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Research Article

Trends of COVID-19 mortality and hospitalization rates in southern states of the United States, 2020-2023

Bever-Leigh Holden*, Precious Patrick Edet, Elizabeth A.K. Jones, Amal K. Mitra

Department of Epidemiology and Biostatistics, Jackson State University, Jackson, Mississippi, USA

Abstract

***Background and Objectives*:** The COVID-19 pandemic, caused by the novel coronavirus SARS-CoV-2, has emerged as one of the most profound global health crises of the 21st century. In the United States, the impact of COVID-19 has been severe, with notable disparities observed in the Southern region. This study aims to evaluate trends in COVID-19 mortality and hospitalization rates in southern states over the course of 2020 to 2023 by presenting a comprehensive analysis of trends in COVID-19 outcomes within Southern states.

***Methods*:** Data for the study was collected from the COVID-19 Data Tracker, a resource provided by the Centers for Disease Control and Prevention (CDC). Stratification techniques were employed to categorize the sample into subgroups of Southern states (Arkansas, Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia). Joinpoint regression models were used to calculate Annual Percentage Change (APC) and Average Annual Percentage Change (AAPC).

***Results*:** Results showed a downward trend in both age adjusted APC and AAPC COVID-19 hospitalization rates and an upward trend in mortality rates for all southern states between 2020 to 2023. Only 3 out of the 12 states have age adjusted mortality rates that are lower than the national age adjusted mortality rate for COVID-19 (286.4 deaths per 100,000). COVID-19 vaccine coverage in 12 southern states is 61.8% - 91.3%.

***Conclusion*:** The study contributes to a deeper understanding of the evolving dynamics of COVID-19 pandemic within the southern U.S. states. The information would be a valuable guidance for public health strategies, resource allocation, and policymaking aimed at addressing this ongoing crisis.

Introduction

The COVID-19 pandemic, caused by the novel coronavirus SARS-CoV-2, emerged as one of the most profound global health crises of the 21st century [1]. Since its inception in late 2019, this highly contagious and potentially lethal virus has threatened human population worldwide causing severe respiratory distress and life-threatening complications [2]. According to the World Health Organization (WHO), a total of 770,875,433 confirmed cases of COVID-19, including 6,959,316 deaths globally were reported as of September 27, 2023 [3]. In addition, the cumulative count of COVID-19 vaccine doses administered globally stands at 13,505,262,477 as of September 19, 2023 [3]. With millions of cases and fatalities recorded worldwide, this pandemic has not

***Correspondence**: *Bever-Leigh Holden, Jackson State University, Department of Epidemiology and Biostatistics, Jackson, Mississippi, USA, Email:bever-leigh.i.holden@students.jsums.edu; beverleighholden@yahoo.com*

only strained healthcare systems but has also disrupted economies, education, and the daily lives of many [4].

In the United States (U.S.), the impact of COVID-19 has been severe, causing 6,368,333 hospitalizations and 1,144,539 deaths as of September 23, 2023 [5], with notable disparities reported, particularly among racial/ethnic minorities and in the Southern region of the country [6,7]. These outcomes have necessitated an unprecedented public health response, including lockdowns, social distancing, mask mandates, and the rapid development of vaccines [8]. As the U.S. grapples with the spread and devastating consequences of COVID-19, public health systems have been challenged to comprehend, mitigate, and respond effectively to the multifaceted dimensions of this disease threat.

According to the CDC, the U.S. federal Public Health Emergency (PHE) declaration for COVID-19 concluded on May 11, 2023, leading to the expiration of the CDC's authorization to collect specific public health data [9]. The CDC is actively integrating its COVID-19 emergency response into existing programs, transitioning to sustainable public health practices [9]. The CDC remains committed to providing valuable COVID-19 updates for informed public health actions, especially for those at the highest risk, prioritizing the protection of the nation's public health [9].

One of such updates was released on September 8, 2023, in a CDC report titled, “Update on SARS CoV-2 Variant BA.2.86,” which announced a new COVID-19 variant called BA.2.86 [10]. According to the CDC, “the current increases in COVID-19 cases and hospitalizations in the United States are not being driven by BA.2.86 and instead are being caused by other predominantly circulating viruses” [10]. The CDC advises individuals aged 5 years and above to receive one dose of a 2023-2024 updated COVID-19 vaccine from Pfizer-BioNTech, Moderna, or Novavax, as a safeguard against severe illness caused by COVID-19 [11].

Southern states, characterized by their unique demographics, healthcare infrastructure, and policies, have faced distinct challenges in dealing with the pandemic [12,13]. These factors account for a high number of White Americans having elevated COVID-19 mortality rates. Additionally, research findings show that in 2022, Southern states including Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee, recorded the highest number of COVID-19-associated deaths, totaling 56,695 [14].To comprehend the gravity of the situation, it is crucial to compare and contrast the experiences of Southern states with national averages as such comparisons enable the identification of COVID-19 patterns and disparities, measurement of COVID-19 trends over a pre-specified fixed interval utilizing Annual Percentage Change (APC) and Average Annual Percentage Change (AAPC) tools, and the assessment of potential factors contributing to variations in COVID-19 outcomes, such as mortality and hospitalization rates.

While the COVID-19 pandemic has prompted a wealth of research, there remains a notable gap in the knowledge regarding COVID-19 trends, and APC and AAPC of hospitalization and mortality rates in Southern states. As a result, our current understanding of the pandemic's trajectory within the Southern states remains incomplete, limiting our ability to tailor public health responses, allocate resources effectively, and inform evidence-based policymaking in this region. To address this knowledge gap, it is imperative that researchers prioritize region-specific studies that employ robust methodologies to analyze APC and AAPC trends in hospitalization and mortality rates. Such research endeavors are essential not only for enhancing our comprehension of the evolving COVID-19 dynamics in the Southern states but also for shaping targeted interventions and public health strategies that can mitigate the impact of the virus in this distinct geographical context.

To address this gap in knowledge, this study aims to evaluate trends in COVID-19 mortality and hospitalization rates in southern states over the course of 2020 to 2023 by presenting a comprehensive analysis of trends in COVID-19 outcomes within Southern states. Through a rigorous examination of these trends, we intend to shed light on the changing dynamics of COVID-19 within this region, thereby informing public health strategies, resource allocation, and policy decisions necessary to combat this ongoing crisis.

Materials and Methods

***Data Collection*:** Data was exported from the CDC's COVID-19 Tracker. The database contains COVID-19 related surveillance data from each state in the United States. SAS Studio [15] was used to calculate standard error for joinpoint regression and MS excel/ text file was used to prepare data (variables: state, year, age adjusted rate, and standard error) for joinpoint regression software. Stratification was used to separate the sample into subgroups of southern states (Arkansas, Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia.

***Statistical Analysis*:** Age-adjusted rates and frequencies were extracted from the CDC database. SAS Studio [15] was used to calculate the standard error for the sample. U.S. Surveillance, Epidemiology, and End Results (SEER) Joinpoint regression program version 5.0 [16] was used to calculate Annual Percentage Change (APC) and Average Annual Percentage Change (AAPC) of hospitalization and mortality rates in southern states. Joinpoint regression describes trends and significant changes in trends. Based on the Bayesian information criterion [17], the Empirical Quantile Method was used to identify the significant best fit line for trend 1. *P*-value was not calculated based on the method. However, each model tested for significance and listed the results for significance. Confidence intervals were calculated for APC and AAPC.

***Calculation of APC and AAPC*:** APC assumes the change at a constant percentage of the rate of the previous year to predict outcomes [18]. Therefore, the following regression model is used to estimate the APC for a series of data:

$\log(R_y) = b_0 + b_1$, where $\log(R_y)$ is the natural log of the rate in year "y".

The APC from year "y" to year "y+1"

$$= \left[\frac{R_{y+1} - R_y}{R_y}\right] * 100$$

$$= \frac{\{e^{b_0 + b_1(y+1)} - e^{b_0 + b_1(y)}\}}{e^{b_0 + b_1(y)}} * 100$$

$$= (e^{b_1} - 1) * 100$$

The AAPC is a weighted average of the slope coefficients of the underlying joinpoint regression model with the weights equal to the length of each segment over the interval [19]. If we denote b_i as the slope coefficient for the i^{th} segment with i indexing the segments in the desired range of years, and w_i as the length of each segment in the range of years, then:

$$AAPC = \left\{\exp\left(\frac{\sum w_1 b_1}{\sum w_1}\right) - 1\right\} * 100$$

Results

Trends of COVID-19 hospitalization and mortality rates in 12 southern states of United States for the period of 2020-2023 have been analyzed.

COVID-19 hospitalization and mortality rates

Details of hospitalizations and deaths due to COVID-19 during 2020-2023 in all the 12 southern states of US are shown in Table-1, 2 and 2a. Between 2020 to 2023, the southern states of the United States (Arkansas, Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Texas) have a total of 2,418,046 hospitalizations, and 420,659 COVID-19 deaths. During this period, all the 12 southern states have experienced declines in COVID-19 hospitalizations. Rate of age adjusted decline of COVID-19 hospitalization in 12 southern states ranged from 57.4% to 90.1% (Table-2a). Highest and lowest decline has been observed in Kentucky (90.1%) and Florida (57.4%) respectively between 2020 to 2023. From 2020-2023, Texas has the highest number of hospitalizations in the southern region (n=607,125, 25.1%) while Kentucky has the highest age adjusted hospitalization rate (62.9 per 100,000) (Table-1and 2).

Between 2020-2023, all the southern states have experienced increases in COVID-19 mortality. The changes within the age-adjusted COVID-19 mortality rates ranged from 61.0% to 78.1% for

Table-1: *Rates of COVID-19 hospitalization, mortality and vaccination against SARS-CoV-2 in 12 southern states of US, 2020-2023 (As of September 9th)*

Variables	Hospitalization[b] (N=2,418,046)	COVID-19 Deaths[c] (N=420,659)	Vaccine Coverage (N=85,900,123)
	Number[a] (%)	Number (%)	Number (%)[d]
Arkansas	67,118 (2.8)	19,545 (4.6)	2,111,165 (70.1)
Alabama	116,641 (4.8)	22,390 (5.3)	3,193,141 (65.1)
Florida	568,353 (23.5)	80,104 (19.0)	17,810,446 (82.6)
Georgia	238,738 (9.9)	36,207 (8.6)	7,287,758 (68.6)
Kentucky	155,421 (6.4)	19,985 (4.8)	3,086,324 (69.1)
Louisiana	95,591 (4.0)	17,688 (4.2)	2,924,163 (62.9)
Mississippi	55,689 (2.3)	14,838 (3.5)	1,839,306 (61.8)
North Carolina	167,597 (6.9)	33,925 (8.1)	9,456,334 (90.2)
South Carolina	94,579 (3.9)	21,315 (5.1)	3,666,079 (71.2)
Tennessee	130,232 (5.4)	28,722 (6.8)	4,413,541 (64.6)
Texas	607,125 (25.1)	102,325 (24.3)	22,317,417 (77.0)
Virginia	120,962 (5.0)	23,615 (5.6)	7,794,449 (91.3)

Note: [a]Total number of cases reported; [b]Total number of hospitalizations from August 1, 2020 - September 2,2023; [c]Total COVID-19 deaths from January 1, 2020 - September 9, 2023; [d]Vaccine coverage percentages by State with at least 1 dose of the vaccine administered as of May 10, 2023.

southern states between 2020-2023. Louisiana has the lowest (61.0%) while Kentucky has the highest (78.1%) increase in mortality rates among the southern states from 2020-2023. From 2020-2023, Texas has the highest number of deaths in the southern region (n=102,325, 24.3%; Table-1). However, Mississippi has the highest age adjusted mortality rate in the southern region (428 deaths per 100,000; Table-2).In terms of weekly COVID-19 deaths as of September 9, 2023, 5 states (41.7%) had 1-9 deaths (Arkansas, Alabama, Kentucky, Louisiana, and Mississippi), 6 states (50%) had 13-24 deaths (Virginia-13 deaths; Georgia-15 deaths; Texas-17 deaths; Tennessee and South Caroline- 19 deaths; North Carolina-24 deaths), and 1 state (8.3%) had 66 deaths (Florida).

COVID-19 vaccine coverage

In the southern states, 85,900,123 individuals have been administered at least 1 vaccine dose (Table-1). All the southern states have more than 60% vaccination coverage with at least 1 dose of a vaccine. The range of COVID-19 vaccine coverage in 12 southern states is 61.8% to 91.3% (Table-1). Virginia has the highest (91.3%) while North Carolina has the lowest (61.8%) vaccine coverage.

COVID-19 mortality by gender, age, and race/ethnicity in the Southern states

Gender: Between 2020-2023, males had higher age adjusted COVID-19 mortality rates (136.6 deaths per 100,000 [2020]; 158.8 deaths per 100,000 [2021]; 80.0 deaths per 100,000 [2021]; 26.5 deaths per 100,000 [2023]) than females (108.4 deaths per 100,000 [2020]; 123.2 deaths per 100,000 [2021]; 64.8 deaths per 100,000 [2020]; 11.9 deaths per 100,000 [2023]) in southern states. Between 2020-2023, the age adjusted mortality rate declined by 80% in males and by 89.0% in females. (Table-3) The trend for the age-adjusted mortality rates in males and females consisted of 1 segment with a significant APC of -20.6% (-50.5% to 7.1%) and -17.8% (-45.8% to 10%) respectively (Table-3).

***Age*:** Between 2020-2023, adults 65 years and older had higher age-adjusted COVID-19 mortality rates (904.9 deaths per 100,000 [2020]; 1085.9 deaths per 100,000 [2021]; 655.1 deaths per 100,000 [2022]; 149.5 deaths per 100,000 [2023]) than any other age group in southern states. Between 2020-2023, the age-adjusted mortality rate remained 0% for the 0-17 age group, but it declined by 99.7%, 92.2% and 83.5% in the 18-39, 40-64 and > 65 years

Table-2: *Trends in COVID-19 hospitalizations and deaths, 2020-2023*

Characteristic	No. of cases (age-adjusted rates)		AAPC % (95% CI)	Trend Segment 1 APC % (95%CI)
	2020	2023	2020- 2023	2020-2023
Hospitalizations				
Arkansas	13,372 (35.4)	222 (7.36)	-40.6 (-55.7 to -33)	-40.6 (-55.7 to -33)
Alabama	24,740 (52.3)	410 (8.36)	-51.1 (-51 to -72.0)	-51.1 (-51 to -72.0)
Florida	70,790 (27.7)	2,536 (11.8)	-27.2 (-39 to -19.4)	-27.2 (-39 to -19.4)
Georgia	44,214 (40.6)	618 (5.82)	-48.2 (-61.8 to -43.1)	-48.2 (-61.8 to -43.1)
Kentucky	40,032 (62.9)	277 (6.20)	-57.4 (-69.4 to -51.8)	-57.4 (-69.4 to -51.8)
Louisiana	17,377 (28.2)	344 (7.4)	-39.2 (-56.1 to -29.4)	-39.2 (-56.1 to -29.4)
Mississippi	14,344 (38.5)	134 (4.5)	-42.4 (-69.2 to -33.1)	-42.4 (-69.2 to -33.1)
North Carolina	26,612 (24.4)	481 (4.59)	-26.2 (-55.7 to -2.1)	-26.2 (-55.7 to -2.1)
South Carolina	13,941 (25.9)	373 (7.24)	-28.8 (-56.7 to -9.6)	-28.8 (-56.7 to -9.6)
Tennessee	28,284 (35.9)	416 (6.09)	-46.6 (-61.1 to -38.8)	-46.6 (-61.1 to -38.8)
Texas	114,624 (34.4)	1,918 (6.6)	-47.9 (-60.8 to -42.2)	-47.9 (-60.8 to -42.2)
Virginia	15,217 (19.8)	377 (4.42)	-20.6 (-48.2 to-3.6)	-20.6 (-48.2 to-3.6)
Mortality				
Arkansas	3,816 (103)	12,558 (338)	25 (-4.5 to 88.0)	25 (-4.5 to 88.0)
Alabama	6,648 (107)	22,390 (360)	23.2 (-3.5 to 78.2)	23.2 (-3.5 to 78.2)
Florida	20,894 (63.2)	80,104 (249)	23.3 (-2 to 76.9)	23.3 (-2 to 76.9)
Georgia	9,910 (87.7)	36,207 (317)	23.5 (-3.5 to 80.6)	23.5 (-3.5 to 80.6)
Kentucky	4,3336 (81.5)	19,985 (372)	29.7 (-5.1 to 115.9)	29.7 (-5.1 to 115.9)
Louisiana	6,907 (129)	17,688 (331)	22.2 (-3 to 70.2)	22.2 (-3 to 70.2)
Mississippi	4,869 (140)	14,838 (428)	25.3 (-3.7 to 86.2)	25.3 (-3.7 to 86.2)
North Carolina	8,220 (66.2)	33,925 (271)	27 (-4.2 to 97.8)	27 (-4.2 to 97.8)
South Carolina	5,529 (85.2)	21,315 (329)	26.4 (-4.9 to 97.1)	26.4 (-4.9 to 97.1)
Tennessee	7,019 (85)	28,722 (346)	26.4 (-4.9 to 97.1)	26.4 (-4.9 to 97.1)
Texas	31,572 (111)	102,325(356)	22.5 (-3.8 to 75.6)	22.5 (-3.8 to 75.6)
Virginia	5,999 (60.30)	23,615 (235)	28.3 (-5.3 to 108.2)	28.3 (-5.3 to 108.2)

Note: Similarities in data may exist in Table-2 because of similarities in rates and predicted trends. APC: Annual percentage change; AAPC: Average annual percentage change; Despite APC being significant, p-value was not available due to the use of the Empirical Quantile Method, which was selected to improve accuracy.

age groups respectively. Adults aged 65 years and older had the lowest decline in age-adjusted mortality rates among all age groups in southern states. The trend for the age-adjusted mortality rates in the 0-17 age group could not be calculated due to 0 COVID-19 morality rates within the reported years. The trend for the age-adjusted mortality rates in the 18-39 age group consisted of 1 segment with a significant APC of -0.8% (-63.7% to 99.2%) The values for 40-60 and above 65 years age groups are -7.5% (-75.6% to 138.3%) and -20.0% (-43.6% to 0.6%) respectively (Table- 3).

***Race/Ethnicity*:** Between 2020-2023, Whites had higher age adjusted COVID-19 mortality rates (138 deaths per 100,000 [2021]; 78.6 deaths per 100,000 [2022]; 15.64 deaths per 100,000 [2023]) than Blacks, American Indian/ Alaska Native (Non-Hispanic), Asians/ Pacific Islander (Non-Hispanic), and Hispanic in each year of the pandemic except for 2020. During 2020, Blacks had a higher age-adjusted COVID-19 mortality rate (91.8 deaths per 100,000) than any other race/ethnicity in southern states. Between 2020-2023, the age adjusted mortality rate declined by 93.2% in Blacks, 100% in American Indians/Alaska Natives (Non-Hispanic),

Table-2a: *Changes in age-adjusted hospitalization and mortality rates in 12 southern states of US*

Name of State	Percentage changes in	
	Hospitalization	Mortality
	% Decline	% Increase
Arkansas	79.2	69.5
Alabama	84	70.3
Florida	57.4	74.6
Georgia	85.7	72.3
Kentucky	90.1	78.1
Louisiana	73.8	61
Mississippi	88.3	67.3
N. Carolina	81.1	75.6
S. Carolina	72.2	74.1
Tennessee	83	75.4
Texas	80.8	68.8
Virginia	77.8	74.3

Table-3: *Trends in COVID-19 mortality by gender, race/ethnicity, and age in southern states, 2020-2023*

Characteristic	Age-adjusted rates		AAPC (95% CI)	Trend Segment 1 APC % (95% CI)
	2020	2023	2020-2023	2020-2023
Gender				
Male-1	136.6	26.5	-20.6	-20.6 (-50.5 to 7.1)
Female-2	108.4	11.9	-17.8	-17.8 (-45.8 to 10)
Race				
Black, NH	91.8	6.2	-14.5	-14.5 (-52.5 to 29.3)
AI/AN, NH	42.2	0	***	***
Asian/PI, NH	25.4	0.44	-3.5	-3.5 (-62.3 to 133.9)
Hispanic	85.8	8.7	-14.1	-14.1 (-57.2 to 34.4)
White, NH	91.3	15.6	-9.1	-9.1 (-46.1 to 34.6)
Age group (years)				
0-17	0	0	***	***
18-39	21.9	0.07	-0.8	-0.8 (-63.7 to 99.2)
40-64	91.2	7.13	-7.5	-7.5 (-75.6 to 138.3)
65+	904.9	149.5	-20.0	20.0 (-43.6 to 0.6)

Note*: NH = Non-Hispanic; AI = American Indian; AN = Alaska Native; PI =Pacific Islander; AAPC: Average annual percentage change; *** indicates that data could not be analyzed because zeros were present within the rates of the category. Despite APC being significant, p-value was not available due to the use of the Empirical Quantile Method, which was selected to improve accuracy*.

98.3% in Asians/Pacific Islanders (Non-Hispanic), 89.9% in Hispanics, and 82.9% in Whites in southern states. Whites had the lowest decline in age-adjusted COVID-19 mortality rates during the period (Table -3). The trend for the age-adjusted mortality rates for American Indians/ Alaska Natives (Non-Hispanic) could not be calculated due to zero COVID-19 morality rates being reported within the reported years. The trend for the age-adjusted mortality rates in different ethnic groups is shown in detail in Table-3.

Discussion

Among all southern states, there is a downward trend in both age adjusted, annual percentage change and average annual percentage change hospitalization rates between 2020 to 2023 (Table 2). However, there is an upward trend in age adjusted, annual percentage change, and average annual percentage change mortality rates in all southern states between 2020 to 2023. Only 3 out of the 12 southern states (25%) have age adjusted COVID-19 mortality rates that are lower than the national average for age adjusted COVID-19 mortality rates (286.4 deaths per 100,000) in the United States [20] These states are Virginia (235 deaths per 100,000), North Carolina (271 deaths per 100,000), and Florida (249 deaths per 100,000). These findings are attributed to Virginia (91.3%), North Carolina (90.2%), and Florida (82.6%) having vaccination rates surpassing or approaching 85%, which is the ideal rate of COVID-19 vaccinations to foster herd immunity [21]. Unfortunately, the other southern states have failed to fall within a significant range of the 85% vaccination rate goal for each state. In addition to low vaccination rates, changes in COVID-19 variants may also be responsible for upward trends in mortality within southern states. These findings emphasize a need for initiatives to address challenges surrounding COVID-19 related issues, such as vaccine misinformation, allocation of resources, strategic planning, and state policies.

As of 2023, there is also a downward trend in mortality rates based on gender, age, and race in all southern states. However, the downward COVID-19 mortality trends by subgroups are lower in females, Whites (Non-Hispanic), and adults 65 years and older. Furthermore, Whites (Non-Hispanic), adults 65 years and older, and males have higher rates of morality than any other group within their respective categories between 2020-2023. These findings are attributed to COVID-19 related complexities within southern states related to socio-political factors. In southern states, white males tend to be more influenced by negative political views regarding PPE (Personal protection equipment), vaccines, and COVID-19 prevention because of their political affiliations. While southern states are experiencing downward trends in mortality by each subgroup, findings still suggest that whites, males, and 65 years and old still depict the need for further intervention and education.

The impact of COVID-19 can vary substantially from one region to another, and there are various theories that can contribute to why certain areas, notably specific southern states, may bear a disproportionately significant burden from the pandemic. It is important to remember that COVID-19's influence could alter overtime as vaccination rates rise, new variations develop, and public health policies are implemented and revised. Regional disparities may also vary as communities adapt to changing circumstances and new data becomes available. Factors such as population density, vaccination hesitancy, healthcare infrastructure, public health measures, demographics, socioeconomic factors, and political and cultural factors all result in the disproportionate rates of mortality in southern regions of the United States.

There was significant geographic variation in COVID-19 cases and fatalities, with certain states bearing a disproportionately higher incidence of the disease [22]. Controlling the spread of the virus is often more difficult in areas with a higher population density. Southern states like Florida and Texas have densely populated metropolitan areas, such as Miami and Houston, where the virus can spread more easily due to close proximity. There was also a distinct urban-rural gap seen, with urban areas having greater case counts, undoubtedly due to population density and mobility, whereas rural areas had fewer cases but faced challenges with healthcare access and resources.

Trust in health experts, government, or public health institutions are closely related to risk perception about COVID-10 immunizations and vaccine adoption [23]. Tailored and evidence-based health communication is critical in encouraging beneficial health behaviors and winning folks' trust. Individuals agreed to accept the vaccine if it was required by their employer, if government officials gave clear and consistent communication about the infection and vaccine regarding the safety and effectiveness of the vaccine, or if it was suggested by their doctor or a health professional. The frequency with which people watched, listened to,

or read the news reflected an increase in vaccine acceptance. However, the media frequently exaggerates the hazards of vaccination, which can contribute to lower vaccine acceptability among some populations. COVID-19 vaccinations and prevention strategies are critical for preserving public health, decreasing virus spread, and ultimately ending the pandemic. To overcome the obstacles posed by COVID-19, a mix of immunization, public health interventions, and responsible individual behavior is required.

Healthcare infrastructure availability and capacity can have a substantial impact on a region's ability to handle COVID-19 cases. Some southern states have struggled with hospital capacity and funding, putting an additional strain on the healthcare system. Shortly after the start of the pandemic in the United States, COVID-19 infections spread quickly, resulting in rapid increases in hospitalizations. At that time the influx put a burden on healthcare infrastructure, such as hospitals, clinics, and emergency services [24]. Many healthcare facilities were suffering from a lack of beds, ventilators, and other crucial services. The epidemic disrupted worldwide supply systems for medical goods and equipment. Personal protection equipment, ventilators, testing kits, and even pharmaceuticals were in short supply. To deal with the pandemic, healthcare infrastructure needed to react quickly. This frequently entailed repurposing non-traditional venues such as COVID-19 treatment centers, establishing field hospitals, and establishing specialist COVID-19 sections within existing healthcare facilities. The state’s public and private clinics and hospitals funding allotment, population size, and demand all contributed to the Southern states’ ability to provide immediate and equitable healthcare to those who sought prevention and treatment options.

Differences in the adoption and adherence to public health measures, such as mask regulations, social distance, and lockdowns all impacted the spread of the virus globally. Variability in adherence to these strategies guided the effects and impact of the COVID-19 burden in various places, especially in Southern regions, where political figures and representatives guided the adoption, or lack thereof, of public health suggested/mandated guidelines. Increases in COVID-19 cases and deaths in the south and rural areas represented disproportionate rates compared to other parts of the country [25]. The findings emphasize the importance of further understanding the factors behind perceptions of COVID-19 risk in rural areas. During national catastrophes, the dissemination of scientifically sound and consistent information is crucial.

COVID-19 mortality rates are heavily influenced by demographics. Age, gender, race/ethnicity, socioeconomic level, occupational risks, and underlying political and health issues can all influence an individual's chance of acquiring the disease and outcome [26,27,28]. Southern states exhibit a higher prevalence of comorbidities, which raises the risk of the severity of the disease if infected [26]. One of the most important demographic parameters influencing COVID-19 mortality is age. Elderly individuals, particularly those over the age of 65, are at a significantly higher risk of serious illness and death if they contract the disease. Younger individuals, particularly children, are often less affected. Early in the pandemic, men were found to have a greater fatality rate than women. This gender disparity could be attributed to a variety of variables, including immune response disparities, the incidence of underlying health disorders, and a person's belief in health-seeking attention/treatment [26]. COVID-19 mortality rates have been found to be unequally distributed between racial and ethnic groupings. Some minority groups, such as Black, and Hispanic have had higher death rates than Whites earlier in the pandemic, which was consistent with the findings of this study. This gap is frequently linked to socioeconomic issues, lack of access to healthcare, and increased prevalence. Individuals with lower socioeconomic level, such as those with poor access to healthcare, unstable housing, and employment that involve close contact with others, are more likely to be exposed to the virus and suffer serious implications. Individuals with preexisting health issues, such as heart disease, diabetes, obesity, and respiratory disorders, are predisposed to catastrophic COVID-19 results. Cities with dense residents frequently have greater death rates than rural areas. Certain occupations, such as

healthcare personnel, first responders, and vital workers, stand a higher risk of acquiring viral infection. This can have an impact on death rates in various occupational populations.

Socioeconomic factors can have a substantial impact on COVID-19 fatality rates. Inequities in access to healthcare facilities, quality of care, and individual habits, have an impact on outcomes. During the initial phase of the COVID-19 epidemic, individuals with limited incomes had restricted access to healthcare, which made early diagnosis and treatment more challenging [27]. People in low-wage occupations were frequently unable to work from home which caused them to be more vulnerable to the virus. Individuals with lower education levels were linked to lower health literacy, which resulted in less effective preventative measures and delayed medical care. A lack of or insufficient health insurance resulted in delayed or inadequate care, increasing the chance of catastrophic COVID-19 outcomes. Overcrowding or inadequate housing rendered social distancing and isolation impossible, leading to an increased likelihood of transmission within homes. Inadequate nutrition caused by food instability was found to weaken the immune system and worsen the results for people infected with the virus. Individuals with limited access to private transportation found it difficult to obtain medical treatment or visit testing and immunization sites. Individual behaviors such as mask-wearing, social distancing, and vaccine hesitancy influenced by socioeconomic disparities, affected COVID-19 outcomes. Economic insecurity, job loss, and social isolation also led to mental health problems, which affected COVID-19 outcomes.

Public health response measures are frequently influenced by political and cultural variables. Political divisions or cultural attitudes on health measures such as masking and vaccination had an impact on the COVID-19 burden in some circumstances [27,28]. COVID-19 is a worldwide pandemic, and international political collaboration was critical to contain its spread. Policies governing foreign travel, trade, and vaccine delivery were critical in impacting the Southern region of the United States' vulnerability to the virus. Clear and consistent messaging from political and social groups is important to persuade people to take precautionary measures to prevent morbidity and mortality.

This study has some limitations. First, only individuals with confirmed COVID-19 cases were included in the study, which may have left out individuals with unconfirmed COVID-19 diagnosis. Second, based on the nature of the study, there is a low capacity to estimate associations. The study is important because it focuses on analyzing trends and changes of COVID-19 hospitalization and mortality over periods of time in all the Sothern states of US.

In summary, COVID-19 pandemic had a significant impact on mortality rates in the United States, with southern regions bearing a disproportionate weight of deaths. COVID-19 has a substantial impact on global healthcare infrastructure, revealing both its strengths and weaknesses. It underlined the significance of robust and adaptive healthcare systems in responding to unforeseen problems such as COVID-19 pandemics. To address the gaps in healthcare system, public health and medical professionals must concentrate on underlying social and economic inequities as well as enhancing healthcare access for vulnerable groups.

Public health measures, such as educational campaigns aimed at vulnerable communities, equal access to testing, treatment, and vaccination are crucial to contain and minimize COVID-19 pandemic. The measures can help minimizing COVID-19 mortality rates, especially in the southern states.

Author's contribution

EAKJ conceptualized the study; AKM validated the study and the original draft; BH, PPE and EAKJ prepared the original draft, reviewed and edited the manuscript.

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