Joinpoint Trend Analysis of Infant Mortality Disparities in Wisconsin, 1999–2016

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Objectives. To address shortcomings of previous research exploring trends in racial, educational, and race by educational disparities in infant mortality rates (IMRs) by using nonlinear methods to compare improvement within and between disparity domains.

Methods. We used joinpoint regression modeling to perform a cross-sectional analysis of IMR trends from linked birth and death certificates in Wisconsin between 1999 and 2016.

Results. In the race and education domains, IMR decreased by 1.9% per year for infants of White mothers and 1.1% per year for infants of less-educated mothers. Further analysis showed these IMR reductions to be among infants of White mothers with more education (–0.6%/year) and Black mothers with less education (–2.0%/year).

Conclusions. As previously reported, gaps in IMR by race and education in Wisconsin appear to be closing; however, only the change by education is statistically significant. Evidence suggests the racial divide in IMR might soon widen after years of progress in reducing IMR among infants of Black mothers.

Public Health Implications. Those advancing strategies to address IMR disparities should pursue data and methods that provide the most accurate and refined information about the challenges that persist and progress that has been realized. (*Am J Public Health.* 2019;109:714–718. doi:10.2105/AJPH.2018.304945)

See also Brown Speights et al., p. 666.

Infant mortality, death in the first year of life, has long been considered an important measure of the overall health and well-being of a population.[1] Infant mortality rates (IMRs) in the United States have been on the decline for several decades, but with persistent, substantial racial disparities.[2–5] According to the most recent publicly available national data,[6] in 2016, the IMR per 1000 live births was 10.9 for non-Hispanic Black or African American mothers, hereon referred to as Black, and 4.9 for non-Hispanic White mothers, hereon referred to as White. While Black–White IMR ratios are generally thought to be on the decline, a 2017 study by Brown Speights et al. found significant differences between states in both the size of the gap between IMR among infants born to Black and White mothers and their progress toward racial equality.[2]

Wisconsin, a state that generally performs midpack (23rd in 2015) for overall IMR, consistently ranks among the worst for IMRs among infants born to Black mothers and Black–White IMR disparity.[7] Data for 2014 to 2016 show an IMR of 13.9 among infants born to Black mothers and a Black–White IMR ratio of nearly 3 to 1.[8] On a positive note, Brown Speights et al. showed an 18% reduction in IMR among infants born to Black mothers in Wisconsin between 2000 and 2012 and, on the basis of this trend, projected Wisconsin to become the 6th state to reach Black–White racial equality in IMRs. However, although this is a welcome and hopeful projection, it is based on the assumption of a linear trend, which may not accurately capture the year-to-year fluctuations and may, therefore, misrepresent disparity reduction and bias the equality projection.

Moreover, while the Black–White IMR ratio is a substantial concern for the nation, not all infant mortality disparities occur solely in the racial domain. Disparities by level of socioeconomic class also persist and, in Wisconsin for example, are spread more widely across the state geographically than are racial disparities. Maternal educational attainment, a commonly used proxy for socioeconomic status, is an important determinant of infant mortality[9] and has been shown to modify the effect of racial differences in infant mortality.[10,11] However, trends in IMR disparities by maternal education and its interaction with race/ethnicity are either not well described or are subject to the same shortcomings as the literature around trends in racial disparities in infant mortality—that is, the use of trend analyses not sophisticated enough to capture yearly fluctuations in the trend.

It was therefore the purpose of this study to approach the issue of racial, educational, and racial-by-educational disparities in infant mortality by analyzing trends with nonlinear methods to compare improvement within and between disparity domains. We used the state of Wisconsin as a case study of how disparities compare across domains and how trends in disparities can differ by analytic method because of its position as one of the worst states for racial disparities while simultaneously being projected among the first wave of states to reach racial equality. In addition, unlike several other states, Wisconsin IMRs and maternal data are also consistently measured and available. The findings of this study have important implications for policymakers and community leaders setting specific targets for intervention and for researchers seeking to

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provide more realistic projections for closing disparities in IMRs.

METHODS

We obtained data on infant deaths from the Wisconsin Interactive Statistics on Health data portal, provided by the Wisconsin Department of Health Services.[8] We used information from linked birth and death certificates to determine the number of infant deaths before 1 year of age, per 1000 live births. We obtained data for White and Black mothers, mothers with "high school graduate or less" and "some college or more" education, and for White and Black mothers by level of education. We excluded mothers with missing data for race or education from all analyses except for the Wisconsin state total.

Because of small numbers of infant deaths in various subgroups, we used 3-year rolling averages (e.g., 1999–2001, 2000–2002) of data between 1999 and 2016 to generate reliable estimates of IMR. We calculated the absolute change in IMR as the difference between the earliest and most recent data points. We calculated a mortality rate ratio at both time points by using the subgroup with the lowest rate as the reference, which was White mothers in the race domain, those with some college or more education in the education domain, and White mothers with some college or more education in the race-by-education domain.

We determined the average annual percentage change (AAPC) with joinpoint, or segmented, regression modeling, calculated by the National Cancer Institute's Joinpoint Regression Program version 4.6.0.0.[12] This method identifies joinpoints that connect distinct line segments, thus allowing for a succinct characterization of changes in data over time.[13] A maximum of 3 joinpoints were allowed based on the number of data points. We calculated the annual percentage change for each segment, and the AAPC across the entire trend line represents the weighted average of the constituent segments, where the weights are proportional to the number of data points in the segment.[14]

RESULTS

Table 1 shows the infant deaths and mortality rates and the absolute change and AAPC in mortality rates over the period examined for both race and education groups separately, and combined. The overall IMR in Wisconsin dropped from 6.8 to 5.9 per 1000 births over the period examined, with an absolute rate improvement of 0.9 per 1000 births and an AAPC of –1.1% per year. The IMR among infants born to Black mothers was much higher than the IMR among infants born to White mothers at both time points and showed the greatest absolute rate improvement of 2.9 per 1000 births, but their AAPC of –1.5% was not significantly different from zero. The IMR among infants born to White mothers, on the other hand, experienced a slightly larger but statistically significant AAPC of –1.9% despite lower IMR and smaller absolute change. In the education domain, IMR among infants born to mothers with high-school or less education was higher than among infants born to those with some college or more at both time points; however, improvement in IMR was only seen for mothers with high-school or less education, characterized by an absolute change of –1.7 per 1000 births and a statistically significant AAPC of –1.4% per year.

Examination of the race–education combined results showed that infants born to Black mothers of both education groups had similar IMRs that were approximately twice as high as IMRs among infants born to White mothers with high-school or less education and 3 times as high as IMRs among infants born to White mothers with some college or more education at both time periods. The largest statistically significant improvement in IMR was seen among infants born to Black mothers with high-school or less education (AAPC = –2.0%), followed by IMR among infants born to White mothers with some college or more education (AAPC = –0.6%).

TABLE 1—Absolute and Annual Percentage Change in Infant Mortality Rate by Subgroup: Wisconsin, 1999–2001 to 2014–2016

	1999–2001		2014–2016			
	Deaths, No.	Mortality Rate per 1000 Births (95% CI)	Deaths, No.	Mortality Rate per 1000 Births (95% CI)	Absolute Rate Change	AAPC %/ year (95% CI)
Wisconsin, total	1404	6.8 (6.4, 7.2)	1179	5.9 (5.5, 6.2)	–0.9	–1.1 (–1.3, –0.8)
Race						
White	931	5.7 (5.3, 6.0)	698	4.8 (4.5, 5.2)	–0.9	–1.9 (–3.3, –0.6)
Black	325	16.8 (15.0, 18.6)	273	13.9 (12.3, 15.5)	–2.9	–1.5 (–3.1, 0.1)
Education						
≥ some college	504	4.7 (4.3, 5.1)	620	4.8 (4.4, 5.2)	0.1	0.1 (–0.2, 0.5)
≤ high school	877	9.0 (8.4, 9.5)	532	7.5 (6.9, 8.2)	–1.7	–1.1 (–1.4, –0.8)
Race by education						
White: ≥ some college	416	4.3 (3.9, 4.7)	427	4.0 (3.6, 4.4)	–0.3	–0.6 (–0.9, –0.3)
White: ≤ high school	503	7.5 (6.9, 8.2)	257	6.7 (5.9, 7.5)	–1.2	–1.1 (–2.5, 0.4)
Black: ≥ some college	66	14.2 (10.8, 17.6)	102	13.6 (11.0, 16.2)	–0.6	–0.1 (–3.0, 2.9)
Black: ≤ high school	251	17.1 (15.0, 19.2)	164	13.7 (11.6, 15.8)	–3.4	–2.0 (–3.9, –0.0)

Note. AAPC = average annual percentage change; CI = confidence interval.

The IMR among infants born to White mothers with high-school or less education and Black mothers with some college or more education did not significantly change over the study period.

Table 2 shows the mortality rate ratios and absolute change and AAPC in rate ratios over the period examined for both race and education groups separately and combined. When we looked by race, because of lower mortality rates within both groups over time (Table 1), the Black–White disparity remained around 3 to 1 from 1999–2001 to 2014–2016. However, there was a significant reduction in the gap between IMRs among infants born to those with a high-school or less education and those with some college or more education characterized by a 1.2% annual reduction in the rate ratio. When we looked by combinations of race and education in 2014 to 2016, we found that the disparity in IMR to the group with the lowest rate, White mothers with some college or more education, to be about 1.75 to 1 for IMR among infants born to White mothers with high-school or less education and about 3.60 to 1 for IMR among infants born to both groups of Black mothers. In addition, these gaps remained relatively stable throughout the study period, with no statistically significant changes to the IMR ratios over time.

These results reflect overall trends from the beginning to the end of the study period but may mask year-to-year changes in trends within the study period. Figure 1 displays the trend in IMRs with the joinpoint method, which allows the identification of segments with differing trends within the entire study period. With this more granular look, we can see that the statistically significant 2.0% AAPC decrease in the IMR for Black mothers with high-school or less education (Table 1) belies the recent reversal of more than a decade's worth of progress at –3.5% per year. Although the 8.2% per year increase since 2012 to 2014 is not statistically significant, it could be a cause for concern. Similarly, the nonsignificant –0.1% AAPC for IMR among infants born to Black mothers with some college or more education masks the 4.5% annual percentage change increase they experienced between 2006–2008 and 2012–2014.

DISCUSSION

The purpose of this study was to reexamine changes over time in IMR and the disparity in IMR between White and Black mothers by using a more sophisticated form of trend analysis than that in previous studies as well as to explore and compare trends by level of education, both independent of and in combination with race. This study adds more detail on the trends than do previous reports and describes disparities in other domains not well explored by using Wisconsin—a bottom-performing state in IMR disparities. Our study indicates that progress in reducing IMR has not been shared equally among Wisconsin mothers. Disparities in IMR by level of education have steadily declined over the last 15 years, but the projection of racial equality by 2035 may not be as promising as previously thought.

Depending on the method, Brown Speights et al.[2] predicted Wisconsin to reach racial equality in IMR by 2035 (based on the percentage reduction in Black IMR from 2000 to 2012) or 2043 (based on the percentage reduction in the Black–White IMR ratio from 2000 to 2012). However, these projections do not take into consideration the data for time points between 2000 and 2012 or the error around the IMR estimates. When doing so, we found that, although the IMR among infants born to Black mothers is trending downward, that change is not statistically significant. Meanwhile, the IMR among infants born to White mothers is steadily decreasing at a pace that is statistically significant, leading to a small, nonsignificant increase in the Black–White IMR ratio. On the basis of these results, we would not conclude that the Black and White IMRs are converging. In fact, if current trends hold, there is reason to speculate an increase in the Black–White IMR ratio in coming years. Given the substantial nature of this public health concern for the nation, and the state of Wisconsin particularly, having an accurate understanding of the change in Black–White IMR disparities is critical to dissuade any complacency based on previously projected progress. Therefore, more advanced methods, such as those employed herein, should be considered for all states advancing initiatives to address IMR disparities.

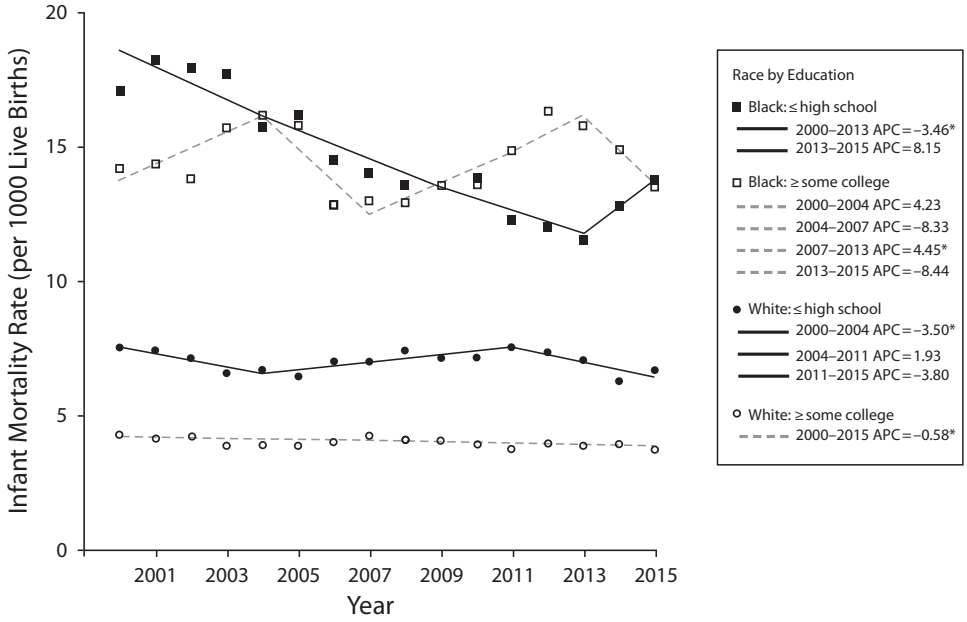
We found the IMR ratio by level of education in the state of Wisconsin to be about half the size of the ratio between Black and White mothers in 2014 to 2016. This finding is logical given that White mothers make up most of both education categories, and the IMR for even White mothers with fewer years of education is less than half that of Black mothers of any level of educational attainment. Unlike the Black–White infant mortality disparity, however, there is evidence to suggest that the IMR gap for mothers with varying levels of education is closing. This progress was driven largely by change in IMR among infants of mothers with high-school or less education. The IMR among infants of Black mothers with high-school or less education, in particular, made substantial reductions of –3.5% per year between 1999–2001 and 2012–2014.

The consistent progress in reducing IMR among Black mothers with high-school or less education that drove down the rates for all mothers with high-school or less education until about 2013 was matched by a worsening of IMR for Black mothers with some college

TABLE 2—Absolute and Annual Percentage Change in Infant Mortality Rate Ratios by Subgroup: Wisconsin, 1999–2001 to 2014–2016

	1999–2001	2014–2016	Absolute Rate Change	AAPC %/year (95% CI)
Race: Black (Ref = White)	2.96	3.28	0.32	0.1 (–2.1, 2.4)
Education: ≤ high school (Ref = ≥ some college)	1.92	1.57	–0.35	–1.2 (–1.7, –0.8)
Race by education (Ref = White: ≥ some college)				
White: ≤ high school	1.76	1.78	0.02	0.3 (–0.3, 1.0)
Black: ≤ high school	4.00	3.65	–0.35	–1.3 (–3.7, 1.1)
Black: ≥ some college	3.32	3.61	0.29	0.9 (–2.5, 4.4)

Notes. AAPC = average annual percentage change; CI = confidence interval.



Note. APC = annual percentage change. Years in the x-axis are midpoint of 3 years (e.g., 2000 = 1999–2001).
*$P < .05$.

FIGURE 1—Trends in Infant Mortality Rate for Race by Education Subgroups: Wisconsin, 1999–2001 to 2014–2016

or more education. For Black mothers with some college or more education to have a similar IMR as Black mothers with high-school or less education is counterintuitive to the notion that increasing education is associated with better birth outcomes[9] but is consistent with previous research.[11] However, for infants born to Black mothers with some college or more education to have higher mortality rates than do those born to Black mothers with high-school or less education between 2011–2013 and 2012–2014 is a striking finding and warrants further research.

There are likely multiple influences responsible for the shifts in Black IMR trends or Black–White disparities, though efforts to address disparities in preterm births and low birth weight may hold promise.[15] A comprehensive approach to preconception care, prenatal care, and postnatal care is an important part of the solution. As outlined by the US Department of Health and Human Services' Advisory Committee on Infant Mortality, there are broader contextual forces to be understood and comprehensively addressed via a national strategy that can improve the social and economic conditions that create health for women before pregnancy, provide quality maternal and neonatal care, and develop opportunities for growing families.[16] Given the recent stalling of positive trends in IMRs,[1,5] an actionable strategy is even more imperative.

Strengths and Limitations

This study draws strengths from several areas. First, while racial disparities in infant mortality are a prescient public health concern for the nation and particularly for the state of Wisconsin, disparities by socioeconomic class should also be of concern and present a burden with a wider geographic distribution throughout the state. We believe including level of education, both as a standalone domain and as an effect modifier in the racial domain, adds much needed context to the discussion of disparities in infant mortality. Second, this study adds to previous research describing state-level trends in infant mortality by using more sophisticated, nonlinear analyses that used all the data points in the trend and considered the error of each estimate. This allowed us to not only describe change over the entire study period but also to detect periods of statistically significant change within the study period. This information could prove invaluable if periods of change could be attributed to the success or failure of certain policies and programs, which may have been missed if one considered only the change over the entire study period.

This study is also not without its limitations. First, we chose Wisconsin as the focus of our analysis because it is one of the worst states for racial infant mortality disparities with a concurrent projection of being one of the first states to reach racial equality.[2] That our findings were counter to those of the previous report cannot be generalized to other states; however, the results of this approach provide evidence that a more sophisticated method for trend analyses can refine what we know about this issue and provide critical information regarding the effects of interventions to address IMR. These analyses should be repeated in other states where data are available to have a better understanding of local infant mortality disparities by race, class, and other domains.

While it is not inherently a limitation, it should be noted that Wisconsin has a small Black population relative to the national average (6% vs 12%). This can lead to small numbers of infant deaths to Black mothers in certain years, especially when one is

categorizing by level of education and, consequently, volatility from year to year in the IMR. For the purposes of this study, we decided 3-year rolling averages of data were sufficient to overcome data source suppression criteria and provide reliable yearly estimates while avoiding excessive data consolidation. We recommend that data users critically consider the trade-offs between using fewer years of data (e.g., the ability to evaluate short-term interventions and policies) versus more years (e.g., less error around the estimate) for their intended purpose and the size of their study sample.

Conclusions

In conclusion, this exploration of the trajectory for IMR disparities via an enhanced approach supports important findings of relevance for those working to improve birth outcomes across the nation and particularly for the state of Wisconsin. While progress has been made in decreasing the overall rate of infant mortality, disparities by race and class persist. Analytic approaches that consider both the experiences of the overall status of the community as well as subpopulations in a community are essential to understand and address the underlying risks and burdens. A more sophisticated analytic approach can enhance the accuracy of information intended to guide actionable strategies to improve health for all and reduce disparities in infant mortality. AJPH

CONTRIBUTORS

K. P. Gennuso and D. A. Kindig originated the study. K. P. Gennuso performed the analytic work with consultation from M. L. Givens. All authors wrote the article.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

HUMAN PARTICIPANT PROTECTION

Institutional review board approval was not required because no human participants were included in this study.

REFERENCES

1. Singh GK, Yu SM. Infant mortality in the United States: trends, differentials, and projections, 1950 through 2010. *Am J Public Health*. 1995;85(7):957–964.

2. Brown Speights JS, Goldfarb SS, Wells BA, Beitsch L, Levine RS, Rust G. State-level progress in reducing the Black–White infant mortality gap, United States, 1999–2013. *Am J Public Health*. 2017;107(5):775–782.

3. Alexander GR, Wingate MS, Bader D, Kogan MD. The increasing racial disparity in infant mortality rates: composition and contributors to recent US trends. *Am J Obstet Gynecol*. 2008;198(1):51.e1–51.e9.

4. Loggins S, Andrade FC. Despite an overall decline in US infant mortality rates, the Black/White disparity persists: recent trends and future projections. *J Community Health*. 2014;39(1):118–123.

5. Mathews T, Driscoll A. Trends in infant mortality in the United States, 2005–2014. NCHS data brief, no 279. Hyattsville, MD: National Center for Health Statistics; 2017.

6. Centers for Disease Control and Prevention, National Center for Health Statistics, Division of Vital Statistics. Linked birth/infant death records 2007–2016, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program, on CDC WONDER on-line database. Available at: https://wonder.cdc.gov/lbd-current.html. Accessed June 25, 2018.

7. Murphy S, Xu J, Kochanek K, Curtin S, Arias E. Deaths: Final data for 2015. *Natl Vital Stat Rep*. 2017; 66(6):1–75.

8. Wisconsin Department of Health Services, Division of Public Health, Office of Health Informatics. Wisconsin Interactive Statistics on Health (WISH) data query system. Infant Mortality Module. Available at: https://www.dhs.wisconsin.gov/wish/index.htm. Accessed November 28, 2017.

9. Gage TB, Fang F, O'Neill E, Dirienzo G. Maternal education, birth weight, and infant mortality in the United States. *Demography*. 2013;50(2):615–635.

10. Din-Dzietham R, Hertz-Picciotto I. Relationship of education to the racial gap in neonatal and postneonatal mortality. *Arch Pediatr Adolesc Med*. 1997;151(8):787–792.

11. Din-Dzietham R, Hertz-Picciotto I. Infant mortality differences between Whites and African Americans: the effect of maternal education. *Am J Public Health*. 1998; 88(4):651–656.

12. Joinpoint Regression Program, Version 4.6.0.0. Bethesda, MD: Statistical Methodology and Applications Branch, Surveillance Research Program, National Cancer Institute; April 2018.

13. Kim HJ, Fay MP, Feuer EJ, Midthune DN. Permutation tests for joinpoint regression with applications to cancer rates. *Stat Med*. 2000;19(3):335–351.

14. Clegg LX, Hankey BF, Tiwari R, Feuer EJ, Edwards BK. Estimating average annual per cent change in trend analysis. *Stat Med*. 2009;28(29):3670–3682.

15. Riddell CA, Morrison KT, Kaufman JS, Harper S. Trends in the contribution of major causes of death to the Black–White life expectancy gap by US state. *Health Place*. 2018;52:85–100.

16. Lu MC, Johnson KA. Toward a national strategy on infant mortality. *Am J Public Health*. 2014;104(suppl 1): S13–S16.