Original Research

Health Care Disparity and Pregnancy-Related Mortality in the United States, 2005–2014

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OBJECTIVE: To quantitate the contribution of various demographic factors to the U.S. maternal mortality ratio.

METHODS: This was a retrospective observational study. We analyzed data from the Centers for Disease Control and Prevention (CDC) National Center for Health Statistics database and the Detailed Mortality Underlying Cause of Death database (CDC WONDER) from 2005 to 2014 that contains mortality and population counts for all U.S. counties. Bivariate correlations between the maternal mortality ratio and all maternal demographic, lifestyle, health, and medical service utilization characteristics were calculated. We performed a maximum likelihood factor analysis with varimax rotation retaining variables that were significant ($P<.05$) in the univariate analysis to deal with multicollinearity among the existing variables.

RESULTS: The United States has experienced an increase in maternal mortality ratio since 2005 with rates increasing from 15 per 100,00 live births in 2005 to 21–22 per 100,000 live births in 2013 and 2014. ($P<.001$) This increase in mortality was most pronounced in non-Hispanic black women, with ratios rising from 39 to 49 per 100,000 live births. A significant correlation between state mortality ranking and the percentage of non-Hispanic black women in the delivery population was demonstrated. Cesarean deliveries, unintended births, unmarried status, percentage of deliveries to non-Hispanic black women, and four or fewer prenatal visits were significantly ($P<.05$) associated with the increased maternal mortality ratio.

CONCLUSION: The current U.S. maternal mortality ratio is heavily influenced by a higher rate of death among non-Hispanic black or unmarried patients with unplanned pregnancies. Racial disparities in health care availability and access or utilization by underserved populations are important issues faced by states seeking to decrease maternal mortality.

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The United States ranks much higher in pregnancy-related mortality in comparison with most other developed countries.[1] Of equal concern is the observation that this situation is not improving; U.S. maternal mortality ratios have remained stable for several decades and appear to be increasing.[2,3] Within the United States, significant variation exists in maternal mortality ratios for individual states.[3] Such differences could be the result of variations in funding, oversight, or organization of state health care services and could reflect the intrinsic quality of available health care. Alternately, this variation may simply be a product of differences in the prevalence of medical risk factors for poor perinatal outcomes or demographic disparities with lack of access to medical–obstetric services.[4,5] We sought to update the available 2006–2010 national mortality report, to investigate factors associated with differential state

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maternal mortality ratios, and to quantitate the contribution of various demographic factors to such variation.

MATERIALS AND METHODS

This was a retrospective, observational study. We used data from the National Vital Statistics System. The birth data are published by the Centers for Disease Control and Prevention's (CDC) National Center for Health Statistics and include all events occurring between 2005 and 2014 for all 50 states and the District of Columbia.[6–16] Maternal demographic characteristics (age, marital status, education, state of residence, and race), lifestyle and health characteristics (tobacco use, previous cesarean delivery, prepregnancy diabetes, gestational diabetes, prepregnancy hypertension, pregnancy-induced hypertension, prepregnancy obesity [body mass index (calculated as weight (kg)/[height (m)]^2) 25 or greater], and eclampsia), and medical service utilization (method of delivery, source of payment, and number of prenatal visits) were extracted from this same CDC database.[16]

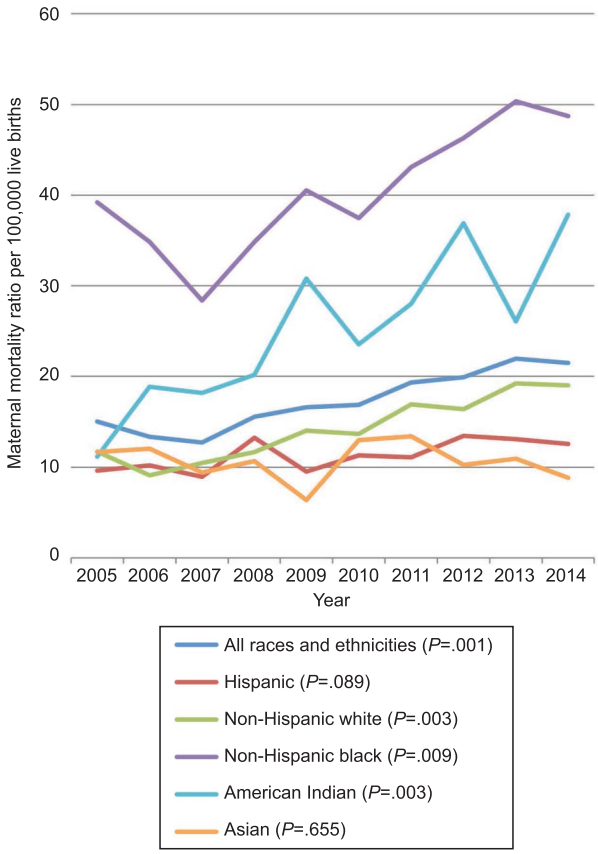

Fig. 1. Trends in maternal mortality ratio (maternal deaths/100,000 live births) by ethnic group and race: United States, 2005–2014. Numbers in parentheses represent *P* values for the Jonckheere-Terpstra test.

Moaddab. Trends in Maternal Mortality: 2005–2014. Obstet Gynecol 2018.

Maternal death data are based on the Detailed Mortality-Underlying Cause of Death database (CDC WONDER) that contains mortality and population counts for all U.S. counties.[17] These data are based on death certificates for U.S. residents. Each death certificate identifies a single underlying cause of death (four-digit International Classification of Diseases, 10th Revision [ICD-10] code) and associated demographic data. When more than one cause or condition was entered by the physician, the underlying cause was determined by the sequence of conditions specified on the certificate.[17] Maternal causes are those assigned to categories A34, O00–O95, and O98–O99 of the ICD-10, Second Edition.[18–20] The CDC WONDER data set terms of use do not permit republication of the publically available individual data from states with annual maternal deaths of nine or less.[17] Therefore, neither the available individual mortality counts nor ratios derived from these counts for individual states are reproduced in this article.[17] A maternal death is defined by the CDC as a death occurring during pregnancy or within 1 year of birth.

Data on urban makeup of the population, percentage of unintended pregnancies, health insurance coverage of women ages 15–49 years, and adult woman poverty rate were also collected.[21,22] The number of missing values used in the final analysis was less than 1% of all data in aggregate; in terms of the data representing the primary focus of this study, only 22 of 7,031 (0.3%) total maternal deaths were not associated with a specific ethnic status.

We used publically available data that do not contain any individual identifiers; thus, this study was exempt from human subject research regulatory and institutional review board approval.

Bivariate correlations between maternal mortality ratio and all maternal demographic, lifestyle, health, and medical service utilization characteristics were calculated. We also performed a maximum likelihood factor analysis with varimax rotation retaining variables that were significant ($P<.05$) in the univariate analysis. Factor analysis was performed to deal with multicollinearity among the existing variables and to better identify variables that most closely and independently predicted maternal mortality ratio. We assessed the association between the extracted factors and maternal mortality ratio by correlation and regression analyses and used the Jouckheera-Terpska test to determine the presence or absence of a trend,

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Table 1. Number of Maternal Deaths and Live Births by Year and Age, United States, 2005–2014

Year	No. of Maternal Deaths by Age (y)			No. of Live Births by Age (y)		
	Younger Than 15	15–44	45 or Older	Younger Than 15	15–44	45 or Older
2005	0	578	45	6,722	4,125,091	6,536
2006	1	532	36	6,396	4,252,185	6,974
2007	1	508	39	6,195	4,302,685	7,353
2008	0	605	55	5,764	4,234,280	7,650
2009	3	601	81	5,029	4,117,747	7,889
2010	1	614	59	4,497	3,987,164	7,725
2011	2	665	98	3,974	3,942,006	7,610
2012	1	656	130	3,674	3,941,512	7,750
2013	0	686	178	3,098	3,920,911	8,172
2014	2	682	171	2,771	3,974,687	8,465
*P**	.394	.003	.003	.001	<.001	.006

* Jonckheere-Terpstra test.

either increasing or decreasing. A *P* value of <.05 was considered statistically significant. In all cases, ethnic designation is as reported in the original CDC data. All analyses were performed in SAS 9.4 and statistical software package SPSS 21.0.

RESULTS

Between 2005 and 2014, there were 40,922,512 live births and 7,031 maternal deaths in the United States (Tables 1 and 2). Table 3 details correlation coefficients between demographic, lifestyle, health, and socioeconomic characteristics and available maternal mortality ratio.[17]

The overall mortality ratio during this period of time was 15.6 per 100,000. As demonstrated in Table 2 and Figure 1, after a slight decrease from 15 to 12 per 100,000 live births between 2005 and 2007, there has been a continued increase in maternal mortality ratio since 2007 with a rate of 21–22 per 100,000 live births in 2013 and 2014 (*P*<.001) This trend was most pronounced in women aged 45 years and older, although the numbers are small in this subgroup. As demonstrated in Figure 1, the recent increase in mortality was most pronounced in non-Hispanic black women and of lesser magnitude in Native American and non-Hispanic white women. This increase was not seen in Asian or Hispanic women after 2008. There was a significant correlation between state mortality ranking and the proportion of non-Hispanic black women in the delivery population and an inverse correlation with deliveries to non-Hispanic white women (Table 3). Of all risk factors examined (Table 3), only gestational diabetes, cesarean deliveries, unintended births, unmarried status, percentage of deliveries to non-Hispanic black women, and four or fewer prenatal visits were significantly (*P*<.05) associated with maternal mortality ratio. The probability level for the χ^2 test was *P*>.05 for the hypothesis of one common factor, indicating the one-factor model was an adequate representation. Regarding these risk

Table 2. Maternal Mortality Ratio, Deaths per 100,000 Live Births by Age

Year 2005	Maternal Mortality Ratio (CI) by Age (y) Per 100,000 Live Births			
	Younger Than 15	15–44	45 or older	All Ages
2006	0	14 (13–15)	688 (487–890)	15
2007	16 (−16 to 43)	13 (11–14)	516 (348–685)	13
2008	16 (−16 to 48)	12 (11–13)	530 (364–697)	12
2009	0	14 (13–15)	719 (529–909)	16
2010	59 (−8 to 127)	15 (13–16)	1,027 (803–1,250)	17
2011	22 (−21 to 66)	15 (14–17)	764 (569–959)	17
2012	50 (−19 to 120)	17 (16–18)	1,288 (1,033–1,543)	19
2013	27 (−26 to 81)	17 (15–18)	1,677 (1,389–1,966)	20
2014	0	18 (16–19)	2,178 (1,858–2,498)	22
2015	72 (−28 to 172.2)	17 (16–18)	2,020 (1,717–2,323)	21
*P**	.121	.003	.001	.001

* Jonckheere-Terpstra test.

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Table 3. Correlation Coefficients Between State-Specific Maternal Demographic, Lifestyle, Health, and Socioeconomic Characteristics and Maternal Mortality in the United States, 2005–2014*

Characteristic	Simple Pearson's Correlation Coefficient	*P*
% deliveries to non-Hispanic black women	0.501	<.001
Unintended pregnancy	0.500	<.001
Unmarried mother	0.423	.002
Four or fewer prenatal visits	0.322	.020
Gestational diabetes	−0.319	.021
Cesarean delivery	0.288	.047
Chronic hypertension	0.069	.627
Pregnancy-induced hypertension	−0.123	.384
Eclampsia	0.003	.982
Diabetes	0.196	.163
Tobacco	−0.094	.510
Obesity	0.163	.249
Maternal education less than high school	0.210	.135
Deliveries paid by governmental insurance	0.282	.050
Women with health care coverage	−0.282	.076
Poverty	0.214	.128
% rural population	−0.069	.624
% deliveries to Hispanic women	−0.006	.964
% deliveries to non-Hispanic white women	−0.254	.069
% deliveries to Native American women	−0.016	.912
% deliveries to Asian women	−0.141	.318
% pregnancies with maternal age older than 45 y	−0.098	.490

* Raw data are available at http://wonder.cdc.gov/.

factors, factor, the highest correlation, based on standardized regression coefficients, was seen with the variable of deliveries to black women (0.39). Weaker regression coefficients included those for unmarried status and cesarean deliveries (0.25), unintended pregnancy (0.17), fewer than four prenatal visits (0.04), and diabetes (−0.05) This factor, which can be interpreted primarily as sociodemographic characteristics, had a correlation of 0.51 with maternal mortality ratio (P=01). The presence of both unmarried status and cesarean delivery on this factor is expected because black ethnicity had a high association with both unmarried status (r=0.65) and with cesarean delivery (r=0.66) (P<.001).

DISCUSSION

The U.S. maternal mortality ratio continues to climb and reached a rate of 21–22 per 100,000 in 2013 and 2014. Many explanations for this trend have been offered. Although the United States has a higher rural population than many European nations, Canada, a nation which is even more rural, has a maternal mortality ratio less than half of the United States'–10 per 100,000 live births.[23] Furthermore, our data failed to identify a statistical correlation between state-specific maternal mortality and either rural status or poverty (Table 3). Immigration has also been cited as a factor in this mortality trend. However, we found lower mortality for Hispanic women who make up the majority of recent immigrants (Fig. 1). This finding has been noted previously and has been attributed to unique social factors and family support often available to these women.[24]

The high U.S. cesarean rate has also been invoked as an explanation for increased mortality, yet our data demonstrate only a weak correlation of mortality with cesarean delivery. Furthermore, previous work has demonstrated that this correlation does not reflect causation; the overwhelming majority of maternal deaths associated with cesarean delivery is a consequence of the indication for the cesarean delivery, not the operation itself.[25] Although medical factors such as hypertensive disease, diabetes, tobacco use, and obesity have been shown to be correlated with increased maternal morbidity, statewide population differences in rates of these conditions were not significantly correlated with mortality ratios (Table 3). The 1999 change in maternal mortality coding practices (ICD-9 to ICD-10) could also be invoked as an explanation for this trend in the United States. However, the continued upward trend in mortality more than a decade later, and the absence of such a trend in

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Canada,[23] which uses the same coding system, casts doubt on this assumption.

Our data suggest that much of the variation in statewide maternal mortality ratios in the United States is accounted for by social rather than medical or geographic factors: unintended pregnancy, unmarried mother, and non-Hispanic black race (Table 3). These data provide evidence for a strong contribution of racial disparity to maternal mortality ratio in the United States. Particularly striking is the close correlation between ethnic background and maternal mortality. A factor derived from factor analysis, which primarily represented ethnic background, accounted for 26% of the differences in statewide mortality. Excellent care is apparently available, but is not reaching all the people.

These data support two conclusions. First, although low state maternal mortality ratios may reflect state-specific excellence in quality, leadership, organization, and funding of obstetric health care, such favorable ranking could simply reflect a different proportion of non-Hispanic black patients in the population rather than intrinsically superior medical care. The converse applies as well.

Second, comparative health care statistics that do not adjust for these important demographic factors are of little significance in judging the intrinsic quality of available health care in an individual state or region. The potential relative contributions of factors such as racial disparities in health care availability and access or utilization by underserved populations are not addressed by our data, but are important issues faced by states seeking to decrease maternal mortality. Ethnic genetic differences may also be involved. In addition, the potential role of unconscious (implicit) bias in this significant racial disparity must be considered.[25]

Finally, available publications consistently document relatively good maternal outcomes for select groups of otherwise healthy older women undertaking pregnancy.[26,27] Such data, coupled with the national age-related mortality ratios presented in Tables 1 and 2, suggest that many older mothers in the United States are not healthy. The mortality ratio in women 45 years of age or older surpasses those in many low-resource nations. Again, these numbers are small, suggesting caution in interpretation of these data. However, careful health screening and preconception counseling are recommended before recommending pregnancy to such women. This is particularly germane to women who plan to conceive after assisted reproductive technologies because in this population, such screening should always be possible.

This study has several limitations. First, it is recognized that significant underreporting of U.S. maternal mortality exists when data are obtained based on ICD cause-of-death codes.[28] Actual maternal mortality rates are therefore likely to be higher than those reported here. In addition, our data sets do not allow a precise determination of the causes of death, although such data have been extensively reported in other recent series from the United States.[29,30]

We conclude that the increased mortality ratios seen in the United States in recent years reflect significant social as well as medical challenges and are closely related to lack of access to health care in the non-Hispanic black population. Our results provide evidence for the strong contribution of racial disparity to the maternal mortality ratio in the United States and suggest that addressing issues related to health care disparity and access for this population will play an important role in national attempts to reverse this mortality trend.

REFERENCES

1. The Organisation for Economic Co-operation and Development (OECD). OECD health data: health status: maternal and infant mortality. Available at: http://stats.oecd.org/index.aspx?DataSetCode=HEALTH_STAT#. Retrieved February 14, 2018.
2. Berg CJ, Callaghan WM, Syverson C, Henderson Z. Pregnancy-related mortality in the United States, 1998 to 2005. Obstet Gynecol 2010;116:1302–9.
3. Creanga AA, Berg CJ, Ko JY, Farr SL, Tong VT, Bruce FC, et al. Maternal mortality and morbidity in the United States: where are we now? J Womens Health (Larchmt) 2014;23:3–9.
4. Brown HL, Small M, Taylor YJ, Chireau M, Howard DL. Near miss maternal mortality in a multiethnic population. Ann Epidemiol 2011;21:73–7.
5. Callaghan WM. State-based maternal death reviews: assessing opportunities to alter outcomes. Am J Obstet Gynecol 2014;211:581–2.
6. Martin JA, Hamilton BE, Sutton PD, Ventura SJ, Menacker F, Kirmeyer S, et al. Births: final data for 2005. Natl Vital Stat Rep 2007;56:1–103.
7. Martin JA, Hamilton BE, Sutton PD, Ventura SJ, Menacker F, Kirmeyer S, et al. Births: final data for 2006. Natl Vital Stat Rep 2009;57:1–104.
8. Martin JA, Hamilton BE, Sutton PD, Ventura SJ, Mathews TJ, Kirmeyer S, et al. Births: final data for 2007. Natl Vital Stat Rep 2010;58:1–85.
9. Martin JA, Hamilton BE, Sutton PD, Ventura SJ, Mathews TJ, Osterman MJ. Births: final data for 2008. Natl Vital Stat Rep 2010;59:1, 3–71.
10. Martin JA, Hamilton BE, Ventura SJ, Osterman MJ, Kirmeyer S, Mathews TJ, et al. Births: final data for 2009. Natl Vital Stat Rep 2011;60:1–70.
11. Martin JA, Hamilton BE, Ventura SJ, Osterman MJ, Wilson E, Mathews TJ. Birth: final data for 2010. Natl Vital Stat Rep 2012;61:1–72.

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12. Martin JA, Hamilton BE, Ventura SJ, Osterman MJ, Mathews TJ. Births: final data for 2011. Natl Vital Stat Rep 2013;62:1–69, 72.
13. Martin JA, Hamilton BE, Osterman MJ, Curtin SC, Mathews TJ. Births: final data for 2012. Natl Vital Stat Rep 2013;62:1–68.
14. Martin JA, Hamilton BE, Osterman MJ, Curtin SC, Matthews TJ. Births: final data for 2013. Natl Vital Stat Rep 2015;64:1–65.
15. Hamilton BE, Martin JA, Osterman MJ, Curtin SC. Births: preliminary data for 2014. Natl Vital Stat Rep 2015;64:1–19.
16. Centers for Disease Control and Prevention, National Center for Health Statistics. VitalStats. Available at: http://www.cdc.gov/nchs/vitalstats.htm. Retrieved February 14, 2018.
17. United States Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics. Underlying cause of death 1999-2014 on CDC WONDER online database. 2015. Available at: http://wonder.cdc.gov/. Retrieved February 14, 2018.
18. Xu JQ, Kochanek KD, Murphy SL, Tejada-Vera B. Deaths: final data for 2007. Natl Vital Stat Rep 2010;58:1–19.
19. Kung HC, Hoyert DL, Xu JQ, Murphy SL. Deaths: final data for 2005. Natl Vital Stat Rep 2008;56:1–120.
20. Xu JQ, Murphy S, Kochanek KD, Bastian B. Deaths: final data for 2013. Natl Vital Stat Rep 2016;64:1–119.
21. Iowa State University, Iowa Community Indicators Program. Urban percentage of the population for states, historical. Available at: http://www.icip.iastate.edu/tables/population/urban-pct-states. Retrieved January 9, 2016.
22. Kost K. Unintended pregnancy rates at the state level: estimates for 2010 and trends since 2002. Available at: https://www.guttmacher.org/pubs/StateUP10.pdf. Retrieved January 9, 2016.
23. Verstraeten BS, Mijovic-Kondejewski J, Takeda J, Tanaka S, Olson DM. Canada's pregnancy-related mortality rates: doing well but room for improvement. Clin Invest Med 2015;38:E15–22.
24. Brown HL, Chireau MV, Jallah Y, Howard D. The "Hispanic paradox": an investigation of racial disparity in pregnancy outcomes at a tertiary care medical center. Am J Obstet Gynecol 2007;197:197.e1–7.
25. Hall WJ, Chapman MV, Lee KM, Merino YM, Thomas TW, Payne BK, et al. Implicit racial/ethnic bias among health care professionals and it influence on health care outcomes: a systematic review. Am J Public Health 2015;105:e60–76.
26. Richards MK, Flanagan MR, Littman AJ, Burke AK, Callegari LS. Primary cesarean section and adverse delivery outcomes among women of very advanced maternal age. J Perinatol 2016;36:272–7.
27. Dildy GA, Jackson GM, Fowers GK, Oshiro BT, Varner MW, Clark SL. Very advanced maternal age: pregnancy after age 45. Am J Obstet Gynecol 1996;175:668–74.
28. Deneux-Tharaux C, Berg C, Bouvier-Colle MH, Gissler M, Harper M, Nannini A, et al. Underreporting of pregnancy-related mortality in the United States and Europe. Obstet Gynecol 2005;106:684–92.
29. Creanga AA, Berg CJ, Syverson C, Seed K, Bruce FC, Callaghan WM. Pregnancy-related mortality in the United States, 2006-2010. Obstet Gynecol 2015;125:5–12.
30. Clark SL, Belfort MA, Dildy GA, Herbst MA, Meyers JA, Hankins GD. Maternal death in the 21st century: causes, prevention, and relationship to cesarean delivery. Am J Obstet Gynecol 2008;199:36.e1–5.

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