



Influenza and Pneumonia Mortality Across the 30 Biggest U.S. Cities: Assessment of Overall Trends and Racial Inequities

Julia F. Lippert¹ · Joanna Buscemi² · Nazia Saiyed³ · Abigail Silva⁴ · Maureen R. Benjamins³

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Abstract

Influenza and pneumonia account for substantial morbidity in the United States and show a demonstrated racial inequity. Detailed race-specific analysis at the city level can be used to guide targeted prevention efforts within the most at-risk communities. The purpose of this study is to analyze city-level data of influenza/pneumonia mortality rates and racial disparities across the 30 biggest U.S. cities over time. We assess racial inequities in influenza/pneumonia mortality in the 30 biggest cities and compare city-level trends overtime through age-adjusted overall and race-specific mortality rates calculated from public death records for the years 2008–2017. The national influenza/pneumonia mortality rate significantly decreased as did 45% of the cities included in the study. Nationally, the Black mortality rate was 16% higher than White mortality rate, and a significant disparity was seen within about one-third of the biggest cities. Over half (56%) of the cities showed reductions in both Black and White mortality; however, there was no overall trend in racial equity with some cities reducing the inequities between the Blacks and Whites and others increasing the inequities. Elevated mortality rates in communities of color can be traced to structural racism, social factors, and access to treatment and prevention services. We recommend an approach utilizing community outreach administered through localized public health organizations and supported by data at the city level.

Keywords Influenza · Pneumonia · Mortality · Racial inequities · Cities

Background

Together influenza and pneumonia account for substantial morbidity in the United States and are consistently within the top ten leading causes of death. In 2019, there were 39 million cases of influenza leading to 26 million medical visits, 740,000 hospitalizations, and 62,000 deaths [1]. Pneumonia leads to more than 1.3 million emergency room visits and approximately 50,000 deaths annually [1, 2]. Overall, these two conditions cost the United States \$34.7 billion in

outpatient visits, hospitalizations, and mortality each year for adults older than 65 years old alone [3].

Age-adjusted mortality rate from influenza and pneumonia has decreased 36% between 1999 and 2010 [4]. This reduction is attributed in part to targeting high risk populations for flu vaccine use and increases in vaccination rates over time, particularly in adults aged 65 and over [3]. Although flu vaccinations are the most effective way of preventing influenza and subsequently pneumonia disease and mortality, vaccination rates vary greatly [5, 6]. In particular, vaccination rates are lower in communities of color [7–9]. Furthermore, people of color are between 1.3 and 23 times more likely than Whites to have the underlying conditions that are associated with severe influenza infections and thus experience disproportionately high rates of poor health outcomes and mortality [10].

The local level trends in influenza and pneumonia mortality are more difficult to discern through available national and state-level data and would be made more apparent through city level data. The Centers for Disease Control and Prevention maintained a voluntary reporting system of influenza/pneumonia mortality rates for 122 cities until 2016 when the system was retired and replaced with the National Center for Health Statistics (NCHS) surveillance system [11].

✉ Julia F. Lippert
jlipper1@depaul.edu

¹ Department of Health Sciences, DePaul University, Chicago, IL 60614, USA

² Department of Clinical Psychology, DePaul University, Chicago, IL 60614, USA

³ Sinai Urban Health Institute, Chicago, IL 60608, USA

⁴ Department of Public Health Sciences, Loyola University Chicago, Maywood, IL 60153, USA

This data, although valuable in tracking the age distribution and mortality changes across cities over time, did not provide information on race to assess potential disparities. The NCHS system does provide race and ethnicity data but at the state and national levels [12].

It has been suggested that the use of more readily available county level data is not an appropriate proxy and that programs operating on the city level should be informed by city level data [13]. City-level surveillance systems are more effective at reporting timely influenza/pneumonia mortality data which can be used during outbreaks and provide practical applications for the development of public health measures [14]. Electronic medical claims data offers another source of city-level data on influenza; however, often are unable to provide race-specific rates [15]. Finally, working with the city as the unit of analysis and race-specific rates at the city level allows for a clear connection to policy that targets the most at risk populations and the structural determinants of health such as race and could help guide policies to address structural racism and health disparities [16].

The objective of this study is to address this gap in detailed city-level data that provides a measure of equity through race-specific rates by analyzing influenza/pneumonia mortality rates across the 30 biggest U.S. cities over two time periods: 2008–2012 and 2013–2017. We assess racial inequities in influenza/pneumonia mortality in these cities and compare city-level trends in mortality rates and inequities over time. These data can ultimately inform city-level opportunities to address influenza/pneumonia mortality and health inequities.

Methodology

Study Population

The 30 most populous cities were identified using 2013 U.S. Census Bureau data. County data was reported for the three cases in which the city and county governments had formed a consolidated city including Louisville/Jefferson County, KY, Nashville/Davidson County, TN, and Indianapolis/Marion County, IN. Data for Las Vegas has been removed from the results due to concerns related to unreliable death certificate data; specifically, deaths among some individuals who resided in unincorporated areas may have been misclassified as Las Vegas deaths. Mortality data was obtained from the National Vital Statistics System (NVSS) of the National Center for Health Statistics (NCHS). Mortality from these diseases is combined in the International Statistical Classification of Diseases and reported on death records. We used race-specific influenza/pneumonia mortality data for the years 2008–2017 at the national and city level and ICD-10 codes: J08-J19.

Study Measures

Age-adjusted overall and race-specific mortality rates were calculated for the United States and the 29 most populous cities. Five-year age-adjusted rates per 100,000 population were calculated using the year 2000 standard U.S. population. Five-year estimates were used to ensure sufficient deaths per city. If a population had less than 20 deaths from influenza/pneumonia for the overall, White, or Black population, it was excluded from the relevant analysis as the rates would be deemed unreliable [17]. Population data used as denominator data to calculate mortality rates was taken from the American Community Survey (ACS) 5-year estimates at the midpoint of the two time periods with 2010 population used in the time period from 2008–2012, known hereafter as T1, and 2015 population used in the time period from 2013–2017, known hereafter as T2.

Non-Hispanic Blacks are included within the Black population in the early ACS reports and race specific data is only available in the decennial census data. Therefore, we used the age-specific proportion of the Black population who was non-Hispanic from the 2010 U.S. Census to estimate the non-Hispanic Black population from the ACS data. Non-Hispanic White and all race population estimates were taken directly from the ACS, and these were used along with the non-Hispanic Black estimates to calculate race-specific mortality data. These population estimates were multiplied by five to estimate the population across the 5-year time periods of T1 and T2.

Health inequities between the Black and White populations were measured by the relative difference between mortality rates. Specifically, the inequity was calculated as a rate ratio of the Black mortality rate divided by the White rate.

Statistical Analysis

Confidence intervals were calculated for the race-specific mortality rates and Black:White rate ratios. To assess change in disparities over time, the percent difference in Black:White mortality rates at T1 and T2 were calculated and then a Z score was computed for the relative percent difference using the method described by Keppel et al [18]. The Z scores for race-specific percent difference from T1 to T2 were calculated to assess race-specific trends over time. Z-scores with an absolute value of 1.96 or greater were considered statistically significant at the 0.05 level. All analyses were conducted using SAS 9.4. Data were collected and synthesized, statistical analysis was performed, and results were obtained in 2020. This study was reviewed by the Sinai Health System Institutional Review Board (MSH #18-40) and did not require full review because it uses publicly available, deidentified data.

Results

The influenza/pneumonia mortality rate (per 100,000 persons) in the U.S. was 16.6 in T1 and 15.5 in T2 showing a significant downward trend (Table 1). At both T1 and T2, New York, NY had the highest influenza/pneumonia mortality rate overall with 29.1 and 24.7 deaths per 100,000 persons, respectively. Seattle, WA had the lowest mortality rate at T1 with 10.4 deaths per 100,000 persons and El Paso, TX had the lowest mortality rate at T2 with 9.3 deaths per 100,000 persons. There were 13 cities with a statistically significant decrease in influenza/pneumonia mortality rates from T1 to T2

and no cities that experienced a statistically significant increase in influenza/pneumonia mortality rates between T1 and T2. There was a significant Black:White disparity nationally at both T1 (RR=1.16; CI_{95%}: 1.15–1.18) and T2 (RR=1.14; CI_{95%}: 1.12–1.15). This disparity significantly decreased from T1 to T2 ($p<0.05$).

At the city level, the Black:White disparity was statistically significant in 10 cities during T1 and 9 during T2 (Fig. 1). In addition, the Black mortality rate in T2 was actually lower than the White rate (RR=0.65; CI_{95%}: 0.50–0.86) for the city of Boston. The city with the highest Black:White disparity was Washington, DC during both T1 (RR=1.73; CI_{95%}:

Table 1 Influenza/pneumonia mortality and disparity data including time trends

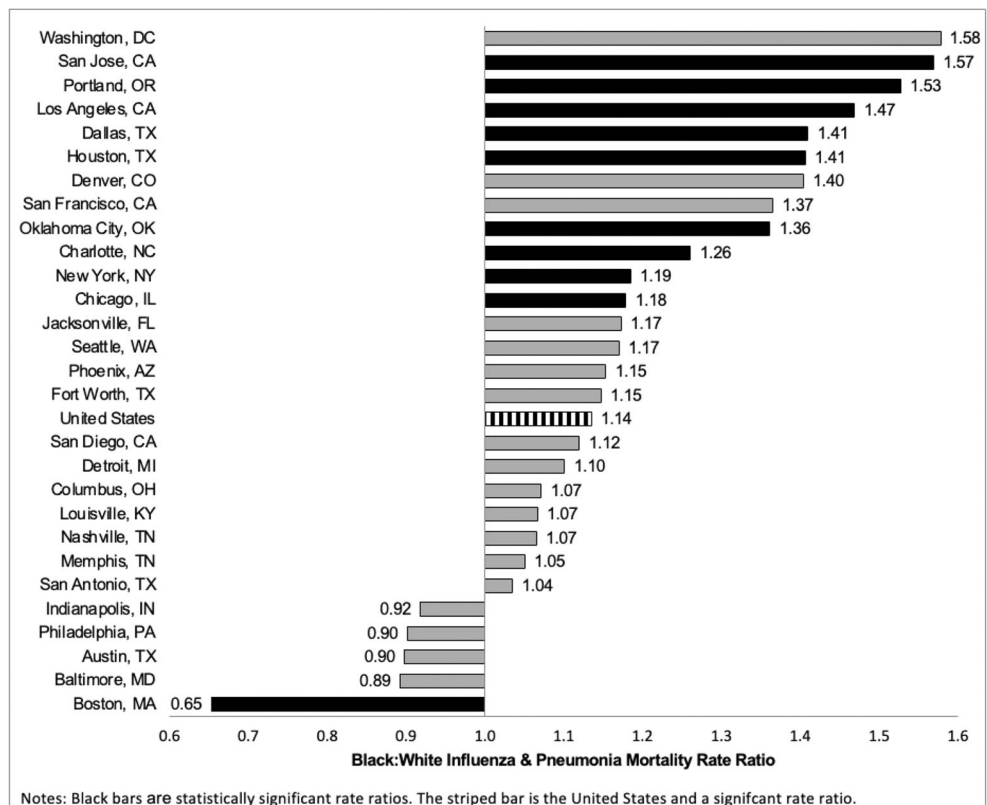
City, state	2008–2012 (T1)				2013–2017 (T2)				Change in total rate (T1–T2) ^a	Change in disparity (T1–T2) ^b
	Total rate	Black rate	White rate	Rate ratio	Total rate	Black rate	White rate	Rate ratio		
<i>United States</i>	16.55	19.02	16.33	1.16	15.49	17.53	15.44	1.14	*	*
Austin, TX	10.84	9.34	11.07	0.84	11.45	10.31	11.46	0.90		
Baltimore, MD	23.13	22.57	24.73	0.91	22.31	21.71	24.31	0.89		
Boston, MA	16.26	13.77	18.82	0.73	13.28	10.45	16.00	0.65	*	
Charlotte, NC	14.88	15.06	15.19	0.99	15.49	18.26	14.47	1.26		
Chicago, IL	20.58	23.81	19.47	1.22	17.51	20.25	17.17	1.18	*	
Columbus, OH	21.15	16.79	22.82	0.74	20.32	22.06	20.58	1.07		*
Dallas, TX	13.84	16.22	12.44	1.30	13.74	17.26	12.24	1.41		
Denver, CO	16.19	15.22	15.44	0.99	12.54	16.97	12.08	1.40	*	
Detroit, MI	18.65	19.07	18.63	1.02	20.08	20.56	18.67	1.10		
El Paso, TX	10.42	7.93	11.35	0.70	9.28	–	10.36	–		
Fort Worth, TX	16.35	16.02	16.40	0.98	13.00	14.68	12.79	1.15	*	
Houston, TX	16.73	21.00	14.55	1.44	16.39	20.00	14.22	1.41		
Indianapolis, IN	16.03	13.77	16.70	0.82	12.57	13.38	14.57	0.92	*	
Jacksonville, FL	18.84	21.90	18.46	1.19	16.99	20.03	17.07	1.17		
Los Angeles, CA	25.17	38.79	23.25	1.67	22.47	30.78	20.95	1.47	*	*
Louisville, KY	16.95	18.28	17.02	1.07	17.49	24.20	22.68	1.07		
Memphis, TN	20.13	22.93	17.54	1.31	19.62	20.35	19.36	1.05		
Nashville, TN	15.97	15.15	16.58	0.91	16.63	18.54	17.39	1.07		
New York, NY	29.05	31.43	27.80	1.13	24.68	27.40	23.11	1.19	*	
Oklahoma City, OK	17.60	12.04	18.76	0.64	11.68	15.22	11.17	1.36	*	*
Philadelphia, PA	15.29	16.08	15.45	1.04	14.67	13.79	15.28	0.90		
Phoenix, AZ	12.46	16.57	11.58	1.43	9.70	10.93	9.47	1.15	*	
Portland, OR	11.84	8.34	12.17	0.69	12.26	18.48	12.10	1.53		*
San Antonio, TX	14.83	23.56	14.59	1.61	12.27	13.16	12.71	1.04	*	*
San Diego, CA	10.95	11.46	10.53	1.09	10.56	11.51	10.27	1.12		
San Francisco, CA	17.13	23.80	17.26	1.38	12.03	16.22	11.87	1.37	*	
San Jose, CA	17.39	16.43	18.85	0.87	12.42	21.25	13.54	1.57	*	
Seattle, WA	10.38	13.13	9.67	1.36	9.57	10.85	9.27	1.17		
Washington, DC	13.99	16.84	9.73	1.73	12.97	15.14	9.59	1.58		

^a Significant at $p<0.05$ based on Z scores for change in total mortality rate between time periods

^b Significant at $p<0.05$ based on Z scores for change in relative percent difference between time periods

Bolded rate ratios are significant at $p<0.05$ based on a 95% confidence interval in total rate ratio between Black and White

Fig. 1 Influenza/pneumonia mortality rate Black:White ratios in 2013–2017 (T2)



1.36, 2.20) and T2 (RR=1.58; CI_{95%}: 1.24, 2.01). Columbus, OH had the lowest disparity during T1 (RR=0.74; CI_{95%}: 0.60, 0.91) and Boston, MA during T2 (RR=0.65; CI_{95%}: 0.50, 0.86).

Between T1 and T2, there was no overall trend upwards or downwards in racial equity with some cities reducing the disparities between the Blacks and Whites and others increasing the disparities as seen in Fig. 2. Nationally, the racial disparity in influenza/pneumonia mortality decreased significantly but only slightly from 1.16 to 1.14. There were only five cities that had significant changes in the Black:White rate ratios from T1 to T2. Three cities went from higher rates in Whites to higher rates in Blacks: Columbus, OH increased in disparity from 0.74 to 1.07, Oklahoma City, OK increased from 0.64 to 1.36, and Portland, OR increased from 0.69 to 1.53. Los Angeles, CA and San Antonio, TX significantly lessened the disparity from a Black:White rate ratio of 1.67 to 1.34 and from 1.61 to 1.04, respectively.

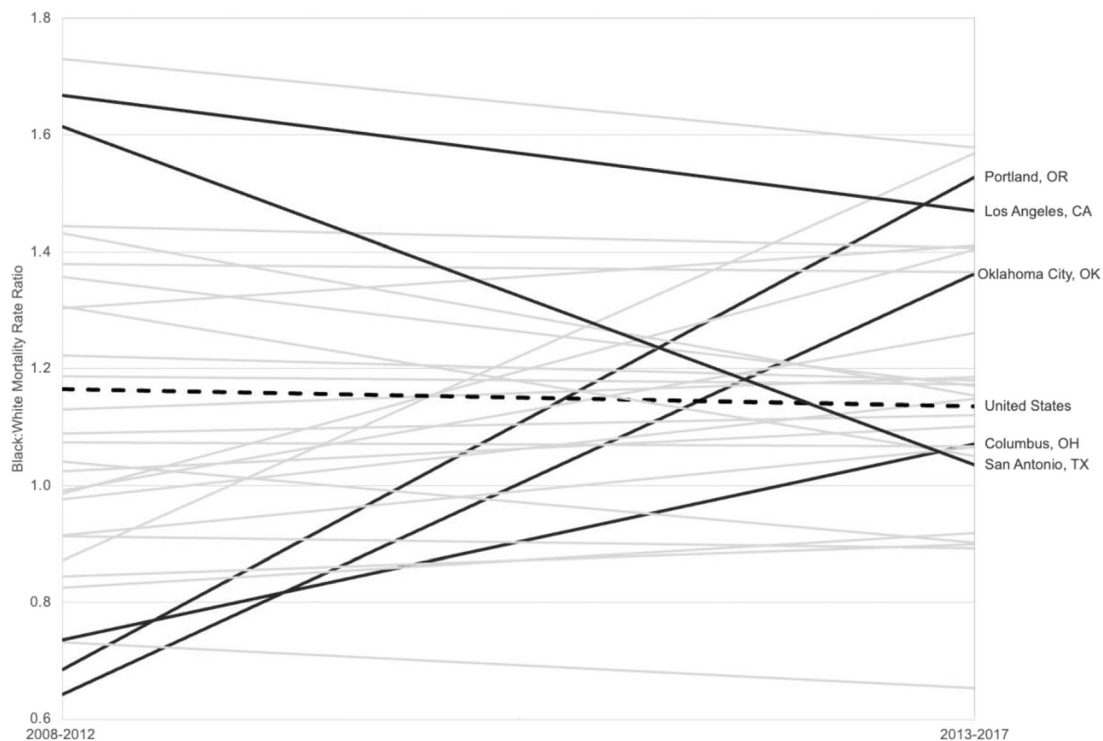
To facilitate an assessment of race-specific improvement over time, cities were plotted according to the percent change in Black and White influenza/pneumonia mortality rates from T1 to T2 as seen in Fig. 3. The horizontal dotted line demarks no change with markers falling to the left of the line indicating a negative change in percentage or decreasing mortality and those to the right of the line indicating a positive change or increasing mortality. The line connecting the Black and White markers for each city indicates the gap between the race-

specific changes. Cities are displayed according to the size of this gap. Three cities (San Jose, CA, El Paso, TX, and Portland, OR) were included but did not have Black mortality data in time T1 and thus change in percentage was unavailable.

The figure shows that in the U.S., both Black and White mortality rates have decreased and the gap between Black and White mortality percent decrease is relatively small. Over half, or 15 cities showed reductions in both Black and White mortality. Four cities showed increased mortality among both Blacks and Whites including Louisville, KY, Austin, TX, Detroit, MI, and Nashville, TN. Five cities had increasing rates in Black mortality but decreasing White mortality, the largest gap in Oklahoma City, OK. Memphis, TN showed the opposite trend with decreased Black mortality and increased White mortality and an improvement gap that favored Blacks of 22%.

Discussion

Although influenza/pneumonia mortality rates are trending downward over time, city-level analyses reveal a persistent Black:White inequity in these rates. Specifically, we found a significant decrease ($p < 0.05$) in influenza/pneumonia mortality nationally and in about half of the most populous cities. Nationally, the Black mortality rate was 16% higher than



Note: Only cities with significant change in disparities are highlighted.

Fig. 2 Change in rate ratios from 2008–2012 (T1) to 2013–2017 (T2)

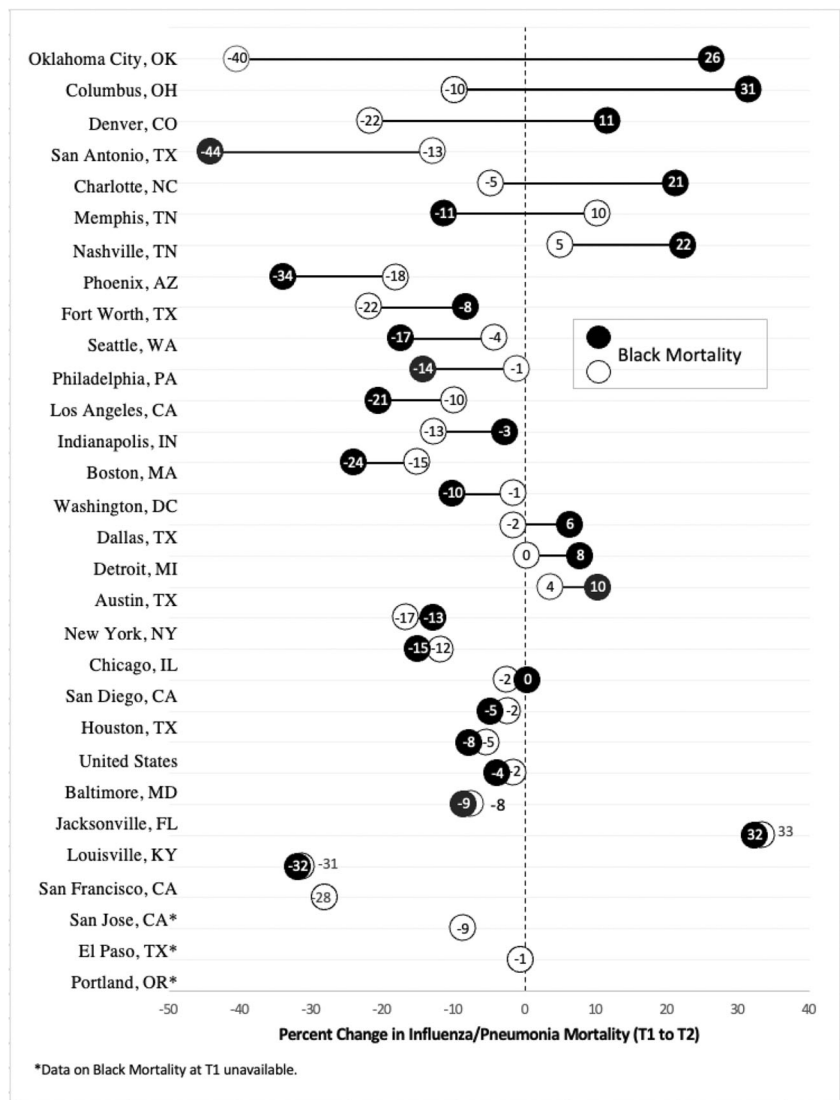
White mortality rate in 2013–2017 and a significant disparity was seen within about one-third of the biggest cities. This Black:White disparity is generally improving over time, but not in all cities. More than half of the cities had Black:White disparity above the national level. Finally, although many cities are moving toward improved mortality rates and decreased racial disparities, there are many big cities that would benefit from targeted interventions to address higher than average influenza/pneumonia mortality inequity.

A long, but quickly growing, body of evidence reveals that elevated mortality rates in communities of color can be traced to structural racism [19–21]. Structural racism can be described as the historical and current day laws, practices, institutions, and norms that create and maintain inequities [22]. In recognition of the role of racism in perpetuating social and health inequities, over twenty cities and counties such as Los Angeles, CA, Chicago, IL, Denver, CO, and Memphis, TN have declared racism to be a public health crisis and call for racial equity and justice in the distribution of resources to alleviate this uneven burden [23]. Given the historical context of racial inequalities in the United States, it is not surprising that the disparity within influenza/pneumonia mortality rates has persisted over time. For example, during the 1918 influenza pandemic, Blacks experienced excess deaths, higher mortality, and higher case fatality rates than Whites [24, 25].

Although the current study focused on specifically on documenting racial inequities in influenza/pneumonia

mortality rates, it is important to discuss the social factors reported in the literature that could be contributing to these mortality disparities. In particular, inequities in structural factors such as access to health care services, lack of workplace benefits and paid sick leave, neighborhood disadvantage, crowded housing, and socioeconomic status all are related to influenza/pneumonia mortality rates [26–29]. Perhaps most importantly, studies document racial differences in access to treatment and prevention services. Mortality rates from pneumonia were higher for Black patients than White patients treated in the same hospital because of a difference in treatment options such as receiving antibiotics and oxygenation within the recommended time [30]. The National Health Interview Survey showed that Black and Hispanic respondents were vaccinated at lower rates with 39% of Black respondents, 37% of Hispanic respondents, and 48% of White respondents receiving the influenza vaccination [31]. This difference has been linked to risk perception with significant differences reported between how Whites and Blacks perceive the risk associated with vaccinations and to providers failing to offer vaccinations to minority patients. This difference is also attributed to a distrust of the medical community with Black communities and the belief that vaccines have side effects [32–36]. More specifically, a study in Chicago, IL found that confidence and trust in a provider had the strongest impact on the likelihood of getting a vaccination in Blacks and high trust resulted in a 25% increase in the likelihood [37].

Fig. 3 Percent change in Black and White influenza and pneumonia mortality rates between T1 (2008–2012) and T2 (2013–2017)



The city-level differences in mortality and inequity seen here may be explained by the underlying social determinants of health. This then indicates the need for a solutions based approach that addresses systemic racism and risk perceptions which can work to reduce disparity in large urban settings [38]. For example, one study highlighted striking Black:White disparities in breast cancer mortality at the city level [39]. These data led to the creation of the Metropolitan Chicago Breast Cancer Task Force which developed a targeted response to the disparity in breast cancer mortality and resulted in a lowering of the mortality rates within Black women in Chicago [40]. City programs have also been successful in reducing influenza/pneumonia mortality over time. Delivery of medical interventions and vaccinations through city-level services such as health centers can reduce the racial disparity in vaccination rates and influenza-attributable mortality [41, 42]. The Metro Health Immunization Program in San Antonio, TX and the Immunization Coalition of Los

Angeles, CA are two such programs focused on improving vaccination rates and limiting the spread of disease within populations that are most at risk for under-immunization. The success of this programming relies on the use of disparity data and the mobilization of city-level resources [43, 44]. Interventions to combat influenza/pneumonia mortality and the associated racial disparities should focus on increasing vaccination distribution programming and decreasing barriers to vaccinations.

However, vaccine hesitancy is on the rise and will impact our ability to face current and future pandemics. The COVID-19 pandemic shares many of the same characteristics as influenza/pneumonia mortality. In preliminary data, Blacks are 2.57 more likely to die from COVID-19 than Whites [45]. The higher Black mortality rates from COVID-19 are similar to influenza/pneumonia mortality patterns, with social and structural underlying causes contributing to higher disease rates and differential access to and quality of care for people of

color [46, 47]. Long-term efforts to combat COVID-19 are predicated on the development and distribution of an effective vaccine. As with influenza, vaccination hesitancy could complicate the public health response [48]. Recent polling showed that 49% of Black respondents agreed with the statement that ‘the dangers of vaccines are being hidden by the medical establishment’ compared to 25% of White respondents and 42% of Black respondents thought that COVID-19 ‘is being used to force a dangerous and unnecessary vaccine on Americans’ as compared to 22% of White respondents [49]. This along with the aforementioned structural impediments to vaccine distribution and infectious disease control will reduce the effectiveness of efforts to address the COVID-19 pandemic. We recommend an approach similar to the successful campaigns that have reduced influenza/pneumonia mortality and racial disparities with community outreach administered through localized public health organizations and supported by data at the city level.

Limitations

There are several limitations to this study. For one, although there are multiple etiologies for influenza and pneumonia, mortality from both are combined under one code in the International Statistical Classification of Diseases. This may cause discrepancies between the provisional and final death counts which, although unwarranted, has called into question the validity of the influenza/pneumonia mortality surveillance data [50]. This is, however, the best available data, and thus we have provided the most accurate analysis possible. It is also important to note that there is a systematic under-detection of influenza due to differential testing requirements as older individuals are often not tested [51]. Another limitation is that our data were analyzed in aggregate 5-year periods due to the relatively low number of influenza/pneumonia deaths in each city. Although a year-to-year analysis would have been more informative, our analysis including the racial disparity would not have been possible for all years and in all cities. In the future, pooled time-series data is suggested to obtain annual mortality estimates.

This study focused on mortality difference between Blacks and Whites although disparities exist within other racial groups. We focused specifically on Black:White inequities given that the level of disparity between these two racial populations is among the highest and the small number of deaths within different subpopulations would have limited our analysis as we were unable to fully analyze inequities in other groups. In addition, we chose to analyze only race as a social determinant of health. This intentional focus was done to highlight the racial disparities within infectious disease. This, however, limits the scope of our findings to racial disparities and excludes discussion of other underlying contributing factors such as socioeconomic factors. Future research

should focus on influenza and pneumonia mortality inequities among other racial or ethnic groups, particularly across cities with large Hispanic or Asian populations. Finally, we recognize that there are numerous ways to quantify inequities [52]. We examined both rate ratios (a relative measure) and rate differences (an absolute measure), but only included rate ratios because the trends were so similar.

Conclusion

Influenza/pneumonia mortality is a leading cause of death in the United States and shows persistent racial disparities in the biggest cities. Despite improvements, when examined at the city level, it is clear that efforts to reduce mortality rates and disparities in mortality rates have not been universally successful across these cities. These findings point to the need for city-level policies and programs that increase access to vaccinations and an equitable approach to addressing influenza/pneumonia mortality.

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Author Contributions Dr. Lippert, the corresponding author was responsible for writing the original draft, review, and editing, data visualization, supervision, and project administration. Dr. Buscemi assisted in writing and the review and editing phases. Ms. Saiyed curated and collected the data for secondary analysis and formal analysis. Dr. Silva assisted in writing and the review and editing phases as well as conceptualization and methodology. Dr. Benjamins was responsible for the original conceptualization and methodology as well as assisted in writing in the review and editing phases.

Data availability More information on the data, methodology, and study materials are available upon request to the corresponding author.

Declarations

Conflicts of interest/Competing interests Authors do not have a commercial or other association that might pose a conflict of interest. No financial disclosures were reported by the authors of this paper.

References

- Centers for Disease Control and Prevention. Deaths: final data for 2017. *Natl Vital Stat Rep.* 2019;68(9). https://www.cdc.gov/nchs/data/nvsr/nvsr68/nvsr68_09_tables-508.pdf
- Rui P, Kang K. National Hospital Ambulatory Medical Care Survey: 2017 emergency department summary tables. *National Center for Health Statistics*; 2017. https://www.cdc.gov/nchs/data/nhamcs/web_tables/2017_ed_web_tables-508.pdf.
- Rothman T. The cost of influenza disease burden in U.S. population. *Int J Econ Manag Sci.* 2017;06(04). <https://doi.org/10.4172/2162-6359.1000443>.

4. Chang M-H, Moonesinghe R, Athar HM, Truman BI. Trends in Disparity by Sex and Race/Ethnicity for the Leading Causes of Death in the United States—1999–2010. *J Public Health Manag Pract.* 2016;22:S13–24. <https://doi.org/10.1097/PHH.0000000000000267>.
5. Grohskopf LA. Prevention and control of seasonal influenza with vaccines: recommendations of the Advisory Committee on Immunization Practices—United States, 2019–20 *Influenza Season.* *MMWR Recomm Rep.* 2019;68. <https://doi.org/10.15585/mmwr.r6803a1>.
6. Nagata JM, Hernández-Ramos I, Kurup AS, Albrecht D, Vivas-Torrealba C, Franco-Paredes C. Social determinants of health and seasonal influenza vaccination in adults ≥ 65 years: a systematic review of qualitative and quantitative data. *BMC Public Health.* 2013;13(1):388. <https://doi.org/10.1186/1471-2458-13-388>.
7. Li Y, Mukamel DB. Racial disparities in receipt of influenza and pneumococcus vaccinations among US nursing-home residents. *Am J Public Health.* 2010;100(S1):S256–62. <https://doi.org/10.2105/AJPH.2009.173468>.
8. National Center for Health Statistics. Selected estimates based on data from the National Health Interview Survey. Published January 14, 2020. <https://www.cdc.gov/nchs/nhis/erkeyindicators.htm>. Accessed 22 April 2020.
9. Strully KW. Health care segregation and race disparities in infectious disease: the case of nursing homes and seasonal influenza vaccinations. *J Health Soc Behav.* 2011;52(4):510–26.
10. Hutchins SS, Fiscella K, Levine RS, Ompad DC, McDonald M. Protection of racial/ethnic minority populations during an influenza pandemic. *Am J Public Health.* 2009;99(Suppl 2):S261–70. <https://doi.org/10.2105/AJPH.2009.161505>.
11. Centers for Disease Control and Prevention. Notice to readers: update to reporting of pneumonia and influenza mortality. 2016. <https://www.cdc.gov/mmwr/volumes/65/wr/mm6539a8.htm>. Accessed 1 Sept 2020
12. Centers for Disease Control and Prevention. ICD-10-CM. [icd10cmtool.cdc.gov](https://icd10cmtool.cdc.gov/?fy=FY2019). Published April 1, 2020. <https://icd10cmtool.cdc.gov/?fy=FY2019>. Accessed 20 Apr 2020.
13. Spoer BR, Feldman JM, Gofine ML, Levine SE, Wilson AR, Breslin SB, et al. Health and health determinant metrics for cities: a comparison of county and city-level data. *Prev Chronic Dis.* 2020; E137;17. <https://doi.org/10.5888/pcd17.200125>.
14. Simonsen L, Clarke MJ, Stroup DF, Williamson GD, Arden NH, Cox NJ. A method for timely assessment of influenza-associated mortality in the United States. *Epidemiology.* 1997;8(4):390–5.
15. Viboud C, Charu V, Olson D, et al. Demonstrating the use of high-volume electronic medical claims data to monitor local and regional influenza activity in the US. Goldstein E, ed. *PLoS ONE.* 2014;9(7):e102429. <https://doi.org/10.1371/journal.pone.0102429>.
16. Riley AR. Neighborhood disadvantage, residential segregation, and beyond—lessons for studying structural racism and health. *J Racial Ethn Health Disparities.* 2018;5(2):357–65. <https://doi.org/10.1007/s40615-017-0378-5>.
17. Kochanek K, Murphy S, Xu J, Arias E. Deaths: final data for 2017. *Natl Vital Stat Rep.* 2019;68(9).
18. Keppel KG, Percy JN, Klein RJ. Measuring progress in Healthy People 2010. *Healthy People 2010 Stat Notes Cent Dis Control Prev Cent Health Stat.* 2004;(25):1-16.
19. Bailey JJ, McCollough MA. Emotional labor and the difficult customer: coping strategies of service agents and... *J Prof Serv Mark.* 2000;20(2):51. https://doi.org/10.1300/J090v20n02_05.
20. Gee GC, Ford CL. Structural racism and health inequities. *Bois Rev Soc Sci Res Race.* 2011;8(1):115–32. <https://doi.org/10.1017/S1742058X11000130>.
21. DuBois WEB. The health and physique of the Negro American. *Am J Public Health.* 2003;93(2):272–6.
22. Bailey ZD, Feldman JM, Bassett MT. How structural racism works—racist policies as a root cause of U.S. racial health inequities. *N Engl J Med.* 2021;384(8):768–73. <https://doi.org/10.1056/NEJMs2025396>.
23. American Public Health Association. Declarations of racism as a public health issue. www.apha.org. Published 2020. <https://www.apha.org/topics-and-issues/health-equity/racism-and-health/racism-declarations>. Accessed 16 July 2020.
24. Acuna-Soto R, Viboud C, Chowell G. Influenza and pneumonia mortality in 66 large cities in the United States in years surrounding the 1918 pandemic. *PLoS ONE.* 2011;6(8). <https://doi.org/10.1371/journal.pone.0023467>.
25. Økland H, Mamelund S-E. Race and 1918 influenza pandemic in the United States: a review of the literature. *Int J Environ Res Public Health.* 2019;16(14):2487. <https://doi.org/10.3390/ijerph16142487>.
26. Cordoba E, Aiello AE. Social determinants of influenza illness and outbreaks in the United States. *N C Med J.* 2016;77(5):341–5. <https://doi.org/10.18043/ncm.77.5.341>.
27. Crighton EJ, Elliott SJ, Moineddin R, Kanaroglou P, Upshur R. A spatial analysis of the determinants of pneumonia and influenza hospitalizations in Ontario (1992–2001). *Soc Sci Med.* 2007;64(8):1636–50. <https://doi.org/10.1016/j.socscimed.2006.12.001>.
28. Kamal KM, Madhavan SS, Amonkar MM. Determinants of adult influenza and pneumonia immunization rates. *J Am Pharm Assoc.* 2003;43(3):403–11. <https://doi.org/10.1331/154434503321831120>.
29. Semenza JC, Suk JE, Tsovala S. Social determinants of infectious diseases: a public health priority. *Eurosurveillance.* 2010;15(27):19608. <https://doi.org/10.2807/ese.15.27.19608-en>.
30. Hausmann LRM, Ibrahim SA, Mehrotra A, Nsa W, Bratzler DW, Mor MK, et al. Racial and ethnic disparities in pneumonia treatment and mortality. *Med Care.* 2009;47(9):1009–17. <https://doi.org/10.1097/MLR.0b013e3181a80fd6>.
31. Mei-Chuan H, Williams W, Peng-Jun L, Woods L, Koppaka R, Lindley M. Vaccination coverage among adults in the United States, National Health Interview Survey, 2017; 2019. <https://www.cdc.gov/vaccines/imz-managers/coverage/adultvaxview/pubs-resources/NHIS-2017.html>. Accessed 17 Dec 2020.
32. Cai S, Feng Z, Fennell ML, Mor V. Despite small improvement, Black nursing home residents remain less likely than Whites to receive flu vaccine. *Health Aff (Millwood).* 2011;30(10):1939–46. <https://doi.org/10.1377/hlthaff.2011.0029>.
33. Chi R-C, Neuzil KM. The association of sociodemographic factors and patient attitudes on influenza vaccination rates in older persons. *Am J Med Sci.* 2004;327(3):113–7. <https://doi.org/10.1097/0000441-200403000-00001>.
34. Freimuth VS, Jamison A, Hancock G, Musa D, Hilyard K, Quinn SC. The role of risk perception in flu vaccine behavior among African American and White adults in the US. *Risk Anal Off Publ Soc Risk Anal.* 2017;37(11):2150–63. <https://doi.org/10.1111/risa.12790>.
35. Hebert PL, Frick KD, Kane RL, McBean AM. The causes of racial and ethnic differences in influenza vaccination rates among elderly Medicare beneficiaries. *Health Serv Res.* 2005;40(2):517–37. <https://doi.org/10.1111/j.1475-6773.2005.00370.x>.
36. Wooten KG, Wortley PM, Singleton JA, Euler GL. Perceptions matter: beliefs about influenza vaccine and vaccination behavior among elderly white, black and Hispanic Americans. *Vaccine.* 2012;30(48):6927–34. <https://doi.org/10.1016/j.vaccine.2012.08.036>.
37. Hughes MM, Saiyed NS, Chen TS. Local-level adult influenza and pneumococcal vaccination disparities: Chicago, Illinois, 2015–2016. *Am J Public Health.* 2018;108(4):517–23. <https://doi.org/10.2105/AJPH.2017.304257>.

38. Metz J, Maybank A, Maio FD. Responding to the COVID-19 pandemic: the need for a structurally competent health care system. *JAMA*. Published online June 4, 2020. <https://doi.org/10.1001/jama.2020.9289>.
39. Sighoko D, Murphy AM, Irizarry B, Rauscher G, Ferrans C, Ansell D. Changes in the racial disparity in breast cancer mortality in the ten US cities with the largest African American populations from 1999 to 2013: The reduction in breast cancer mortality disparity in Chicago. *Cancer Causes Control*. 2017;28(6):563–8. <https://doi.org/10.1007/s10552-017-0878-y>.
40. Metropolitan Chicago Breast Cancer Task Force. Metropolitan Chicago Breast Cancer Task Force. [Chicagobreastcancer.org](http://www.chicagobreastcancer.org). Published 2020. <http://www.chicagobreastcancer.org/>. Accessed 10 July 2020.
41. Antunes JLF, Waldman EA, Borrell C, Paiva TM. Effectiveness of influenza vaccination and its impact on health inequalities. *Int J Epidemiol*. 2007;36(6):1319–26. <https://doi.org/10.1093/ije/dym208>.
42. Nowalk MP, Zimmerman RK, Tabbarah M, Raymund M, Jewell IK. Determinants of adult vaccination at inner-city health centers: a descriptive study. *BMC Fam Pract*. 2006;7(2).
43. City of San Antonio. Immunization program. [sanantonio.gov](https://www.sanantonio.gov/Health/HealthServices/Immunizations). Published 2020. <https://www.sanantonio.gov/Health/HealthServices/Immunizations>. Accessed 17 July 2020.
44. County of Los Angeles Public Health. Immunization Coalition of Los Angeles County. [publichealth.lacounty.gov](http://publichealth.lacounty.gov/ip/ICLAC/index.htm). Published 2020. <http://publichealth.lacounty.gov/ip/ICLAC/index.htm>. Accessed 17 July 2020.
45. Gross CP, Essien UR, Pasha S, Gross JR, Wang S, Nunez-Smith M. Racial and ethnic disparities in population level Covid-19 mortality. medRxiv. Published online May 11, 2020:2020.05.07.20094250. <https://doi.org/10.1101/2020.05.07.20094250>
46. Hooper MW, Nápoles AM, Pérez-Stable EJ. COVID-19 and racial/ethnic disparities. *JAMA*. 2020;323(24):2466–7. <https://doi.org/10.1001/jama.2020.8598>.
47. Price-Haywood EG, Burton J, Fort D, Seoane L. Hospitalization and mortality among Black patients and White patients with Covid-19. *N Engl J Med*. 2020;382(26):2534–43. <https://doi.org/10.1056/NEJMsa2011686>.
48. Schoch-Spana M, Brunson EK, Long R, Ravi S, Ruth A, Trotochaud M. The public's role in COVID-19 vaccination: planning recommendations informed by design thinking and the social, behavioral, and communication sciences. *John Hopkins Center for Health Security*. 2020;47.
49. Stoler J, Klofstad C, Uscinski JE. Will Black Americans fear a vaccine more than COVID-19? | Opinion. *Newsweek*. Published online July 8, 2020. <https://www.newsweek.com/will-black-americans-fear-vaccine-more-covid-19-opinion-1516087>. Accessed 23 July 2020.
50. Wright PF, Webster RG. Orthomyxoviruses. In: *Fields' Virology*. Vol 47. Lippincott, Williams, & Wilkins; 2001:1533-1579.
51. Reed C, Chaves SS, Kirley PD, et al. Estimating influenza disease burden from population-based surveillance data in the United States. *PLOS ONE*. 2015;10(3):e0118369. <https://doi.org/10.1371/journal.pone.0118369>.
52. Keppel K, Pamuk E, Lynch J, et al. Methodological issues in measuring health disparities. *Vital Health Stat* 2. 2005;(141):1-16.

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