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COVID-19 Morbidity and Mortality in Saudi Arabia: A Year-wise Geographic Analysis

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Abstract:

Background: During the three years of the COVID-19 epidemic, the disease spread to 205 locations across Saudi Arabia's 13 administrative areas. There were serious repercussions of mortality and morbidity. However, since to the hard work of all the sectors and authorities involved, the pandemic was successfully managed..

Aims and Objectives: This analytical investigation of COVID-19 aims to pinpoint the locations affected over three years. It also investigates the morbidity and mortality burden of the epidemic and identifies locations (governorates) and administrative areas for the volume and severity of COVID-19 cases, year-wise.

Methods: Daily reports of COVID-19 cases published by the Saudi Arabian Ministry of Health from March 15, 2020, to April 30, 2023, were analyzed in this research. Annual counts, estimates of crude infection rates, and case fatality rates with monthly averages were calculated for the entire country, its administrative areas, and 205 affected locations.

Results: Despite a progressive trend, the impact of the second and third waves of COVID-19 on morbidity and mortality varied across administrative areas, governorates, and locations. Both major administrative areas of Riyadh, Makkah,Madina, and the Eastern Region, as well as smaller ones, such as Al-Baha, Jazan and Aseer, faced serious repercussions of morbidity. Additionally, mortality was notable in the smaller administrative areas, namely, Al-Jouf, Hail, Jazan, Aseer, Northern Borders, and Al-Baha. Beyond, certain locations within these administrative areas outside populous cities and administrative headquarters emerged as COVID-19 hotspots, particularly in terms of mortality.

Conclusion: The COVID-19-related morbidity and mortality rates in Saudi Arabia exhibited a discernible pattern across the administrative areas, governorates, and locations, with numbers and infection rates fluctuating every month, showing both increases and decreases. Although mortality rates were higher in the first year, significant control measures were implemented that led to a reduction in this rate later. The fatality rate displayed notable variations across administrative areas. This analysis holds significance for the development of epidemic control systems, the implementation of resistance measures at the grassroots level, and the establishment of surveillance systems. Furthermore, it contributes to a clearer understanding of the situation that will facilitate international comparisons and the formation of collaborative networks.

Keywords: Case fatality, Administrative areas, Infection rate, Locations, Overview, Collaborative Networks.

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1. INTRODUCTION

Saudi Arabia has a history of facing epidemics, where SARS-CoV and MERS-CoV originated in 2002 and 2012, respectively. The subsequent emergence of the new variant, SARS-CoV2 (COVID-19), had a profound impact globally, including in the Middle East [1]. The total number of confirmed COVID-19 cases and related deaths in Saudi Arabia varied from those in other countries such as Brazil, India, South Africa, Spain, and the USA [2]. Notably, Saudi Arabia earned acclaim for its early and proactive measures in combating the virus, leveraging its robust social healthcare system and prior experience in managing similar viruses [3, 4]. Infections, as well as mortality per population, were comparatively lower in Saudi Arabia than in other countries. Although a large number of cases with risks leading to death were found to be among males, their share was higher among older individuals, foreigners, and those who traveled abroad [5].

Efforts were made in Saudi Arabia to forecast morbidity and mortality, aiming to predict daily deaths and recoveries [2, 6]. The mathematical model adopted to forecast morbidity and mortality to predict daily deaths and recoveries depicted the impact of variation in the virus removal rate from the environment, which reduced disease prevalence faster through the simulation of sensitive parameters [2, 6, 7].

The fatality rate in Saudi Arabia, specifically the infection fatality rate, was found to be lower than in Western European countries. However, it was four times higher than the death rate for influenza and pneumonia in the country, with wide geographic and meteorological differentials [8, 9]. These findings highlight the severity of the COVID-19 epidemic, particularly when associated with old age-related morbidity with comorbidities contributing to the burden of disease: such instances were observed among pediatric cases [10-15].

Researchers carried out macro-level analysis using the national COVID-19 database in Saudi Arabia for various reasons: to give an overview of the scenario, to explain the proportion of the population affected, to systematically review the published research, to test an analysis of variance (ANOVA) model of localities and administrative areas classified by infrastructure development, and to analyze geographical dimensions [16-20]. While the first three were published earlier, the fourth one is very recent.

2. AIMS AND OBJECTIVES

COVID-19 has increased interest in the use of database research for analyses to generate constructive results for discussions related to aspects of public health, encompassing infection, mortality, awareness, behavior modifications, physical distancing, and protective measures against symptoms of contagious illnesses. With the support of academic institutions and government machinery, Saudi Arabia has actively engaged in an infodemic of COVID-19, involving collection, compilation, and analysis. In this context, the current research aimed to analyze COVID-19 data from Saudi Arabia through affected locations (the smallest geographical unit available) over three years to investigate specific morbidity and mortality rates. Attempts are made to identify neighborhoods from 136 governorates under 13 administrative areas to examine the volume and severity of cases year-wise.

3. METHODS

This analysis relies exclusively on the daily reports of COVID-19 cases published by the Ministry of Health of Saudi Arabia (https://sehhty.com), recognized as the most reliable source of information [16-20]. The consolidated illustrations and analysis are based on daily data available from March 15, 2020, to April 30, 2023. Rather than adopting sample selection procedures, this paper analyzes entire cases to reflect the national scenario, a methodology commonly used in demographic research. The data were separated into three periods to analyze the annual trends: 2020-21, 2021-22, and 2022-23. The first group includes data from March 15, 2020, to March 31, 2021; the second encompasses data from April 1, 2021, to March 31, 2022, and the third spans data from April 1, 2022, to April 30, 2023. This analysis specifically focuses on annual counts of COVID-19 cases and deaths to estimate crude infection rates and case fatality rates. The crude infection rate is calculated per 1,000 population based on the population size in 2022 (as given by the General Authority for Statistics, Saudi Arabia), while the case fatality rate is expressed as deaths per 1,000 COVID-19 cases. This method can be demonstrated in the formula below:

a. Crude Infection Rate $CIR = \left(\frac{Pit}{P}\right) x1000$; where P_{it} stands for persons infected at time t, and P stands for total persons at time t.

b. Case Fatality Rate $CFR = \left(\frac{Pidt}{Pit}\right) x1000$; where Pidt stands for infected persons dead at time t, and Pit stands for infected persons at time t.

These calculations are performed for the entire country and its 13 administrative areas, 134 governorates, and 205 affected locations. Such an analysis has significance for a grassroots-level understanding. It offers a local perspective, especially in planning and implementing developmental programs and infrastructure building, which are particularly important in the context of Vision 2030. It has added importance as the infection spreads from locality to locality depending upon pressures of population and infrastructure. Additionally, the average monthly COVID-19 cases are estimated for the specified period, and the months with the highest numbers of reported cases and deaths are identified.

4. RESULTS

Firstly, the count of COVID-19 cases and the crude infection rate across various administrative areas of Saudi Arabia are presented. According to the analysis, a total of 390,325 COVID-19 cases were reported in the period 2020-21, with 360,239 cases and 89,871 cases in 2021-22 and 2022-23, respectively (Table **1**). This suggests a decline in COVID-19 infections over time. The crude infection rate decreased from 12 cases per 1,000 population in 2020-21 to nearly 3 cases per 1,000 population in 2022-23.

Table 1. Number of locations affected by COVID-19 by time period across administrative areas.

Administrative Area	2020-2021				2021-2022				2022-2023				Total
a. Number of cases													
Range	**0-100**	**101-200**	**200-500**	**501+**	**0-100**	**101-200**	**200-500**	**501+**	**0-100**	**101-200**	**200-500**	**501+**	**(N)**
Riyadh	5	6	9	13	2	12	9	10	22	7	2	2	33
Makkah	7	7	9	6	4	5	8	12	25	1	0	3	29
Madina	2	1	5	3	0	1	2	8	8	1	1	1	11
Qassem	2	2	2	9	1	1	5	8	12	0	1	2	15
Eastern Region	5	2	2	17	3	5	2	16	17	1	3	5	26
Aseer	1	2	7	15	0	5	10	10	18	2	3	2	25
Tabouk	2	3	2	1	1	0	5	2	7	0	0	1	8
Hail	2	3	3	1	0	2	6	1	8	0	0	1	9
Northern Borders	4	1	1	2	4	1	1	2	7	0	1	0	8
Jazan	3	3	5	6	0	2	6	9	12	0	4	1	17
Najran	1	2	2	2	0	0	4	3	6	0	0	1	7
Al-Baha	0	1	4	4	1	1	4	3	7	0	1	1	9
Al-Jouf	4	2	1	1	4	0	3	1	7	1	0	0	8
Total	38	35	52	80	20	35	65	84	156	13	16	20	205
b. Crude infection rate (per 1,000 population)													
Range	0-5	5-10	10-15	15-112	0-5	5-10	10-15	15-155	0-5	5-10	10-15		(N)
Riyadh	5	10	4	14	3	15	6	9	31	1	1		33
Makkah	8	8	8	5	7	6	3	13	27	1	1		29
Madina	2	4	1	4	0	1	3	7	10	1	0		11
Qassem	1	5	3	6	2	2	3	8	15	0	0		15
Eastern Region	5	2	6	13	5	5	4	12	24	1	1		26
Aseer	2	5	7	11	4	4	7	10	23	1	1		25
Tabouk	4	4	0	0	0	4	2	2	8	0	0		8
Hail	3	4	1	1	2	2	2	3	9	0	0		9
Northern Borders	2	3	0	3	2	3	3	0	8	0	0		8
Jazan	7	5	2	3	3	5	3	6	16	1	0		17
Najran	2	0	2	3	0	2	0	5	7	0	0		7
Al-Baha	0	2	2	5	1	3	3	2	7	1	1		9
Al-Jouf	6	1	0	1	5	2	0	1	8	0	0		8
Total	47	53	36	69	34	54	39	78	193	7	5		205
c. Highest number of COVID cases reported in a month													
Range	0-50	50-100	100-200	200-500	501+	0-50	50-100	100-200	200-500	501+	0-50	50-100	100-200	200-500	501+	(N)
Riyadh	8	7	10	4	4	8	7	11	5	2	26	4	1	1	1	33
Makkah	5	10	7	4	3	5	5	6	6	7	26	0	0	0	3	29
Madina	4	1	4	0	2	0	1	1	6	3	9	0	1	0	1	11
Qassem	2	3	3	5	2	1	5	5	1	3	12	0	2	1	0	15
Eastern Region	6	3	3	4	10	5	3	5	5	8	17	2	2	2	3	26
Aseer	2	3	5	9	6	3	6	8	4	4	22	1	1	0	1	25
Tabouk	3	3	1	0	1	1	1	3	2	1	6	1	1	0	0	8
Hail	2	3	2	1	1	1	6	1	0	1	8	0	1	0	0	9
Northern Borders	2	3	2	1	0	4	1	1	2	0	8	0	0	0	0	8
Jazan	4	5	1	3	4	2	2	5	4	4	12	4	0	1	0	17
Najran	2	2	1	0	2	0	1	3	2	1	6	0	1	0	0	7
Al-Baha	1	0	6	2	0	1	2	3	3	0	7	1	0	1	0	9
Al-Jouf	6	1	0	1	0	4	2	1	1	0	8	0	0	0	0	8
Total	47	44	45	34	35	35	42	53	41	34	167	13	10	6	9	205
d. Average number of COVID cases in a month													
Range	0-20	20-40	40-60	61+		0-20	20-40	40-60	61+		0-20	20-40	40-60	61+		(N)
Riyadh	13	7	6	7		14	9	1	9		29	2	1	1		33
Makkah	14	9	0	6		11	6	3	9		26	0	0	3		29

(Table 1) contd.....

Administrative Area	2020-2021				2021-2022				2022-2023				Total
a. Number of cases													
Range	**0-100**	**101-200**	**200-500**	**501+**	**0-100**	**101-200**	**200-500**	**501+**	**0-100**	**101-200**	**200-500**	**501+**	**(N)**
Madina	4	4	1	2	2	1	3	5	9	1	0	1	11
Qassem	5	1	4	5	4	3	1	7	12	1	1	1	15
Eastern Region	9	0	3	14	8	2	1	15	19	2	1	4	26
Aseer	5	5	5	10	8	7	1	9	21	2	1	1	25
Tabouk	5	2	0	1	1	4	1	2	7	0	0	1	8
Hail	7	1	0	1	2	6	0	1	8	0	1	0	9
Northern Borders	5	1	1	1	5	1	1	1	8	0	0	0	8
Jazan	9	2	1	5	4	4	2	7	14	2	0	1	17
Najran	4	1	0	2	0	4	1	2	6	0	1	0	7
Al-Baha	2	3	3	1	4	2	1	2	7	1	0	1	9
Al-Jouf	6	1	0	1	4	3	0	1	8	0	0	0	8
Total	88	37	24	56	67	52	16	70	174	11	6	14	205

Note: Crude infection rate is the number of COVID-19 cases in the reference time period per 1,000 population in the year 2022.

Table 2. COVID – 19 infections.

Administrative Area	2020-2021			2021-2022			2022-2023		
	Number of Cases	**Crude Rate**	**Mean/month**	**Number of Cases**	**Crude Rate**	**Mean/month**	**Number of Cases**	**Crude Rate**	**Mean**
Riyadh	87,244	10.0	6,980	112,302	12.9	9,359	31,786	3.6	2,445
Makkah	92,318	11.2	7,385	89,111	10.8	7,426	24,425	3.0	1,879
Madina	30,865	14.4	2,469	20,800	9.7	1,733	5,182	2.4	399
Qassem	14,991	11.1	1,199	13,033	9.7	1,086	2,405	1.8	185
Eastern Region	93,442	18.4	7,475	55,918	11.0	4,660	14,150	2.8	1,088
Aseer	28,998	13.4	2,320	22,433	10.4	1,869	4,088	1.9	314
Tabouk	5,354	6.0	428	6,176	6.9	515	1,207	1.4	93
Hail	7,944	10.9	636	6,225	8.5	519	708	1.0	54
Northern Borders	3,281	8.6	262	3,487	9.1	291	266	0.7	20
Jazan	12,429	8.9	994	17,889	12.9	1,491	2,926	2.1	225
Najran	6,888	11.6	551	6,251	10.6	521	812	1.4	62
Al-Baha	4,888	15.0	391	4,494	13.8	375	1,749	5.4	135
Al-Jouf	1,683	2.7	135	2,120	3.4	177	167	0.3	13
Total	390,325	12.0	31,226	360,239	11.0	30,020	89,871	2.8	6,913

4.1. Morbidity

An analysis of regional distribution reveals that both the COVID-19 count and the crude infection rate were consistently lowest in the Al-Jouf administrative area throughout the time period. However, in 2020-21, the Eastern Region reported the highest number of COVID-19 cases (93,442), followed by the Makkah administrative area (92,318). In both 2021-22 and 2022-23, the Riyadh administrative area recorded the highest count of COVID-19 cases (112,302 and 31,786, respectively), followed by the Makkah administrative area (89,111 and 24,425).

Examining infection rates, in the period 2020-21, the Eastern Region had the highest rate (18.4 cases per 1,000 population), closely followed by Al-Baha (14.9 cases per 1,000 population). However, in both 2021-22 and 2022-23, Al-Baha maintained the highest infection rate (13.7 and 5.3 cases per 1,000 population, respectively), followed by Riyadh administrative area (12.9 and 3.6 cases per 1,000 population, accordingly).

In the 2020-21 period, out of the 205 locations examined, 80 locations were identified as having more than 500 cases. Over the course of the study period, the number of locations with such high case counts decreased. The Eastern Region had the highest number of locations, with more than 500 cases (17 locations), followed by Aseer (15 locations) and Riyadh (13 locations).

Conversely, 38 locations had fewer than 100 cases during the same period. Despite an overall reduction in the number of COVID-19 cases, there was a decrease in the number of locations with fewer than 100 cases (20 locations) and a slight increase in those with more than 500 cases (84 locations) in 2021-22, The rise in locations with over 500 cases in 2021-22 can be attributed to increases in the number of locations in Makkah, Madina, and Jazan administrative areas. Notably, the number of

locations with fewer than 100 cases increased to 156 due to the overall reduction in cases over the study period. The highest number of cases during all three time periods was recorded in location, namely Riyadh city in Riyadh administrative area, with 68,987 cases in the first period, 97,677 cases in the second period, and 28,719 cases in the third period.

While examining the crude infection rate across locations, a decrease in the number of locations was observed with an infection rate below 5 per 1,000 population (between 2020-21 and 2021-22). Consequently, there was a slight increase in the number of locations with an infection rate above 15 per 1,000 population in 2021-22 as compared to 2020-21 (Table **2**).

In 2020-21, the highest number of locations with an infection rate above 15 per 1,000 population was found in Riyadh (14), followed by the Eastern Region (13) and Aseer (11). However, in 2021-22, in Makkah administrative area, it has been noticed that the maximum number of locations with an infection rate above 15 per 1,000 population. The highest infection rates per 1,000 population during different time periods were noted in Ballasmar of Aseer for the periods 2020-21 and 2021-22. However, during the period 2022-23, the highest infection rate was identified in Ad Dhahran, Eastern Region.

Next, the highest number of reported cases in a month across different locations was analyzed. Overall, the peak count of monthly cases exceeded 500 in 35 locations in 2020-21, 34 locations in 2021-22, and 9 locations in 2022-23. The Eastern Region consistently had the highest number of locations, with more than 500 cases in a month throughout the study period. However, Riyadh city in Riyadh administrative area reported the highest counts of 25,946, 39,752, and 10,158 cases in 2020-21, 2021-22, and 2022-23, respectively, followed by Jeddah in Makkah administrative area with the highest count of 10,980 cases, 19,770 cases, and 4,159 cases in a month in the corresponding periods.

On average, the monthly COVID-19 cases were 31,226 in 2020-21, 30,200 in 2021-22, and 6,913 in 2022-23. In 2020-21, the Eastern Region reported the highest monthly average (7,475 cases), followed by Makkah (7,385 cases) and Riyadh (6,980 cases) administrative areas. However, during the 2021-22 and 2022-23 periods, the highest monthly average shifted to Riyadh (9,359 and 2,445 cases, respectively), followed by Makkah (7,426 and 1,877 cases, respectively) and the Eastern Region (4,660 and 1,088 cases, respectively).

The location-specific analysis revealed that among the 205 locations, 56 had more than 60 cases on average per month during the period 2020-21. This number increased to 70 locations in 2021-22 and decreased to 14 locations in 2022-23. In both 2020-21 and 2021-22, Riyadh had the highest monthly average cases, followed by Jeddah and Makkah cities. Despite a decrease in the overall number of COVID-19 cases, the number of locations with a monthly average of less than 20 cases also decreased, from 88 locations in 2020-21 to 67 locations in 2021-22.

Among the 205 locations in 2020-21, the highest numbers of COVID-19 cases were reported by 90 locations in July 2020, 52 locations in August 2020, and 33 locations in June 2020. However, in the 2021-22 period, the maximum number of COVID-19 cases was reported in January 2022, with 131 locations, and February 2022 saw the highest number in 17 locations. In the 2022-23 period, June 2022 emerged as the peak month, reported by 110 locations, followed by July 2022 with 35 locations.

Table 3. Mortality from COVID-19.

-	2021-2022			2021-2022			2022-2023		
	Number of Deaths	Case Fatality Rate	Mean/ Month	Number of Deaths	Case Fatality Rate	Mean/ Month	Number of Deaths	Case Fatality Rate	Mean/ Month
Riyadh	1,304	14.9	104	281	2.5	23	47	1.5	4
Makkah	2,509	27.2	201	733	8.2	61	116	4.7	9
Madina	230	7.5	18	92	4.4	8	9	1.7	1
Qassem	221	14.7	18	79	6.1	7	23	9.6	2
Eastern Region	908	9.7	73	477	8.5	40	113	8.0	9
Aseer	484	16.7	39	239	10.7	20	111	27.2	9
Tabouk	91	17.0	7	27	4.4	2	4	3.3	0
Hail	140	17.6	11	88	14.1	7	31	43.8	2
Northern Borders	90	27.4	7	23	6.6	2	15	56.4	1
Jazan	486	39.1	39	205	11.5	17	75	25.6	6
Najran	76	11.0	6	40	6.4	3	24	29.6	2
Al-Baha	69	14.1	6	31	6.9	3	24	13.7	2
Al-Jouf	69	41.0	6	54	25.5	5	8	47.9	1
Total	6,677	17.1	534	2,369	6.6	197	600	6.7	46

Note: Case fatality rate is the number of deaths per 1000 COVID-19 cases in the reference time period.

4.2. Case Fatality

The count of COVID-19 deaths, by both administrative areas and locations, was examined. In the 2020-21 period, a total of 6,667 COVID-19 deaths were recorded, with 2,369 in 2021-22 and 600 in 2022-23 (Table **3**). The highest death count in 2020-21 was observed in Makkah administrative area (2,509 cases), followed by Riyadh (1,304 cases) and the Eastern Region (908 cases). However, the case fatality rate was highest in the Al-Jouf administrative area (41.0 per 1,000 cases), followed by Jazan (39.1 per 1,000 cases) and the Northern Borders (27.4 per 1,000 cases).

In 2021-22, the highest death count was again seen in Makkah administrative area (733 cases), followed by the Eastern Region (477 cases) and Riyadh (281 cases). Despite the high number of death cases in these administrative areas, the top three areas with the highest case fatality rates were Al-Jouf (25.5 per 1,000 cases), Hail (14.1 per 1,000 cases), and Jazan (11.5 per 1,000 cases). In 2022-23, the three administrative areas reporting the highest deaths were Makkah (116 cases), Eastern Region (113 cases), and Aseer (111 cases). However, in the same period, the administrative areas with the highest case fatality rates were the Northern Borders (56.4 per 1,000 cases), Al-Jouf (47.9 per 1,000 cases), and Hail (43.8 per 1,000 cases).

The spatial distribution of the COVID-19 mortality cases revealed that the number of locations with fewer deaths consistently increased over the period examined (Table **3**). For instance, the number of locations that reported less than 2 deaths reduced drastically from 131 in 2020-21 to 166 in 2022-23. In both the 2020-21 and 2021-22 periods, the maximum number of deaths was reported in the location, namely Jeddah in Makkah administrative area. However, in 2022-23, the maximum number of deaths was reported in Ad Dammam in the Eastern Region.

Concerning the case fatality rate in 2020-21, the three locations with the highest rates were AlAridah, followed by Al Harth (both in the Jazan administrative area) and Al-Baha city in the Al-Baha administrative area. In 2021-22, the areas of AlQurayyat and Tubarjal in Al-Jouf and AlQunfudhah in Makkah administrative areas reported the highest rates. However, given the declining number of cases over the period, interpreting the case fatality rate by location for the year 2022-23 should be approached with caution. For instance, we observed an increase in the number of locations estimating a case fatality rate of 10 per 1,000 cases, rising from 22 locations to 35 locations between the periods 2021-22 and 2022-23 (Table **4**).

Table 4. COVID-19 deaths by time period and administrative area.

-	2021-2022				2021-2022				2022-2023				Total (N)
-	0-1	1-5	5-10	10+	0-1	1-5	5-10	10+	0-1	1-5	5-10	10+	
a. Locations by mortality													
Riyadh	21	6	2	4	28	2	1	2	29	3	0	1	33
Makkah	24	2	0	3	23	2	0	4	24	2	0	3	29
Madina	9	0	1	1	8	2	0	1	10	0	1	0	11
Qassem	10	2	0	3	13	0	0	2	13	1	0	1	15
Eastern Region	13	3	3	7	17	2	1	6	20	2	2	2	26
Aseer	13	4	1	7	15	4	3	3	15	5	2	3	25
Tabouk	6	1	0	1	3	3	2	0	7	1	0	0	8
Hail	7	1	0	1	8	0	0	1	8	0	0	1	9
Northern Borders	6	0	0	2	5	2	0	1	7	0	0	1	8
Jazan	5	3	1	8	11	1	1	4	12	1	1	3	17
Najran	5	1	0	1	6	0	0	1	6	0	0	1	7
Al-Baha	8	0	0	1	8	0	0	1	8	0	0	1	9
Al-Jouf	4	2	0	2	5	0	0	3	7	0	1	0	8
Total	131	25	8	41	150	18	8	29	166	15	7	17	205
b. Number of locations according to case fatality rate													
Administrative area/Rate	No death	<5	5-10	10+	No death	<5	5-10	10+	No death	<5	5-10	10+	-
Riyadh	18	4	6	5	26	3	4	0	28	2	0	3	33
Makkah	22	3	0	4	22	3	1	3	24	1	1	3	29
Madina	9	1	1	0	7	3	1	0	10	1	0	0	11
Qassem	10	3	0	2	12	1	0	2	13	0	1	1	15
Eastern Region	12	7	2	5	15	5	3	3	20	1	3	2	26
Aseer	12	4	2	7	10	5	6	4	13	0	1	11	25
Tabouk	5	1	0	2	3	2	2	1	6	1	0	1	8
Hail	6	1	0	2	8	0	0	1	7	0	0	2	9
Northern Borders	6	0	0	2	5	1	2	0	6	0	0	2	8
Jazan	2	2	0	13	7	5	2	3	11	0	0	6	17

(Table 4) contd.....

-	2021-2022				2021-2022				2022-2023				Total (N)
-	0-1	1-5	5-10	10+	0-1	1-5	5-10	10+	0-1	1-5	5-10	10+	
Najran	5	1	0	1	6	0	0	1	6	0	0	1	7
Al-Baha	6	2	0	1	8	0	0	1	8	0	0	1	9
Al-Jouf	4	0	0	4	4	1	0	3	5	0	1	2	8
Total	117	29	11	48	133	29	21	22	157	6	7	35	205
c. Number of locations according to highest number of COVID deaths													
Administrative area/Rate	0-1	1-5	5-10	10+	0-1	1-5	5-10	10+	0-1	1-5	5-10		N
Riyadh	23	6	1	3	29	3	0	1	31	1	1		33
Makkah	24	2	0	3	24	1	0	4	25	3	1		29
Madina	9	1	0	1	9	1	0	1	10	1	0		11
Qassem	12	1	0	2	13	0	2	0	14	1	0		15
Eastern Region	13	6	2	5	18	2	4	2	21	2	3		26
Aseer	16	4	1	4	19	3	1	2	19	4	2		25
Tabouk	7	0	0	1	3	5	0	0	8	0	0		8
Hail	7	1	0	1	8	0	0	1	8	0	1		9
Northern Borders	6	0	1	1	6	1	1	0	7	1	0		8
Jazan	6	5	2	4	12	2	1	2	13	4	0		17
Najran	5	1	0	1	6	0	0	1	6	1	0		7
Al-Baha	8	0	0	1	8	0	1	0	8	1	0		9
Al-Jouf	6	1	1	0	5	1	1	1	7	1	0		8
Total	142	28	8	27	160	19	11	15	177	20	8		205

In the context of analyzing location-specific data on the highest number of reported deaths in a given month, it is noteworthy that during the time periods 2020-21 and 2021-2022, Riyadh consistently recorded the highest count of deaths in a single month. In the total analysis, for the 2020-21 year, a minimum of one death was recorded as the highest monthly count in 27 places, while in 2021-22, same occurrence was observed in 15 locations. Notably, no location reported the highest monthly death toll exceeding 10 in the period 2022-23.

In the Eastern Region, five locations reported the highest monthly death toll, surpassing ten during the time 2020-21. Similarly, both Aseer and Jazan administrative areas had four locations, each reporting the highest monthly death toll exceeding ten.

Overall, the average monthly deaths were estimated to be 534 in 2020-21, decreasing to 197 in 2021-22 and further to 46 in 2022-23. Makkah administrative area consistently exhibited the highest average monthly deaths across all three time periods. Following Makkah, the Riyadh administrative area recorded the second-highest monthly average deaths in the 2020-21 period, whereas the Eastern Region had the second-highest monthly average deaths in 2021-22.

Analyzing the highest number of deaths within each month across three periods, it is evident that in the 2020-21 period, August 2020 recorded the highest number of fatalities in 19 locations, followed by September 2020 (18 locations) and July 2020 (14 locations). Moving to the 2021-22 period, the peak month was May 2021, where 17 locations reported the highest number of deaths, followed by April 2021 (14 locations) and July 2021 (12 locations). Similarly, in 2022-23, June 2022 emerged as the peak month with the highest number of deaths in 8 locations, followed by April 2022 and May 2022 (7 locations each).

5. DISCUSSION

The Saudi Arabian Ministry of Health took proactive measures to control the further spread of COVID-19 viruses, even in the absence of scientifically proven measures. The country implemented rigorous screening at airports, established quarantine facilities nationwide, built specialized hospitals for patient care, allocated research funds for clinical and scientific research on epidemics, developed diagnostics systems, fast-track development of vaccines, and sought the expertise of foreign consultants, and thereby conducting mass detection testing [1, 3, 16]. Additionally, there were efforts to forecast the number of confirmed cases, recovered cases, and deaths from COVID-19 with the support of the Ministry of Health, Saudi Arabia. This involved designing model-based forecasts and predictions [2, 6, 19]. These comprehensive interventions paved the way for the epidemic to be more controlled in Saudi Arabia than in other countries, including fellow members of the Arab League.

The existing social health care model has traditionally assigned responsibility and accountability for providing services to citizens by the government and to non-citizens by their employers [3]. But, in the case of COVID-19, the government extended its services uniformly to all individuals, alleviating the situation. Drawing from the experiences of combating previous outbreaks like MERS-CoV, Saudi Arabia, as a frontline fighter, demonstrated a high sense of alertness and readiness. This resulted in the implementation of measures with geographic diversities to establish an informed public health system with robust infection control policies and measures [4, 20].

Despite these efforts, there were higher rates of morbidity and mortality from COVID-19 as compared to the neighboring Arab countries. This indicates gaps in

preparedness strategies for prevention and management, underscoring the crucial importance of risk factors (predictors) associated with death. Notably, the elderly, particularly foreign males, individuals with comorbid cardiac and respiratory diseases, as well as those with obesity and diabetes, faced higher mortality risks [5, 10, 11, 13, 14, 18]. Similar trends were observed globally, highlighting the lack of models to counteract the rapid spread within a short timeframe. Such diseases contribute to critical illness states, resulting in higher mortality rates, even among pediatric cases [12, 16]. This explains the toll of COVID-19 witnessed by Saudi Arabia, aligning with the challenges faced by other leading countries worldwide. Models played a crucial role in forecasting anticipated infection cases and mortality, providing essential information for policy implementation at local community clinics within neighborhoods. Simultaneously, these models help identify parameters contributing to disease prevalence [6, 7, 19]. The insights gained from these methods support effective measures for infection eradication. Through this analysis, 205 locations affected by the epidemic were classified based on four measures such as number of infections, crude infection rate, highest number of cases in a given month, and average cases per month, which explains the situation by administrative areas over different years. Such an analysis goes beyond the geographic distribution of cases already explained [20]. This historical demonstration holds relevance for shaping policies and informing future interventions, particularly in emergencies and epidemics.

Concerning fatality rates, two types of calculations are available: case fatality rate– CFR (ratio between confirmed deaths and confirmed cases) and infection fatality rate – IFR (the number of deaths from COVID-19 disease divided by the total number of cases of COVID-19). As the former one is easier and straightforward, deaths are accounted for, generally, as disease-specific. Thus, the rates calculated here are infection fatality to a large extent but are complicated by multiple pathologies. Similar analyses were done earlier [16, 17]. While the COVID-19-specific case fatality rate in Saudi Arabia is comparatively lower than that of Western Europe, it stands approximately four times higher than the rates of influenza and pneumonia in the country. Notably, the Makkah administrative area reported the highest rate, followed by Madina, Jazan, Eastern Region, and Riyadh, in that order, at certain points in time, with variations observed at other times [8, 15, 20]. These differences are attributed to geographic differences leading to meteorological conditions, such as reduced temperature, humidity, and wind speed, which are associated with an increase in the number of positive cases, specifically in Saudi Arabia [9]. Climatic conditions vary from one location to another in the country, giving rise to geographic diversity [20]. The observed differentials in COVID-19 morbidity and mortality across administrative areas and locations could be attributed to this heterogeneity.

The national database of the Saudi Arabian Ministry of Health enables cases to be examined by administrative area and locality. While such an analysis paves the way for a local-level understanding of the characteristics of affected population groups against a background of homogenous national infrastructure, a more detailed analysis would have been possible with a detailed database of the socio-economic and demographic characteristics of people infected and died. Moreover, the 205 locations affected vary in terms of geographic area, population size, and structures and systems in place.

This study is relevant for epidemic control systems as it employs a prospective information-based approach. Such an analysis helps develop resistance measures at the grassroots level and effective surveillance systems. Furthermore, the study provides a comprehensive overview of the COVID-19 period, facilitating a clearer understanding of international comparisons and collaborative networks. The analyses presented in this paper differ from others, in particular, in terms of depth, thus increasing the relevance and validity of findings.

This study was based on databases published by the Ministry of Health to monitor the COVID-19 spread in the country to create awareness and thus to build a surveillance system to combat the rapid spread of infection, which caused a heavy burden. There are no age, sex, or any other socio-demographic variables in the data. This limitation affects in-depth analyses and interpretations based on statistical analyses or modeling. It is hoped that the Ministry will soon make the database available to the Saudi academic community for such analyses.

CONCLUSION

This analytical research spans three years of COVID-19 morbidity and mortality rates in Saudi Arabia, encompassing the onset, peak, decline, and eventual decrease of the epidemic. An evident pattern of infection emerges when the administrative areas are analyzed, and the locations affected are examined in terms of the number of cases, crude infection rate, the highest number of cases reported in a month, and monthly averages. Over these three years, there was a discernible increase in infection rates, explained as waves, followed by a subsequent decrease in absolute numbers, rates, and means.

Mortality, specifically the case fatality rate, was initially high, in particular, due to the characteristics of the infected population, and this was more pronounced in the first year of the epidemic. However, significant control measures were implemented, resulting in a subsequent substantial reduction. The fatality rate also exhibited marked variations across administrative areas, considering the range of absolute numbers, case fatality rate, and locations with the highest number of fatalities.

AUTHORS' CONTRIBUTION

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

ABBREVIATION

ANOVA = Analysis of Variance

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

HUMAN AND ANIMAL RIGHTS

Not Applicable.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIAL

The data supporting the findings of the article is available in the (Saudi Arabian Ministry of Health database) at (https://sehhty.com), from corresponding author [H.M.A] and can be provided in Excel sheets format upon request.

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CONFLICT OF INTEREST

The author declares no conflict of interest, financial or otherwise.

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