Possible Factors Illuminating Increased Disparities in Neonatal Mortality in Wisconsin from 1991-2005

Wen-Jan Tuan, MS; Peggy Hatfield, PhD, MS; Abhik Bhattacharya, PhD; Gloria E. Sarto, MD, PhD; Pamela J. Kling, MD

ABSTRACT

Background: Neonatal mortality has been perceived as one of the critical and sensitive measures that reflect not only the heath status of infants and their mothers, but also the general well-being of a society. However, our knowledge of racial disparities in neonatal mortality associated with low birth weight and short gestation is relatively limited. As part of continuing statewide efforts to achieve better birth outcomes, this study intends to develop a better understanding of potential mechanisms contributing to the discrepancy in neonatal mortality rates (NMR) to help public health practitioners formulate more effective interventions to prevent unnecessary infant deaths.

Objectives: To assess racial/ethnic disparities in neonatal morality risks by infant birth weight and gestational age in Wisconsin from 1991 through 2005, and to provide more information for programs emphasizing the development of policies and environmental changes to reduce and prevent infant mortality in minority populations.

Methods: Linked birth/infant death data were obtained from the Wisconsin Interactive Statistics on Health (WISH) query system by birthweight, prematurity, race/ethnicity for the periods, 1991-1995, 1996-2000, and 2001-2006. The probability of neonatal mortality was analyzed through log-linear Poisson regression models to test for the pattern of variation of neonatal mortality risks in relation to infant's race/ethnicity, birth weight, prematurity, and their interactions.

Results: The proportion of the neonatal deaths to the infant deaths has gradually increased over time, and accounted for more than two-thirds of Wisconsin infant deaths. Despite a large decrease in white NMRs, neonatal mortality risks for blacks and Hispanics did not significantly change. This discord led to a widened racial/ethnic gap in NMRs. Substantial variations on neonatal mortality risks by birth weight and preterm birth were found among whites, blacks, and Hispanics infants. Notably, among low birth weight and preterm infants, blacks and Hispanics appeared to have more favorable NMRs than whites. White infants had the lowest NMRs only delivered at full-term and about 2500 g.

Conclusion: Wisconsin infant mortality rates are largely driven by neonatal deaths. This shows an urgent need to develop effective public health interventions to prevent early neonatal deaths. To reduce racial/ethnic disparities in NMRs, the design of the interventions should also take into account the variation of the effects of birth weight and gestation age on neonatal mortality among racial/ethnic groups. It is hoped the result of this study will provide a critical understanding: when it comes to racial/ethnic disparities, there is far more to low birth weight or short gestational age than simply not having enough weight or days.

Author Affiliations: University of Wisconsin Health Innovation Program, University of Wisconsin School of Medicine and Public Health (Tuan); Center for the Study of Cultural Diversity in Healthcare, University of Wisconsin School of Medicine and Public Health (Hatfield, Sarto); UW Hospital (Bhattacharya); Pediatrics Division of Neonatology, University of Wisconsin School of Medicine and Public Health (Kling).

Corresponding Author: Wen-Jan Tuan, 546 Warf Office Building, 610 Walnut St, Madison, WI 53726; phone 608.262.7385; e-mail tuan@wisc.edu.

INTRODUCTION

The overall national rate of neonatal mortality (number of deaths of infants 0-27 days of age per 1000 live births) declined substantially during the past century.[1-3] The gain in neonatal survival can be attributed largely to improvements in the care of at-risk infants (delivered preterm and/or low birth weight).[1] These improvements notwithstanding, in 2004, complications caused by short gestation and low birth weight (LBW) constituted the second leading cause of death among infants <1 year of age.[4] The number of infants born at <37 weeks gestation (preterm) increased 20% since 1990.[1] Similarly, the number of infants weighing

less than 2500 g (LBW) rose over 20% during the past 2 decades.[1] Infants weighing less than 1500 g (very low birth weight [VLBW]) and those LBW infants weighing between 1500 and 2499 g are at significantly greater risk of disability and death.

The probability of an infant born either preterm or LBW is not distributed uniformly among the US population. In 2005, non-Hispanic black (18.4%) infants were more likely to be born premature than their non-Hispanic white (11.7% of total births) or Hispanic (12.1%) counterparts.[1] The percent of births characterized as LBW followed the same pattern, with non-Hispanic black infants (13.9%) posting higher rates than either non-Hispanic white (7.3%) or Hispanic (6.9%) infants. Studies into the potential interaction of gestational age and birth weight on birth outcomes identified several additional disparities. Non-Hispanic black infants born preterm and LBW experienced a lower risk of neonatal mortality than non-Hispanic white or Hispanic neonates; nonetheless, the substantially greater occurrence of these births vastly overshadowed this higher rate of survival.[1,3] In addition, non-Hispanic black neonates born at or above normal weight and gestational age were more than twice as likely to die as non-Hispanic white or Hispanic neonates. Conversely, for neonates born at >3500 g and 37-41 weeks, Hispanics displayed the lowest neonatal mortality rate.[1] Factors accounting for these differences, including biological, socioeconomic, and environmental remain under investigation.

In Wisconsin, disparities in rates of infant mortality persist, as non-Hispanic black babies experience death rates about 3-fold higher than non-Hispanic white babies. In 2004, the state infant mortality rate (death <1 year of age [IMR]) for non-Hispanic black infants reached an historical high of 19.2 per 1000 live births, a rate 4.3 times that of non-Hispanic white infants.[5] Hispanic populations similarly exhibited a discrepancy in IMR compared with the non-Hispanic white population.[6,7] As part of continuing statewide efforts to achieve better birth outcomes, the current research assesses racial/ethnic variations and disparities in birth weight/gestational age-specific neonatal mortality in Wisconsin. These efforts will provide more information for programs emphasizing the development of policies and environmental changes to reduce and prevent infant mortality in minority populations.

METHODS

This study examined the effects of infant birthweight and prematurity on neonatal death rates and disparities among racial/ethnic groups in Wisconsin from 1991 through 2005 (the latest year data are available). Infant mortality data were obtained through Wisconsin Interactive Statistics on Health (WISH) query system,[8] created from linked birth/infant death records for Wisconsin residents during the period of 1991-2005. Neonates who died in Wisconsin, but were born outside Wisconsin, were excluded in the database. In addition, only singleton live births to mothers with a reported maternal race/ethnicity of non-Hispanic white, non-Hispanic black, or Hispanic were selected for the study. For the remainder of this article, the term "white" will refer to non-Hispanic whites and the term "black" will refer to non-Hispanic blacks. Births to mothers recorded as American Indian, Asian, and other ethnicities were not included due to small numbers in each group.

Neonatal mortality rates (NMR) were computed as the number of deaths of infants aged 0-27 days per 1000 live births in a calendar year. Data on live births and neonatal deaths were stratified based on 4 commonly used risk categories of birth weight: extremely low birth weight (<1000 grams), very low birth weight (1000-1499 grams), low birth weight (1500-2499 grams), and normal birth weight (2500 grams and above). Premature birth is defined as newborns whose gestational age was less than 37 completed weeks at the time of delivery, and as full-term births whose gestational age reached 37 weeks or more at birth. The data were further organized into 3 consecutive 5-year periods: 1991-1995, 1996-2000, and 2001-2005.

Racial disparity on neonatal deaths was measured as rate ratio, obtained by dividing the rate of infant deaths in a minority population by the rate of infant deaths in the white population. The probability of neonatal mortality was analyzed through log-linear Poisson regression models to test for the pattern of variation of neonatal mortality risks in relation to infant's race/ethnicity, birth weight, prematurity, and their interactions. The multivariate log-linear analysis commenced a saturated model (including all the variables and their interactions), followed by a backward hierarchical process used to eliminate components that had the least impact on the overall fit of the model. The backward elimination process stopped when the most parsimonious model that still had acceptable fit was found. Poisson regression has been widely used in estimating mortality or morbidity rates in epidemiologic studies.[9,10] Least-squared means were compared by a Chi-square analysis to determine the relationships between those factors and the frequency of neonatal mortality. A confidence interval for the rate ratio was calculated to assess whether a substantial difference existed

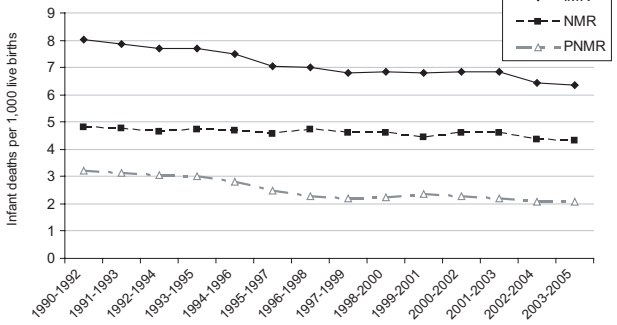

Figure 1. Three-year running averages of infant mortality rates, neonatal mortality rates, and postneonatal mortality rate in Wisconsin, 1990-2005.

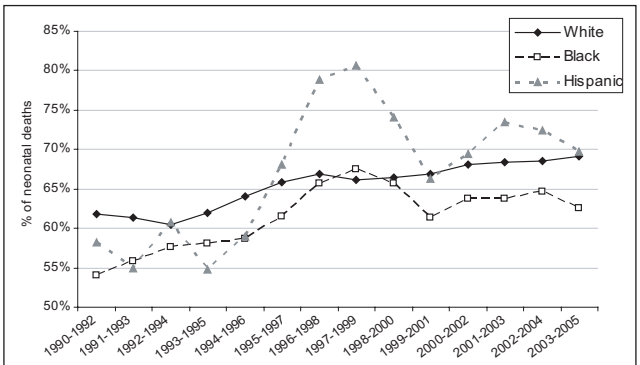

Figure 2. Three-year running averages of percentages of neonatal deaths to the total infant deaths by whites, blacks, and Hispanics in Wisconsin, 1991-2005.

between 2 rates. Rate ratios whose confidence interval did not include 1.0 indicated that the mortality disparity was statistically significant at an α level of .05. Log-linear Poisson regression models were computed by using PROC GENMOD procedure (SAS Institute Inc).

RESULTS

Over 1 million singleton births were reported in Wisconsin during 1991-2005. Of those infants, 809,280 (80%) were white, 96,124 (10%) black, 56,937 (6%) Hispanic, and 43,241 (4%) were other races (including 258 infants whose race/ethnicity was unknown). The analysis indicated a general downward trend in overall postneonatal mortality rates (death from 28 days to the first birthday) during the past decades, whereas overall neonatal mortality rates remained essentially the same (Figure 1). This shift in the distribution of infant deaths to earlier in life resulted in an increase in the proportion of neonatal deaths to two-thirds of the total infant deaths. The proportionate contribution of neonatal mortality to infant mortality also varied considerably among race/ethnic groups (Figure 2).

Approximately 12% of singleton infants born to black mothers weighed less than 2500 g (Table 1). The proportion of the LBW black babies was 2-3 times more than white (4.3%) and Hispanic (5.4%) infants. Moreover, of these infants, nearly 86% of the black neonatal deaths occurred to those weighing <2500 g, compared with 83% for Hispanics and 72% for whites. In addition, we detected a substantial variation in preterm births across racial/ethnic groups (7.9% for whites, 16.4% for blacks, 10.1% for Hispanics). Again, a substantial proportion of the neonatal deaths occurred among those infants born prematurely (85%, black; 76%, Hispanic; 70%, white). For infants weighing between 1000 and 2499 grams, NMR was lowest among blacks compared with either whites or Hispanics (Table 1). Preterm Hispanic babies weighing more than 1000 g also exhibited lower risks of neonatal mortality, compared to whites.

To further characterize these data, we applied multivariate log-linear regression analyses to specifically examine the effects of birth weight, short gestation, and race/ethnicity on neonatal mortality rates. Most prior studies used contingency tables based on Chi-square tests to examine the difference of NMRs between 2 factors, without controlling for the effects of other factors. Unlike traditional Chi-square tests, the use of log-linear regression allowed us to evaluate higher-order interaction effects among factors of interest. It also allowed us to compare models with different factor compositions, as a means to develop more precise models. The analysis on NMRs revealed that a 3-way interaction among birth weight, prematurity, and race/ethnicity was statistically significant (P×B×R, Table 2), along with a 2-way interaction between birth weight and race/ethnicity (B×R, Table 2). The interaction terms suggested that the effect of birth weight on NMRs changed among racial/ethnic groups, and the correlation of NMRs between birth weight and race/ethnicity varied by preterm and full-term infants. The final log-linear model also showed large 2-way interactions between time period and race/ethnicity (T×R, Table 2), and time period and short gestation (T×P, Table 2). These latter findings indicated the magnitude of the racial/ethnic effect on NMRs changed over time. Similarly, the difference on NMRs between preterm and full-term infants varied among the 3 5-year periods examined in the study.

Table 1 also provides the estimates of the NMRs and their rate ratios obtained based on the final log-linear model. The mortality rate ratio of Hispanics to whites was significant for preterm birth weights ≥2500 g, indicating a comparative survival advantage of Hispanics neonates born in the normal weight level. Conversely,

Table 1. Neonatal Mortality Rate (NMR) and Rate Ratio by Race/Ethnicity, Birth Weight, and Prematurity, Wisconsin, 1991-2005

Prematurity/ Birth Weight	% of Neonatal Deaths*	% of Live Births*	NMR†	Rate Ratio‡	95% CI
Preterm					
<1000 g					
Black	74.1	1.5	434.6	1.03	0.93 – 1.13
Hispanic	61.4	0.6	480.4	1.14	0.96 – 1.34
White	48.4	0.4	422.9	1.00	
1000-1499 g					
Black	2.2	1.0	19.3	0.33¶	0.20 – 0.53
Hispanic	4.2	0.5	42.5	0.72	0.39 – 1.33
White	6.2	0.3	59.0	1.00	
1500-2499 g					
Black	6.7	4.9	12.1	0.72§	0.54 – 0.95
Hispanic	8.9	2.3	17.3	1.02	0.67 – 1.56
White	10.8	2.0	16.9	1.00	
2500+ g					
Black	2.2	8.9	2.2	0.73	0.45 – 1.18
Hispanic	1.2	6.7	0.8	0.26§	0.08 – 0.81
White	4.9	5.1	3.1	1.00	
Full-Term					
<1000 g					
Black	0.8	<0.1	304.3	1.41	0.51 – 3.88
Hispanic	0.4	<0.1	100.0	0.46	0.57 – 3.70
White	0.3	<0.1	216.2	1.00	
1000-1499 g					
Black	0.1	0.1	14.5	0.14	0.02 – 1.09
Hispanic	1.5	<0.1	181.8	1.81	0.59 – 5.48
White	0.5	<0.1	100.7	1.00	
1500-2499 g					
Black	2.5	4.3	5.1	0.39¶	0.25 – 0.62
Hispanic	6.2	2.0	14.3	1.11	0.66 – 1.85
White	6.1	1.5	13.0	1.00	
2500+ g					
Black	11.4	79.3	1.3	1.61¶	1.30 – 1.99
Hispanic	16.2	87.9	0.8	1.05	0.77 – 1.44
White	22.7	90.6	0.8	1.00	

* Percent of neonatal deaths and percent of live births are calculated by racial/ethnic category.
† NMR denotes the number of neonatal deaths per 1000 live births.
‡ The rate ratio is the minority group NMR divided by the white NMR.
§ $P < .05$
¶ $P < .01$

full-term Hispanic babies weighing ≥1000 g had higher NMRs, although the disparity between Hispanics and whites was not significant. Analysis of NMRs for infants weighing less than 1000 g demonstrated a higher NMR among Hispanic preterm babies, whereas full-term black neonates experienced the highest NMR.

We examined the neonatal mortality rate of singleton infants by racial/ethnic group over 3 consecutive 5-year periods to elucidate trends in NMR (Figure 3). Black neonates consistently experienced higher NMRs than other race/ethnic groups, with a rising trend. Nonetheless, tests for the temporal change on NMRs among blacks were not statistically significant across time periods. We did observe decreases in NMRs for both white and Hispanics babies in the past decade. The downward trend was statistically significant for whites, but not for Hispanics. Although the analysis of neonatal mortality did not vary substantially among time periods within a specific minority group, the NMR gap between blacks and whites did show a significant increase over time (Table 3). The black-white rate ratio increased during both time periods, with an overall increase of 43% from 1991-1995 to 2001-2005 ($P<0.01$). For Hispanics, the NMR rate ratio increased 28% from 1991-1995 to 1996-2000 (Pa=0.16), followed by a 23% reduction from 1996-2000 to 2001-2005 ($P=0.08$).

Table 2. Final Log-linear Model of Neonatal Mortality Risks by Time Period, Birth Weight, Prematurity, Race/Ethnicity, and their Interactions

Factor	df	χ^2	*P*-value
Time period (T)	2	18.4	<.01
Birthweight (B)	3	391.2	<.01
Prematurity (P)	1	6.1	0.01
Race/ethnicity (R)	2	13.0	<.01
T×R	4	15.0	<.01
T×P	2	12.9	<.01
B×P	3	5.8	0.12
P×R	2	1.2	0.54
B×R	6	35.4	<.01
P×B×R	6	22.6	<.01

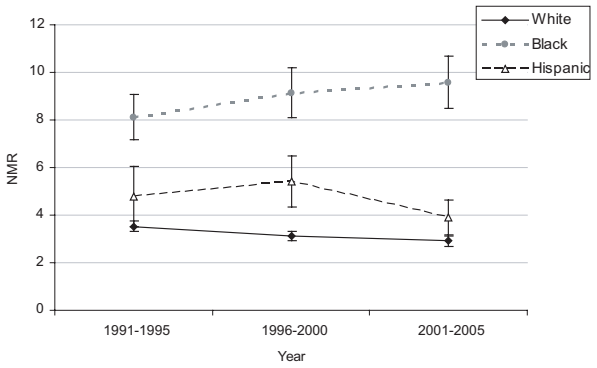

Figure 3. Neonatal mortality rates by whites, blacks, and Hispanics, Wisconsin, 1991-1995 to 2001-2005.

Neonatal mortality risks of both preterm and full-term infants gradually declined over the past 15 years (Table 3). The rate ratio of preterm to full-term infants in 1991-1995 was similar to the rate ratio in 1996-2000 (*P*=0.93), indicating that the percentages of NMR reduction among preterm (8.5%) and full-term (7.3%) babies were consistent between the 2 time periods. There was a marked increase in the rate ratios of the preterm to full-term infants from 1996-2000 to 2001-2005 (*P*=0.02). The NMR difference between preterm and full-term babies increased during the most recent 5-year period. The gap reflected a disproportional improvement resulting from full-term infants experiencing a 27.5% decrease in NMR between 1996-2000 and 2001-2005, in comparison with 2.7% for preterm babies.

DISCUSSION

Using log-linear regression analysis to examine Wisconsin neonatal mortality, we identified interactions among several factors, including race/ethnicity, birth weight, and short gestation. Our results confirmed many of the previously described racial/ethnic disparities in birth outcomes.[1-3] Namely, black neonates born weighing less than 2500 g and preterm demonstrated a higher rate of survival than comparable white or Hispanic neonates, whereas black infants born at or above optimal birth weight and gestation demonstrated a lower comparable rate of survival.[1-3] This finding is contradictory to the common perception that populations with a higher rate of low birth weights should encounter higher neonatal mortality risks than populations with a lower rate of low birth weights. Some researchers explain this paradoxical phenomenon by the Wilcox-Russell Hypothesis,[11] suggesting that infant mortality may be independent of birth weight. Nonetheless, the higher rate of survival was offset by a much higher proportion of black infants born preterm and LBW. The overall percentage of Hispanic infants with low birth weights was comparable with that of whites, although Hispanics had a much greater proportion of preterm births. White neonates experienced the most favorable NMR compared to black and Hispanic infants only at full-term and above 2500 g.

Our analysis of the Wisconsin data sets demonstrated a temporal pattern of NMRs differing from the nationwide trend showing a considerable decline in neonatal mortality among infants of all racial/ethnic populations.[1] During the period 1991-2005, deaths of singleton neonates increased as a proportion of total infant deaths for all races in Wisconsin. Despite this overall rise in neonatal deaths, the NMRs of whites declined over time. The lower NMR most likely resulted from the overall larger percentage of full-term births for white neonates, a factor that is associated with a greater survival advantage. In contrast, the proportion of deaths and the risk of neonatal mortality increased for black infants. The temporal change of neonatal mortality risks was significant for white infants, but not for black and Hispanic infants. The data further demonstrated the widening black-white disparities for NMRs. The discrepancy is likely attributed to a combination of an increase in black NMRs and a gradual decline in white NMRs. The reasons for this disparity are likely complex and multifactorial, and may possibly include other maternal- or pregnancy-related factors.[12]

The white NMR reduction in the 1990s could be a result of the implementation of the nationwide Healthy Start program in 1991, and the recent decline might reflect the expansion of the population coverage through the State Child Health Insurance Program starting in 1997.[13] It seems maternal and child health programs targeted to improving birth outcomes did not achieve similar effects on the survival of black infants. One

Table 3. Neonatal Mortality Rate and Rate Ratio by Time Period and Race/Ethnicity, and Time Period and Prematurity, Wisconsin, 1991-1995 to 2001-2005

	1991-1995			1996-2000			2001-2005		
	NMR*	Rate Ratio†	95% CI	NMR	Rate Ratio	95% CI	NMR	Rate Ratio	95% CI
Race									
Black	8.1	2.30‡	2.01 - 2.63	9.1	2.92‡	2.55 - 3.34	9.6	3.29‡	2.88 - 3.76
Hispanic	4.8	1.35‡	1.03 - 1.78	5.4	1.73‡	1.41 - 2.14	3.9	1.33‡	1.09 - 1.63
White	3.5	1.00		3.1	1.00		2.9	1.00	
Prematurity									
Preterm	34.5	27.4‡	24.3 - 30.9	31.5	27.0‡	23.8 - 30.7	30.7	36.3‡	31.5 - 41.8
Full-term	1.3	1.00		1.2	1.00		0.8	1.00	

* Neonatal mortality rate (NMR) denotes the number of neonatal deaths per 1000 live births.
† The rate ratio is the minority group NMR divided by the white NMR.
‡ $P < .05$

explanation for these results is that blacks and whites did not receive the same level of prenatal care, because of SES- or resource-related factors, such as education and transportation availability.[14] Considerable variation in the extent of the decline in neonatal mortality for preterm and full-term infants also exists, regardless of race/ethnicity. The exact cause of the high overall preterm birth rates is still unknown, and requires further investigation.[15] Nonetheless, it is reasonable to suggest neonatal survival rates can be substantially improved by preventing preterm births.

Testing additional determinants of NMRs will permit a refinement of the model and further the development of effective interventions. For example, a recent study examined the contribution of political and social welfare determinants to the infant mortality of wealthy countries, including the United States.[16] The results suggested mechanisms underlying infant mortality and low birth weight rates respond differently to political and social determinants, although the percentage of the population under public medical care is significantly correlated with both rates.

There are some limitations with respect to the analysis and data that may affect the findings of the study. The linked birth/infant death data extracted from WISH were obtained in an aggregate level by birth weight, short gestation, race/ethnicity, and time period, as opposed to individual-level data. The use of the group data restricts our ability to control other maternal and SES-related factors at the individual level. In addition, drawing inferences from group data can be prone to ecological fallacy. Nonetheless, as each individual in a birth weight-gestational age-race/ethnicity group has the characteristics associated with the specific birth weight-gestational age-race category, the potential bias associated with ecological fallacy is minimized. Last, because there were a relatively small number of full-term infants weighing <1500 grams observed, the result of the neonatal mortality risk estimates and rate ratios should be interpreted with caution.

CONCLUSION

Conventional public health practices in reduction of neonatal deaths often focus on the improvement in quality of the pregnancy and delivery care, which requires more sophisticated medical interventions, especially to keep low birth weight and premature infants alive. Yet there is no clear evidence whether those preventions are also effective in eliminating overall racial disparities on NMRs. Our analysis revealed substantial variations on neonatal mortality risks by birth weight and prematurity among whites, blacks, and Hispanics infants. Nevertheless, the causes of racial disparities on NMRs among low birthweight babies can be complicated and attributed to a combination of maternal psychological, socioeconomic, behavioral, and environmental risk factors.[11,13] This study demonstrates the importance of the birthweight and prematurity effects in explaining that neonatal mortality rates can generate a critical understanding: when it comes to racial/ethnic disparities, there is far more to low birthweight or short gestational age than simply not having enough weight or days.

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