DIFFERENT RACE COMBINATION COUPLES AND BIRTH OUTCOMES IN THE UNITED STATES: FROM 1989 TO 2013

By

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ABSTRACT

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A large body of previous studies showed consistent results on race disparities of maternal race/ethnicity and fetal growth restrictions, while studies on paternal race/ethnicity as well as the combination of maternal and paternal race/ethnicity is limited. Increasing trend of mixed race marriage has led to an increasing trend of mixed-race baby boom. These give us more opportunities to look at the paternal race/ethnicity and fetal growth restrictions as well as looking at the trend of prevalence of those outcomes among different race combinations.

This dissertation has two main aims. The first is to investigate the association between maternal/paternal race/ethnicity combinations and infant fetal growth (LBW and SGA), examining combinations between non-Hispanic white, non-Hispanic black, Hispanic, Asian/Pacific Islander and “missing”. The second is to investigate whether the association between different combinations of maternal/paternal race/ethnicity and SGA differs by year of birth (1989-2013), and to investigate whether any observed trend can be explained by changes in the demographic characteristics of parents in mixed-race partnerships.

The population of this dissertation is from U.S. natality data from 1989 to 2013 for all singleton births to women 15-44 with available data on maternal age, race/ethnicity, nativity, marital status, education, parity, birthweight and gestational age (n= 90,771,339). We examined the unadjusted prevalence and adjusted odds of low birth weight (<2500 g, LBW) and small for gestational age (<10th percentile, SGA) by maternal and paternal race/ethnicity categories (i.e.,

all possible combinations of non-Hispanic black [” black”], non-Hispanic white [” white”], Hispanic, and Asian, as well as all combinations where paternal race/ethnicity was missing).

The dissertation showed results that: both black and “missing” paternal race/ethnicity were strongly associated with LBW and SGA, within maternal race/ethnicity. However, for Asian mothers, all paternal racial/ethnic groups—including both black and “missing”—conferred lower odds of SGA compared to Asian paternal race (e.g., OR for black vs. Asian paternal race: 0.70 [95%CI: 0.69,0.72], OR for “missing” vs. Asian paternal race: 0.91 [95%CI: 0.90,0.93]). Second, results showed that the prevalence of SGA among all mothers (i.e., white, black, Hispanic, Asian) partnering with a father of a different race/ethnicity have increased over time, the prevalence of SGA in half, not all, of the mixed-race groups relative to the white/white group decreased over time, and the difference in prevalence between mixed race and white/white could not be explained by these demographic characteristics (education, marital status, parity, nativity, maternal age).

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KEY TO ABBREVIATIONS

Low Birth Weight (LBW)

Very Low Birth Weight (VLBW)

Small for Gestational Age (SGA)

Relative Risk (RR)

Prevalence Ratio (PR)

SMR (Standardized Morbidity Ratio)

CHAPTER 1 INTRODUCTION AND AIMS

The percentage of interracial marriages, among all marriages in the U.S, has increased over time, from 6.7% in 1980 to 14.6% in 2008 (1) . This trend has led to an “interracial baby boom”: in the 1970s only about 1 percent of infants were born from interracial marriage, whereas by 2000, that number had reached more than 5 percent (2). It is well known that maternal race/ethnicity is strongly associated with birth outcomes. In 2014, Non-Hispanic black women had higher rates of preterm delivery (13.2%), very preterm delivery (3.1%), low birthweight babies (13.2%) and very low birthweight (2.9%) compared to Non-Hispanic white women. (8.9%, 1.3%, 7.0%, 1.1%, respectively) (3) However, paternal race/ethnicity, which incorporates both biological and sociological factors, also appears to play an important role in gestational age and birth weight of neonates (4–6). The increasing prevalence of mixed-race infants gives researchers more opportunities to investigate the relationship between paternal race/ethnicity and birth outcome, because if we only compare black mother/black father couples with white mother/white father couples we were not be able to make the distinction between effect from father or from mother. However, the existing literature lacks studies examining paternal race/ethnicity groups other than black or white as well as studies investigating this association across time. My study filled these gaps by examining the relationship between different maternal/paternal race/ethnicity combinations (including Hispanics and Asians) and measures of fetal growth (i.e., LBW, SGA). We included “missing” paternal race/ethnicity as a separate category to gain further knowledge of paternal “missingness” as a risk factor for poor fetal growth. I also examined this association across time. The aims of this dissertation are:

Aim 1. To investigate the association between maternal/paternal race/ethnicity combinations and infant fetal growth (LBW and SGA), examining combinations between non-Hispanic white, non-Hispanic black, Hispanic, Asian/Pacific Islander and "missing".

Hypothesis 1a. When stratified by mother's race/ethnicity, the odds of LBW or SGA will be the lowest when paternal race/ethnicity is white

Hypothesis 1b. When stratified by mother's race/ethnicity, the odds of LBW or SGA will be the highest when paternal race/ethnicity is "missing".

Aim 2. To investigate whether the association between different combinations of maternal/paternal race/ethnicity and SGA differs by year of birth (1989-2013), and to investigate whether any observed trend can be explained by changes in the demographic characteristics of parents in mixed-race partnerships.

Hypothesis 2a. The prevalence of SGA among all mothers (i.e., white, black, Hispanic, Asian) partnering with a father of a different race/ethnicity have increased over time**.**

Hypothesis 2b. The prevalence of SGA in the mixed race groups relative to the white/white group will decrease over time. That is, the prevalence ratio [PR] for SGA for each mixed race group compared to the white/white group in 2013 will be smaller than the PR in 1989.

Hypothesis 2c. The difference in prevalence between mixed race and white/white will be explained by these demographic characteristics (education, marital status, parity, nativity, maternal age).

CHAPTER 2 BACKGROUND AND SIGNIFICANCE

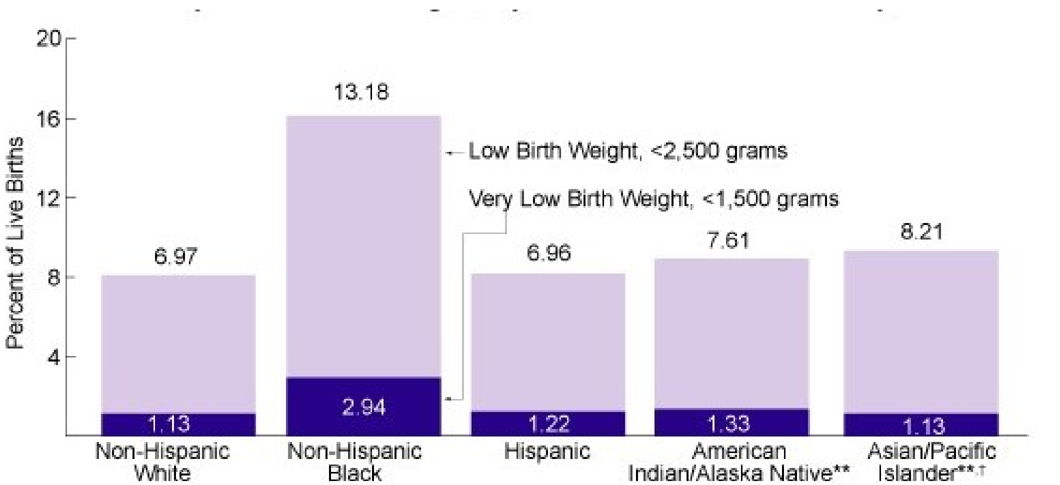
2.1 Race and Low Birth Weight, Small for Gestational Age

Low birth weight (LBW, <2500 g) and small for gestational age (SGA, <10th percentile of birth weight for gestational age) represent two main factors associated with infant mortality and morbidity (7). Serious long-term consequences of LBW and SGA include substantial medical costs after discharge from the hospital, high risks of subnormal growth, heath conditions (e.g., cerebral palsy, blindness, deafness, respiratory conditions), and poor neurodevelopmental outcomes(8), and—at the population-level—economic burden on special education and social services (9).

Non-Hispanic black (hereafter, “black”) women have had a higher risk of delivering LBW infants than Hispanic women and non-Hispanic white (hereafter, “white”) women for as long as data have been collected in the United States (U.S.) (3). In 1989, the risk of low birth weight for black women was 13.6% while for Hispanic women it was 6.2% and for white women it was 5.6% in the U.S. This disparity persists in 2014; black women are still almost two times more likely to have babies of low birthweight compared to Asian women, Hispanic women, and white women (13.2% vs. 8.1%, 7.1% and 7.0%, respectively)(3).

Figure 2.1 showed that in 2012, there were still racial disparities of having LBW or Very Low Birth Weight (VLBW, birth weight<1,500 g) babies, non-Hispanic black had much higher risk (13.18%) of having LBW babies compared to other race/ethnicity groups, and two times the risk of having VLBW babies compared to other race/ethnicity groups, too.

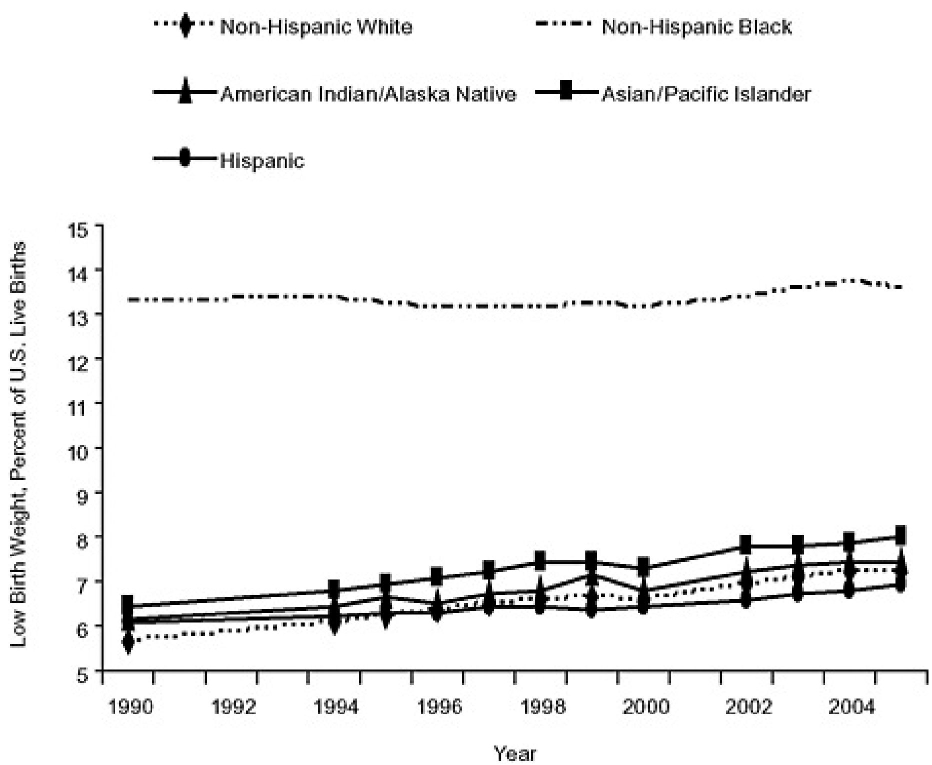
Figure 2.1 Percent of live singleton births born LBW and VLBW, by maternal race/ethnicity, 2012



*Data for 2012 are preliminary. **Includes Hispanics. †Separate data for Asians and Native Hawaiians and Other Pacific Islanders not available.

Source: Hamilton BE, Martin JA, Ventura SJ. Births: Preliminary data for 2012. National vital statistics repoı vol 62 no 3. Hyattsville, MD: National Center for Health Statistics. 2013.

Figure 2.2 Trend of percent of singleton live births born LBW by maternal race/ethnicity in U.S, from 1990 to 2006.



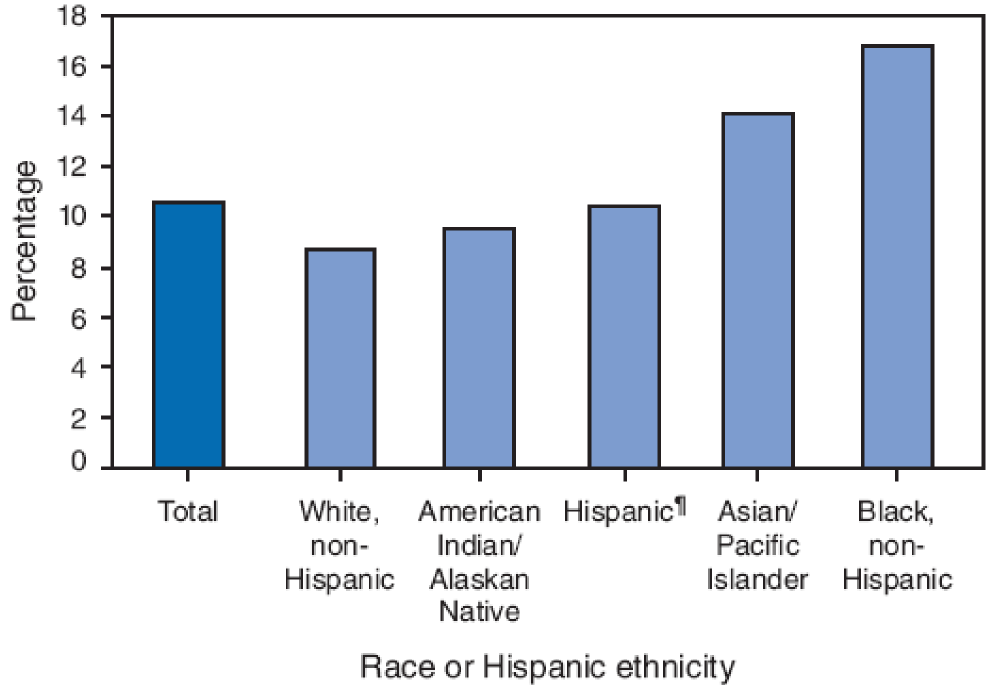
Source: National Academies Press

Figure 2.2 shows change in percentage of having LBW babies in different maternal race/ethnicity groups from 1990 to 2006. Non-Hispanic blacks were always the highest, Asian/Pacific Islander were always the second. All the groups showed a steady increasing trend.

Because LBW may be caused by either reduced fetal growth or shortened gestation, disparities in LBW may reflect disparities in either or both processes. For this reason, some researchers consider SGA (typically, $<10^{th}$ percentile of birth weight for gestational age compared to a national reference) a better measure of fetal growth because it captures size *adjusted for* gestational age and can also be calculated separately by infant sex and race. Racial disparities have also been documented for SGA. A study from Colorado (1989-2000) showed black women had a higher risk of having SGA babies than white women, both as teenagers (1.7% vs 1.2%; $P <0.01$) and in their mid-twenties (2.6% vs 1.0%, respectively; $P < 0.01$) (10). However, no national estimates of SGA by race and by year have been published. Also, there are no published standards for Asian infants, but prevalence of SGA is typically higher in this group due to smaller body size of parents(11). It is well-known that small for gestational age (SGA, $<10^{th}$ percentile of birth weight for gestational age) is highly associated with infant morbidity and mortality (12). Long-term consequences of being born SGA also include substantial medical costs after discharge from the hospital, economic burden on special education and social services, subnormal growth, health conditions (e.g., cerebral palsy, respiratory conditions), poor neurodevelopmental outcomes, and excessive BMI in later life (9,13).

It is well known that there are racial disparities in SGA, blacks are more likely to have SGA babies than whites. Proposed explanations include black women’s exposure to racism, lack of perinatal care, and low SES status(14–16). However, there remains debate as to whether these disparities are due primarily to genetic factors (17–19) or to social factors, such as social economic status (SES) level, access to perinatal care, or racism (15,20,21). Examining changes in rates of SGA by race over time may enable us to gain more insight into the proportional contribution of genetic vs. social factors to racial disparities. We assume that genetic factors remain comparatively constant over time whereas social factors likely change. Thus, if the race disparity in SGA changes over time, it is unlikely that genetic factors explain the entire disparity. Previous research on the overall trend of SGA using data from 1978 to1996 showed a decrease in SGA among term babies (>=37 weeks) but a non-linear trend (e.g. 1978-1981 the percentage of having SGA babies among <33 weeks increase from 8.3 to 12.7 while from 1981 to 1983, the percentage dropped to 6.5, and after 1983 the percentage increased again) in preterm babies (22). More recent works have demonstrated a marked increase in SGA from 1990 to 2005 among non-Hispanic whites (23) as well as an increase in SGA overall (among both blacks and whites) from 1997 to 2011 (24). Two trend-studies (one from 1985 to 1996, another from 1989 to 1998) have shown decreasing trends of SGA among white and black term babies and increasing trends of SGA among black preterm babies (15, 16). However among white preterm babies one study (1989 to 1998) showed increasing trend of SGA whereas the other study (1985 to 1996) showed no trend (25,26). There is no recent data on differences in trends of SGA by race.

Figure 2.3 Percentage of singleton live births Small-for-Gestational-Age* Births by Race and Hispanic Ethnicity---United States, 2005



Source: QuickStats: Percentage of Small-for-Gestational-Age* Births by Race and Hispanic Ethnicity---United States, 2005, Centers of Disease Control and Prevention

Figure 2.3 shows that in 2005, non-Hispanic black women were the most likely to have SGA babies, followed by Asian/Pacific Islander. Hispanic, American Indian/Alaska Native, and non-Hispanic white women were the least likely to have SGA babies.

Previous studies could not give enough evidence that genetics do fully explain race disparities in birth outcomes. Race, when considered as a social construct, is linking to upstream cause such as: education, income and occupation (27–29) as well as stressful experience such as: race discrimination and neighborhood disadvantage(14,30). It also links through down-stream causes such as smoking(31) and prenatal care access and directly link to LBW/SGA. So the difference in percentage of LBW and SGA of different race/ethnicity groups may due to the social construct brought by race.

The above studies focus exclusively on maternal race/ethnicity, although research suggests that paternal race/ethnicity may also play an important role in birth outcomes (4,5,32). There was only one study that investigated trends of low birth weight (LBW) by both maternal and paternal race/ethnicity from 1978 to 1997 (33).For both white and black mothers, the relative risk (RR) for LBW for partnering with a father of the other race (compared to same race) declined over time (33). This change over time might be explained by more acceptance of mixed-race partnership throughout the years.

2.2 Interracial marriage

According to U.S. Census Bureau, 14.6% of all 3.8 million newly married couples in the United States in 2008 were of mixed race (34). Nine percent of whites, 16% of blacks, 26% of Hispanics and 31% of Asians married someone whose race/ethnicity was different from their own (34).

Figure 2.4 In 2008, the percentage of married to other race/ethnicity than themselves in different regions.

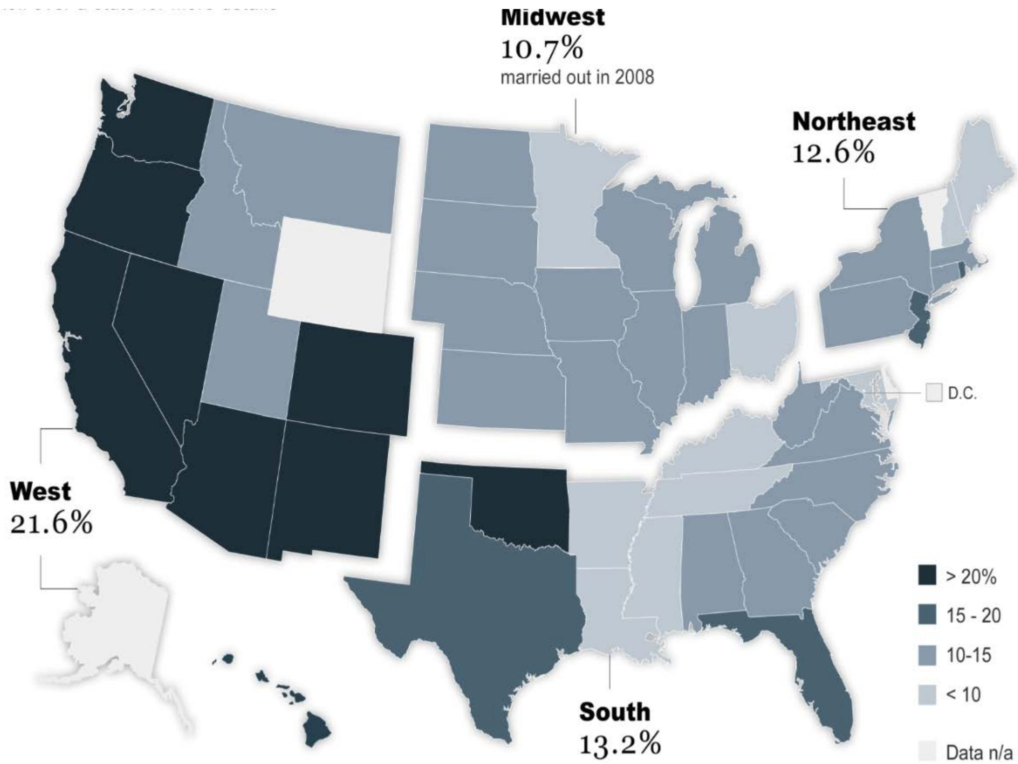


Figure 2.4 In 2008, the percentage of m 1

Source: Pew Research Center analysis of the U.S. Census Bureau's 2008 American Community Survey (ACS), based on Integrated Public-Use Microdata (IPUMS) series.

Figure 2.4 shows the percentage of those who married to the person not of their own race/ethnicity in 2008. West region showed the highest percentage (21.6%), followed by South (13.2%), and mid-west showed the lowest percentage, but it still exceeded 10%. (10.7%)

2.3 Who enters mixed-race marriages?

Since we have learned the surprisingly prevalence and incidence of mixed-race marriage for the past decades, it is important for us to know the characteristics of women who enter into partnerships with men of a different racial/ethnic group that yield a live birth so that we can have more idea to figure out the explanation of race disparities between mixed-race and white/white combination.

Table 2.1 Prevalence of each maternal/paternal race/ethnicity combination for live singleton births to US residents from 1989 to 2013.

Maternal Race/ethnicity	Paternal Race/ethnicity	1989	1994	1999	2004	2009	2013
White	White	58.82	54.69	52.23	47.64	44.12	44.58
	Black	0.62	0.93	1.23	1.33	1.60	1.74
	Hispanic	1.60	1.87	2.06	2.45	2.81	2.99
	Asian	0.30	0.33	0.40	0.49	0.53	0.58
Black	White	0.17	0.22	0.30	0.36	0.46	0.57
	Black	9.61	8.61	8.95	8.39	8.64	9.00
	Hispanic	0.13	0.15	0.17	0.23	0.32	0.36
	Asian	0.02	0.02	0.03	0.03	0.04	0.05
Hispanic	White	1.34	1.58	1.79	1.99	2.28	2.51
	Black	0.22	0.33	0.43	0.54	0.72	0.81
	Hispanic	10.03	12.62	14.35	17.54	18.34	17.09
	Asian	0.09	0.10	0.13	0.15	0.18	0.18
Asian	White	0.51	0.60	0.71	0.87	0.96	1.03
	Black	0.06	0.09	0.10	0.12	0.14	0.16
	Hispanic	0.09	0.11	0.14	0.18	0.23	0.24
	Asian	2.40	2.82	3.27	3.97	4.25	4.63

Table 2.1 shows the prevalence of each maternal/paternal race/ethnicity combination for live singleton births to US residents from 1989 to 2013. For same-race couples, the prevalence of births to white mothers/white fathers decreases throughout the years, black mothers/black fathers keeps consistent, but Hispanic mothers/Hispanic fathers and Asian mothers/Asian fathers increases throughout the years. For all the mixed-race couples, the prevalence increases throughout the years.

Table 2.2 Prevalence of maternal demographics in all race-combination groups in 1989 and 2013 and the change in the prevalence between 1989 and 2013.

		Parity (Primaparous)			Parity (Multiparous)			Marital Status (Unmarried)		
Maternal race/ethnicity	Paternal race/ethnicity	1989	2013	change	1989	2013	change	1989	2013	change
White										
	White	34.98	33.83	-1.15	23.66	24.58	0.92	7.85	20.88	13.03
	Black	30.14	31.10	0.96	25.65	29.58	3.93	41.28	60.89	19.61
	Hispanic	31.74	31.61	-0.13	25.62	26.60	0.98	21.79	38.78	16.99
	Asian	31.53	33.00	1.47	23.31	21.21	-2.10	14.37	17.63	3.26
Black										
	White	29.75	30.14	0.39	24.43	24.29	-0.14	30.87	44.35	13.48
	Black	31.32	29.88	-1.44	33.30	33.16	-0.14	43.27	60.00	16.73
	Hispanic	28.84	29.88	1.04	29.15	27.09	-2.06	50.11	61.24	11.13
	Asian	35.23	30.74	-4.49	23.67	26.37	2.70	37.01	42.08	5.07
Hispanic										
	White	33.00	32.75	-0.25	23.27	22.91	-0.36	15.27	30.36	15.09
	Black	29.97	30.08	0.11	25.69	29.40	3.71	47.45	64.94	17.49
	Hispanic	29.33	30.44	1.11	35.49	38.01	2.52	28.17	48.63	20.46
	Asian	29.99	31.51	1.52	24.71	24.51	-0.20	28.29	37.94	9.65
Asian										
	White	33.01	33.74	0.73	18.82	15.58	-3.24	6.97	11.82	4.85
	Black	31.29	30.39	-0.90	24.33	25.75	1.42	24.33	43.14	18.81
	Hispanic	28.23	32.30	4.07	22.43	20.78	-1.65	27.45	35.82	8.37
	Asian	33.02	37.36	4.34	23.75	17.41	-6.34	5.78	9.45	3.67

Table 2.2 (cont'd)

Maternal race/ ethnicity	Paternal race/ ethnicity	Education (0-11 years) 1989	2013	Diff	Education (HS grad) 1989	2013	Diff	Education (Some college) 1989	2013	Diff	Education (College grad and more) 1989	2013	Diff
White													
	White	41.78	20.4	-21.38	10.49	5.04	-5.45	23.50	31.01	7.51	24.24	43.54	19.3
	Black	45.92	31.34	-14.58	20.13	11.76	-8.37	21.84	36.90	15.06	12.12	20.01	7.89
	Hispanic	45.4	27.14	-18.26	19.92	9.63	-10.29	21.43	35.33	13.9	13.26	27.89	14.63
	Asian	35.02	13.5	-21.52	9.77	3.05	-6.72	25.84	27.11	1.27	29.38	56.34	26.96
Black													
	White	40.55	24.52	-16.03	12.22	8.09	-4.13	28.75	38.86	10.11	18.49	28.53	10.04
	Black	45.97	32.14	-13.83	19.02	11.74	-7.28	24.11	36.57	12.46	10.91	19.55	8.64
	Hispanic	46.43	30.27	-16.16	20.40	12.33	-8.07	24.34	40.52	16.18	8.82	16.87	8.05
	Asian	39.68	21.19	-18.49	11.39	8.42	-2.97	31.32	38.40	7.08	17.62	31.98	14.36
Hispanic													
	White	43.71	23.86	-19.85	13.45	7.26	-6.19	26.33	36.55	10.22	16.51	21.72	5.21
	Black	46.18	33.31	-12.87	26.60	14.19	-12.41	20.14	38.63	18.49	7.08	8.14	1.06
	Hispanic	58.63	45.24	-13.39	26.56	23.40	-3.16	10.47	22.15	11.68	4.35	4.68	0.33
	Asian	49.39	26.26	-23.13	17.73	8.24	-9.49	23.57	36.91	13.34	9.31	19.5	10.19
Asian													
	White	33.74	10.16	-23.58	6.10	1.68	-4.42	24.80	23.05	-1.75	35.35	54.36	19.01
	Black	48.21	25.25	-22.96	11.80	5.52	-6.28	25.21	37.13	11.92	14.79	19.98	5.19
	Hispanic	45.02	20.94	-24.08	14.12	5.88	-8.24	24.53	35.04	10.51	16.32	24.86	8.54
	Asian	38.66	17.54	-21.12	7.36	5.58	-1.78	19.50	16.89	-2.61	34.48	53.8	19.32

Table 2.2(cont'd)

Maternal race/ ethnicity	Paternal race/ ethnicity	Nativity (Foreign born) 1989	2013	Diff	Maternal age (<20) 1989	2013	Diff	Maternal age (20-29) 1989	2013	Diff	Maternal age (30-39) 1989	2013	Diff	Maternal age (>=40) 1989	2013	Diff
White																
	White	4.22	6.48	2.26	7.14	3.63	-3.51	58.76	49.12	-9.64	32.95	44.56	11.61	1.15	2.69	1.54
	Black	6.45	4.56	-1.89	16.45	7.85	-8.60	57.90	58.93	1.03	24.56	31.19	6.63	1.09	2.03	0.94
	Hispanic	4.92	6.00	1.08	14.47	7.08	-7.39	61.13	54.88	-6.25	23.49	35.79	12.30	0.91	2.25	1.34
	Asian	7.15	12.56	5.41	8.34	1.99	-6.35	53.01	37.42	-15.59	36.99	56.35	19.36	1.66	4.24	2.58
Black																
	White	13.34	13.90	0.56	12.13	7.51	-4.62	58.63	53.93	-4.70	27.55	35.21	7.66	1.69	3.35	1.66
	Black	8.54	18.61	10.07	15.62	7.95	-7.67	59.51	56.24	-3.27	23.86	33.03	9.17	1.01	2.78	1.77
	Hispanic	10.70	10.09	-0.61	19.32	10.89	-8.43	60.90	60.13	-0.77	18.97	26.82	7.85	0.81	2.16	1.35
	Asian	21.35	20.01	-1.34	15.12	5.55	-9.57	54.63	52.56	-2.07	29.36	38.72	9.36	0.89	3.18	2.29
Hispanic																
	White	33.55	26.08	-7.47	8.45	5.32	-3.13	59.52	48.97	-10.55	30.80	42.28	11.48	1.23	3.43	2.20
	Black	31.68	18.27	-13.41	22.16	10.21	-11.95	58.40	60.53	2.13	18.57	27.44	8.87	0.86	1.82	0.96
	Hispanic	66.69	57.45	-9.24	14.86	9.42	-5.44	61.30	53.87	-7.43	22.62	33.99	11.37	1.22	2.72	1.50
	Asian	33.92	26.98	-6.94	15.73	5.84	-9.89	59.75	48.86	-10.89	23.37	42.18	18.81	1.15	3.12	1.97
Asian																
	White	73.36	62.73	-10.63	3.12	0.93	-2.19	47.94	26.94	-21.00	46.15	64.26	18.11	2.79	7.87	5.08
	Black	75.81	55.34	-20.47	10.60	4.33	-6.27	56.96	46.30	-10.66	30.32	45.31	14.99	2.12	4.06	1.94
	Hispanic	52.73	50.27	-2.46	14.93	4.91	-10.02	56.53	42.92	-13.61	27.18	48.01	20.83	1.36	4.15	2.79
	Asian	90.03	87.25	-2.78	3.59	0.93	-2.66	50.77	37.29	-13.48	43.55	57.62	14.07	2.09	4.16	2.07

Table 2.2 shows prevalence of maternal demographics in all race-combination groups in 1989 and 2013 and the change in the prevalence between these 1989 and 2013. Due to the size limit, we separated them to three tables: (1) parity + marital status (2) Education (3) Nativity + maternal age.

There were no obvious trends for parity– some combinations were more likely to be primaparous/ multiparous and some less likely. The most likely to be primaparous were Asian/Asian (4.34) while they were least likely to be multiparous as well (-6.34). All the combinations are more likely to be unmarried in 2013 compared to 1989, white mother/black father are the most likely to be unmarried (19.61).

For all the combinations, the education level showed a shift from lower level to the higher level from 1989 to 2013 (All the combinations had less HS grad or less, and more college education or more). For some colleges, Asian mother/white father and Asian mother/Asian father had less percentage, too.

Asian/black has the greatest increase in native born compared 2013 to 1989, while black/black has the greatest decline in native born compared 2013 to 1989.

Hispanic/black has the most decline (11.95) in maternal age (<20), Asian/white and white/Asian has the most and second most decline (21 and 15.59) in maternal age (20-29) while white/black and Hispanic/black are the only two increase. Asian/Hispanic has the highest increase in maternal age (30-39) while white/black has the least increase in this category. Asian/white has the highest increase in maternal age (>=40) while white black still has the least increase in this category.

Over the twentieth century, individuals in interracial marriages have shifted from being more likely less-educated to high-educated (35). Study from National Health Interview Survey data (1997–2001) found that interracial marriage was associated with higher risk of severe distress for white and Hispanic women, and for Hispanic men who married to non-Hispanic white spouses, compared to couples of same race/ethnicity (36).

2.4 Perinatal outcomes in mixed race/ethnicity couples

Evidence suggests that couples with mixed race/ethnicity with one partner being white have worse perinatal and maternal outcomes than couples where both partners are white. Data from 1995 to 2001 in U.S showed that interracial couples with a white mother/black father and black mother/white father combination had higher relative risks (RR) (1.17 and 1.37, respectively) of still birth compared to couples where both parents were white (37). A retrospective study from 2000 to 2005 in Lucile Packard Children's Hospital at Stanford University found that mothers from Asian mother/white father and White mother/Asian father combination had higher odds of gestational diabetes mellitus than mothers (aOR: 2.6 and 2.4, respectively) from couples where both partners were white (38). A meta-analysis which included 8 studies showed that both white mother/black father and black mother/white father were more likely to have low birthweight babies (OR: 1.2 and 1.8), preterm births (OR: 1.2 and 1.4) and still births (OR: 1.4 and 1.5) compared to the white mother/white father group [12] .

Studies in multiple populations and time periods have also shown with consistency that the odds of having a LBW or SGA baby for families with black fathers are higher than the odds for families with white fathers, within the maternal race (8,39–41). A study of Missouri births from 1989 to 1997 showed the risk of having a preterm baby was higher when the father was black compared to when he was white, within maternal race (40). In 1991, Migone and colleagues, using data from 1983 on single live births in the United States, found a significantly higher risk of LBW (OR 2.37) in infants with African American fathers compared to families with white fathers, within maternal race (41). Moreover, only one study did not show significant difference in risk of low birth weight for mixed-race infants compared to infants with both white parents, which may be due to the limited sample size(42) (1,149). Most studies classify infants' race/ethnicity using maternal race/ethnicity as a proxy because paternal race/ethnicity is often unavailable, however, it is important to study paternal race separately when we have the data.

When considering the role of paternal race/ethnicity in impacting on birth outcomes, paternal race/ethnicity may indicate both biological and social factors. For example, some studies suggested that paternal genetics explained association between paternal age and LBW, PTB, or SGA, through higher expression of paternal gene on placenta and lower opportunities of mutation in young men than older men (43–45). Other paternal biological factors, such as age, height and weight are important characteristics related to adverse birth outcomes (6,46).Paternal own size at birth has been found to influence the birth weight of his children within maternal size (39). In addition, research from Norway showed paternal birthweight was a significant and independent predictor of LBW in offspring (47).

These above studies were focused more on paternal biologic factors. Sociologically, both maternal and paternal race/ethnicity as well as their interaction may contribute to differences in social norms, culture, and behaviors brought to the family. A large body of evidence supports associations between maternal social factors and birth outcomes, such as education (48) and the socioeconomic context of where mothers live (49,50).Researchers have now developed interest in paternal social factors as well. In 2010, Gold and colleagues analyzed 1998-2002 California birth cohort data and found a significantly higher odds of still birth in black paternal families compared to families with white fathers, within the maternal race (Black Father/Black Mother, OR: 2.11, White Father/Black Mother: OR 2.01, Black Father/White Mother: OR 1.84, White Father/White Mother as reference) (39). Based on their findings that white mother/black father combination had better maternal and perinatal outcomes than black mother/white father combination, they hypothesized that this was due to the persistent effects of racial discrimination throughout childhood and adulthood to black women is more than to black men [10,12]. In these studies, race was not only considered a genetic risk factor but also a proxy for social factors, but they had no way of distinguishing the two.

If we assume that the genetic aspect of paternal race will remain the same, within time and place, if association between paternal race/ethnicity and preterm birth changes from year to year, or from region to region, we may infer that those changes are related to changes in social characteristics in time and place. Therefore, studies on birth outcomes over time and place may enable us to separate genetic and social factors related to race because the genetic factors remain consistent over time and throughout the places. A study from Parker et al. (2000) examined the trend in LBW and VLBW between 1978-1997(51), but there have been no studies examining trends since then. In that study, the author found that among black mothers, the risk of LBW with white fathers was consistently lower than the risk of LBW with black fathers in adjusted models across the years. (1978-1981: RR 0.83, 1982-1985: RR 0.78, 1986-1989: RR 0.76, 1990-1993: RR 0.78, 1994-1997: RR 0.78) for black vs white fathers. However, following adjustment for age, marital status, parity, nativity, metropolitan residence and maternal education, there was a decreasing trend of relative risks across years in the risk of LBW comparing black fathers to white fathers among white mothers (1978-1981 RR: 1.22, 1982-1985 RR: 1.17, 1986-1989 RR: 1.15 1990-1993: RR 1.13, 1994-1997: RR 1.05, all the RR are statistically significant.) This means, the difference in risk of LBW between families with combination of mixed race/ethnicity compared to families with both same-race parents are getting smaller across the year. This finding suggests more acceptance of interracial marriage as well as the sociodemographic shift in who enters an interracial marriage. This implies that the characteristic of individual in this situation has been shifted from border behavior to general behavior who is in interracial marriage.

Overall, in the literature investigating perinatal health outcomes, paternal factors have been included much less than maternal factors in analysis. Mostly, the reason for not including paternal factors was due to a lot missing or unreported information related to the father. But a study showed that infants whose paternal race/ethnicity was unreported on their birth certificates had the worst adverse birth outcomes (52). This study and another study (53) indicating a significant correlation between lack of paternal involvement and adverse birth outcomes suggested that paternal factors are not only genetic in nature but social in reality as well.

The major gaps in the literature on disparities between mixed-race couples and same-race couples on birth outcomes are:

1. Few studies have examined the role of maternal/paternal race/ethnicity on perinatal health for racial/ethnic groups other than black and white(54). The only study to include other racial/ethnic groups used data from New York City and found that all mixed-race couples had higher risk of adverse birth outcomes (LBW, SGA, preterm birth, and infant mortality) when compared to white/white couples. However, these findings may not generalize to the rest of the U.S. due to the unique nature of the New York City population in terms of race/ethnicity, country of origin of minority racial/ethnic groups (e.g., many Hispanic mothers are of Puerto Rican or Dominican origin), and SES levels.

2. Most previous studies have excluded births with “missing” paternal race/ethnicity. However, this “missingness” of paternal race/ethnicity may be an important risk factor. Infants whose paternal race/ethnicity was unreported on their birth certificates have higher risk of infant mortality and morbidity compared to infants with the same maternal race/ethnicity where paternal race/ethnicity was not missing (52,55). Although the reasons for “missing” paternal race/ethnicity data on birth records are often unknown, missingness may suggest a lack of paternal involvement, which has been shown to be associated with adverse birth outcomes (53).
3. In the existing literature is that no previous research has examined the change in prevalence of SGA over time among different maternal/paternal race/ethnicity combinations (aside from black/white). This is important because of the increasing prevalence of interracial marriages.
4. No previous literature has examined whether the relationship between paternal race/ethnicity and SGA has changed over time within maternal race/ethnicity groups. This is important because paternal race/ethnicity may play a significant role in birth outcomes with public health intervention implications.
5. No previous study tried to investigate whether changes in maternal demographic characteristics of individuals entering interracial partnerships over time could explain trends of SGA over time among different maternal/paternal race/ethnicity combinations.

The overall aim of this study is to address the aforementioned gaps in the literature, to test the association between maternal/paternal race/ethnicity combination and fetal growth overall, as well as by years separately.

CHAPTER 3 MATERIALS AND METHODS

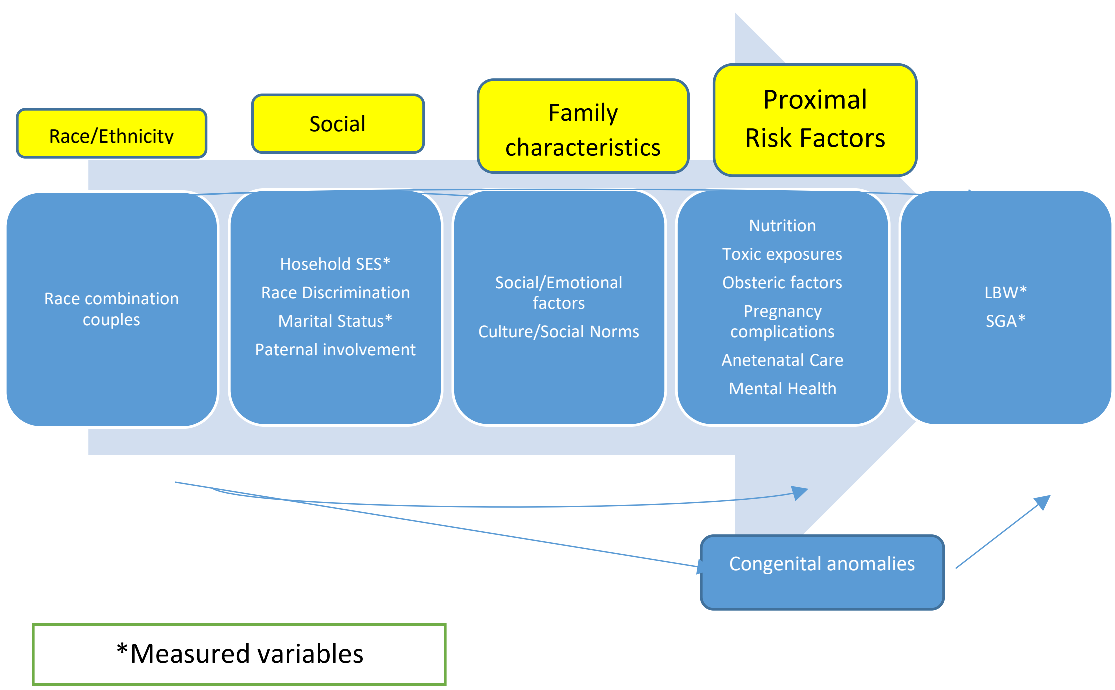
This chapter showed details of the methods for each of the 2 studies. In this chapter: study 1 addresses aim 1 and study 2 addresses aim 2. First, the chapter describes the overview of the study framework and study population. Next the chapter describes the analysis for each study separately.

3.1 Overview

This was a repeated cross-sectional study extracting data from the United States (U.S.) vital statistics natality files, which include data from birth certificates for all births occurring within the U.S. to both U.S. residents and non-residents. This study included live singleton births from 1989 to 2013 to U.S. residents only.

3.1.1 Conceptual Framework

Figure 3.1 Conceptual framework of this proposed study.



This figure describes the proposed framework linking paternal race/ethnicity to LBW through social factors, family characteristics and proximal risk factors.

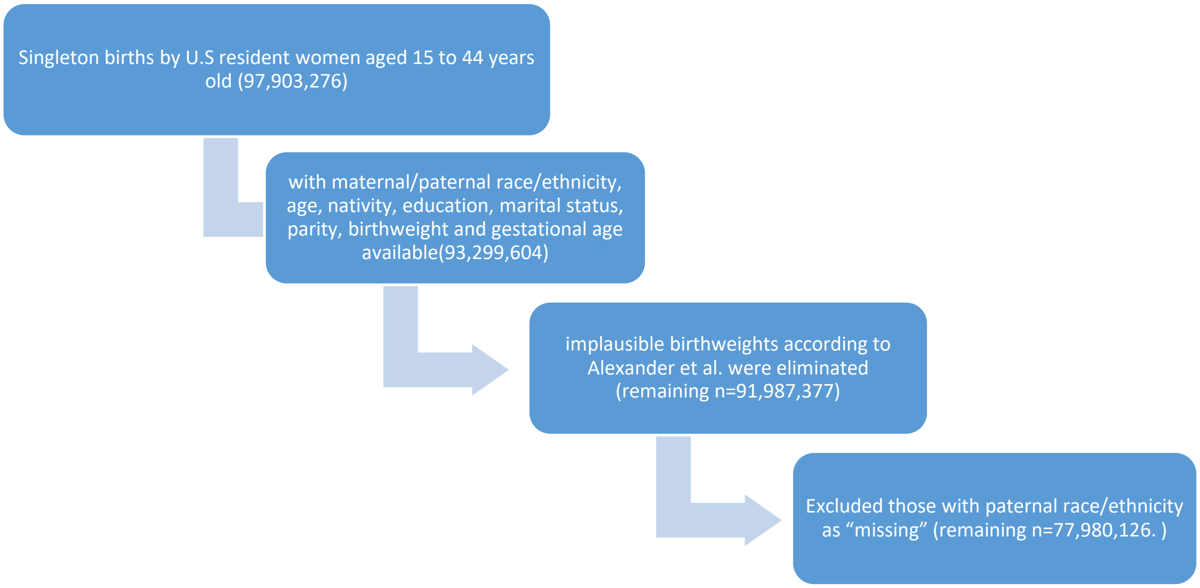
3.1.2 Study Population

The study population were all singleton births, maternal age within 15 and 44 years old, U.S. residents in the natality file from 1989 to 2013.

3.1.3 Eligibility criteria

The eligible population in our study was extracted from the U.S. vital statistics natality files from 1989 to 2013: singleton births by U.S. resident women aged 15 to 44 years old (n= 97,903,276). Those with maternal/paternal race/ethnicity, age, nativity, education, marital status, parity, birthweight and gestational age available were included in our analytic sample (n=93,299,604). Those of implausible birthweights according to Alexander et al. were eliminated (remaining n=91,987,377) (56) . This was our study sample for paper 1. Finally, those with either maternal race/ethnicity or paternal race/ethnicity reported as anything other than non-Hispanic white, non-Hispanic black, Hispanic, or Asian according to our definitions described below were also excluded (n=14,007,251 was excluded). Then, our final analytic sample for paper 2 was n=77,980,126.

Figure 3.2 Eligibility and sample selection



3.1.4 Measurement of Key Study Variables

3.1.4.1 Study 1: Paternal race/ethnicity and risk of adverse birth outcomes in the United States, 1989-2013

The dependent variables were: (1) LBW (birthweight<2500 grams), (2) SGA, defined as 10^{th} percentile of weight for age based on published data(57). In this analysis, we chose to focus primarily on measures of fetal growth, as measures of length of gestation, such as preterm birth, have exhibited strong temporal trends over the study period(58,59). Neither LBW nor SGA is a perfect measure of fetal growth: whereas LBW can result from either shortened length of gestation or poor fetal growth, SGA relies on estimates of gestation length, which are based on last menstrual period (LMP) and are thus notoriously imprecise(60,61); we thus used both measures.

Maternal and paternal race/ethnicity were based on the race/ethnicity listed on the birth certificate. Those whose ethnicity belonged to Mexican, Puerto Rican, Cuban, Central or South

American, or “Other and unknown Hispanic” were defined as Hispanic, within their race. Individuals not identifying as Hispanic were then categorized as black, white, or Asian/Pacific Islander (hereafter, “Asian”, which included Chinese, Japanese, Filipino, Asian Indians, and “Other Asian/Pacific Islander”). Those with paternal race/ethnicity blank or listed as “missing” were categorized as “Missing”. Due to small sample sizes, we did not include American Indian/Alaska Natives or those reporting multiple race/ethnicities.

The covariates were parity (number of previous live births and categorized as 0 [reference], 1, or 2), marital status (married [reference] vs unmarried), maternal education level (less than high school, high school, college, more than college [reference]), nativity (U.S. born [reference], foreign born) and maternal age (<20, 20-29 [reference], 30-39, >=40). Covariates were chosen based on prior literature and because they were associated with both maternal race/ethnicity and birth outcomes. We did not control for smoking and access of prenatal care because we thought these may be potential mediators and we did not want our models to be over controlled.

3.1.4.2 Study 2: different race-combination couples and trend of prevalence of SGA in the United States, 1989-2013

The dependent variable was: SGA, defined in the same way as in study 1 (57). The main explanatory variable was defined as the same way as in study 1, but excluded those with paternal race/ethnicity as “missing”. We then created the combination variable including the 16 categories shown in Table 1. The demographic characterisitcs we included in this study were the same as we included in study 1.

3.2 Analysis Plan

3.2.1 Study 1: Paternal race/ethnicity and risk of adverse birth outcomes in the United States, 1989-2013

For Study 1, we first tested the hypothesis 1(a) and 1(b) that “Within mother’s race/ethnicity, the odds of LBW or SGA will be the lowest when paternal race/ethnicity is white.”and “Within mother’s race/ethnicity, the odds of LBW or SGA will be the highest when paternal race/ethnicity is “missing”.”

To do this, we stratified our sample by maternal race/ethnicity, using for each stratum the paternal race/ethnicity of the mother as the reference group. We used logistic regression to estimate the unadjusted odds ratios (OR) for LBW and SGA comparing each paternal race/ethnicity group to the reference paternal race/ethnicity group. Reference groups were defined as the same-race couples for each stratum, for example, for white mother, white mother/white father was the reference group. Second, we added to the models, fixed effects for year of birth and state of birth to control for secular trends and time-invariant state characteristics that could be associated with both the probability of mixed-race/ethnicity couples and LBW and SGA. Finally, we added individual-level covariates (maternal age, parity, maternal nativity, maternal education, marital status) to the models.

We also conducted analyses using VLBW (birthweight < 1500 g) as an outcome. In contrast to LBW and SGA, VLBW is a rarer and more extreme outcome that reliably indicates high risk infants. We conducted additional analyses on term babies only for the same models using LBW and SGA as outcomes; by excluding preterm infants, we can better isolate infants who are LBW or SGA due to fetal growth restriction. SAS 9.4 was used to analyze the data.

3.2.2 Study 2: different race-combination couples and trend of prevalence of SGA in the United States, 1989-2013

First, to test the hypothesis 2a, we drew the trend lines for each race combination group, stratified by maternal race/ethnicity to get the idea of how the change look like regarding the prevalence of SGA in each race combination group. Then, we described the changes in composition of maternal/paternal race/ethnicity combinations in terms of maternal demographic variables of interest (e.g., married, unmarried, nulliparous, primaparous, multiparous, etc.) as well as changes in SGA within each group from 1989 to 2013.

Meanwhile, to further testing hypothesis 2a, we conducted a set of logistic regression models for the odds of SGA stratified by the four maternal race/ethnicity groups. We used these models instead of putting all the combinations in one model because these models are more explicit about how paternal race/ethnicity impacted the odds of having SGA babies throughout the years for the same maternal race/ethnicity. These models included the four paternal race groups as the independent variable, a continuous variable for year of birth, and an interaction term between each paternal race/ethnicity and year of birth, which indicated whether the prevalence of having SGA babies increased, decreased, or did not change from 1989 to 2013 for each paternal race/ethnicity group relative to the same race couples. We tested for nonlinear trends by adding higher order terms of year and found no evidence of nonlinearity.

Finally, in order to test the hypothesis (2b and 2c) the prevalence of SGA in the mixed race groups relative to the white/white group will get smaller over the time and the difference in prevalence between 1989 and 2013 comparing mixed race and white/white will be explained by these demographic characteristics (education, marital status, parity, nativity, maternal age), we used the methods in Tyler Vanderweele et al. (62). First, we fit a set of logistic regression models of SGA including all maternal demographic characteristics (maternal age, nativity, education, parity and marital status as well as state), separately for each race-combination group in both 1989 and 2013. We obtained a set of coefficients for each maternal demographic characteristic from these regression models. Using these coefficients, we then calculated the predicted probability of SGA for each race-combination group in both 1989 and 2013 (except for white mother/white father in 1989) but using the distribution of maternal demographic characteristic from the population of births to white mothers/white fathers in 1989. We then averaged these predicted probabilities over each race-combination group, called as adjusted prevalence. Using all the adjusted prevalence divided by the adjusted prevalence of white mother/white father in 1989, we got the SMRs for each race combination in both 1989 and 2013. The procedure produced the counterfactual outcome of what the prevalence of SGA among other race-combination groups would have been in 1989 and 2013 had the maternal demographic distributions in these combination groups been the same as the maternal demographic distributions in the white-white group in 1989. If there were differences adjusted prevalence (SMR>1 or SMR<1) on SGA, this would be due to the changing influence (coefficients) of maternal demographic variables. Raw prevalence ratio was defined as raw prevalence of each combination divided by the raw prevalence of white mother/white father in 1989.

We also did the same analysis between 2003 and 2004 as our sensitivity analyses because from 2003, some states started to use the new version of natality file and we wanted to make sure the change over time was not due to the change of the natality file version change.

SAS 9.4 was used to analyze the data.

CHAPTER 4 RESULTS

4.1 Study 1： Paternal race/ethnicity and risk of adverse birth outcomes in the United States, 1989-2013

First, characteristics of the study population are presented in Table 4.1. The percentage of LBW and SGA was highest among black mother/“missing” father couples (13.05% and 15.55%) and lowest among white mother/white father couples (4.50% and 7.17%). Within maternal race/ethnicity, the highest percentages for LBW were always in the “missing” father category, the second highest were for black fathers, and the lowest was for white fathers. For SGA, this pattern was the same when maternal race/ethnicity was white or Hispanic. However, for black mothers, the second highest percentage for SGA was found for Asian fathers, while for Asian mothers, the highest percentage for SGA was found for Asian fathers.

Within paternal race/ethnicity, the highest percentage of having LBW babies was for black mothers. If paternal race/ethnicity was white, black or Asian, white mothers had the lowest percentage of having LBW babies; however, if paternal race/ethnicity was Hispanic or “missing”, Hispanic mothers were at the lowest percentage of having LBW babies. For SGA, the pattern was similar in all paternal race/ethnicity groups: white mothers had the lowest risk of having SGA babies while black mothers had the highest risk. Only one exception: Hispanic mothers had the lowest percentage of SGA compared to other maternal race/ethnicity groups when paternal race/ethnicity was “missing”. Mothers who were nulliparous, unmarried, or native born, those with educational attainment of 9-11 years, and mothers less than 20 years old had the highest percentages of LBW babies. Mothers who were nulliparous, unmarried, or foreign born, those with educational attainment of 9-11 years, and mothers less than 20 years old had the highest percentages of SGA babies.

Table 4.1 Characteristics of the study sample, singleton births to U.S. resident women age 15 to 44 years old in the natality file from 1989 to 2013 (N=90,771,339 births)

			LBW		SGA	
Maternal race/ethnicity	Paternal race/ethnicity	Total Frequency	Frequency	Row %	Frequency	Row %
White						
	White	45,559,015	2,052,022	4.50	3,264,868	7.17
	Black	1,113,311	71,032	6.38	103,645	9.31
	Hispanic	2,056,974	109,204	5.31	179,250	8.71
	Asian	390,507	18,750	4.80	37,045	9.49
	Missing	4,920,997	404,558	8.22	572,397	11.63
Black						
	White	303,238	24,354	8.03	32,923	10.86
	Black	7,934,869	825,948	10.41	1,052,825	13.27
	Hispanic	195,816	18,335	9.36	25,807	13.18
	Asian	26,220	2,331	8.89	3,632	13.85
	Missing	5,175,807	675,568	13.05	805,081	15.55
Hispanic						
	White	1,727,674	82,191	4.76	130,921	7.58
	Black	448,153	31,727	7.08	45,844	10.23
	Hispanic	13,937,222	719,306	5.16	1,259,355	9.04
	Asian	124,951	7,027	5.62	13,386	10.71
	Missing	2,469,375	176,954	7.17	275,819	11.17
Asian						
	White	698,565	35,783	5.12	56,955	8.15
	Black	100,210	7,236	7.22	10,275	10.25
	Hispanic	145,153	9,944	6.85	15,370	10.59
	Asian	3,218,248	200,052	6.22	437,928	13.61
	Missing	225,034	18,780	8.35	30,380	13.50
Parity	Nulliparous	37,135,151	2,619,947	7.06	4,150,845	11.18
	Primaparous	29,284,946	1,431,043	4.89	2,254,338	7.70
	Multiparous	24,351,242	1,440,112	5.91	1,948,523	8.00
Marital status	Married	59,621,905	2,833,559	4.75	4,575,095	7.67
	Unmarried	31,149,434	2,657,543	8.53	3,778,611	12.13

LBW: Low Birth Weight

SGA: Small for Gestational Age

Table 4.1 (cont'd)

			LBW		SGA	
Maternal race/ethnicity	Paternal race/ethnicity	Total Frequency	Frequency	Row %	Frequency	Row %
Education attainment	0-8 years	5,133,797	300,550	5.85	497,954	9.70
	9-11 years	14,121,856	1,193,827	8.45	1,744,834	12.36
	HS grad/GED	28,462,106	1,902,692	6.69	2,845,677	10.00
	Some college	21,049,080	1,180,586	5.61	1,765,590	8.39
	College grad	13,980,080	580,502	4.15	939,138	6.72
	More than college	8,024,420	332,945	4.15	560,513	6.99
Maternal Nativity	Native born	71,472,566	4,477,288	6.26	6,525,137	9.13
	Foreign born	19,298,773	1,013,814	5.25	1,828,569	9.48
Maternal Age	<20	9,994,192	853,437	8.54	1,285,176	12.86
	20-29	48,366,027	2,833,932	5.86	4,580,695	9.47
	30-39	30,522,619	1,658,514	5.43	2,323,642	7.61
	>=40	1,888,501	145,219	7.69	164,193	8.69

In Table 4.2a, we show the results of multivariate logistic regressions examining the role of paternal race/ethnicity on LBW, stratifying by maternal race/ethnicity. We only present results of our fully-adjusted multivariate logistic regression models (unadjusted results available from the author upon request). For white mothers, all other paternal race/ethnicities were associated with higher odds of LBW compared to white fathers (Column 3). For black mothers, all paternal race/ethnicities except for the missing group were associated with lower odds of LBW compared to black fathers (Column 4). For both Hispanic and Asian mothers, black and "missing" fathers were associated with higher odds of LBW compared to fathers of the same race/ethnicity of the mother, while white fathers were associated with lower odds of LBW (Column 5 and Column 6).

For SGA, within maternal race/ethnicity, white fathers were again associated with the lowest odds of SGA (Table 4.2b). Other findings for SGA diverged from the LBW findings, however. Of note, black and “missing” paternal race/ethnicity were still associated with increased odds of SGA for white and Hispanic mothers (compared to fathers of the same race/ethnicity as the mother); however, these ORs were smaller than for LBW. On the other hand, the Asian paternal race/ethnicity category was most strongly associated with SGA within maternal race/ethnicity. Moreover, for Asian mothers, all paternal race/ethnicity categories were protective against SGA compared to Asian paternal race/ethnicity (Column 6).

The direction of association between covariates and outcomes also differed across maternal race/ethnicity groups (Table 4.1.2a and Table 4.1.2b). For example, white and black mothers <20 years old were less likely to have LBW or SGA babies compared to white and black mothers in the 20-29 year age group, while for Hispanic and Asian mothers this pattern was reversed. On the other hand, the odds of SGA in white and black mothers 30-29 years old were higher than the odds in the 20-29 year age group, whereas older Hispanic and Asian mothers were less likely to have SGA babies compared to the younger age group.

Results of VLBW were similar to LBW, except that Asian paternal race/ethnicity was protective against VLBW for black and Hispanic mothers. (Appendix Table 1). Analyses among term babies (gestational age >=37 weeks) also showed similar associations to the full sample for all birth outcomes (LBW, SGA, VLBW) with only a few exceptions (Appendix Table 2a-c).

Table 4.2a Multivariate adjusted[1] odds ratios (OR) and 95% confidence intervals (95% CI) for the association between paternal race/ethnicity and low birth weight, stratified by maternal race/ethnicity, in United States, 1989-2013

	Maternal race/ethnicity							
	White		Black		Hispanic		Asian	
	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI
Paternal race/ethnicity								
White	Ref	Ref	0.80	0.79,0.81	0.84	0.83,0.85	0.76	0.75,0.77
Black	1.17	1.16,1.18	Ref	Ref	1.18	1.17,1.19	1.05	1.02,1.07
Hispanic	1.07	1.06,1.08	0.90	0.88,0.91	Ref	Ref	0.98	0.96,1.01
Asian	1.14	1.12,1.16	0.93	0.89,0.97	1.02	0.99,1.04	Ref	Ref
Missing	1.26	1.25,1.26	1.13	1.12,1.13	1.18	1.18,1.19	1.08	1.06,1.10
Parity								
Nulliparous	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Primaparous	0.63	0.63,0.63	0.77	0.77,0.77	0.68	0.68,0.69	0.68	0.67,0.69
Multiparous	0.66	0.66,0.66	0.82	0.82,0.83	0.69	0.68,0.69	0.67	0.66,0.68
Marital status								
Married	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Unmarried	1.31	1.30,1.31	1.22	1.21,1.22	1.13	1.13,1.14	1.19	1.17,1.20
Education attainment								
0-8 years	2.34	2.32,2.36	1.64	1.62,1.67	1.33	1.31,1.35	1.16	1.14,1.19
9-11 years	2.37	2.35,2.38	1.69	1.67,1.71	1.40	1.38,1.42	1.24	1.22,1.26
HS grad/GED	1.69	1.68,1.70	1.42	1.41,1.44	1.29	1.27,1.31	1.18	1.17,1.20
Some college	1.34	1.33,1.34	1.25	1.24,1.26	1.21	1.20,1.23	1.18	1.16,1.19
College grad	1.02	1.02,1.03	1.07	1.06,1.08	1.05	1.03,1.07	1.06	1.05,1.07
More than college	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Nativity								
Native born	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Foreign born	0.93	0.92,0.93	0.67	0.67,0.68	0.78	0.77,0.78	0.93	0.91,0.94

[1]Adjusted model includes fixed effect covariates (birthyear, state) as well as maternal age, nativity, education, parity and marital status.

Table 4.2a (cont'd)

	Maternal race/ethnicity							
	White		Black		Hispanic		Asian	
	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI
Maternal Age								
<20	0.83	0.83,0.83	0.87	0.87,0.88	1.03	1.03,1.04	1.25	1.23,1.28
20-29	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
30-39	1.25	1.25,1.26	1.40	1.39,1.41	1.30	1.29,1.30	1.13	1.12,1.14
>=40	1.85	1.83,1.86	1.92	1.90,1.95	1.97	1.95,2.00	1.66	1.63,1.69

[1]Adjusted model includes fixed effect covariates (birthyear, state) as well as maternal age, nativity, education, parity and marital status.

Table 4.2b Multivariate adjusted[1] odds ratios (OR) and 95% confidence intervals (95% CI) for the association between paternal race/ethnicity and small for gestational age, stratified by maternal race/ethnicity, from 1989 to 2013

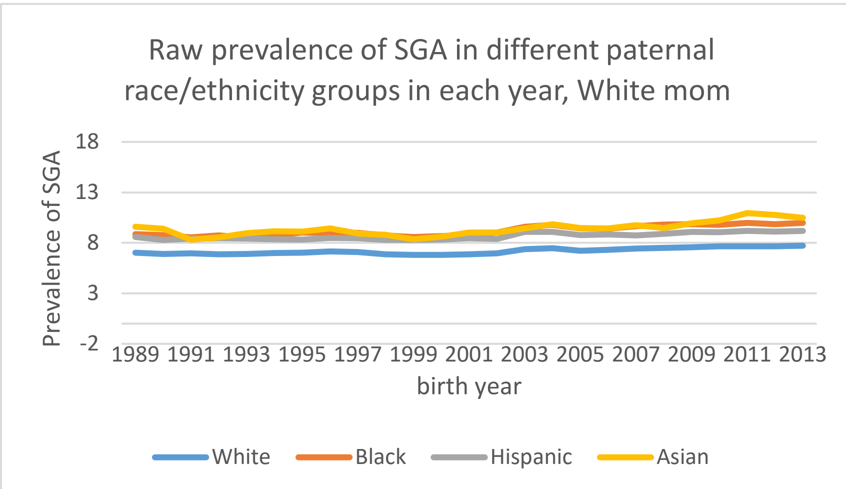
	Maternal race/ethnicity							
	White		Black		Hispanic		Asian	
	OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI
Paternal race/ethnicity								
White	Ref	Ref	0.80	0.79,0.81	0.82	0.82,0.83	0.55	0.54,0.55
Black	1.08	1.07,1.08	Ref	Ref	1.04	1.03,1.05	0.70	0.69,0.72
Hispanic	1.07	1.07,1.08	0.93	0.92,0.94	Ref	Ref	0.72	0.71,0.73
Asian	1.42	1.40,1.43	1.07	1.03,1.11	1.19	1.17,1.21	Ref	Ref
Missing	1.14	1.14,1.14	1.05	1.04,1.05	1.08	1.08,1.09	0.91	0.90,0.93
Parity								
Nulliparous	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Primaparous	0.66	0.66,0.67	0.72	0.72,0.73	0.66	0.66,0.66	0.65	0.65,0.66
Multiparous	0.65	0.65,0.65	0.70	0.70,0.70	0.60	0.60,0.61	0.56	0.55,0.56
Marital Status								
Married	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Unmarried	1.26	1.26,1.27	1.14	1.13,1.14	1.09	1.09,1.10	1.03	1.02,1.04
Education attainment								
0-8 years	2.20	2.19,2.22	1.50	1.48,1.52	1.24	1.23,1.25	1.02	1.00,1.04
9-11 years	2.20	2.19,2.21	1.56	1.55,1.58	1.24	1.23,1.26	1.06	1.05,1.08
HS grad/GED	1.58	1.57,1.58	1.37	1.36,1.38	1.16	1.14,1.17	1.04	1.03,1.05
Some college	1.23	1.22,1.23	1.20	1.19,1.21	1.07	1.06,1.08	1.07	1.06,1.08
College grad	0.99	0.98,0.99	1.03	1.02,1.04	1.00	0.99,1.01	1.02	1.01,1.02
More than college	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Nativity								
Native born	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Foreign born	1.06	1.06,1.07	0.75	0.75,0.76	0.90	0.90,0.91	0.97	0.96,0.98
Maternal Age								
<20	0.81	0.81,0.82	0.90	0.90,0.91	1.03	1.02,1.03	1.07	1.05,1.09
20-29	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
30-39	1.04	1.04,1.04	1.06	1.06,1.06	0.96	0.95,0.96	0.94	0.94,0.95
>=40	1.24	1.23,1.25	1.22	1.21,1.24	1.12	1.11,1.14	0.99	0.98,1.01

Table 4.2b (cont'd)

[1]Adjusted model includes fixed effect covariates (birthyear, state) as well as maternal age, nativity, education, parity and marital status.

4.2 Study 2: Different race-combination couples and trend of prevalence of SGA in the United States, 1989-2013

Figure 4.1 Raw prevalence of SGA from 1989 to 2013 by maternal/paternal race-combinations in United States



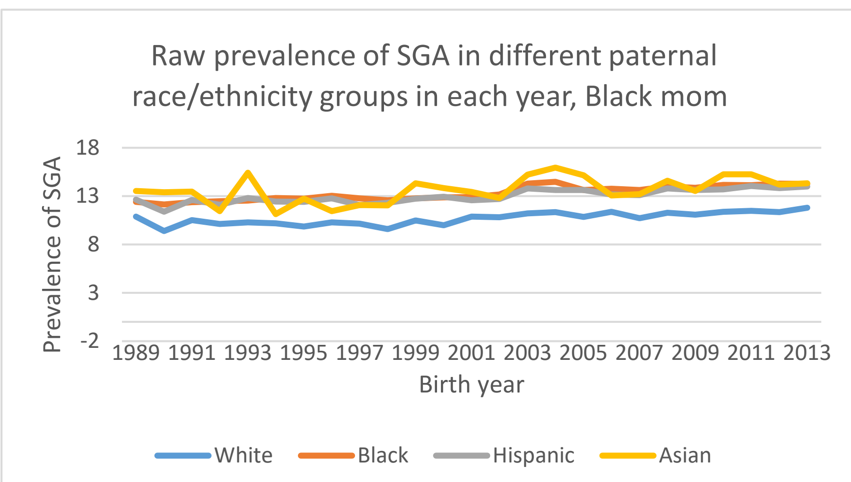
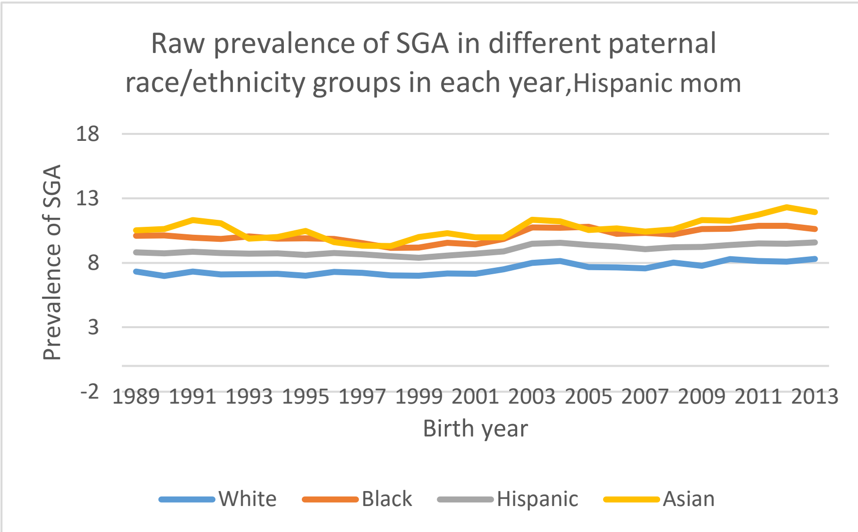


Figure 4.1 (cont'd)



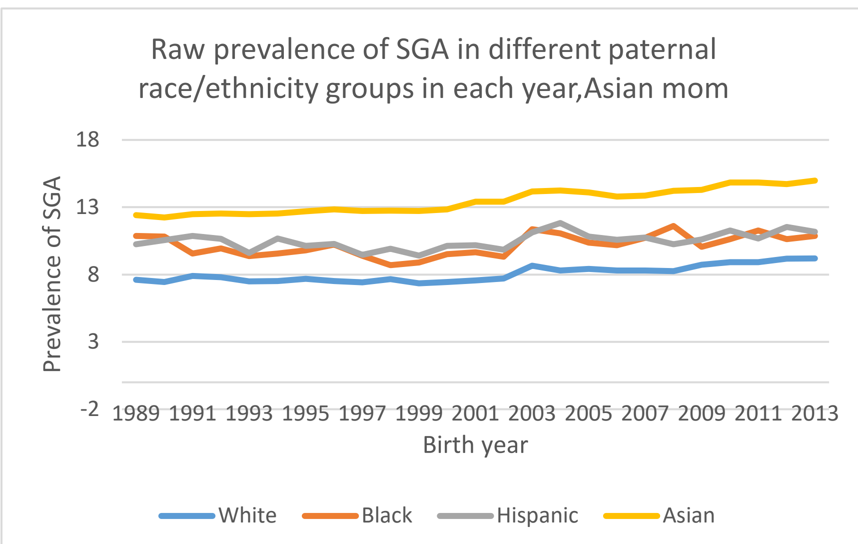


Figure 4.1 shows prevalence of SGA increased slightly over time for all race-combination groups from 1989 to 2013. Within maternal race/ethnicity, those partner with white fathers were always at the lowest prevalence of having SGA babies from 1989 to 2013. There were no obvious difference between black fathers, Hispanic fathers and Asian fathers except for among Asian mothers. For Asian mothers, partner with Asian fathers were apparently at the highest prevalence of having SGA babies.

Table 4.3 Frequency of singleton births of 16 race-combination groups in United States, 1989-2013

Maternal race/ethnicity		White	Black	Hispanic	Asian
	White	45,559,015	1,113,311	2,056,974	390,507
Paternal	Black	303,238	7,934,869	195,816	26,220
race/ethnicity	Hispanic	1,727,674	448,153	13,937,222	124,951
	Asian	698,565	100,210	145,153	3,218,248

Table 4.3 gives the counts of singleton births in each of the 16 race-combination groups in the 25-year period.

Table 4.4 Race-combination couples and pregnancy characteristics for all singleton live births, from the National Center for Health Statistics Natality Files in 1989 and 2013.

Maternal race/ethnicity	Paternal race/ethnicity	Total 1989	Total 2013	Total Difference between 1989 and 2013	% Small for Gestation Age 1989	% Small for Gestation Age 2013	% Small for Gestation Age Difference between 1989 and 2013
Overall					8.8	10.0	1.2
White							
	White	58.8	44.6	-14.2	7.0	7.7	0.7
	Black	0.6	1.7	1.1	8.9	10.0	1.1
	Hispanic	1.6	3.0	1.4	8.6	9.2	0.6
	Asian	0.3	0.6	0.3	9.6	10.5	0.9
Black							
	White	0.2	0.6	0.4	10.9	11.8	0.9
	Black	9.6	9.0	-0.6	12.4	14.3	1.9
	Hispanic	0.1	0.4	0.2	12.6	14.0	1.4
	Asian	0.0	0.1	0.0	13.5	14.3	0.8
Hispanic							
	White	1.3	2.5	1.2	7.3	8.3	1.0
	Black	0.2	0.8	0.6	10.1	10.6	0.5
	Hispanic	10.0	17.1	7.1	8.8	9.6	0.8
	Asian	0.1	0.2	0.1	10.5	11.9	1.4
Asian							
	White	0.5	1.0	0.5	7.6	9.2	1.6
	Black	0.1	0.2	0.1	10.9	10.9	0.0
	Hispanic	0.1	0.2	0.2	10.3	11.2	0.9
	Asian	2.4	4.6	2.2	12.5	15.0	2.5
Parity	Nulliparous	41.5	40.1	-1.5	10.3	12.3	2.0
	Primaparous	32.5	31.8	-0.7	7.5	8.4	0.9
	Multiparous	26.0	28.2	2.2	7.9	8.5	0.6
Marital status	Married	73.5	59.7	-13.8	7.5	8.4	0.9
	Unmarried	26.5	40.3	13.8	12.2	12.4	0.2
Education attainment	0-8 years	5.6	3.9	-1.7	10.0	9.5	-0.5
	9-11 years	16.9	11.9	-5.0	12.0	12.9	0.9
	HS grad/GED	39.2	25.0	-14.2	9.1	11.4	2.4
	Some college	20.5	29.4	8.8	7.5	9.7	2.2
	College grad	11.7	19.1	7.3	6.0	7.9	1.9
	More than college	6.0	10.8	4.7	6.2	8.1	1.9
Maternal Nativity	Native born	85.4	77.3	-8.1	8.7	9.9	1.2
	Foreign born	14.6	22.7	8.1	9.1	10.2	1.1
Maternal Age	<20	12.6	7.0	-5.6	11.5	14.0	2.5
	20-29	58.2	51.7	-6.4	8.8	10.6	1.8
	30-39	28.1	38.6	10.4	7.4	8.5	1.1
	>=40	1.1	2.7	1.6	8.2	9.2	1.1

Table 4.4 shows that there were significant shifts in maternal demographic characteristics from 1989 to 2013: fewer births were from white mother/white father and black mother/black father couples, and more births were from unmarried, more educated and older women. The prevalence of SGA was higher in almost all maternal demographic and race-combination categories in 2013 compared to 1989 except for among Asian mothers/black fathers and women with 0-8 years of education.

Table 4.5 Change in log odds (β coefficient) associated with every 10-year increment for small for gestation age for each race-combination group 1989-2013

Maternal race/ethnicity

		White		Black		Hispanic		Asian	
		Change in log odds	95%CI	Change in log odds	95%CI	Change in log odds	95%CI	Change in log odds	95%CI
Paternal race/ethnicity	White	0.08	0.08,0.08	0.08	0.07,0.10	0.08	0.07,0.08	0.01	0.09,0.11
	Black	0.10	0.09,0.11	0.09	0.09,0.10	0.07	0.06,0.09	0.07	0.04,0.10
	Hispanic	0.07	0.06,0.07	0.08	0.06,0.10	0.06	0.06,0.06	0.05	0.02,0.07
	Asian	0.13	0.11,0.15	0.09	0.04,0.15	0.09	0.07,0.12	0.10	0.10,0.11

[1]We use 10-year increment because the original parameters were too small.

Table 4.5 shows change in log odds associated with every 10-year increment for small for gestation age for each race-combination group. The log odds of SGA in all groups increased from 1989 to 2013. The largest increase was for the white mother/Asian father group (log odds = 0.13) and the smallest increase was for the Asian mother/Hispanic father group (log odds = 0.05). Within the same maternal race/ethnicity, Asian fathers have the highest log odds of change on prevalence of having SGA babies over time compared to other fathers, whereas Hispanic fathers have the lowest increase. Also, we found that those partnering with Hispanic fathers were the same/or had smaller log odds comparing to white mother/white father. For Asian mother, those of mixed-race couples had smaller log odds comparing to white mother/white father.

Table 4.6 Raw and adjusted prevalence, raw prevalence ratio and standardized morbidity ratio in 1989-1991 and 2011-2013, adjusted prevalence are based on white mother/white father combinations in the same year group

1 2 3 4 5 6 7 8

Race-combination couples	Raw prevalence in 1989 to 1991	Raw prevalence ratio in 1989 to 1991	Adjusted prevalence Using White Mother/White Father demographic characteristic distribution in 1989 to 1991	SMR in 1989 to 1991	Raw prevalence in 2011 to 2013	Raw prevalence ratio in 2011 to 2013	Adjusted prevalence Using White Mother/White Father demographic characteristic distribution in 2011 to 2013	SMR in 2011 to 2013
White Mother/White Father	0.07	1.00	0.07	1.00	0.08	1.00	0.08	1.00
White Mother/Black Father	0.09	1.25	0.07	1.02	0.10	1.29	0.08	1.07
White Mother/Hispanic Father	0.08	1.21	0.07	1.01	0.09	1.19	0.08	1.11
White Mother/Asian Father	0.09	1.30	0.07	1.04	0.11	1.40	0.11	1.40
Black Mother/White Father	0.10	1.47	0.10	1.44	0.12	1.50	0.11	1.39
Black Mother/Black Father	0.12	1.77	0.08	1.13	0.14	1.85	0.09	1.14
Black Mother/Hispanic Father	0.12	1.75	0.12	1.73	0.14	1.82	0.13	1.65
Black Mother/Asian Father	0.13	1.93	NA	NA	0.15	1.90	NA	NA
Hispanic Mother/White Father	0.07	1.03	0.07	1.04	0.08	1.07	0.08	1.01
Hispanic Mother/Black Father	0.10	1.44	0.08	1.18	0.11	1.40	0.10	1.31
Hispanic Mother/Hispanic Father	0.09	1.26	0.07	1.04	0.10	1.24	0.08	1.04
Hispanic Mother/Asian Father	0.11	1.55	0.11	1.52	0.12	1.56	0.13	1.67
Asian Mother/White Father	0.08	1.10	0.07	1.03	0.09	1.18	0.09	1.21
Asian Mother/Black Father	0.10	1.49	0.10	1.43	0.11	1.42	0.11	1.37
Asian Mother/Hispanic Father	0.11	1.52	0.09	1.23	0.11	1.45	0.11	1.38
Asian Mother/Asian Father	0.12	1.78	0.08	1.14	0.15	1.93	0.10	1.24

Columns 1 and 5 of Table 4.6 show the raw prevalence of SGA for each race-combination group in the combination of 1989-1991 and 2011-2013, respectively. Next, we calculated the raw prevalence ratio (PR) for SGA in 1989-1991 (column 2) and 2011-2013 (column 6) comparing all race combinations to white mother/white father couples in the same year. For example, the raw PR for SGA comparing black mothers/white fathers to white mothers/white fathers in 1989-1991 is 0.09/0.07=1.25. For 1989-1991, black mother/Hispanic father had the second highest raw PR among mixed-race couples (1.75). (Black mother/Asian father had the highest raw PR, but for the adjusted PR, it appeared to have quasi-complete separation problem), Asian mother/Asian father appeared to have the highest raw PR overall; while for 2011-2013, Asian mother/Asian father still had the highest raw PR (1.93) and Black mother/Hispanic father had the highest raw PR (1.82) among mixed-race couples, except for Black mother/Asian father due to the quasi-complete separation again. For quasi-complete separation, for example, if there is some overlap when x predicts y, (e.g., y = 0 when x < 3, but when x = 3, y=0 or y=1) then "quasi-complete separation" occurs. Also, A 2 by 2 table with an empty cell is called quasi-complete separation, too.

We then estimated what the SGA prevalence would have been in each race combination group if women in those groups had, counter to fact, the same distribution of demographic characteristics as white mothers partnering with white fathers in their same year cohort (eg. All the race combination couples in 1989-1991 compared to white mother/white father in 1989-1991; meanwhile, all the race combination couples in 2011-2013 compared to white mother/white father in 2011-2013). Using the coefficients from logistic regression models described in the methods section, we calculated what the adjusted prevalence in each race combination group would have been had the demographic distribution been fixed as their own period of time among white mother/white father combination (columns 3 and 7, respectively for 1989-1991 and 2011-2013). Using the adjusted prevalence, we calculated the standardized morbidity ratio (SMR) for 1989-1991 (column 4) and 2011-2013 (column 8). The difference between SMR and raw PR was the part of relative prevalence could be explained by the adjusted covariates, while the residue part could be explained as the impact by "unadjusted characteristics". If the SMR is close to the raw PR of the same year (or if the adjusted prevalence is close to the raw prevalence), then we can assume that the demographic factors did not impact SGA. Let's take white mother/black father in 1989-1991 as an example, the raw PR was 1.25, after adjustment by the demographic distribution of white mother/white father, the SMR should turned to be 1.00. However, the SMR we calculated was 1.02, which meant the demographic information we adjusted could only explain the difference from 1.25 to 1.02, but the difference between 1.02 and 1.00 was still un-explained by the measured demographic characteristics. In 1989-1991, (scenario 1:) combinations with white mothers, Hispanic mother/Hispanic father and Asian mother/white father were in this similar situation (most difference could be explained by the demographic information, the SMR was closed but not equaled to 1.00), indicating the prevalence of SGA would have been lower had the demographic distribution been the same as the white mother/white father group in 1989-1991, some combinations (scenario 2: eg. Black mother/black father, PR:1.77, SMR:1.13) had the adjustment changed a lot by demographic information, but there was still decent amount of unmeasured demographic characteristics so that the SMRs were not close to 1.00. Besides, some combinations (scenario 3: eg. Hispanic mother/Asian father, PR:1.55, SMR: 1.52), there was no big difference between PR and SMR. In 2011-2013, there were still combinations fitted into the previous scenarios: eg. Scenario 1: Hispanic mother/white father; scenario 2: black mother/black father; scenario 3: white mother/Asian father. And there appeared scenario 4: SMR was much bigger than PR (eg. Hispanic mother/Asian father), which indicated that those adjusted demographic information might be protective effect with their own demographic information compared to white mother/white father in 2011-2013. There are some same raw PRs matching with different SMRs were due to rounding.

Our sensitivity analyses showed similar trend between 2003 and 2004 compared to 1989-1991 and 2011-2013, so we concluded that changing in natality file version did not have any impact on our results. We also did analyses using 1989 and 2013 alone (Appendix, Table 5).

CHAPTER 5: DISCUSSION, LIMITATIONS/STRENGTHS, AND FUTURE RESEARCH DIRECTIONS

In this chapter, results and main findings of the three studies are summarized. Discussion includes explanations and comparisons of our findings and previous literature. Next, the strengths and limitations of all three studies are stated. Finally, future research directions and public health implications are proposed.

5.1 Summary of Study Findings and Comparison to Previous Literature

In study 1, Using U.S. vital statistics natality data for all singleton births in the United States from 1989 to 2013, our study investigated relations between paternal race/ethnicity and measures of fetal growth among four maternal race/ethnicity groups. Within mother's race/ethnicity, white paternal race/ethnicity was associated with the lowest odds of both LBW and SGA. For all maternal racial/ethnic groups, black and "missing" paternal race/ethnicity conferred the highest odds of LBW, while Asian and "missing" paternal race/ethnicity conferred the highest odds of SGA.

Our findings that infants with black fathers always had higher odds of both LBW and SGA compared to those with white fathers within mother's race/ethnicity were consistent with previous studies(10,37,39,41). One possible explanation for this finding is that, due to the race/ethnicity disparities in SES (socio-economic status), the additive SES in couples where one parent is black may be lower than in white/white couples, and lower SES is strongly associated with higher prevalence of adverse birth outcomes(59,63). Racial discrimination may also explain some of the increased prevalence of LBW and SGA seen among black fathers(64); discrimination in mothers is hypothesized to impact birth outcomes via stress and health behavior pathways, yet these mechanisms remain untested in fathers.

Meanwhile, our study added two more racial/ethnic groups not previously examined in most studies of paternal race/ethnicity: Hispanic and Asian. Only one previous study included both Hispanic and Asian fathers; this study compared all combinations with white mother/white father couples. Our study found that for black mothers, Asian paternal race/ethnicity was protective against LBW but not SGA compared to black mother/black father couples. Also, this previous study was only in New York City and ours included all the singleton birth in United States resulting in a higher proportion of Hispanics (33.2% vs. 20.6%) and Asians (15.0% vs. 4.8%) in their sample compared to our national sample. This previous work also represented families living only in urban areas whereas ours included rural area as well.

Our results also differed from a study conducted at Stanford University(38), which found significantly higher odds of having LBW babies in Asian mother/Asian father compared to white mother/white father, while white mother/Asian father and Asian mother/white father combinations showed no significant difference. Our findings, on the other hand, showed significantly higher odds of both LBW and SGA babies for Asian fathers compared to all other paternal races/ethnicities within maternal race/ethnicity. Again, the limited sample of the previous study (one hospital) may have explained the difference in findings from our national sample.

Our finding that Asian race/ethnicity was consistently associated with increased prevalence of SGA but that the associations between Asian paternal race/ethnicity and LBW differ by maternal race/ethnicity indicates that SGA in Asian babies may not reflect pathological fetal growth restriction but simply smaller body size. A previous study from Canada also showed that if parental race/ethnicity was Asian, infant birth weight was lower than if parental race/ethnicity was from white European descent(65–67). In our analyses of only term births, the direction of association between Asian paternal race/ethnicity and SGA was more similar to the association with LBW, suggesting that any difference between LBW and SGA in the whole sample may reflect the contribution of PTB to LBW. Thus, Asian paternal race/ethnicity may be protective against PTB for blacks but not whites.

Finally, within mother's race/ethnicity, the odds of LBW was highest for records where father's race/ethnicity was missing. This indicates that paternal race/ethnicity is associated with adverse birth outcomes, which is consistent with previous studies(68–70). Missing paternal race/ethnicity may be a marker for other characteristics(52,55). For example, prior research has indicated that records with missing paternal information are more likely to lack perinatal care access and be current smokers(55,70,71). Our data (not shown, available from the authors upon request) confirmed that within mother's race/ethnicity, mothers with "missing" paternal race/ethnicity were the most likely to be current smokers and had the fewest number of prenatal care visits compared to records with available data on paternal race/ethnicity.

In study 2, using U.S. vital statistics natality data for all singleton births in the United States from 1989 to 2013 (same sample but excluded those with father's race/ethnicity as "missing"), our study investigated whether the demographic characteristics of mothers partnering with a father of a different race/ethnicity have changed over time**.** We did not find a pattern differentiated same race/ethnicity couples and mixed-race couples for parity or nativity, but both same race/ethnicity and mixed-race couples had an increasing trend of unmarried, higher education level and older age.

Meanwhile, we found that all the race combination groups had an increasing trend of SGA. This finding showed that our hypothesis 2a: "The prevalence of SGA among mothers (i.e., white, black, Hispanic, Asian) partnering with a father of a different race/ethnicity have changed over time." is true. This finding was reasonable because of the increasing trend of unmarried and older age for all race combinations, and these two factors were well-known related to higher prevalence of SGA (72,73). Those partnering with Hispanic fathers were the same/or had smaller log odds comparing to white mother/white father. For Asian mother, those of mixed-race couples had smaller log odds comparing to white mother/white father. In other words, for those mixed-race couples who partner with Hispanic father or Asian mother, our results showed that the hypothesis 2(b) (i.e., that the prevalence of SGA in the mixed-race groups relative to the white/white group will get smaller over the time) was not true because only 50%(6/12) mixed-race groups had slightly smaller PR in 2011-2013 than in 1989-1991.

In this paper we examined the effect of some specific changing demographics (nativity, parity, maternal age, marital status and education) on the rate of SGA. Our analysis surprisingly showed that the changes on that demographic information had different effect on SGA prevalence rate depends on different race combinations. Only small amount of the mixed-race combinations showed true in this situation (4 combinations out of 12 in 1989-1991, and 1 combination out of 12 in 2011-2013) In another word, given what we had known about the associations between those demographic characteristics and SGA, the SGA rate would have been the same for most of the race combinations if the demographics in 1989-1991/2011-2013 would be the same as in white mother/white father in their same years. These findings showed that our hypothesis 2(c) was not true. Now even more race combinations (eg. Hispanic mother/Asian father) had higher SMR in 2013 (1.67) than in raw RR (1.56). We had to remember that not all the demographic changes would lead to higher rates of SGA. Some have the opposite effect which would lead to this scenario. For example, the education level shifts the fastest to the higher level in Asian mother/Asian father combination.

Our analysis did not suggest that our hypothesis 2(c) (i.e., that the difference in prevalence between mixed race and white/white would be explained by demographic characteristics) was true. We hypothesized 2 (c) because there were evidence showed more acceptance in mixed-race marriage and the generally increased SES status. Changing adjusted demographics do not seem to explain the increase in SGA rates among any race combination couple. This leads to the conclusion that the overall rise in SGA prevalence, but the smaller gap between mixed-race group and white mother/white father over these years has been driven by changes in some un-adjustable characteristics, such us: race discrimination, acceptance rate of mixed-race marriage.

Our study did not include paternal race/ethnicity as “missing”, the percentage of “missing” fathers within maternal race/ethnicity group was shown in appendix, table 4. Only percentage of black mother/missing father decreases apparently through the years. This won’t impact our current findings because those with “missing” fathers have their own characteristics and there was no similarity between these groups and our current study groups.

Our study was the first study taking on account of trend on SGA among all race combination groups. We tried to use the same method as standardized mortality ratio but the sample size got too small because we stratified to too many categories. Then we used method from Tyler (62). First, we have used demographic information from white mother/white father in 1989 to get predicted probabilities for SGA from a model using data both in 1989 and 2013 to get the standardized RR in all the race combination groups in both 1989 and 2013 (1989 white mother/white father was 1.000.

5.2 Limitations and Strengths

5.2.1 Limitations

There were some limitations in our study 1. First, we were not able to adjust for father's SES status or father's level of involvement in the pregnancy, limiting our ability to investigate mechanisms behind the associations identified. (For example, father's education was only recorded from 1989 to 1995, and from 2010 to 2013.) Another limitation is that all data, including both maternal and paternal race/ethnicity, maternal education, maternal age, parity, marital status and nativity were self-reported. Moreover, those with missing paternal race/ethnicity should technically be included in their correct race/ethnicity group, resulting in potential misclassification and resulting bias in coefficients for those other groups. However, we believe that those categorized as "missing" do represent a different construct of paternal race/ethnicity. Furthermore, there was potential measurement error in measuring gestational age because gestational age was measured based on last menstrual period (LMP)(57), and LMP are not always accurate enough as reported by women themselves(74). Last but not the least, according to the natality file, we were not able to define how many births a woman had given to within this 25-year time period among those women who had more than one baby. In this situation, a woman might be count more than one time to calculate the association between the birth outcome and their race combination groups, and it was possible that women were partnering with different race/ethnicities when having babies.

There were still some limitations in study 2 as well. First, like all the previous national based paternal studies, we were not able to adjust for father's SES status or father's level of involvement in the pregnancy, which limited our opportunity to investigate mechanisms behind the associations identified. (Eg, paternal education was only existed from two periods: 1989 to

1995, and 2010 to 2013.) Another limitation, also as limitation of using Natality file, is that all data, including LMP (to measure SGA), both maternal and paternal race/ethnicity, maternal education, maternal age, parity, marital status and nativity were self-reported. It will be a better measure if we have any indicators represent the acceptance of interracial relationships.

Secondly, some race combinations were only included limited sample size so that there were problems in “Quasi-complete separation of data points detected”, which means the result was not that valid to explain. Those combinations were: 1989: black mother/Asian father, Hispanic mother/black father, Asian mother/black father; 2013: Asian mother/black father.

5.2.2 Strengths

A main strength of this study was that it used a very large sample size across 25 years throughout the whole U.S., which represented almost all the singleton birth from 1989 to 2013 and reduced concerns about the external validity of the sample. The availability of data on paternal race/ethnicity was more than 80% in each year. Most previous studies of race/ethnicity-combination couples and birth outcomes only included white-black couples. Interracial couples including Hispanics and Asians had not been included except for one study(75). Previous studies only accounted for a short period of time or included only a few states.

5.3 Health Implications

There are growing numbers of families with different parental race/ethnicity combinations because of more immigrants(76) and more acceptance of interracial dating and marriage. For example, only 48% of the American public supported Whites dating Blacks in 1987 while this percentage had increased to 83% in 2009(34), thus we must begin to gain a better understanding of birth outcomes among these families. Paternal information should be included on birth certificates for future research since more paternal SES and involvement information might increase our understanding of the mechanisms behind observed paternal race/ethnicity disparities in birth outcomes. For study 2, our study built solid evidence that the trend of having SGA babies were due to the social piece of both maternal and paternal race/ethnicity instead of genetics piece.

5.4 Future Directions

Further studies should focus on the cause for different orders among different race combination baby groups. Paternal information should be included on birth certificates for future research. From study 2, we concluded that future study should use some available state based datasets which included paternal social factors (if exists) to find out the social effect brought in by race/ethnicity.

APPENDICES

APPENDIX A: Tables

Table A.1 Multivariate adjusted[1] odds ratios (OR) and 95% confidence intervals (95% CI) for the association between paternal race/ethnicity and very low birth weight, stratified by maternal race/ethnicity,1989-2013

	Maternal race/ethnicity	White		Black		Hispanic		Asian	
		OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI
Paternal race/ethnicity	White	Ref	Ref	0.75	0.73,0.77	0.79	0.78,0.81	0.90	0.87,0.93
	Black	1.35	1.33,1.38	Ref	Ref	1.32	1.29,1.36	1.52	1.43,1.61
	Hispanic	1.13	1.11,1.15	0.87	0.84,0.90	Ref	Ref	1.23	1.17,1.30
	Asian	1.00	0.96,1.05	0.78	0.71,0.86	0.90	0.84,0.96	Ref	Ref
	Missing	1.33	1.31,1.34	1.16	1.15,1.17	1.21	1.19,1.22	1.19	1.13,1.24
Parity	nulliparous	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	primaparous	0.55	0.55,0.56	0.68	0.61,0.68	0.63	0.62,0.63	0.73	0.71,0.75
	multiparous	0.56	0.56,0.57	0.64	0.63,0.65	0.61	0.60,0.61	0.75	0.73,0.78
Marital status	Married	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Unmarried	1.31	1.30,1.32	1.11	1.10,1.12	1.17	1.15,1.18	1.31	1.31,1.40
Education attainment	0-8 years	2.22	2.16,2.27	1.41	1.36,1.45	1.40	1.35,1.45	1.31	1.23,1.39
	9-11 years	2.30	2.27,2.34	1.44	1.41,1.48	1.52	1.47,1.58	1.38	1.32,1.46
	HS grad/GED	1.81	1.79,1.84	1.36	1.33,1.39	1.44	1.39,1.49	1.41	1.35,1.46
	Some college	1.48	1.46,1.50	1.28	1.25,1.31	1.38	1.33,1.43	1.36	1.31,1.41
	College grad	1.10	1.08,1.11	1.12	1.10,1.15	1.09	1.05,1.13	1.18	1.14,1.22
	More than college	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Nativity	Native born	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	Foreign born	0.92	0.90,0.93	0.74	0.73,0.75	0.76	0.75,0.77	0.89	0.87,0.92
Maternal Age	<20	0.90	0.89,0.91	0.78	0.77,0.79	0.95	0.93,0.96	1.40	1.33,1.48
	20-29	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
	30-39	1.36	1.35,1.37	1.58	1.57,1.60	1.67	1.65,1.69	1.42	1.38,1.46
	>=40	2.17	2.13,2.21	2.06	2.01,2.11	2.69	2.62,2.77	2.55	2.43,2.68

[1] Adjusted model includes fixed effect covariates (birthyear, state) as well as maternal age, nativity, education, parity and marital status.

Table A.2a Multivariate adjusted[1] odds ratios (OR) and 95% confidence intervals (95% CI) for the association between paternal race/ethnicity and low birth weight among term babies, stratified by maternal race/ethnicity, 1989-2013

	Maternal race/ethnicity	White		Black		Hispanic		Asian	
		OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI
Paternal race/ethnicity	White	Ref	Ref	0.78	0.76,0.80	0.81	0.80,0.83	0.59	0.58,0.60
	Black	1.11	1.10,1.13	Ref	Ref	1.12	1.10,1.14	0.80	0.77,0.83
	Hispanic	1.06	1.05,1.07	0.91	0.89,0.93	Ref	Ref	0.78	0.75,0.81
	Asian	1.31	1.28,1.34	1.04	0.97,1.11	1.12	1.08,1.17	Ref	Ref
	Missing	1.24	1.24,1.25	1.12	1.11,1.13	1.19	1.18,1.20	1.01	0.98,1.04

Table A.2b Multivariate adjusted[1] odds ratios (OR) and 95% confidence intervals (95% CI) for the association between paternal race/ethnicity and small for gestational age among term babies, stratified by maternal race/ethnicity,1989-2013

	Maternal race/ethnicity	White		Black		Hispanic		Asian	
		OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI
Paternal race/ethnicity	White	Ref	Ref	0.79	0.78,0.80	0.82	0.81,0.82	0.54	0.54,0.55
	Black	1.07	1.07,1.08	Ref	Ref	1.04	1.03,1.06	0.69	0.68,0.71
	Hispanic	1.07	1.06,1.08	0.93	0.91,0.94	Ref	Ref	0.71	0.70,0.72
	Asian	1.43	1.42,1.45	1.08	1.04,1.12	1.21	1.19,1.23	Ref	Ref
	Missing	1.15	1.15,1.16	1.07	1.06,1.07	1.10	1.09,1.10	0.92	0.91,0.94

Table A.2c Multivariate adjusted[1] odds ratios (OR) and 95% confidence intervals (95% CI) for the association between paternal race/ethnicity and very low birth weight among term babies, stratified by maternal race/ethnicity,1989-2013

	Maternal race/ethnicity	White		Black		Hispanic		Asian	
		OR	95%CI	OR	95%CI	OR	95%CI	OR	95%CI
Paternal race/ethnicity	White	Ref	Ref	0.77	0.65,0.91	0.82	0.75,0.91	0.80	0.68,0.95
	Black	1.18	1.07,1.31	Ref	Ref	1.24	1.08,1.43	1.27	0.92,1.74
	Hispanic	1.14	1.05,1.23	0.98	0.83,1.17	Ref	Ref	1.08	0.81,1.44
	Asian	1.23	1.02,1.48	0.71	0.40,1.26	0.86	0.62,1.19	Ref	Ref
	Missing	1.33	1.26,1.40	1.19	1.14,1.25	1.21	1.12,1.30	1.05	0.82,1.35

[1] Adjusted model (2a, 2b, 2c) includes fixed effect covariates (birthyear, state) as well as maternal age, nativity, education, parity and marital status.

Table A.3 Distribution of characteristics in different race/ethnicity combination group from 1989 to 2013 in United States

	WW	WB	WH	WA	WM	BW	BB	BH	BA	BM	HW	HB	HH	HA	HM	AW	AB	AH	AA	AM
Age																				
<20	5.95	13.90	12.60	5.22	27.09	10.50	13.35	17.16	10.41	28.36	7.48	16.70	13.51	10.76	27.01	2.05	8.12	9.96	2.45	16.64
20-29	51.41	60.42	56.62	45.05	56.4	54.24	56.09	58.50	54.13	56.36	50.78	60.35	57.64	54.07	54.71	34.45	52.12	50.38	43.74	53.63
30-39	40.33	24.05	28.98	46.25	15.21	32.54	28.54	22.80	32.68	14.33	39.08	21.65	27.10	33.08	16.96	58.23	36.74	36.86	50.73	26.93
>=40	2.31	1.63	1.80	3.48	1.29	2.72	2.02	1.54	2.78	0.96	2.67	1.30	1.75	2.09	1.32	5.26	3.02	2.80	3.07	2.80
education																				
0-8 years	1.43	1.43	2.00	0.65	4.11	0.86	1.65	1.33	0.93	2.97	2.18	1.86	22.81	2.22	20.29	1.04	1.17	1.29	5.16	11.22
9-11 years	7.95	17.23	16.02	5.84	30.40	10.97	15.84	17.60	9.91	34.33	10.41	20.27	27.53	12.81	37.58	3.08	8.51	9.69	6.58	21.80
HS grad	29.52	37.73	34.15	22.56	40.64	30.85	37.85	35.62	30.05	41.25	30.57	37.57	29.20	35.48	28.85	17.84	32.61	30.2	21.13	36.20
some college	26.22	28.18	27.04	26.04	19.41	33.04	28.64	31.87	34.08	18.10	30.24	29.49	13.95	29.18	10.94	24.04	32.27	30.49	18.73	18.96
college grad	22.35	9.94	13.04	24.85	3.59	14.78	10.52	8.95	15.30	2.47	16.60	7.30	4.23	12.72	1.61	31.27	17.28	18.86	27.09	7.93
more than college	12.53	5.50	7.76	20.06	1.85	9.51	5.50	4.63	9.73	0.87	9.99	3.51	2.23	7.58	0.73	22.73	8.17	9.47	21.31	3.88
nativity																				
native born	94.52	95.05	94.07	89.85	96.60	85.52	86.20	89.28	78.34	94.54	68.96	77.02	33.02	69.72	47.71	30.62	34.68	47.19	10.65	27.09
foreign born	5.48	4.95	5.93	10.15	3.40	14.48	13.80	10.72	21.66	5.46	31.04	22.98	66.98	30.28	52.29	69.38	65.32	52.81	89.35	72.91
marital status																				
married	85.52	43.34	65.92	82.77	8.29	60.95	47.22	42.40	60.36	2.41	76.51	39.62	60.73	65.30	5.35	90.13	62.78	65.84	91.19	12.54
unmarried	14.48	56.66	34.08	17.23	91.61	39.05	52.78	57.60	39.74	97.59	23.49	60.38	39.27	34.70	94.65	9.87	37.22	34.16	8.81	87.46
parity																				
nalliparous	41.18	42.34	42.33	45.24	54.01	44.30	36.77	43.74	43.99	41.10	43.35	42.43	34.20	42.82	45.57	49.49	44.70	47.09	45.31	52.68
primaparous	34.69	30.78	31.62	32.91	24.40	30.86	30.77	29.19	31.01	26.82	33.21	29.72	30.79	31.78	25.03	33.71	30.79	31.10	35.65	25.06
multiparous	24.13	26.88	26.05	21.85	21.59	24.84	32.46	27.07	25.00	32.08	23.44	27.85	35.02	25.40	29.40	16.79	24.50	21.81	19.04	22.26

Table A.4 Distribution of percentage of “missing” father within maternal race/ethnicity by year, from 1989 to 2013.

	Maternal race/ethnicity			
Birthyear	White	Black	Hispanic	Asian
1989	8.24	40.48	11.92	5.17
1990	8.43	41.67	12	5.61
1991	9	42.99	12.76	6.11
1992	9.08	42.25	12.7	6.44
1993	9.21	42.39	12.93	6.78
1994	9.1	42.38	13.33	6.67
1995	8.84	40.92	13.13	6.47
1996	8.66	39.86	13.12	6.09
1997	8.61	39.22	13.69	5.58
1998	8.7	37.84	13.57	5.37
1999	8.76	36.76	13.51	5.22
2000	8.54	36.29	13.35	5.04
2001	8.62	35.76	12.93	4.94
2002	8.78	35.53	13	4.99
2003	8.89	35.69	13.21	4.8
2004	9.24	36.29	13.15	4.82
2005	9.59	36.16	13.25	4.82
2006	9.74	36.38	13.43	4.7
2007	9.78	36.33	13.53	4.71
2008	9.86	35.94	13.59	4.53
2009	9.86	36.06	13.49	4.65
2010	9.92	35.73	13.53	4.47
2011	9.81	35.13	13.3	4.53
2012	9.67	34.27	13.19	4.39
2013	9.33	33.34	13	4.39

Table A.5 Raw and adjusted prevalence, raw prevalence ratio and standardized morbidity ratio in 1989 and 2013, adjusted prevalence are based on white mother/white father combinations in 1989

	1	2	3	4	5	6	7	8
Race-combination couples	**Raw prevalence in 1989**	**Raw prevalence ratio in 1989**	**Adjusted prevalence Using White Mother/White Father demographic characteristic distribution in 1989**	**SMR in 1989**	**Raw prevalence in 2013**	**Raw prevalence ratio in 2013**	**Adjusted prevalence Using White Mother/White Father demographic characteristic distribution in 1989**	**SMR in 2013**
White Mother/White Father	0.07	1.00	0.07	1.00	0.08	1.00	0.07	1.00
White Mother/Black Father	0.09	1.27	0.08	1.11	0.10	1.30	0.10	1.39
White Mother/Hispanic Father	0.09	1.23	0.08	1.11	0.09	1.20	0.09	1.31
White Mother/Asian Father	0.10	1.37	0.09	1.31	0.11	1.36	0.11	1.51
Black Mother/White Father	0.11	1.56	0.11	1.53	0.12	1.53	0.12	1.67
Black Mother/Black Father	0.12	1.77	0.12	1.69	0.14	1.86	0.14	2.01
Black Mother/Hispanic Father	0.13	1.80	0.14	1.97	0.14	1.82	0.12	1.77
Black Mother/Asian Father	0.14	1.93	NA	NA	0.14	1.86	0.14	1.94
Hispanic Mother/White Father	0.07	1.04	0.07	1.04	0.08	1.08	0.09	1.31
Hispanic Mother/Black Father	0.10	1.44	NA	NA	0.11	1.38	0.10	1.37
Hispanic Mother/Hispanic Father	0.09	1.26	0.09	1.29	0.10	1.25	0.10	1.43
Hispanic Mother/Asian Father	0.11	1.50	0.09	1.34	0.12	1.55	0.12	1.69
Asian Mother/White Father	0.08	1.09	0.08	1.09	0.09	1.20	0.09	1.33
Asian Mother/Black Father	0.11	1.56	NA	NA	0.11	1.42	NA	NA
Asian Mother/Hispanic Father	0.10	1.46	0.09	1.24	0.11	1.46	0.09	1.34
Asian Mother/Asian Father	0.13	1.79	0.08	1.14	0.15	1.95	0.16	2.29

Table A.6 Raw and adjusted prevalence, raw prevalence ratio and standardized morbidity ratio in 1989 and 2013, adjusted prevalence are based on white mother/white father combinations in the same year

	1	2	3	4	5	6	7	8
Race-combination couples	**Raw prevalence in 1989**	**Raw prevalence ratio in 1989**	**Adjusted prevalence Using White Mother/White Father demographic characteristic distribution in 1989**	**SMR in 1989**	**Raw prevalence in 2013**	**Raw prevalence ratio in 2013**	**Adjusted prevalence Using White Mother/White Father demographic characteristic distribution in 2013**	**SMR in 2013**
White Mother/White Father	0.07	1.00	0.07	1.00	0.08	1.00	0.08	1.00
White Mother/Black Father	0.09	1.27	0.08	1.11	0.10	1.30	0.08	1.00
White Mother/Hispanic Father	0.09	1.23	0.08	1.11	0.09	1.20	0.09	1.13
White Mother/Asian Father	0.10	1.37	0.09	1.31	0.11	1.36	0.10	1.25
Black Mother/White Father	0.11	1.56	0.11	1.53	0.12	1.53	0.11	1.38
Black Mother/Black Father	0.12	1.77	0.12	1.69	0.14	1.86	0.13	1.63
Black Mother/Hispanic Father	0.13	1.80	0.14	1.97	0.14	1.82	0.13	1.63
Black Mother/Asian Father	0.14	1.93	NA	NA	0.14	1.86	0.14	1.75
Hispanic Mother/White Father	0.07	1.04	0.07	1.04	0.08	1.08	0.08	1.00
Hispanic Mother/Black Father	0.10	1.44	NA	NA	0.11	1.38	0.10	1.25
Hispanic Mother/Hispanic Father	0.09	1.26	0.09	1.29	0.10	1.25	0.10	1.25
Hispanic Mother/Asian Father	0.11	1.50	0.09	1.34	0.12	1.55	0.12	1.5
Asian Mother/White Father	0.08	1.09	0.08	1.09	0.09	1.20	0.09	1.13
Asian Mother/Black Father	0.11	1.56	NA	NA	0.11	1.42	NA	NA
Asian Mother/Hispanic Father	0.10	1.46	0.09	1.24	0.11	1.46	0.10	1.25
Asian Mother/Asian Father	0.13	1.79	0.08	1.14	0.15	1.95	0.16	2.00

Table A.7 Raw and adjusted prevalence, raw prevalence ratio and standardized morbidity ratio in 1989-1991 and 2011-2013, adjusted prevalence are based on white mother/white father combinations in 1989 to 1991

	1	2	3	4	5	6	7	8
Race-combination couples	**Raw prevalence in 1989 to 1991**	**Raw prevalence ratio in 1989 to 1991**	**Adjusted prevalence Using White Mother/White Father demographic characteristic distribution in 1989 to 1991**	**SMR in 1989 to 1991**	**Raw prevalence in 2011 to 2013**	**Raw prevalence ratio in 2011 to 2013**	**Adjusted prevalence Using White Mother/White Father demographic characteristic distribution in 1989 to 1991**	**SMR in 2011 to 2013**
White Mother/White Father	0.07	1.00	0.07	1.00	0.08	1.00	0.07	1.00
White Mother/Black Father	0.09	1.25	0.07	1.02	0.10	1.29	0.09	1.31
White Mother/Hispanic Father	0.08	1.21	0.07	1.01	0.09	1.19	0.09	1.26
White Mother/Asian Father	0.09	1.30	0.07	1.04	0.11	1.40	0.11	1.56
Black Mother/White Father	0.10	1.47	0.10	1.44	0.12	1.50	0.12	1.74
Black Mother/Black Father	0.12	1.77	0.08	1.13	0.14	1.85	0.08	1.19
Black Mother/Hispanic Father	0.12	1.75	0.12	1.73	0.14	1.82	0.13	1.88
Black Mother/Asian Father	0.13	1.93	NA	NA	0.15	1.90	NA	NA
Hispanic Mother/White Father	0.07	1.03	0.07	1.04	0.08	1.07	0.07	1.03
Hispanic Mother/Black Father	0.10	1.44	0.08	1.18	0.11	1.40	0.10	1.43
Hispanic Mother/Hispanic Father	0.09	1.26	0.07	1.04	0.10	1.24	0.08	1.06
Hispanic Mother/Asian Father	0.11	1.55	0.11	1.52	0.12	1.56	0.14	1.96
Asian Mother/White Father	0.08	1.10	0.07	1.03	0.09	1.18	0.10	1.37
Asian Mother/Black Father	0.10	1.49	0.10	1.43	0.11	1.42	0.11	1.59
Asian Mother/Hispanic Father	0.11	1.52	0.09	1.23	0.11	1.45	0.11	1.49
Asian Mother/Asian Father	0.12	1.78	0.08	1.14	0.15	1.93	0.09	1.28

APPENDIX B: SAS Programming Codes

```
/*aim 1*/
%include " E:\nchs\SAS program\SAS Programs\Seashore\format.txt"; run;
/*proc freq data=dis.y2012_1_2;*/
ods pdf file="D:\dissertation\freq.pdf";

proc freq data=dis.y2012_1_2_330;
tables  lbw*(racecom agecat2a nativity marital mateduc parity);
tables SGA*(racecom agecat2a nativity marital mateduc parity );
tables racecom*(agecat2a nativity marital mateduc parity);
run;
proc print data=freq1;
format count 10.;run;
ods pdf close;

ods pdf file="D:\dissertation\unadjustedfixadjusted.pdf";
%macro outcome(var);
/*proc logistic  data=dis.y2012_1_2;*/
proc logistic  data=dis.y2012_1_2_330;
class racecom(ref='1');
model &var(event='1') = racecom;
title 'unadjusted model';
run;
proc logistic  data=dis.y2012_1_2_330;
class racecom(ref='1')momstatefips(ref='1')birthyear(ref='2013');
model &var(event='1') = racecom birthyear momstatefips;
title 'fixed-effect model';
run;
proc logistic  data=dis.y2012_1_2_330;
class racecom(ref='1')agecat2a(ref="20-29") nativity(ref="native born") marital(ref='married') mateduc(ref='More
than college') parity(ref='nulliparous') momstatefips(ref='1')birthyear(ref='2013');
model &var(event='1') = racecom agecat2a nativity marital mateduc parity  birthyear momstatefips;
format agecat2a agecat2a. nativity nativity.
marital marital. mateduc mateduc. parity parity. ;
title 'adjusted model';
run;
%mend;
%outcome(vlbw);
%outcome(lbw);
%outcome(sga);
ods pdf close;

data z;
set dis.y2012_1_2_330;
if ptb=0;run;
 /*term babies, adjusted model*/
ods pdf file="D:\dissertation\adjustedorterm330.pdf";
%macro outcome(var);
proc logistic  data=z;
class racecom(ref='1')agecat2a(ref="20-29") nativity(ref="native born") marital(ref='married') mateduc(ref='More
than college') parity(ref='nulliparous') momstatefips(ref='1')birthyear(ref='2013');
model &var(event='1') = racecom agecat2a nativity marital mateduc parity  birthyear momstatefips;
format agecat2a agecat2a. nativity nativity.
marital marital. mateduc mateduc. parity parity. ;
title 'adjusted model, vlbw';
```

```
run;
%mend;
%outcome(vlbw);
%outcome(lbw);
%outcome(sga);

ods pdf close;

/*run the model testing within each mom, concordance pair Vs once with missing father*/

data a;
set dis.y2012_1_2_330;
if racecom>=1 and racecom<=5 ;
run;
data b;
set dis.y2012_1_2_330;
if racecom>=6 and racecom<=10 ;run;
data c;
set dis.y2012_1_2_330;
if racecom>=11 and racecom<=15 ;run;
data d;
set dis.y2012_1_2_330;
if racecom>=16 and racecom<=20 ;run;

/*ods pdf file="D:\dissertation\adjustedorseparate.pdf";*/
ods pdf file="D:\dissertation\adjustedorseparate.pdf";
%macro outcome(dsn,var);
proc logistic  data=&dsn;
class racecom(ref='1') agecat2a(ref="20-29") nativity(ref="native born") marital(ref='married') mateduc(ref='More
than college') parity(ref='nulliparous')momstatefips(ref='1')birthyear(ref='2013') ;
model &var(event='1') = racecom agecat2a nativity marital mateduc parity  birthyear momstatefips;
format agecat2a agecat2a. nativity nativity.
marital marital. mateduc mateduc. parity parity. ;
title 'adjusted model, vlbw';
run;
%mend;
%outcome(a,lbw);
%outcome(a,vlbw);
%outcome(a,sga);
%outcome(b,lbw);
%outcome(b,vlbw);
%outcome(b,sga);
%outcome(c,lbw);
%outcome(c,vlbw);
%outcome(c,sga);
%outcome(d,lbw);
%outcome(d,vlbw);
%outcome(d,sga);
ods pdf close;


data a;
set z;
if racecom>=1 and racecom<=5 ;
run;
```

```
data b;
set z;
if racecom>=6 and racecom<=10 ;run;
data c;
set z;
if racecom>=11 and racecom<=15 ;run;
data d;
set z;
if racecom>=16 and racecom<=20 ;run;

/*ods pdf file="D:\dissertation\adjustedorseparateterm.pdf";*/
ods pdf file="D:\dissertation\adjustedorseparateterm.pdf";
%macro outcome(dsn,var);
proc logistic  data=&dsn;
class racecom(ref='1') agecat2a(ref="20-29") nativity(ref="native born") marital(ref='married') mateduc(ref='More
than college') parity(ref='nulliparous')momstatefips(ref='1')birthyear(ref='2013') ;
model &var(event='1') = racecom agecat2a nativity marital mateduc parity  birthyear momstatefips;
format agecat2a agecat2a. nativity nativity.
marital marital. mateduc mateduc. parity parity. ;
title 'adjusted model, vlbw';
run;
%mend;
%outcome(a,lbw);
%outcome(a,vlbw);
%outcome(a,sga);
%outcome(b,lbw);
%outcome(b,vlbw);
%outcome(b,sga);
%outcome(c,lbw);
%outcome(c,vlbw);
%outcome(c,sga);
%outcome(d,lbw);
%outcome(d,vlbw);
%outcome(d,sga);
ods pdf close;


data q1989;
set dis.y2012_1_2_330;
if birthyear=1989;run;
data q2013;
set dis.y2012_1_2_330;
if birthyear=2013;run;
%MACRO DO_BRANCH;
%do i=1 %to 20;
data r&i;
set q1989;
if racecom=&i;
%end;
run;
%MEND DO_BRANCH;
%DO_BRANCH;

%MACRO DO_BRANCH;
%do i=1 %to 20;
```

```
data r&i;
set q2013;
if racecom=&i;
%end;
run;
%MEND DO_BRANCH;
%DO_BRANCH;
data a1;
set q1989;if racecom=1;run;
ods pdf file='C:\Users\Seashore\Downloads\dissertation\BA1989.pdf';
%macro get_coefficient;
%do i=1 %to 20;
proc logistic  data=r&i outest=est&i;
class momstatefips agecat2a(ref="2") nativity(ref="1") marital(ref='1') mateduc(ref='6') parity(ref='0') / param=ref;
model sga(event='1') =momstatefips agecat2a nativity marital mateduc parity / expb;
title 'estimate 2013';
%end;
run;
%mend get_coefficient;
%get_coefficient;

proc logistic  data=a1 inest=est19;
class momstatefips agecat2a(ref="2") nativity(ref="1") marital(ref='1') mateduc(ref='6') parity(ref='0') / param=ref;
model sga(event='1') =momstatefips agecat2a nativity marital mateduc parity / expb maxiter=1;
output out=mydata predicted=pa;
title 'estimate 2013';
run;
proc means data = mydata;
var pa;
run;
ods pdf close;
/*1989:8*/
data x;
set a1;
if momstatefips in (23,33,38,40,50,53,55) then delete;run;

proc logistic  data=x inest=est8;
class momstatefips agecat2a(ref="2") nativity(ref="1") marital(ref='1') mateduc(ref='6') parity(ref='0') / param=ref;
model sga(event='1') =momstatefips agecat2a nativity marital mateduc parity / expb maxiter=1;
output out=mydata predicted=pa;
title 'estimate 1989';
run;
proc means data = mydata;
var pa;
run;
/*1989:9*/
data x;
set a1;
if momstatefips in (10,16,23,30,31,38,40,46,49,50,53,54) then delete;run;

proc logistic  data=x inest=est9;
class momstatefips agecat2a(ref="2") nativity(ref="1") marital(ref='1') mateduc(ref='6') parity(ref='0') / param=ref;
model sga(event='1') =momstatefips agecat2a nativity marital mateduc parity / expb maxiter=1;
output out=mydata predicted=pa;
title 'estimate 1989';
run;
```

```
proc means data = mydata;
var pa;
run;
/*1989:12*/
data x;
set a1;
if momstatefips in (22,23,33,50,54) then delete;run;

proc logistic  data=x inest=est12;
class momstatefips agecat2a(ref="2") nativity(ref="1") marital(ref='1') mateduc(ref='6') parity(ref='0') / param=ref;
model sga(event='1') =momstatefips agecat2a nativity marital mateduc parity / expb maxiter=1;
output out=mydata predicted=pa;
title 'estimate 2013';
run;
proc means data = mydata;
var pa;
run;
/*1989:14*/
data x;
set a1;
if momstatefips in (1,10,22,23,33,38,40,46,50,53,54,55) then delete;run;

proc logistic  data=x inest=est14;
class momstatefips agecat2a(ref="2") nativity(ref="1") marital(ref='1') mateduc(ref='6') parity(ref='0') / param=ref;
model sga(event='1') =momstatefips agecat2a nativity marital mateduc parity / expb maxiter=1;
output out=mydata predicted=pa;
title 'estimate 1989';
run;
proc means data = mydata;
var pa;
run;
/*1989:17*/
data x;
set a1;
if momstatefips in (50,53,55) then delete;run;

proc logistic  data=x inest=est17;
class momstatefips agecat2a(ref="2") nativity(ref="1") marital(ref='1') mateduc(ref='6') parity(ref='0') / param=ref;
model sga(event='1') =momstatefips agecat2a nativity marital mateduc parity / expb maxiter=1;
output out=mydata predicted=pa;
title 'estimate 1989';
run;
proc means data = mydata;
var pa;
run;
/*1989:18*/
data x;
set a1;
if momstatefips in (10,22,23,30,33,40,47,50,54) then delete;run;

proc logistic  data=x inest=est18;
class momstatefips agecat2a(ref="2") nativity(ref="1") marital(ref='1') mateduc(ref='6') parity(ref='0') / param=ref;
model sga(event='1') =momstatefips agecat2a nativity marital mateduc parity / expb maxiter=1;
output out=mydata predicted=pa;
title 'estimate 1989';
run;
```

```
proc means data = mydata;
var pa;
run;
/*2013: 8*/
data x;
set a1;
if momstatefips in (0,9,15,23,44) then delete;run;

proc logistic  data=x inest=est8;
class momstatefips agecat2a(ref="2") nativity(ref="1") marital(ref='1') mateduc(ref='6') parity(ref='0') / param=ref;
model sga(event='1') =momstatefips agecat2a nativity marital mateduc parity / expb maxiter=1;
output out=mydata predicted=pa;
title 'estimate 2013';
run;
proc means data = mydata;
var pa;
run;
/*2013: 9*/
data x;
set a1;
if momstatefips in (4,5,9,15,16,44,50,53,54,55) then delete;run;

proc logistic  data=x inest=est9;
class momstatefips agecat2a(ref="2") nativity(ref="1") marital(ref='1') mateduc(ref='6') parity(ref='0') / param=ref;
model sga(event='1') =momstatefips agecat2a nativity marital mateduc parity / expb maxiter=1;
output out=mydata predicted=pa;
title 'estimate 2013';
run;
proc means data = mydata;
var pa;
run;
/*2013: 12*/
data x;
set a1;
if momstatefips in (22,23,33,50,54) then delete;run;

proc logistic  data=x inest=est12;
class momstatefips agecat2a(ref="2") nativity(ref="1") marital(ref='1') mateduc(ref='6') parity(ref='0') / param=ref;
model sga(event='1') =momstatefips agecat2a nativity marital mateduc parity / expb maxiter=1;
output out=mydata predicted=pa;
title 'estimate 2013';
run;
proc means data = mydata;
var pa;
run;
/*2013: 14*/
data x;
set a1;
if momstatefips in (4,5,23,44,50,54) then delete;run;

proc logistic  data=x inest=est14;
class momstatefips agecat2a(ref="2") nativity(ref="1") marital(ref='1') mateduc(ref='6') parity(ref='0') / param=ref;
model sga(event='1') =momstatefips agecat2a nativity marital mateduc parity / expb maxiter=1;
output out=mydata predicted=pa;
title 'estimate 2013';
run;
```

```
proc means data = mydata;
var pa;
run;
/*2013:17*/
data x;
set a1;
if momstatefips in (4,9,44,50) then delete;run;

proc logistic  data=x inest=est17;
class momstatefips agecat2a(ref="2") nativity(ref="1") marital(ref='1') mateduc(ref='6') parity(ref='0') / param=ref;
model sga(event='1') =momstatefips agecat2a nativity marital mateduc parity / expb maxiter=1;
output out=mydata predicted=pa;
title 'estimate 2013';
run;
proc means data = mydata;
var pa;
run;

/*2013:18*/
data x;
set a1;
if momstatefips in (4,23,44) then delete;run;

proc logistic  data=x inest=est18;
class momstatefips agecat2a(ref="2") nativity(ref="1") marital(ref='1') mateduc(ref='6') parity(ref='0') / param=ref;
model sga(event='1') =momstatefips agecat2a nativity marital mateduc parity / expb maxiter=1;
output out=mydata predicted=pa;
title 'estimate 2013';
run;
proc means data = mydata;
var pa;
run;
```

REFERENCES

REFERENCES

1. Passel JS, Wang W, Taylor P. One-in-Seven New US Marriages is Interracial or Interethnic. *Pew Soc. Demogr. Trends*. 2010;

2. Herman M. Forced to choose: Some determinants of racial identification in multiracial adolescents. *Child Dev.* 2004;730–748.

3. Hamilton BE, Martin JA, osterman MJ. Births: Final Data for 2014. *Natl. Vital Stat. Rep.* 2015;64(12).

4. Misra DP, Caldwell C, Young AA, et al. Do fathers matter? Paternal contributions to birth outcomes and racial disparities. *Am. J. Obstet. Gynecol.* 2010;202(2):99–100.

5. Ma S. Paternal race/ethnicity and birth outcomes. *Am. J. Public Health*. 2008;98(12):2285–2292.

6. Magnus P, Gjessing H, Skrondal A, et al. Paternal contribution to birth weight. *J. Epidemiol. Community Health*. 2001;55(12):873–877.

7. Nordentoft M, Lou HC, Hansen D, et al. Intrauterine growth retardation and premature delivery: the influence of maternal smoking and psychosocial factors. *Am. J. Public Health*. 1996;86(3):347–354.

8. Hack M, Klein NK, Taylor HG. Long-term developmental outcomes of low birth weight infants. *Future Child.* 1995;176–196.

9. Moster D, Lie RT, Markestad T. Long-term medical and social consequences of preterm birth. *N. Engl. J. Med.* 2008;359(3):262–273.

10. Sheeder J, Lezottte D, Stevens-Simon C. Maternal age and the size of white, black, Hispanic, and mixed infants. *J. Pediatr. Adolesc. Gynecol.* 2006;19(6):385–389.

11. Wang X, Guyer B, Paige DM. Differences in gestational age-specific birthweight among Chinese, Japanese and white Americans. *Int. J. Epidemiol.* 1994;23(1):119–128.

12. Regev RH, Lusky A, Dolfin T, et al. Excess mortality and morbidity among small-for-gestational-age premature infants: a population-based study. *J. Pediatr.* 2003;143(2):186–191.

13. Meas T, Deghmoun S, Armoogum P, et al. Consequences of being born small for gestational age on body composition: an 8-year follow-up study. *J. Clin. Endocrinol. Metab.* 2008;93(10):3804–3809.

14. Blumenshine P, Egerter S, Barclay CJ, et al. Socioeconomic disparities in adverse birth outcomes: a systematic review. *Am. J. Prev. Med.* 2010;39(3):263–272.

15. Dominguez TP. Race, racism, and racial disparities in adverse birth outcomes. *Clin. Obstet. Gynecol.* 2008;51(2):360–370.

16. Tan H, Wen SW, Walker M, et al. Parental race, birth weight, gestational age, and fetal growth among twin infants in the United States. *Early Hum. Dev.* 2004;80(2):153–160.

17. Menon R. Spontaneous preterm birth, a clinical dilemma: etiologic, pathophysiologic and genetic heterogeneities and racial disparity. *Acta Obstet. Gynecol. Scand.* 2008;87(6):590–600.

18. Anum EA, Springel EH, Shriver MD, et al. Genetic contributions to disparities in preterm birth. *Pediatr. Res.* 2009;65(1):1.

19. Plunkett J, Muglia LJ. Genetic contributions to preterm birth: implications from epidemiological and genetic association studies. *Ann. Med.* 2008;40(3):167–179.

20. Lu MC, Halfon N. Racial and ethnic disparities in birth outcomes: a life-course perspective. *Matern. Child Health J.* 2003;7(1):13–30.

21. Rosenthal L, Lobel M. Explaining racial disparities in adverse birth outcomes: Unique sources of stress for Black American women. *Soc. Sci. Med.* 2011;72(6):977–983.

22. Kramer MS, Morin I, Yang H, et al. Why are babies getting bigger? Temporal trends in fetal growth and its determinants. *J. Pediatr.* 2002;141(4):538–542.

23. Donahue SM, Kleinman KP, Gillman MW, et al. Trends in birth weight and gestational length among singleton term births in the United States: 1990–2005. *Obstet. Gynecol.* 2010;115(2 Pt 1):357.

24. Catov JM, Lee M, Roberts JM, et al. Race disparities and decreasing birth weight: are all babies getting smaller? *Am. J. Epidemiol.* 2015;183(1):15–23.

25. Ananth CV, Wen SW. Trends in fetal growth among singleton gestations in the United States and Canada, 1985 through 1998. In: *Seminars in perinatology*. Elsevier; 2002:260–267.

26. Ananth CV, Demissie K, Kramer MS, et al. Small-for-gestational-age births among black and white women: temporal trends in the United States. *Am. J. Public Health.* 2003;93(4):577–579.

27. Martin JA, (US) NC for HS, others. Births: final data for 2001. US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics; 2002.

28. Krieger N. Women and social class: a methodological study comparing individual, household, and census measures as predictors of black/white differences in reproductive history. *J. Epidemiol. Community Health*. 1991;45(1):35–42.

29. Oliver ML, Shapiro TM. Black wealth, white wealth: A new perspective on racial inequality. Taylor & Francis; 2006.

30. Braveman P. Black–White Disparities in Birth Outcomes: Is Racism-Related Stress a Missing Piece of the Puzzle? In: *Handbook of African American Health*. Springer; 2011:155–163.

31. Ventura SJ, Hamilton BE, Mathews T, et al. Trends and variations in smoking during pregnancy and low birth weight: evidence from the birth certificate, 1990–2000. *Pediatrics*. 2003;111(Supplement 1):1176–1180.

32. Palomar L, DeFranco EA, Lee KA, et al. Paternal race is a risk factor for preterm birth. *Am. J. Obstet. Gynecol.* 2007;197(2):152–e1.

33. Parker JD. Birth weight trends among interracial black and white infants. *Epidemiology*. 2000;11(3):242–248.

34. Passel JS, Wang W, Taylor P. One-in-Seven New US Marriages is Interracial or Interethnic. *Pew Soc. Demogr. Trends*. 2010;

35. Fryer RG. Guess who's been coming to dinner? Trends in interracial marriage over the 20th century. *J. Econ. Perspect.* 2007;21(2):71–90.

36. Bratter JL, Eschbach K. 'What about the couple?'Interracial marriage and psychological distress. *Soc. Sci. Res.* 2006;35(4):1025–1047.

37. Getahun D, Ananth CV, Selvam N, et al. Adverse perinatal outcomes among interracial couples in the United States. *Obstet. Gynecol.* 2005;106(1):81–88.

38. Nystrom MJ, Caughey AB, Lyell DJ, et al. Perinatal outcomes among Asian–white interracial couples. *Am. J. Obstet. Gynecol.* 2008;199(4):385–e1.

39. Gold KJ, DeMonner SM, Lantz PM, et al. Prematurity and low birth weight as potential mediators of higher stillbirth risk in mixed black/white race couples. *J. Womens Health*. 2010;19(4):767–773.

40. Palomar L, DeFranco EA, Lee KA, et al. Paternal race is a risk factor for preterm birth. *Am. J. Obstet. Gynecol.* 2007;197(2):152–e1.

41. Migone A, Emanuel I, Mueller B, et al. Gestational duration and birthweight in White, Black and mixed-race babies. *Paediatr. Perinat. Epidemiol.* 1991;5(4):378–391.

42. Collins Jr JW, David RJ. Race and birthweight in biracial infants. *Am. J. Public Health*. 1993;83(8):1125–1129.

43. Miozzo M, Simoni G. The role of imprinted genes in fetal growth. *Neonatology*. 2002;81(4):217–228.

44. Schwartz D, Mayaux M, Spira A, et al. Semen characteristics as a function of age in 833 fertile men. *Fertil. Steril.* 1983;39(4):530–535.

45. Crow JF. The origins, patterns and implications of human spontaneous mutation. *Nat. Rev. Genet.* 2000;1(1):40–47.

46. Oken E, Kleinman KP, Rich-Edwards J, et al. A nearly continuous measure of birth weight for gestational age using a United States national reference. *BMC Pediatr.* 2003;3(1):6.

47. Chen X-K, Wen SW, Krewski D, et al. Paternal age and adverse birth outcomes: teenager or 40+, who is at risk? *Hum. Reprod.* 2008;23(6):1290–1296.

48. Nicolaidis C, Ko CW, Saha S, et al. Racial discrepancies in the association between paternal vs. maternal educational level and risk of low birthweight in Washington State. *BMC Pregnancy Childbirth*. 2004;4(1):1.

49. Gorman BK. Racial and ethnic variation in low birthweight in the United States: individual and contextual determinants. *Health Place*. 1999;5(3):195–207.

50. Metcalfe A, Lail P, Ghali WA, et al. The association between neighbourhoods and adverse birth outcomes: A systematic review and meta-analysis of multi-level studies. *Paediatr. Perinat. Epidemiol.* 2011;25(3):236–245.

51. Parker JD. Birth weight trends among interracial black and white infants. *Epidemiology*. 2000;11(3):242–248.

52. Alio AP, Mbah AK, Kornosky JL, et al. Assessing the impact of paternal involvement on racial/ethnic disparities in infant mortality rates. *J. Community Health*. 2011;36(1):63–68.

53. Stutzer A, Frey BS. Does marriage make people happy, or do happy people get married? *J. Socio-Econ.* 2006;35(2):326–347.

54. Borrell LN, Rodriguez-Alvarez E, Savitz DA, et al. Parental Race/Ethnicity and Adverse Birth Outcomes in New York City: 2000–2010. *Am. J. Public Health*. 2016;106(8):1491–1497.

55. Tan H, Wen SW, Walker M, et al. Missing paternal demographics: A novel indicator for identifying high risk population of adverse pregnancy outcomes. *BMC Pregnancy Childbirth*. 2004;4(1):1.

56. Alexander GR, Kogan M, Bader D, et al. US birth weight/gestational age-specific neonatal mortality: 1995–1997 rates for whites, Hispanics, and blacks. *Pediatrics*. 2003;111(1):e61–e66.

57. Oken E, Kleinman KP, Rich-Edwards J, et al. A nearly continuous measure of birth weight for gestational age using a United States national reference. *BMC Pediatr.* 2003;3(1):6.

58. Gyamfi-Bannerman C, Ananth CV. Trends in spontaneous and indicated preterm delivery among singleton gestations in the United States, 2005–2012. *Obstet. Gynecol.* 2014;124(6):1069–1074.

59. Hamilton BE, Martin JA, Ventura SJ, et al. Births: preliminary data for 2006. *Natl. Vital Stat. Rep.* 2007;56(7):1–18.

60. Hutcheon JA, Platt RW. The missing data problem in birth weight percentiles and thresholds for “small-for-gestational-age.” *Am. J. Epidemiol.* 2008;167(7):786–792.

61. Dietz PM, England LJ, Callaghan WM, et al. A comparison of LMP-based and ultrasound-based estimates of gestational age using linked California livebirth and prenatal screening records. *Paediatr. Perinat. Epidemiol.* 2007;21(s2):62–71.

62. VanderWeele TJ, Lantos JD, Lauderdale DS. Rising preterm birth rates, 1989–2004: changing demographics or changing obstetric practice? *Soc. Sci. Med.* 2012;74(2):196–201.

63. Oliver ML, Shapiro TM. Black wealth, white wealth: A new perspective on racial inequality. Taylor & Francis; 2006.

64. Giurgescu C, McFarlin BL, Lomax J, et al. Racial Discrimination and the Black-White Gap in Adverse Birth Outcomes: A Review. *J. Midwifery Women’s Health*. 2011;56(4):362–370.

65. Wen SW, Kramer MS, Usher RH. Comparison of birth weight distributions between Chinese and Caucasian infants. *Am. J. Epidemiol.* 1995;141(12):1177–1187.

66. Singh GK, Yu SM. Birthweight differentials among Asian Americans. *Am. J. Public Health*. 1994;84(9):1444–1449.

67. Kierans WJ, Joseph K, Luo Z-C, et al. Does one size fit all? The case for ethnic-specific standards of fetal growth. *BMC Pregnancy Childbirth*. 2008;8(1):1.

68. Ma S. Paternal race/ethnicity and birth outcomes. *Am. J. Public Health*. 2008;98(12):2285.

69. Magnus P, Gjessing H, Skrondal A, et al. Paternal contribution to birth weight. *J. Epidemiol. Community Health*. 2001;55(12):873–877.

70. Misra DP, Caldwell C, Young AA, et al. Do fathers matter? Paternal contributions to birth outcomes and racial disparities. *Am. J. Obstet. Gynecol.* 2010;202(2):99–100.

71. Martin LT, McNamara MJ, Milot AS, et al. The effects of father involvement during pregnancy on receipt of prenatal care and maternal smoking. *Matern. Child Health J.* 2007;11(6):595–602.

72. Doctor BA, O’riordan MA, Kirchner HL, et al. Perinatal correlates and neonatal outcomes of small for gestational age infants born at term gestation. *Am. J. Obstet. Gynecol.* 2001;185(3):652–659.

73. Jolly M, Sebire N, Harris J, et al. The risks associated with pregnancy in women aged 35 years or older. *Hum. Reprod.* 2000;15(11):2433–2437.

74. Lynch CD, Zhang J. The research implications of the selection of a gestational age estimation method. *Paediatr. Perinat. Epidemiol.* 2007;21(s2):86–96.

75. Borrell LN, Rodriguez-Alvarez E, Savitz DA, et al. Parental Race/Ethnicity and Adverse Birth Outcomes in New York City: 2000–2010. *Am. J. Public Health*. 2016;106(8):1491–1497.

76. Jiménez TR. Replenished ethnicity: Mexican Americans, immigration, and identity. Univ of California Press; 2010.