and only 1 death.

c. Change point 3

The change points 3 covered most of the winter season, specifically the month of June 2020, July 2020, as well as August 2020, during which the temperatures are low. In that case, the temperatures were conducive for COVID-19 to establish and that caused a surge in the numbers of confirmed cases.

d. Change point 4, 5, and 6

The change points 4, 5, and 6 covered week 16 up to week 35. During this period, the capacity of the health-care system in Botswana quickly reached its limit in terms of a shortage of space, a limited number of breathing aids like ventilators. As time went on, the Government decided that those who are confirmed cases can quarantine and isolate themselves in their homes. This led to a surge in the number of COVID-19 cases, especially since it was just after the winter season.

e. Change point 7

A lengthy period is shown at change point 7 starting from week 36 up to week 58, and this was January 2021 to June 2021. The numbers of COVID-19 infected, recovery, and death cases drastically increased. The start of the change point 7 occurred immediately after a long festive season where most of the people travelled from highly affected places. This had a negative effect as the number increased from January 2021.

f. Change point 8

For the change point 8, week 59 up to week 70 covered the months of June 2021 until September 2021. High numbers of COVID-19 infected, recovery, and death cases were recorded as compared to other change points. At this change point, the Government had declared another State of Public Emergency as an extension. Additionally, the Government of Botswana had directed that the curfew hours of 8 pm to 4 am be imposed to avoid illegal social gatherings. Just like change point 3, change point 8 also covered part of the winter season.

The low temperature caused COVID-19 surge of COVID-19 cases, especially among COVID-19 patients quarantined and isolated at their respective homes. This was because the health facilities in the whole country were limited. The strategy of the Government of Botswana was to prevent the spread of COVID-19 through quality clinical care for those who are infected, contact tracing and testing, movement restrictions, gathering prohibitions, hand-washing, good hygiene promotion, and generalized and partial lockdown. Despite all these measures, COVID-19 cases increased.

g. Change point 9

The number of COVID-19 cases seemed to have gone down at change point 9. This could be because the Government through the Ministry of Health and Wellness continued emphasizing and encouraging people to follow COVID-19 protocols. An extension of State of Public Emergency for another 6 months was still on during this period. This was also a period where COVID-19 vaccines purchased by the Government started arriving in large numbers and people got their shots in large numbers.

h. Change point 10 and 11

A large number of people received their vaccination against COVID-19 in the country, covering week 78 to week 85 for change points 10 and 11. The Government of Botswana then decided to roll out the vaccination programme to those who are 18 years old. This implied that the majority of those in the age category of 18 are in both public and private schools. Those with an age category of 30 years old and above had already been vaccinated against COVID-19.

i. Change point 12

The last change point as shown in the figure above is the 12th change point. Even though the numbers of those who were infected, recovered, and dead had gone down, there was an upward shift from change point 11. It was the beginning of the festive season and many people travelled for holidays. The Government of Botswana decided that the State of Public Emergency should come to an end. Religious gatherings, social gatherings, music festivals were fully opened and this was a possibility that issues related to COVID-19 protocols were not adhered to.

The results for the estimated posterior change point probabilities shown in Table 4 which gives a list of eleven (11) identified change points as well as their locations. Moreover, maximum posterior probability values corresponding to their locations are shown. These results were obtained under the threshold value of 0.7, 1.1 and 1.2 for theta, alpha and beta respectively for the posterior probabilities. The eleven (11) change points traced at positions 5, 9, 15, 21, 28, 35, 58, 70, 77, 81, and 85 categorize the actual arrangement of data into twelve (12) segments. The results for eleven (11) change points detected within the data indicate that the posterior probability of a change was at least 0.51 for the 2nd, 4th, 6th, 7th, 8th, and 10th respectively. The 1st, 3rd, 5th, 9th, and 11th had probabilities which are slightly lower than other change points

Table 4. Number of locations with their posterior probabilities

Changepoint	Location	Posterior probabilities
[1,]	5	0.314
[2,]	9	0.660
[3,]	15	0.330
[4,]	21	0.649
[5,]	28	0.338
[6,]	35	0.603
[7,]	58	0.512
[8,]	70	0.543
[9,]	77	0.426
[10,]	81	0.534
[11,]	85	0.399

Table 5 the total number of segments of the data and it provides the beginning and the end position of a specific segment. The mean and the standard deviation correspond to their respective segments. Moreover, LL of CI and UL of CI correspondingly the lower

and upper limits of the 95% confidence interval for the unknown mean of a particular segment.

Table 5. Means, standard deviations, and confidence intervals for segments

Changepoint	Begin	End	Mean	SD	CI95%	
					Lower Limit	Upper Limit
[1,]	1	5	0.61	0.00	0.61	0.61
[2,]	6	9	0.61	0.00	0.61	0.61
[3,]	10	15	0.80	0.29	0.60	0.99
[4,]	16	21	1.47	0.67	1.02	1.92
[5,]	22	28	1.52	0.50	1.21	1.83
[6,]	29	35	1.58	0.60	1.21	1.95
[7,]	36	58	6.13	1.28	5.69	6.57
[8,]	59	70	10.38	2.96	8.97	11.79
[9,]	71	77	3.42	0.57	3.06	3.77
[10,]	78	81	1.55	0.80	0.89	2.20
[11,]	82	85	1.75	0.23	1.53	1.97
[12,]	86	94	4.16	1.58	3.34	4.98

DISCUSSION

In a study conducted by (Shang and Xu, 2022) in Belgium, their findings showed that the change points were detected in 2020, and those change points were in week 13 as well as in week 18. In addition, this study revealed that week 12 was the end of the pre-COVID-19 period. Thus, starting from week 13 the surge of weekly rates revealed that there was an outbreak of COVID-19 among the Belgium population. In comparison to the findings of this study, it is clear that the numbers of COVID-19 infection, recovery, and death cases drastically increased from week 36 to week 70 (Dehning et al., 2020; Kilai et al., 2022; Xu et al., 2022). Thereafter, infection, recovery, and death rates dropped every week. Botswana's healthcare system struggled during COVID-19 because of staff, limited infrastructure, and healthcare resources. Healthcare facilities were overwhelmed and the country relied on both regional and international support. The government experienced a shortage of Intensive Care Unit (ICU) beds and ventilators.

As per the change points 1 and 2, soon after a few weeks when COVID-19 was detected in Botswana, the government imposed a lockdown period of 28 days and a 6-month State of Public Emergency. The Government of Botswana also opened the National Health Laboratory satellite testing centers in districts with large populations. COVID-19 interventions Botswana included the State of Public Emergencies, curfews and vaccination campaigns correlated positively with significant variations in COVID-19 cases. It was clear especially in the first weeks that strict measures such as State of Public Emergency and curfew reduced COVID-19 transmission rate. It is notable from the change points that as strict measures were relaxed by the government of Botswana, there was a significant increase in COVID-19 cases especially during winter season.

Almost similar interventions were imposed in Poland at week 37 (change point 264 days) where strict COVID-19 restrictions were announced by the Polish Prime Minister Mateusz Morawiecki who stated that a full lockdown of 1 to 10 weeks may be imposed. The Prime Minister further announced that most of the retail malls, museums, theaters, cinemas, and galleries would close. Bars and restaurants were closed then and older people were encour-

aged to remain at home because the daily cases were increasing (Jegede and Szajowski, 2022). The Botswana government's decision to implement the State of Public Emergency, curfew and other measures can therefore be considered effective because it helped curb the COVID-19 virus.

From week 36 to week 58, that is, January 2021 to June 2021, COVID-19 disease activity increased in Botswana as it was shown at change point 7. This was caused by a long festive season where most people traveled from highly affected places. Clearly, due to the State of Public Emergencies and curfews that were imposed by the government of Botswana, the number of infected individuals declined. The health achievement during COVID-19 in Botswana relied on the public adhering to the guidelines such as wearing mask, social distancing of 1-2 meters and washing hands regularly. Misinformation in terms of adherence to COVID-19, disbelief on the vaccine, and lack of education on the guidelines affected adherence, which ended up causing an increase in cases when restrictions were relaxed. In the same way, a study conducted by (Jegede and Szajowski, 2022) revealed that COVID-19 increased from week 42 (10th December 2020) and the Poland authorities took a step to strengthen COVID-19 restrictions beginning 28th December 2020 to 17th January 2021. The authors observed that the festive season led to a high contact rate within the population on New Year's Eve.

The findings showed that from week 59 to week 70, the months of June 2021 until September 2021, high numbers of COVID-19 were recorded at change point 8 as compared to other change points. During this period, the Government of Botswana declared a State of Public Emergency, curfew hours starting from 8 pm to 4 am were imposed, and other restriction measures such as washing hands regularly with soap and clean water, social distancing of 1-2 meters, and regular use of face masks. On the contrary, Poland recorded high numbers of COVID-19 on the 9th of March 2021. Still on the subject of COVID-19, (He et al., 2022; Jegede and Szajowski, 2022) found that high numbers were located at week 55, early March 2021, and Poland was experiencing a third wave of COVID-19. Moreover, the authors report that a total lockdown was declared in Poland during the same period. When Botswana increasingly rolled out the COVID-19 vaccine, both infected and recovered, and deaths began to decline significantly.

AUTHOR CONTRIBUTION

Abidile L collected and consolidated the data and methodology for the study. Nyakudya M N worked on the literature review and background. The authors jointly conducted the analysis, developed the study's findings, and finally proofread the report.

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CONFLICT OF INTEREST

Both authors declare that there is no conflict of interest concerning this study.

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