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COVID-19 trends in Tennessee and the United States over 40 weeks

Abstract

Coronavirus disease 2019 (COVID-19) occurred and spread in Spring 2020 in the United States. The study of early COVID-19 incidence rates distribution and trends between the State of Tennessee in comparison with US rates can offer important insights into public health system surveillance and epidemic control measures.

Objective: The purpose of this study is to evaluate weekly trends in the COVID-19 crude incidence rates experienced in the first 40 weeks of the pandemic in the US and Tennessee in 2020 using Joinpoint Regression Trend Analysis Software and provide the important insights into public health system surveillance and epidemic control measures.

Methods: Joinpoint regression modeling was used to evaluate weekly COVID-19 incidence rates experienced in the first 40 weeks of the pandemic. COVID-19 incidence rates over 40 weeks between the State of Tennessee and the United States were compared using data obtained from the Johns Hopkins University & Medicine Coronavirus Research Center.

Results: Evaluation of weekly trends comparing the crude incidence rates within Tennessee versus the United States reveal that there were significant historical shifts that occurred over time. The initial two months of the pandemic, the incidence rate in Tennessee was below the national rate before catching up in week 8. Beyond week 9, Tennessee rates remained above the national average through week 40. A sustained decrease in the rate, was observed from approximately week 18 through week 26.

Conclusions: Joinpoint regression analysis results offer important investigative insights into public health surveillance and epidemic control interventions. Our findings show that Tennessee COVID-19 case rates were below national rates for the first 8 weeks of the pandemic and in the 30 weeks that followed, the incident rate in Tenseness rose and remained above the national rate. There as a notable 8-week decrease in COVID-19 cases occurring between approximately week 18 and 26, which offers a critical window of insight into public health and ecological influences that may be attributed to this decline. While overall trends between Tennessee and the overall were similar over the course of the pandemic, Tennessee rates remained higher over the longer duration. Investigation into extraneous factors that may have contributed to the steady rise, and period of decline, are important to support intervention strategies that may have effectively curbed coronavirus spread, as well as into factors that may have catalyzed the collective 32 weeks associated with increased incidence rates across the State.

Keywords: joinpoint regression, COVID-19, incidence rates, pandemic, trends

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Todd R. Ashworth, MS,[1] Sheryl Strasser, PhD,[2] Billy Brooks, DrPH,[1] Shimin Zheng, PhD[1]

[1]Department of Biostatistics and Epidemiology, East Tennessee State University, Johnson City, TN 37614, USA
[2]Department of Health Policy & Behavioral Sciences, School of Public Health, Georgia State University, Atlanta, GA 30302, USA

Correspondence: Shimin Zheng, Department of Biostatistics and Epidemiology, East Tennessee State University, Johnson City, TN 37614, USA, Email ZHENS@mail.etsu.edu

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Introduction

COVID-19 is a virus where those infected may experience wide-ranging symptoms and severity. On 21st of January 2020 the first confirmed case of COVID-19 was reported in the US.[2] By 1st of January 2021 cases and deaths in the US had risen to 19,998,736 and 345,492, respectively.[3] On 5th of March 2020, the state of Tennessee reported their first case of COVID-19. From 5th of March 2020 through 1st of January 2021, Tennessee grew to 586,802 cases and 6,907 deaths.[3] On 13th of March 2020, a national emergency for COVID-19 was declared. By 30th of March 2020 more than half of States and territories issued stay-at-home advisories or mandatory stay-at-home orders. However, Tennessee waited until 31st of March 2020 to issue a stay-at-home and advisory and until 2nd of April 2020, to issue a mandatory stay-at-home order. The mandatory stay-at-home order in Tennessee ended by 30th of April, making it one of the last to issue the order and one of the first to end it. Further, Tennessee did not have a statewide mask mandate, instead that was issued by some local jurisdictions within the state.

Similar to the rest of the nation, Tennessee has seen fluctuations in incidence rates over several months appearing to coincide with various interventions and seasons. With these fluctuations a need has occurred to adequately track changes in trends in a relatively short amount of time. The ability to evaluate these changes can indicate the efficacy of particular interventions or indicate increases that may be a result of recent events. Appropriate evaluation of trends can aid in informing future mitigation strategies. Joinpoint regression has the capability of evaluating trends along a timeline. Further, joinpoint can identify changes in trends more quickly than other models allowing for rapid, well informed decision.

Joinpoint regression trend analysis can be used to evaluate annual trends in cancer and other diseases. More recently, Joinpoint regression analysis has been used to evaluate trends in COVID-19 and other infectious disease.[4–8] Viera De Souza et al. (2020) used jointpoint regression method to evaluate the trends in various regions in Brazil for the first 100 days. Khachfe, Chahrour, Sammouri Salhab, Makki, and Fares (2020) used joinpoint regression to evaluate COVID-19

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cases through March 14th, 2020.[7] In their conclusion, they discussed the interventions taken by China may have played a significant role in containing COVID-19 after the initial outbreak. Chien and Lin (2020) used joinpoint regression to evaluate mitigation strategies among 62 countries.[5] In that study, the authors found countries with better governance consistently had better outcomes. The purpose of this study is to evaluate weekly trends in the crude incidence rates in the US and Tennessee using Joinpoint Regression Trend Analysis Software.[9]

Methods

New COVID-19 cases for every state and Washington DC were obtained weekly from the Johns Hopkins University & Medicine Coronavirus Research Center.[3] COVID-19 case data were collected for 40 weeks beginning March 27th, 2020 through January 1st, 2021. New cases were calculated by subtracting the cumulative cases from the previous week. The 2019 five-year population estimates for each state and Washington DC were obtained from the United States Census Bureau.[10] The cases for each state and Washington DC were summed each week to determine the total cases in the US for that week.

Joinpoint Regression Trend Analysis Software detects changes in trends over time.[9] A detected change is marked by a point followed by a new segment. Changes in trends can be in either direction or in magnitude. A rate of change is calculated for each segment, which is tested to determine if it is significantly different. Each segment is also tested to determine if it is significantly different from the segment before. Using the Joinpoint Trend Analysis Software from the National Institute of Health, crude incidence rates for each week were calculated and evaluated for trends for the US and Tennessee respectively. The Tennessee joinpoint regression line was then compared to the US.

Results

The Joinpoint regression analysis (Figure 1) found three points in Tennessee, indicating three potential changes in trends over the 40-weeks. The three points create four individual segments, which independently evaluate trends over a specific time. Segment 1 covered weeks 1 to 18, starting with an incidence rate of 17.22 cases per 100,000 (noted as 17.22/100k) population in week 1 and ended at 277.2/100k. Segment 1 indicated a significant weekly increase of about 17.5% (p<.001, 95% CI: 13.7%, 21.4%). Segment 2 covered weeks 18 to 26. The week 26 incidence rate decreased to 132.97/100k. The incidence rate from week 18 to 26 was significantly decreasing about 8.2% weekly (p=.03, 95% CI: -15%, -.9%). Segment 3 spanned weeks 26 to 38. The incidence rate in week 38 increased to 957.72/100k, indicating a significant increase of about 17.4 percent weekly (p<.001, 95% CI: 14%, 20.9%). Segment four covered weeks 38 to 40. The incidence rate decreased to 600.73/100k. The average weekly decrease was about 10.5%, not significant. The insignificance was likely due to only 2 observations for the segment.

In the US, Joinpoint regression (Figure 2) found five points indicating six changes in COVID-19 incidence rate trends. Segment 1 spanned weeks 1 to 11. The week one incidence rate in the US was 53.3/100k population, and week 11 was 46.75/100k. The 3.31% decrease was not significant (p=.06, 95% CI: -6.6%, .1%), indicating the incidence rate remained stable. Segment 2 covered weeks 11 to 16. The incidence rate in week 16 increased to 142.83/100k, leading to a significant weakly increase of 25.6% (p<.001, 95% CI: 12.2%, 40.6%). Segment 3 consisted of weeks 16 to 27, ending with an incidence rate of 83.44/100k. The 5.8% weekly decrease was statistically significant (p<.001, 95% CI: -8.0%, -3.4%). Segment for included weeks 27 to 34. By week 34, the incidence rate increased to 363.13/100k. The weekly increase in segment 4 was significant at 24.6% (p<.001, 95% CI: 19.5%, 30.0%). Weeks 34 to 38 made up segment 5, where the incidence rate increased to 487.47/100k. Segment five indicates a reduction in the rate of increase to 8.7% weekly. Despite the reduction of the rate of increase, the increase was still significant (p=.04, 95% CI: .4%, 17.8%). The final segment (segment 6) contained weeks 34 to 38. The week 38 incidence rate decreased to 364.31/100k. The weekly decrease for segment 6 was 11.5% but was not significant (95% CI: -24.5%, 3.8%, p=.13,). Significance was likely not detected due to only three observations being present in the segment.

Figure 1 COVID-19 estimated incidence rate trends: Tennessee.

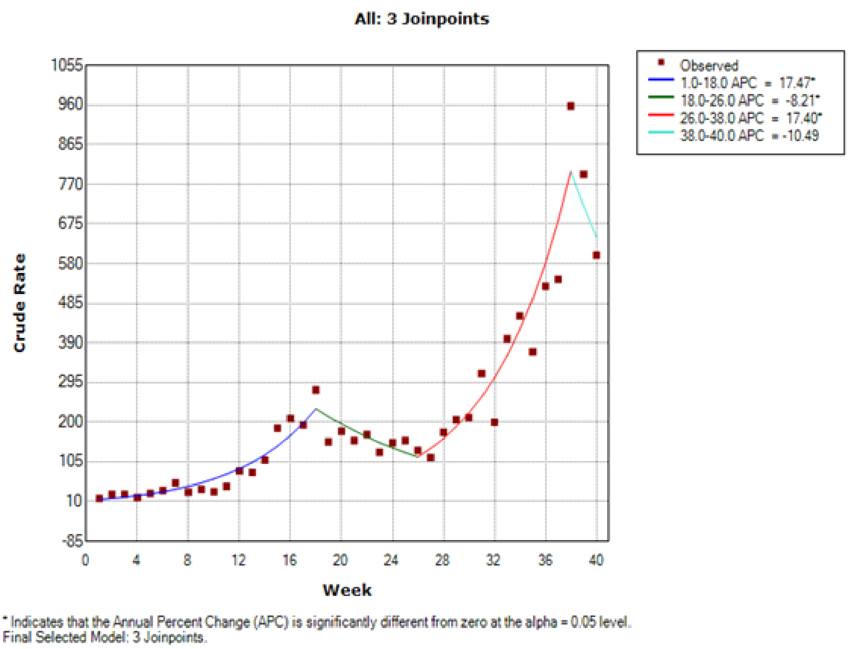

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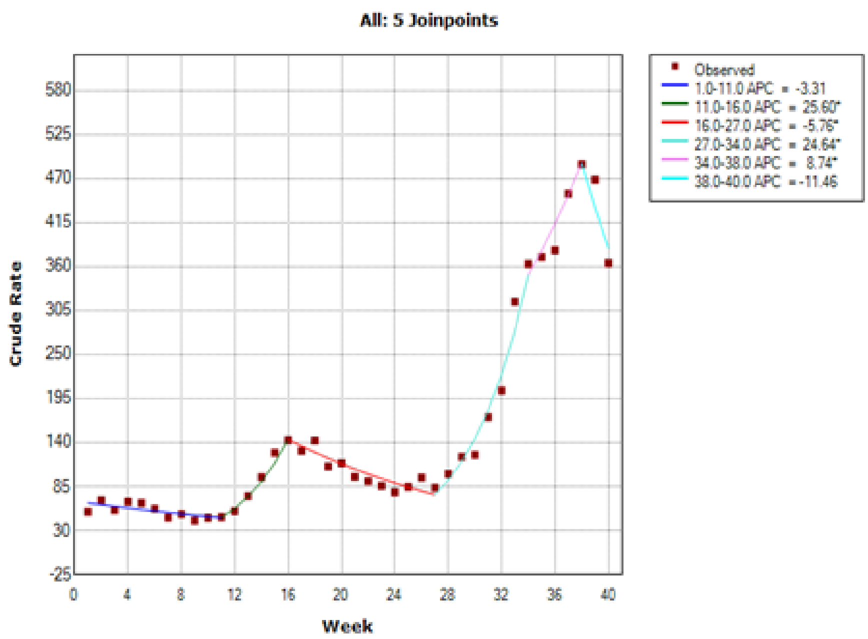
Figure 2 COVID-19 estimated incidence rate trends: United States.



* Indicates that the Annual Percent Change (APC) is significantly different from zero at the alpha = 0.05 level.
Final Selected Model: 5 Joinpoints.

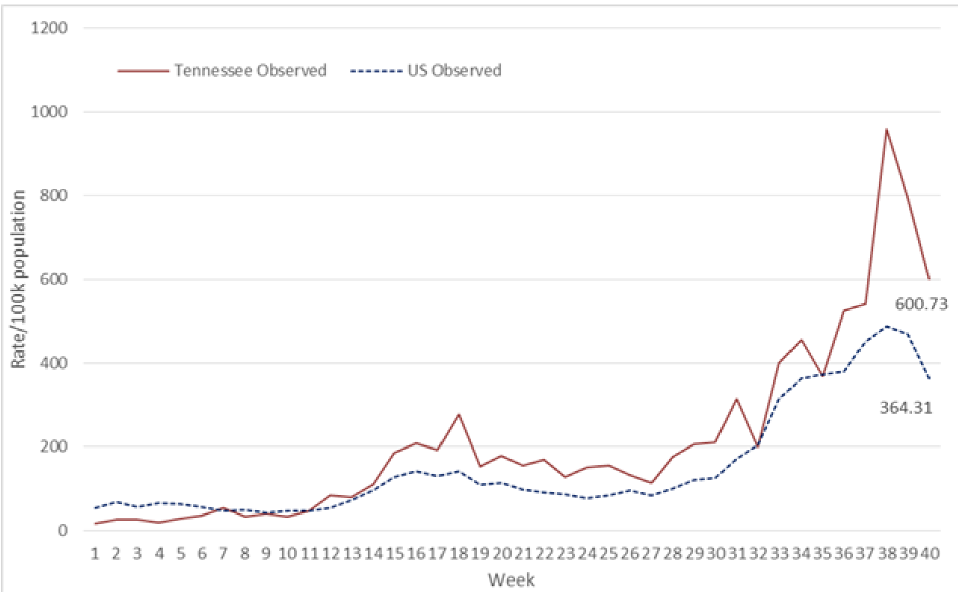
Data derived from the Johns Hopkins University Corona Virus Resource Center[3]

Data derived from the United States Census Bureau[10]

Comparison

The observed COVID-19 incidence rate in Tennessee was lower than in the US in weeks 1 through 10 (Figure 3). By week 12, the incidence rate in Tennessee surpassed the United States rate. From week 12 until week 35, the observed incidence rate appeared to remain slightly higher than the US. After week 35, Tennessee's incidence rate increased substantially to nearly double the incidence rate in the US.

Figure 3 COVID-19 Crude incidence rates: Tennessee and United States.



Data derived from the Johns Hopkins University Corona Virus Resource Center[3]

Data derived from the United States Census Bureau[10]

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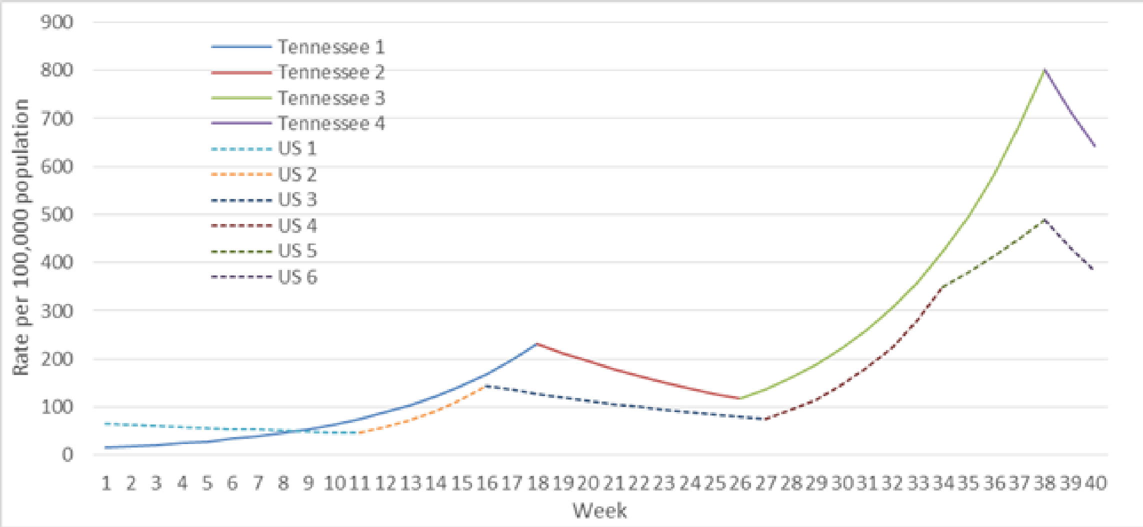
As indicated by the estimated incidence rates in Figure 4, incidence rate trends indicated that while the US remained stable, Tennessee increased until week 18. After week 18, trends closely mirrored that of the US until week 34. In week 34, the US's steep incline reduced while Tennessee maintained the same trajectory until week 38.

Figure 4 COVID-19 Estimated incidence rates trends: Tennessee and the United States.



Data derived from the Johns Hopkins University Corona Virus Resource Center[3]

Supplementary Table 1 Joinpoint regression model estimates: Tennessee

Model Statistics						
Number of Joinpoints	**Number of Observations**	**Number of Parameters**	**Degrees of Freedom**	**Sum of Squared Errors**	**Mean Squared Error**	**Autocorrelation Parameter**
3	40	8	32	19720.71	616.27	Uncorrelated
Estimated Joinpoints						
Joinpoint	**Estimate**		**Lower CI**		**Upper CI**	
1	18		14		20	
2	26		22		30	
3	38		37		38	
Estimated Regression Coefficients						
Standard Paramaterization						
Parameter	**Parameter Estimate**		**Standard Error**	**Test Statistic (t)**		**Prob > |t|**
Intercept 1	2.55		0.21	11.86		0
Slope 1	0.16		0.02	9.98		0
Slope 2 - Slope 1	-0.25		0.04	-6.07		0.000001
Slope 3 - Slope 2	0.25		0.04	6.17		0.000001
Slope 4 - Slope 3	-0.27		0.14	-2.01		0.05431
General Parameterization						
Parameter	**Parameter Estimate**		**Standard Error**	**Test Statistic (t)**		**Prob > |t|**
Intercept 1	2.55		0.21	11.86		0
Intercept 2	6.99		0.82	8.51		0
Intercept 3	0.59		0.48	1.25		0.22

Citation: Ashworth TR, Strasser S, Brooks B, et al. COVID-19 trends in Tennessee and the United States over 40 weeks. *Biom Biostat Int J.* 2021;10(2):59–66. DOI: 10.15406/bbij.2021.10.00331

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Table Continued...

General Parameterization				
Intercept 4	10.9	5.3	2.06	0.05
Slope 1	0.16	0.02	9.98	0
Slope 2	-0.09	0.04	-2.3	0.03
Slope 3	0.16	0.01	11.28	0
Slope 4	-0.11	0.13	-0.82	0.42

Supplementary Table 2 Joinpoint weekly percent change estimates: Tennessee

Weekly Percent Change (WPC)

Segment	Lower Endpoint	Upper Endpoint	WPC	Lower CI	Upper CI	Test Statistic (t)	Prob > |t|
1	1	18	17.5*	13.7	21.4	10	0
2	18	26	-8.2*	-15	-0.9	-2.3	0
3	26	38	17.4*	14	20.9	11.3	0
4	38	40	-10.5	-32	17.8	-0.8	0.4

*Indicates that the Weekly Percent Change (WPC) is significantly different from zero at the alpha = .05 level

Average Weekly Percent Change (AWPC)

Range	Lower Endpoint	Upper Endpoint	AWPC	Lower CI	Upper CI	Test Statistic~	P-Value~
Full Range	1	40	10.1*	7.3	13	7.3	0

*Indicates that the Weekly Percent Change (WPC) is significantly different from zero at the alpha = .05 level

Supplementary Table 3 Joinpoint regression model estimates: United States

Model Statistics

Number of Joinpoints	Number of Observations	Number of Parameters	Degrees of Freedom	Sum of Squared Errors	Mean Squared Error	Autocorrelation Parameter
5	40	12	28	122322.91	4368.68	Uncorrelated

Estimated JoInpoInts

JoInpoInt	Estimate	Lower CI	Uooer CI
1	11	8	13
2	16	14	18
3	27	22	30
4	34	28	35
5	38	33	38

Estimated Regression Coefficients

Standard Paramaterization

Parameter	Parameter Estimate	Standard	Test Stati sti c (t)	Prob > I t I
Intercept 1	4.2	0.1	42.23	0
Slope 1	-0.03	0.02	-1.99	0.058
Slope 2 - Slope 1	0.26	0.057	4.59	0.000131
Slope 3- Sl ope 2	-0.29	0.06	-5.IS	0.000032
Slope 4 - Sl ope 3	0.28	0.02	11.96	0
Slope 5- Sl ope 4	-0.14	0.04	-3.14	0.004618
Slope 6 - Sl ope 5	-0.21	0.09	-2.39	0.025493

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Table Continued...

General Parameterization					
Parameter		Parameter Estimate	Standard Error	Test Statistic (t)	Prob > I t I
Intercept 1		4.2	0.1	42.23	0
Intercept 2		1.32	0.76	1.75	0.09
Intercept 3		5.92	0.25	23.75	0
Intercept 4		-1.63	0.63	-2.58	0.01661
Intercept 5		3.01	1.39	2.17	0.040897
Intercept 6		10.82	3.03	3.57	0.001641
Slope 1	-0.03	-0.03	0.017	-1.99	0.058123
Slope 2	0.23	0.23	0.054	4.18	0.000357
Slope 3	-0.06	-0.06	0.01	-5.06	0.00004
Slope 4	0.22	0.22	0.02	10.89	0
Slope 5	0.08	0.08	0.04	2.18	0.040121
Slope 6	-0.12	-0.12	0.08	-1.58	0.127236

Supplementary Table 4 Joinpoint weekly percent change estimates: United States

Weekly Percent Change (WPC)							
Segment	Lower Endpoint	Upper Endpoint	WPC	Lower CI	Upper CI	Test Statistic (t)	Prob > |t|
1	1	11	-3.3	-6.6	0.1	-2	0.1
2	11	16	25.6*	12.2	40.6	4.2	0
3	16	27	-5.8*	-8	-3.4	-5.1	0
4	27	34	24.6*	19.5	30	10.9	0
5	34	38	8.7*	0.4	17.8	2.2	0
6	38	40	-11.5	-24.5	3.8	-1.6	0.1

*Indicates that the Weekly Percent Change (WPC) is significantly different from zero at the alpha = .05 level

Average Weekly Percent Change (AWPC)							
Range	Lower Endpoint	Upper Endpoint	AAPC	Lower CI	Upper CI	Test Statistic~	P-Value~
Full Range	1	40	4.7*	2.4	7	4.1	0

*Indicates that the Weekly Percent Change (WPC) is significantly different from zero at the alpha = .05 level

Discussion

The present analysis, based on weekly confirmed cases of COVID-19 within Tennessee, may suggest that national guidance restricting travel as well as social distancing, the use of personal masks and implementation of quarantine measures may have limited impact for residents. However, in week 9 and beyond, Tennessee's COVID-19 case rates surpassed the national incidence rate for the next 30 weeks. The results of our joinpoint regression models showcase inverse trends compared with other countries whereby national governments mandated lockdowns and universal social restrictions were associated with case incidence trend plateaus, stabilization, and decreases.[11-13] While this may stem from joinpoint regression modeling using weekly, versus daily COVID-19 positive case rates, cautious investigation into continually updated information about global epidemic control measures is imperative. To illustrate, an alternative explanation for the differences in Tennessee COVID-19 cases rates surpassing those of the national rate may be an artifact of increasing screening capabilities, access to testing, and inconsistent case reporting practices especially within the first 8 weeks of the pandemic. Therefore, it is plausible that COVID-19 case rates were underreported as scale up of testing occurred in the earlies weeks of the pandemic.

Further, research to support the efficacy of early disease transmission prevention behaviors to slow the spread, such as guidance on social distancing, surface sanitation, mask guidance, as well as quarantine parameters in relationship to their ability to 'flatten the curve', or contributing to a plateau effect on case surge, is variable and in some cases negligible.[14,15] As State governors had the latitude to establish COVID-19 prevention and control measures independent from national authorities, the extent county-level plans throughout Tennessee[16] aligned with White House and United States Centers for Disease Control COVID-19 guidance[17] is not well understood within the context of COVID-19 incidence trends.

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Future research would benefit from a more sophisticated analysis of geospatial trends related to COVID-19 transmission. Data suggested that early hotspots occurred in densely populated areas; whereas later stages of the pandemic outbreaks have tended to arise in small-scale more scattered outbreaks.[18] Given the geographic features of Tennessee, in which the Appalachian Mountains span the State, the rurality may play a major role in case incidence rate trends. According to US Census data from 2010, 93% of Tennessee's land area is classified as rural. Residents living in rural areas likely faced barriers to accessing testing and health care in the early period of the pandemic and this may account for Tennessee eclipsing the national case rate after the 2nd montha.[19]

In tandem with the rural setting of Tennessee, an ecological perspective may also yield insightful information for understanding COVID-19 spread that occurred in Tennessee. As a historically 'red' or majority Republican-voting State, this may bear implications on the public health and service net afforded to residents.[20] Findings indicate that in the first quarter of pandemic, Republican-led states (based on political affiliation of State governors) reported lower COVID-19 incidence rates compared to Democratic-led states; however, the association reversed within the month of June, 2020 and States with Republican governors observed higher incidence (RR=1.10, 95% PI=1.01, 1.18). The research team also noted that Republican-led states had higher test positivity rates starting on May 30 (RR=1.70, 95% PI=1.66, 1.73) and lower testing rates by September 30 (RR=0.95, 95% PI=0.90, 0.98).[21]

Investigating COVID-19 transmission dynamics that occurred within Tennessee would also benefit from a more comprehensive comparison across similar states in terms of socioeconomic, demographic, and indicators of health and wellbeing. To elaborate, according to the most recent ACS the median household income of Tennessee is $53,320 (41st out of 50) in year 2019, which trails the national median income.[22] Additionally, the population density in Tennessee was 158.8 people per square mile (26th out of 56) in year 2014.[23] In Tennessee, the largest ethnic group is Non-Hispanic White (77.58%), followed by Non-Hispanic African American (16.76%), Hispanic White (3.7%), those reporting two or more races (2.20%), and Non-Hispanic Asian (1.75%) among others.[24] Many factors can influence COVID-19 incidence rates. From Figures 3 and 4 it can be hypothesized that during the first 10 weeks of the COVID-19 pandemic, incidence rates in Tennessee were lower than the national rate perhaps due to the geographical features of Tennessee. The shift that occurred after the initial 10-week period, when Tennessee passed the national rate, may be due to economic rankings and the racial composition of State residents of Tennessee. Further, research evidence supports that the racial protests that followed the death of George Floyd may have impacted public health restrictive measures resulting in a a spike of COVID-19 cases.[25] While these events follow the timeframe of our analyses, this does not rule out local events that may have transpired within Tennessee, as well as growing sentiments of personal despair, depression, and tensions spurred by COVID-19 (recognized globally by public health officials as the *pandemic fatigue* phenomena) all which may be contextualized to explain the steady incidence rate observed starting in week 26 and ultimately peaking in week 38.[24,26]

Conclusion

Results from our joinpoint regression analysis indicate that Tennessee demonstrated a fairly steady increase of confirmed COVID-19 cases over 40 weeks, with a singular disruption in the trend occurring from week 18 through 26. The elevated incidence rate observed in Tennessee warrants additional investigation into variables that may bear potential impacts sustaining COVID-19 spread. These factors may include variability in local safety and social distancing mandates regarding testing, contact tracing, and quarantine practices. Further, subsequent research comparing Tennessee using regional comparisons, or comparisons with suitably matched states based on socioeconomic, demographic, economic indicators, and perhaps, noteworthy social events and political influences, would also provide more insights into COVID-19 infectious disease and death rates unfolding in Tennessee early in the COVID-19 pandemic.

Acknowledgments

None.

Conflicts of interest

None.

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