Describing national trends in preterm infant mortality in the United States by race and socioeconomic status: a population study (1995-2020) of 100 million births

Introduction

Worldwide, prematurity is the leading cause of infant mortality [1,2]. Since the turn of the century, considerable advances in the field of neonatology have resulted in gains in preterm infant survival [3–7]. Despite its leading economic status, The United States (US) has one of the top ten preterm birth rates worldwide [8–10], within which there are stark inequalities in the rates of preterm birth and mortality across socioeconomic strata, racial groups, and geographic regions [11–15].

The objective of this study was to characterise trends in preterm infant mortality by maternal race and socioeconomic status, to assess how inequalities in preterm infant mortality rates have changed over a twenty-year period. US preterm-infant mortality rates have been reported on a yearly basis by the National Centre for Health and Statistics (NCHS)[5], yet trends in preterm infant mortality have not previously been quantified by race and socioeconomic status at a national level over such a long period. This information is critical for providing public health officials, policy makers and clinicians with the information necessary to reduce health disparities, as well as determining the effectiveness of existing health policy.

Methods

This is a retrospective longitudinal descriptive study of 100 million births across the US over a 26-year period using the US Period Linked Birth/Infant Death Dataset, compiled by the Centre for Disease Control and Prevention's (CDC) National Centre for Health Statistics (NCHS). The dataset contains linked infant birth and death certificates from all 50 US states and the District of Columbia. Between 1995 and 2020 two versions of the US standard birth certificate were used: the 1989 certificate and the 2003 revision, which introduced several new data items, and was implemented between 2003-2016. Within each infant's birth and death certificate, multiple variables, including maternal and infant characteristics, method of delivery, complications at birth, and underlying cause of death are available for analysis [16].

Where the death occurs in a different state to that of the infant's birth, records are exchanged for linkage purposes, after which the NCHS performs follow-up linking for unlinked infant death certificates[7,17,18]. The data are then coded uniformly and rigorously quality controlled and, if required, the NCHS will impute missing data. These edited mortality and natality data files are used to create an annual national linked birth-death file for public use. Data from 1995 to 2020 were available at the time of completing this study.

Defining Prematurity

The World Health Organisation (WHO) definition of prematurity includes infants born alive before 37 completed weeks of gestation[19]. They further categorise preterm births, based on gestational age, into moderate to late preterm (32 to <37) weeks, very preterm (28 to <32 weeks) and extremely preterm (<28 weeks). The CDC national definition of "live birth" is determined by whether the infant shows signs of life at the point of delivery. This is not limited by duration of pregnancy and is subsequently adapted by individual US states as outlined in the CDC "State Definitions and Reporting Requirements" [20–23]. To mitigate the impact of non-viable gestations, we chose to only include babies born at ≥ 22 weeks. The definitions of categories of prematurity used for analysis are as follows:

- Total preterm (22 to <37 weeks)
- Extremely preterm (22 to <28 weeks)
- Very preterm (28 to <32 weeks)
- Moderately preterm (32 to <37 weeks)

Subgroup definitions

Subgroups were defined to ensure analogous information was present on both the 1989 and 2003 birth certificates. As maternal race and Hispanic origin are reported independently, race/ethnicity was split into 'White Non-Hispanic' (referred to as White), 'Black Non-Hispanic' (referred to as Black) and 'Hispanic'. Factors related to maternal socioeconomic status used in analyses included maternal education, antenatal care, smoking and insurance status [20–22]. Two other important metrics of socioeconomic status, maternal income, and occupation were not available for analysis [23,24]. Smoking status was defined according to whether a mother had smoked one or more cigarettes at some point during the pregnancy. A mother's education status was categorised according to the number of years of education completed, grouped into low (high school education or less), intermediate (high school graduate, associated degree, or some college credit) and high (completed a bachelor's degree or higher). Antenatal care was categorised according to the Kessner criteria, determined by the number of antenatal care visits attended relative to the length of gestation [25]. Maternal insurance status was categorised as self-funded, private or government insurance (Medicaid and other government insurance types: Federal, State and Local), however was only available for analyses from 2011 onwards.

Subgroup analyses

The percentage of preterm births in each subgroup was calculated. Infant mortality was defined as death from 0 to 364 days after birth. Preterm infant mortality rates were calculated for each year between 1995 -2020, split into categories of prematurity, alongside each week between 22-27 weeks

to account for the large changes in mortality rate by week, at extreme gestations. To evaluate trends in preterm mortality rate, a Poisson regression model was used with year as a covariate to calculate a regression coefficient relating to the overall change in preterm infant mortality between 1995 to 2020. To counter year-to year fluctuations, three-year average mortality rates for 1995-1997 and 2018-2020 were calculated with associated rate ratios, to evaluate the change in relative risk of mortality between subgroup categories and a chosen reference over time. All statistical and data analyses were performed using Stata 17.

Results

Maternal race and socioeconomic characteristics

This study included 103,921,783 infants born across the USA between 1995 and 2020, of which 12,256,303 were born prematurely, and 437,650 preterm infants died within the first year of life. Baseline maternal characteristics changed over the study period. Maternal smoking decreased from 13.0% to 6.0%, the percentage of mothers with a Bachelor's degree increased from 22.1% to 33.5%, however antenatal care coverage remained broadly constant over time (table 1). Maternal racial composition changed, with a reduced percentage of White mothers (63.0% vs 59.5%), a comparable percentage of Black mothers (15.1% vs 16.0%) and an increased percentage of Hispanic mothers (16.8% vs 23.8%) (table 1).

Premature birth rates

Between 1995 and 2020, the percentage of premature births (22-37 weeks) gradually oscillated, with a peak of 12.7% in 2006. Consistent with reported patterns of preterm birth, we noted higher rates of preterm birth in mothers who smoked, were less educated, did not have private insurance and mothers who were Black [26–28]. Mothers receiving inadequate antenatal care consistently had the highest rate of preterm birth in any subgroup (table 1).

Trends in preterm infant mortality

During the study period, the total preterm infant mortality rate (IMR) decreased from 34.81 per 1000 preterm births (95% CI, 34.24 to 35.38) in 1995, to 22.35 (95% CI 21.89 to 22.80) in 2020. The greatest rate of improvement was seen in very and extremely preterm infants, among whom mortality rates increase steeply with decreasing gestational age. Very preterm IMR decreased from 53.08 per 1000 (95% CI, 50.92 to 55.25) to 36.12 (95% CI, 34.28 to 37.96), whilst extremely preterm IMR decreased from 352.60 per 1000 (95% CI, 343.79 to 361.40) to 246.61 (95% CI, 239.08 to 254.14). Separating each week of extreme gestation, the rate of improvement was notably less marked for those born at 22 weeks (regression coefficient -0.003 95% CI -0.004 to -0.002), compared to those born between 23 and 27 weeks (table 3). Although, moderately preterm IMR decreased relatively the

least (-0.008 95% CI -0.009 to -0.007), overall preterm IMR improved from 11.09 (95% CI, 10.74 to 11.44) to 8.00 (95% CI, 7.71 to 8.29).

Trends in preterm infant mortality by maternal race

Overall, Black infants were more likely to die following preterm birth than White and Hispanic infants across the study period, however once born extremely prematurely Black and Hispanic infants had a narrow survival advantage over White infants (table 2,3 figure 1). During the study, the total preterm IMR decreased from 31.59 per 1000 (95% CI 31.16 to 32.01) to 21.81 (95% CI 21.43 to 22.18) for White infants, 44.51 per 1000 (95% CI 43.74 to 45.27) to 31.09 (95% CI 30.44 to 31.74) for Black infants and 27.34 per 1000 (95% CI 26.62 to 28.06) to 20.13 (95% CI 19.63 to 20.62) for Hispanic infants. The rate of decrease in total preterm IMR was higher in Black infants (-0.015, 95%CI -0.016 to -0.015) than in White (-0.013, 95%CI -0.014 to -0.013) and Hispanic infants (-0.0010, 95%CI -0.011 to -0.009) infants; however, the relative risk of preterm IMR among Black and Hispanic infants compared with White infants remained the same (table 2). This trend was seen across all categories of prematurity (table 2), and therefore the proportional inequality in preterm infant mortality has remained constant over time. Once born extremely prematurely (22-27 weeks), the rate of improvement in preterm IMR was consistent between racial groups. There were also no changes in the relative risk of preterm infant mortality among Black and Hispanic infants compared to White infants (table 3).

Trends in preterm infant mortality by factors related to maternal socioeconomic status

Across all categories of prematurity, mothers receiving inadequate antenatal care had the highest preterm mortality rate (table 2), with mothers who smoked, who were less educated, or who lacked private insurance having higher preterm mortality rates within their respective categories. Again, once born extremely prematurely, mortality rates were comparable, except for infants who received adequate antenatal care, who had lower preterm IMRs than those who didn't (table 2, 3). During the study period, the rate of decrease in total preterm IMR was higher in non-smokers compared to smokers (-0.015 vs -0.010), higher in those with high levels of education compared to those without (-0.016 vs – 0.010, -0.011), and higher in those who had received adequate antenatal care compared to those who did not (-0.014 vs -0.012, -0.013) (table 2). Correspondingly, the relative risk of total preterm IMR between these groups increased, amounting to a proportional increase in inequality over time (table 2). Across all categories, preterm IMRs decreased more greatly for very and extremely premature infants compared to moderately premature infants, except at very low gestational ages (table 2, 3). For those born extremely prematurely (22-27 weeks), the rates of improvement in preterm IMR were comparable between subgroups, and there were no differences in the relative risk of preterm infant mortality (table 3).

As analysis of Insurance status was only available from 2011 onwards; the trends in preterm IMR should be interpreted in this context. With respect to the total preterm infant mortality, the proportional inequality between mothers with private compared to government insurance remained constant, whilst inequality narrowed between mothers without insurance compared to those with government insurance (table 4). Again, once born extremely prematurely, preterm mortality rates were similar between different insurance groups, apart from at very low gestational ages (22, 23 weeks), where mothers with government insurance fared better. Over time, there were no differences between these groups in the trend coefficients or relative risk of infant mortality by week at extreme gestational ages.

Discussion

This is the first population study to explore trends in preterm infant mortality in the US over two decades according to maternal race and factors associated with maternal socioeconomic status. Through the NCHS robust national birth statistics reporting, we have been able to include over 100 million births over a 26-year period. Our study shows that in the US, across all categories of prematurity, there has been significant improvement in preterm infant mortality. Yet, the rates of improvement have differed between population subgroups across gestational ages, with social and racial disparities in preterm health remaining present.

The improvement in preterm infant mortality rates in the US between 1995 and 2020 is a trend seen globally in high-income settings [4]. This reflects known improvements in multiple facets of obstetric and neonatal care during this period, including the use and timing of antenatal steroids, exogenous surfactant and other facets of respiratory care, alongside antibiotics, neonatal thermoregulation, and nutrition[3,29–34]. Other studies have demonstrated that these interventions have translated into reduced neonatal morbidity and improved neurodevelopmental outcomes[29,35]. These clinical and technological advances have been focussed on infants born at the extremes of gestation, where mortality rate is highest, reflected in the greater survival gains seen in very and extremely premature infants, most notably in those born between 23 and 27 weeks. The smaller survival gains seen in infants born at 22 weeks likely reflects the proximity to the limit of viability and the severity of the pathophysiology at such low gestations. Overall, the improvements in mortality at extreme gestational ages were most apparent from the early 2000s and appear to be continuing (figure 1). In contrast, despite overall reductions in preterm IMR for moderately premature infants, the rate of improvement appears to slow after 2005 (figure 1). This may suggest that we are close to reaching the natural limit in mortality reduction among the moderately premature infants, but considerable opportunity remains to reduce mortality rates among extremely premature infants. It will be instructive to see how this develops in subsequent years, particularly with increasing numbers of babies born at 22 weeks' gestation receiving active survival-focused care.

Understanding and reducing racial inequalities in preterm infant health is a major public health issue in the US. It is already known that Black infants are 1.5 to 2 times more likely to be born prematurely than White infants, with higher proportions of multiple births among Black infants [5,6,36–39]. The aetiology of these differences is believed to be multifactorial; however, the relative contribution of genetic, physiological, and sociological factors is debated [26,36,40–43]. Although studies of population based datasets have looked at racial disparities in preterm mortality and morbidity, this is the first study to quantify this over two decades at a national level in the US [44,45].

Our trend analyses demonstrate that the absolute improvement in total preterm IMR was greater for Black infants than for White and Hispanic infants, however the proportional inequalities have remained constant over time with the overall risk of premature infant death in Black infants remaining approximately 1.4 times higher than for White infants. This difference has generally been attributed to a higher proportion of Black infants being born at the extremes of prematurity [46]. Indeed, our analyses show that once born very or extremely prematurely, Black, and Hispanic infants had a slight survival advantage compared to White infants. This may be due to differences in the aetiology resulting in extreme prematurity between different racial groups. Indeed, it has been suggested that the balance between maternal vs. infant ill-health as the cause of prematurity may vary between racial groups [45]. These trends in mortality rates for extremely premature infants have persisted over time, with similar survival gains seen between racial groups. Similarly, although Black infants born moderately prematurely had a higher risk of death, their survival gains were equivalent to White and Hispanic infants. This suggests that, at a national level, once born prematurely the neonatal care received by different racial groups is broadly equitable, despite regional, and neonatal centre-specific health disparities being previously reported [51–53]. Thus, it appears that all racial groups can access the advancements in neonatal care which account for the majority of improvement in preterm infant survival.

Regarding socioeconomic factors, our findings are consistent with previously reported disparities in both preterm birth rate and infant mortality, in relation to mothers' education, insurance, antenatal care and smoking status [47–49]. From the characteristics assessed, antenatal care status was the biggest predictor of both preterm birth and preterm infant mortality. Within our analyses, antenatal care status was the strongest marker of deprivation, with complex financial, structural and geographical barriers all contributing to mothers' ability to access adequate antenatal care [50,51]. The widening inequality in preterm mortality is unsurprising given that mothers unable to access antenatal care would not have benefitted from advances in antenatal care practice. This adds to an economic case for free antenatal care for all pregnant Americans[52–54]. Although we note increasing levels of maternal education, the widening inequality in preterm infant mortality amongst mothers with differing educational attainment confirms the relationship between education status and maternal and child health [55]. Regarding insurance status, equitable gains were seen amongst the different insurance groups, with the relative inequality remaining constant. Further expansion of government insurance provision to those without insurance remains important, although previous studies have debated the impact of the expansion of Medicaid on infant mortality [56,57]

As seen with maternal race, once born extremely prematurely, preterm infant survival was comparable between subgroups, with equitable reductions in mortality rate over time. This again suggests that at a national level, most infants receive equitable neonatal care once born. However, further analysis of

the aetiology resulting in extreme prematurity between groups would aid interpretation of this finding [31–33]. Overall, this finding emphasises the importance of preventing infants being born at extremely early gestational ages as a means of reducing inequalities in preterm mortality rates between mothers of differing racial and socioeconomic groups. This highlights the need for targeted healthcare and economic policy focussed on preventing prematurity to reduce social and racial disparities in preterm health. The gestational age at which an infant is born remains the major determinant of their risk of death

Strengths and Limitations

The key strengths of our study include the size and validity of the NCHS US Period Linked Birth/Infant Death Dataset, the length of time over which the study extends, and the variety of maternal characteristics assessed. Our study has several limitations. Firstly, we were unable to calculate adjusted odds ratios to account for confounders due to the separation of files containing the denominator (live births) and numerator (infant deaths) data. This meant our analyses were limited to reporting overall unadjusted trends, and could not explore the causation for changes in infant mortality rates. Secondly, despite the CDC national definition of "live birth" remaining consistent across the study period, we were unable to account for inconsistencies in the interpretation of "live birth" between US States [58–60]. We sought to mitigate this by using a 22-week gestational age cut-off, alongside reporting national trends. Lastly, further trend analyses according to maternal comorbidities such as diabetes, hypertension, and obesity would have been instructive. Uncontrolled maternal comorbidity negatively impacts preterm infant health and may represent an important route through which both a lack of antenatal care, alongside a mother's socioeconomic status, result in an increased risk of preterm birth and mortality [61–63]. Better indices of SES, such as maternal occupation and income, alongside indexes of deprivation, such as the Multidimensional Deprivation Index (MDI), were not available in the dataset [64]. Additionally, we were unable to perform State-level analysis. This would have allowed assessment of regional inequalities which have been previously reported [65,66].

Concluding remarks

This population-level study analyses trends in preterm mortality within the US over the last quarter of a century. Overall, we highlight considerable progress: our results demonstrate a steady improvement in preterm mortality rate across all categories of prematurity. Yet racial and socioeconomic disparities persist. Our findings suggest that the proportional inequalities in total preterm IMR between Black and other racial groups have remained constant over time. Unfortunately, we found an overall widening of the inequality in preterm mortality in those from socioeconomically disadvantaged groups. Our results confirm the critical importance of mothers receiving antenatal care.

References

1. Chawanpaiboon S, Vogel JP, Moller AB, et al. Global, regional, and national estimates of levels of preterm birth in 2014: a systematic review and modelling analysis. *Lancet Glob Health*. 2019;7(1):e37-e46. doi:10.1016/S2214-109X(18)30451-0
2. Liu L, Oza S, Hogan D, et al. Global, regional, and national causes of under-5 mortality in 2000–15: an updated systematic analysis with implications for the Sustainable Development Goals. *The Lancet*. 2016;388(10063):3027-3035. doi:10.1016/S0140-6736(16)31593-8
3. Morgan AS, Mendonça M, Thiele N, David AL. Management and outcomes of extreme preterm birth. *BMJ*. 2022;376. doi:10.1136/BMJ-2021-055924
4. Hug L, Alexander M, You D, Alkema L. National, regional, and global levels and trends in neonatal mortality between 1990 and 2017, with scenario-based projections to 2030: a systematic analysis. *Lancet Glob Health*. 2019;7(6):e710-e720. doi:10.1016/S2214-109X(19)30163-9/ATTACHMENT/EBBCA448-F5F6-40F2-B6D2-6C8E058354A6/MMC1.PDF
5. MacDorman MF, Callaghan WM, Mathews TJ, Hoyert DL, Kochanek KD. Trends in preterm-related infant mortality by race and ethnicity, United States, 1999-2004. *Int J Health Serv*. 2007;37(4):635-641. doi:10.2190/HS.37.4.C
6. Luke B, Brown MB. The Changing Risk of Infant Mortality by Gestation, Plurality, and Race: 1989–1991 Versus 1999–2001. *Pediatrics*. 2006;118(6):2488. doi:10.1542/PEDS.2006-1824
7. Ely DM, Driscoll AK. National Vital Statistics Reports Volume 69, Number 7 July 16, 2020, Infant Mortality in the United States, 2018: Data From the Period Linked Birth/Infant Death File. *National Vital Statistics Reports*. 2018;69(7). Accessed May 2, 2022. https://www.cdc.gov/nchs/products/index.htm.
8. Chawanpaiboon S, Vogel JP, Moller AB, et al. Global, regional, and national estimates of levels of preterm birth in 2014: a systematic review and modelling analysis. *Lancet Glob Health*. 2019;7(1):e37-e46. doi:10.1016/S2214-109X(18)30451-0/ATTACHMENT/3B7A79C8-B16F-410C-A7C7-3B3039631E52/MMC1.PDF
9. Walani SR. Global burden of preterm birth. *International Journal of Gynecology & Obstetrics*. 2020;150(1):31-33. doi:10.1002/IJGO.13195
10. Harrison MS, Goldenberg RL. Global burden of prematurity. *Semin Fetal Neonatal Med*. 2016;21(2):74-79. doi:10.1016/J.SINY.2015.12.007
11. King JP, Gazmararian JA, Shapiro-Mendoza CK. Disparities in mortality rates among US infants born late preterm or early term, 2003-2005. *Matern Child Health J*. 2014;18(1):233-241. doi:10.1007/S10995-013-1259-0
12. Mathews TJ, Macdorman MF, Thoma ME. Infant Mortality Statistics From the 2013 Period Linked Birth/Infant Death Data Set Non-Hispanic black Total Non-Hispanic white Hispanic. *National Vital Statistics Reports*. 2013;64(9).
13. MacDorman MF, Callaghan WM, Mathews TJ, Hoyert DL, Kochanek KD. Trends in preterm-related infant mortality by race and ethnicity, United States, 1999-2004. *International Journal of Health Services*. 2007;37(4):635-641. doi:10.2190/HS.37.4.c
14. Ebrahimvandi A, Hosseinichimeh N, Iams J. Understanding State-Level Variations in the US Infant Mortality: 2000 to 2015. *Am J Perinatol*. 2019;36(12):1271-1277. doi:10.1055/S-0038-1675835
15. Womack LS, Rossen LM, Hirai AH. Urban-Rural Infant Mortality Disparities by Race and Ethnicity and Cause of Death. *Am J Prev Med*. 2020;58(2):254-260. doi:10.1016/J.AMEPRE.2019.09.010
16. Methodological Issues and the 2003 Revision of Standard Instruments - Vital Statistics - NCBI Bookshelf. Accessed April 27, 2022. https://www.ncbi.nlm.nih.gov/books/NBK219875/

17. Ely DM, Driscoll AK. Infant Mortality in the United States, 2017: Data From the Period Linked Birth/Infant Death File. Published online 2017. Accessed May 2, 2022. https://www.cdc.gov/nchs/products/index.htm.

18. Ely DM, Driscoll AK. Infant Mortality in the United States, 2019: Data From the Period Linked Birth/Infant Death File. *National Vital Statistics Reports*. 2019;70(14). Accessed May 2, 2022. https://www.cdc.gov/nchs/products/index.htm.

19. Preterm birth. Accessed April 5, 2022. https://www.who.int/news-room/fact-sheets/detail/preterm-birth

20. Lawrence D, Fagan P, Backinger CL, Gibson JT, Hartman A. Cigarette smoking patterns among young adults aged 18-24 years in the United States. *Nicotine Tob Res*. 2007;9(6):687-697. doi:10.1080/14622200701365319

21. Higgins ST, Chilcoat HD. Women and Smoking: An Interdisciplinary Examination of Socioeconomic Influences. *Drug Alcohol Depend*. 2009;104(Suppl 1):S1. doi:10.1016/J.DRUGALCDEP.2009.06.006

22. Osterman MJK, Martin JA. Timing and Adequacy of Prenatal Care in the United States, 2016. Published online 2016.

23. Allen L, Williams J, Townsend N, et al. Socioeconomic status and non-communicable disease behavioural risk factors in low-income and lower-middle-income countries: a systematic review. *Lancet Glob Health*. 2017;5(3):e277-e289. doi:10.1016/S2214-109X(17)30058-X

24. Wang D, Dai X, Mishra SR, et al. Association between socioeconomic status and health behaviour change before and after non-communicable disease diagnoses: a multicohort study. *Lancet Public Health*. 2022;7(8):e670-e682. doi:10.1016/S2468-2667(22)00157-8/ATTACHMENT/7C1BD188-7682-4ED3-943E-7D8CE54650A5/MMC1.PDF

25. Rowe S, Karkhaneh Z, MacDonald I, et al. Systematic review of the measurement properties of indices of prenatal care utilization. *BMC Pregnancy Childbirth*. 2020;20(1):1-9. doi:10.1186/S12884-020-2822-5/TABLES/4

26. Thoma ME, Drew LB, Hirai AH, Kim TY, Fenelon A, Shenassa ED. Black-White Disparities in Preterm Birth: Geographic, Social, and Health Determinants. *Am J Prev Med*. 2019;57(5):675-686. doi:10.1016/J.AMEPRE.2019.07.007

27. Dunlop AL, Essalmi AG, Alvalos L, et al. Racial and geographic variation in effects of maternal education and neighborhood-level measures of socioeconomic status on gestational age at birth: Findings from the ECHO cohorts. *PLoS One*. 2021;16(1):e0245064. doi:10.1371/JOURNAL.PONE.0245064

28. Ratnasiri AWG, Gordon L, Dieckmann RA, et al. Smoking during Pregnancy and Adverse Birth and Maternal Outcomes in California, 2007 to 2016. *Am J Perinatol*. 2020;37(13):1364-1376. doi:10.1055/S-0039-1693689/ID/JR190293-34

29. Stoll BJ, Hansen NI, Bell EF, et al. Trends in Care Practices, Morbidity, and Mortality of Extremely Preterm Neonates, 1993-2012. *JAMA*. 2015;314(10):1039-1051. doi:10.1001/JAMA.2015.10244

30. Soll RF, Edwards EM, Badger GJ, et al. Obstetric and neonatal care practices for infants 501 to 1500 g from 2000 to 2009. *Pediatrics*. 2013;132(2):222-228. doi:10.1542/PEDS.2013-0501

31. Doyle LW, Ehrenkranz RA, Halliday HL. Late (> 7 days) postnatal corticosteroids for chronic lung disease in preterm infants. *Cochrane Database Syst Rev*. 2014;2014(5). doi:10.1002/14651858.CD001145.PUB3

32. Kleinhout MY, Stevens MM, Osman KA, et al. Evidence-based interventions to reduce mortality among preterm and low-birthweight neonates in low-income and middle-income

countries: a systematic review and meta-analysis. *BMJ Glob Health*. 2021;6(2):e003618. doi:10.1136/BMJGH-2020-003618

33. Ottolini KM, Andescavage N, Keller S, Limperopoulos C. Nutrition and the developing brain: the road to optimizing early neurodevelopment: a systematic review. *Pediatr Res*. 2020;87(2):194-201. doi:10.1038/S41390-019-0508-3
34. Abiramalatha T, Ramaswamy VV, Bandyopadhyay T, et al. Delivery Room Interventions for Hypothermia in Preterm Neonates: A Systematic Review and Network Meta-analysis. *JAMA Pediatr*. 2021;175(9). doi:10.1001/JAMAPEDIATRICS.2021.0775
35. Bell EF, Hintz SR, Hansen NI, et al. Mortality, In-Hospital Morbidity, Care Practices, and 2-Year Outcomes for Extremely Preterm Infants in the US, 2013-2018. *JAMA*. 2022;327(3):248-263. doi:10.1001/JAMA.2021.23580
36. Burris HH, Hacker MR. Birth outcome racial disparities: A result of intersecting social and environmental factors. *Semin Perinatol*. 2017;41(6):360-366. doi:10.1053/J.SEMPERI.2017.07.002
37. Santos P, Joglekar G, Faughnan K, Darden J, Hendrich A. Disproportionate Preterm Delivery Among Black Women: a State-Level Analysis. *J Racial Ethn Health Disparities*. 2020;7(2):290-297. doi:10.1007/S40615-019-00657-X
38. Kothari CL, Corbit K, Presberry J, Bautista T, O'Rourke B, Lenz D. Race, Multiraciality, Income, and Infant Mortality: Markers of Racial Equity. *J Child Fam Stud*. 2022;31(3):689-702. doi:10.1007/S10826-022-02246-9/TABLES/3
39. MacDorman MF. Race and ethnic disparities in fetal mortality, preterm birth, and infant mortality in the United States: an overview. *Semin Perinatol*. 2011;35(4):200-208. doi:10.1053/J.SEMPERI.2011.02.017
40. Manuck TA. Racial and ethnic differences in preterm birth: A complex, multifactorial problem. *Semin Perinatol*. 2017;41(8):511-518. doi:10.1053/J.SEMPERI.2017.08.010
41. Ekeke P, Rankin K, DeSisto C, Collins JW. The Excess Preterm Birth Rate Among US-Born (Compared to Foreign-Born) Black Women: The Role of Father's Education. *Matern Child Health J*. Published online 2021. doi:10.1007/S10995-020-03117-9
42. Kramer MR, Hogue CR. What Causes Racial Disparities in Very Preterm Birth? A Biosocial Perspective. *Epidemiol Rev*. 2009;31(1):84-98. doi:10.1093/AJEREV/MXP003
43. Ananth C V., Joseph KS, Demissie K, Vintzileos AM. Trends in twin preterm birth subtypes in the United States, 1989 through 2000: impact on perinatal mortality. *Am J Obstet Gynecol*. 2005;193(3 Pt 2):1076.e1-1076.e9. doi:10.1016/J.AJOG.2005.06.088
44. Travers CP, Carlo WA, McDonald SA, et al. Racial/Ethnic Disparities Among Extremely Preterm Infants in the United States From 2002 to 2016. *JAMA Netw Open*. 2020;3(6). doi:10.1001/JAMANETWORKOPEN.2020.6757
45. Kroll ME, Kurinczuk JJ, Hollowell J, Macfarlane A, Li Y, Quigley MA. Ethnic and socioeconomic variation in cause-specific preterm infant mortality by gestational age at birth: national cohort study. *Arch Dis Child Fetal Neonatal Ed*. 2020;105(1):56-63. doi:10.1136/ARCHDISCHILD-2018-316463
46. Schempf AH, Branum AM, Lukacs SL, Schoendorf KC. The contribution of preterm birth to the black-white infant mortality gap, 1990 and 2000. *Am J Public Health*. 2007;97(7):1255-1260. doi:10.2105/AJPH.2006.093708
47. DIng G, Yu J, Chen Y, Vinturache A, Pang Y, Zhang J. Maternal Smoking during Pregnancy and Necrotizing Enterocolitis-associated Infant Mortality in Preterm Babies. *Sci Rep*. 2017;7. doi:10.1038/SREP45784

48. Dietz PM, England LJ, Shapiro-Mendoza CK, Tong VT, Farr SL, Callaghan WM. Infant morbidity and mortality attributable to prenatal smoking in the U.S. *Am J Prev Med*. 2010;39(1):45-52. doi:10.1016/J.AMEPRE.2010.03.009

49. Brandon GD, Adeniyi-Jones S, Kirkby S, Webb D, Culhane JF, Greenspan JS. Are outcomes and care processes for preterm neonates influenced by health insurance status? *Pediatrics*. 2009;124(1):122-127. doi:10.1542/PEDS.2008-1318

50. Escañuela Sánchez T, Linehan L, O'Donoghue K, Byrne M, Meaney S. Facilitators and barriers to seeking and engaging with antenatal care in high-income countries: A meta-synthesis of qualitative research. *Health Soc Care Community*. 2022;30(6):e3810-e3828. doi:10.1111/HSC.14072

51. Holcomb DS, Pengetnze Y, Steele A, Karam A, Spong C, Nelson DB. Geographic barriers to prenatal care access and their consequences. *Am J Obstet Gynecol MFM*. 2021;3(5). doi:10.1016/j.ajogmf.2021.100442

52. Shah JS, Revere FL, Toy EC. Improving Rates of Early Entry Prenatal Care in an Underserved Population. *Matern Child Health J*. 2018;22(12):1738-1742. doi:10.1007/S10995-018-2569-Z

53. Gadson A, Akpovi E, Mehta PK. Exploring the social determinants of racial/ethnic disparities in prenatal care utilization and maternal outcome. *Semin Perinatol*. 2017;41(5):308-317. doi:10.1053/J.SEMPERI.2017.04.008

54. Vintzileos AM, Ananth C V., Smulian JC, Scorza WE, Knuppel RA. The impact of prenatal care in the United States on preterm births in the presence and absence of antenatal high-risk conditions. *Am J Obstet Gynecol*. 2002;187(5):1254-1257. doi:10.1067/MOB.2002.127140

55. Cantarutti A, Franchi M, Monzio Compagnoni M, Merlino L, Corrao G. Mother's education and the risk of several neonatal outcomes: An evidence from an Italian population-based study. *BMC Pregnancy Childbirth*. 2017;17(1):1-10. doi:10.1186/S12884-017-1418-1/TABLES/3

56. Cook A, Stype A. Medicaid expansion and infant mortality: the (questionable) impact of the Affordable Care Act. *J Epidemiol Community Health*. 2021;75(1):10-15. doi:10.1136/JECH-2019-213666

57. Bellerose M, Collin L, Daw JR. The ACA Medicaid Expansion And Perinatal Insurance, Health Care Use, And Health Outcomes: A Systematic Review. *Health Aff (Millwood)*. 2022;41(1):60-68. doi:10.1377/HLTHAFF.2021.01150

58. Woods CR, Davis DW, Duncan SD, Myers JA, O'Shea TM. Variation in classification of live birth with newborn period death versus fetal death at the local level may impact reported infant mortality rate. *BMC Pediatr*. 2014;14(1):108. doi:10.1186/1471-2431-14-108

59. Ehrenthal DB, Wingate MS, Kirby RS. Variation by state in outcomes classification for deliveries less than 500 g in the United States. *Matern Child Health J*. 2011;15(1):42-48. doi:10.1007/S10995-010-0566-Y

60. State Definitions and Reporting Requirements. Published online 1997.

61. Kiefer MK, Adebayo A, Cleary E, et al. Gestational Weight Gain and Adverse Maternal and Neonatal Outcomes for Pregnancies Complicated by Pregestational and Gestational Diabetes. *Am J Perinatol*. 2022;39(7). doi:10.1055/S-0041-1739512

62. Graham J, Zhang L, Schwalberg R. Association of maternal chronic disease and negative birth outcomes in a non-Hispanic Black-White Mississippi birth cohort. *Public Health Nurs*. 2007;24(4):311-317. doi:10.1111/J.1525-1446.2007.00639.X

63. Venkatesh KK, Lynch CD, Powe CE, et al. Risk of Adverse Pregnancy Outcomes Among Pregnant Individuals With Gestational Diabetes by Race and Ethnicity in the United States, 2014-2020. *JAMA*. 2022;327(14):1356-1367. doi:10.1001/JAMA.2022.3189

64. Bureau UC. Multidimensional Deprivation in the United States: 2017. Accessed August 17, 2022. https://www.census.gov/library/publications/2019/acs/acs-40.html

65. Howell EM, Blondel B. International infant mortality rates: bias from reporting differences. *Am J Public Health*. 1994;84(5):850. doi:10.2105/AJPH.84.5.850

66. Profit J, Gould JB, Bennett M, et al. Racial/ethnic disparity in NICU quality of care delivery. *Pediatrics*. 2017;140(3). doi:10.1542/PEDS.2017-0918/38311