Paternal Race/Ethnicity and Birth Outcomes

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Objectives. I sought to identify whether there were associations between paternal race/ethnicity and birth outcomes among infants with parents of same- and mixed-races/ethnicities.

Methods. Using the National Center for Health Statistics 2001 linked birth and infant death file, I compared birth outcomes of infants of White mothers and fathers of different races/ethnicities by matching and weighting racial/ethnic groups following a propensity scoring approach so other characteristics were distributed identically. I applied the same analysis to infants of Black parents and infants with a Black mother and White father.

Results. Variation in risk factors and outcomes was found in infants of White mothers by paternal race/ethnicity. After propensity score weighting, the disparities in outcomes by paternal or parental race/ethnicity could be largely attributed to nonracial parental characteristics. Infants whose paternal race/ethnicity was unreported on their birth certificates had the worst outcomes.

Conclusions. The use of maternal race/ethnicity to refer to infant race/ethnicity in research is problematic. The effects of maternal race/ethnicity on birth outcomes are estimated to be much larger than that of paternal race/ethnicity after I controlled for all covariates. Not listing a father on the birth certificate had a strong association with outcomes, which might be a source of bias in existing data and a marker for identifying infants at risk. (*Am J Public Health.* 2008;98:2285–2292. doi:10.2105/AJPH.2007.117127)

Despite great improvement in birth outcomes in the United States, significant and continuing differences persist across racial and ethnic groups. The low-birthweight (LBW; defined as a birthweight less than 2500 g) rate of non-Hispanic Black infants has been steadily nearly double that of non-Hispanic White infants.[1,2] Therefore, Black mothers are usually the focus of birth-outcome disparity research and policy, whereas White mothers are regarded to be at a lower risk. These disparities are believed to result from complex interactions among genetic variations, social and environmental factors, and specific health behaviors.[3–5]

Most previous research, when referring to an infant's race/ethnicity, used maternal race/ethnicity instead of infant race/ethnicity both because the child's race may not be clear in the case of mixed race and because the mother's race/ethnicity is thought to have more influence on birthweight than the father's race/ethnicity.[6] Furthermore, the father's information is often not available in the data sets of choice.

This common practice might be a serious analytic shortcoming because it overlooks the father's race/ethnicity and it treats infants of mixed-race parents and those of same-race parents equally. Furthermore, even when the father's race/ethnicity is available and included as an indicator variable, most models don't allow coefficients of covariates to differentiate between groups, which implicitly assumes no other difference between parents of mixed- and same-race/ethnicity except for their race/ethnicity.

Many studies have shown different patterns in socioeconomic characteristics between intermarriage and endogamous marriage in the United States. On the basis of 1990 US census data, Fu found that Black or Mexican American husbands' White wives had less schooling than did the White wives of White husbands.[7] Fu explained this pattern by using both the status exchange and in-group preference hypotheses. Status exchange hypothesizes that in a marriage market framework, minority men marry less-desired White women (e.g., of lower education) in exchange for higher social status. The second hypothesis, in-group preference, simply suggests that people prefer members from their own group, and thus, intermarriage is the less desirable scenario.

According to the National Center for Health Statistics (NCHS) natality files, between 1968 and 1996, the proportion of infants born to 1 Black and 1 White parent increased gradually from 0.33% to 1.77%, and the proportion of infants born to 1 Asian/Pacific Islander parent and 1 White parent also increased substantially, from 0.25% to 1.21%.[8] These mixed-race infants provide a unique chance to investigate associations between both maternal and paternal race/ethnicity and infant outcomes. To date, only a few studies have examined birth outcomes of interracial infants, and all of these studies focused on Black and White mixed-race infants. Together they found that mixed-race couples differed significantly with respect to their sociodemographic characteristics from the endogamous couples. After control for those variables, biracial infants were found to have worse birth outcomes than infants with 2 White parents but better than infants with 2 Black parents.[6,8–12] (Henceforth, infant's race/ethnicity will be referred to by the notation "maternal race/ethnicity–paternal race/ethnicity" [e.g., White–Black].)

However, these studies have several limitations. First, they didn't examine groups other than Black and White race. Second, paternal information is often missing from natality data, especially for infants of Black mothers. Although these infants are more likely to have adverse birth outcomes,[10–13] they are often omitted from studies. Third, none of these studies examined Apgar score (a routine evaluation of the general physical condition of the newborn usually performed at 1 and 5 minutes after delivery) as a birth outcome, although it has been repeatedly found to have strong predictive power for infant mortality.[14,15] In terms of method, previous studies used multivariate regressions or logistic models with a categorical variable of race combinations. A potential concern regarding this approach is that it assumes covariates have the same effects (coefficients) on outcomes of interest across all racial combinations.

I investigated differences in birth outcomes (i.e., birthweight, LBW rate, 5-minute

Apgar score, and infant mortality) for infants born to non-Hispanic White mothers and non-Hispanic Black fathers (henceforth, White and Black refer to non-Hispanic White and non-Hispanic Black) and those born to White mothers and fathers of 6 other selected racial/ethnic groups. I hypothesized that paternal race/ethnicity might affect birth outcome, but this influence would be smaller than that of maternal race/ethnicity because mothers play a more important role than fathers in the course of pregnancy and delivery.

TABLE 1—Mean Birthweights, by Selected Maternal and Paternal Race/Ethnicity: National Center for Health Statistics Linked Birth and Infant Death File, 2001

	Maternal Race/Ethnicity					
	Non-Hispanic Black (n = 590 105)		Non-Hispanic White (n = 2 327 114)		Mexican (n = 615 683)	
Paternal Race/Ethnicity	Mean Birthweight, g (Range)	% Births	Mean Birthweight, g (Range)	% Births	Mean Birthweight, g (Range)	% Births
Non-Hispanic Black	3131 (3129–3133)	59.5	3323 (3318–3329)	2.1	3310 (3296–3324)	1.3
Non-Hispanic White	3216 (3205–3227)	2.2	3378 (3376–3378)	84.1	3376 (3371–3382)	6.6
Mexican	3181 (3157–3205)	0.4	3330 (3326–3335)	2.3	3338 (3337–3340)	75.6
Puerto Rican	3154 (3131–3177)	0.5	3308 (3296–3319)	0.4	3311 (3288–3334)	0.4
Central/South American[a]	3198 (3167–3230)	0.3	3345 (3332–3357)	0.4	3336 (3326–3345)	2.3
Cuban	3165 (3076–3254)	0.0	3354 (3326–3382)	0.1	3326 (3284–3369)	0.1
East Asian[b]	3202 (3080–3325)	0.0	3319 (3299–3336)	0.2	3319 (3273–3364)	0.1
Asian Indian	3123 (3028–3218)	0.0	3287 (3254–3320)	0.1	3362 (3275–3448)	0.0
American Indian	3233 (3181–3285)	0.1	3341 (3330–3352)	0.5	3322 (3294–3350)	0.3
Missing	3040 (3037–3043)	36.2	3227 (3224–3229)	8.6	3249 (3245–3253)	12.5

Note. Percentages do not add to 100% because the total number includes other racial/ethnic groups not presented here as subgroups.

[a]Central or South American may include a couple of ethnicities depending on the definition of ethnicity. However, on October 30, 1997, the Office of Management and Budget published *Standards for Maintaining, Collecting, and Presenting Federal Data on Race and Ethnicity*,[16] which allows federal agencies to collect information that reflects the increasing diversity of our nation's population stemming from growth in interracial marriages and immigration. With respect to ethnicity, the Hispanic or Latino category is defined as, "A person of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin, regardless of race."[16] This subcategory of South or Central American has since been widely used in data collection and publications.

[b]Includes Chinese, Korean, and Japanese (Southeast Asian was excluded from the study because of extremely small numbers).

METHODS

Data

The NCHS 2001 birth cohort data consists of all live births and all deaths from 2001 linked to the corresponding birth certificates. This data set has rich information on birth outcomes (e.g., birthweight, 5-minute Apgar score) and parents' demographic and socioeconomic background (e.g., race/ethnicity, maternal education).

The analyzed data set was reduced in several ways. I excluded non-White mothers and twins from the main analysis. The original sample size (i.e., the birth cohort of 2001) was 4 025 933 live births, among which 128 717 (3%) were twins or plural births. (Table 1 provides an overview of infants of mixed-race and same-race parents and offers some sense of why I chose to focus on White mothers only: both Black mothers and Mexican mothers have a high rate of male partners unreported on the birth certificate.) California data were excluded from these analyses because maternal tobacco and alcohol use during pregnancy are important behavioral risk factors that were included as variables in this study but these were not reported on California birth certificates. Because I focused on both maternal and paternal influence on birth outcomes and there is a high proportion of unreported fathers for Black and Mexican mothers, the primary analysis was of the singleton live births to White mothers. Comparisons with White and Black mothers and their partners are briefly discussed at the end of the "Results" section. Seven paternal race/ethnicity categories were selected, each comprising at least 0.15% of the subpopulation of White mothers. After restricting the data according to these criteria, 2 054 542 births in 2001 were available for analysis.

Measures

Independent variables that were considered to be potential risk factors for birth outcomes based on previous studies included parental characteristics and behaviors and children's characteristics. Previous research has shown nonlinear effects of parental age on infant outcomes[17]; therefore, both maternal and paternal age were included and categorized into 3 groups: less than 20 years, 20 to 34 years, and more than 34 years. Maternal educational attainment has been shown to have a profound effect on number of births and risk of adverse birth outcomes[13]; therefore, it was categorized into 3 groups: less than high school (≤9 years of formal education), high school (10–12 years), and some college or beyond (>12 years).

Because income data are not available in vital statistics records, maternal education was used as a proxy for socioeconomic status, as is common in studies that use data from vital statistics records.[15,18] Infants born to unmarried mothers have been found to have a higher LBW rate[10]; therefore, maternal marital status was included in the analysis. Adequacy of prenatal care was coded according to standard methods to include the month prenatal care began, number of prenatal visits, and gestation period.[19]

Children's characteristics, including gestational age, gender, live birth order (first, second, third, and above), were included because female infants on average are smaller than male infants and previous research[20] has shown that first-born children have a higher risk of LBW. Mother's nativity was included because previous studies have found that infants of US-born mothers are at higher risk of death.[21] Maternal smoking and drinking behaviors during pregnancy have repeatedly been linked to adverse birth outcomes. Outcomes of interest included birthweight, LBW rate, 5-minute Apgar score, and 1-year infant mortality.

Propensity Score

I used propensity score analysis to adjust confounding factors across groups. Demographers have long discussed how to decompose the mean difference in the outcome variable between groups into the portion attributable to differences in the distribution of confounding variables and differences in the key explanatory variable of interest,[22] and propensity scoring is one available nonparametric method to achieve this goal. A propensity score is a model-based predicted probability of an individual's membership in the reference group, given his or her covariates (i.e., characteristics). Rosenbaum and Rubin[23] demonstrated that the propensity score captures all of the variance in the covariates necessary for adjusting between-group comparisons to match 2 different groups on the basis of this single variable (the propensity score).

I estimated the propensity scores using a nonparametric regression technique that minimizes imbalance in covariate distributions between groups,[24] then used the estimated propensity score to weight each individual infant in the comparison group (e.g., White–White) to match the reference group (White–Black). In this approach, an individual more similar to those in the reference group receives a higher propensity score and, thus, higher weight. This method creates a hypothetical group of study participants who are similar to the members in the reference group in terms of all characteristics other than actual group membership (i.e., maternal and paternal race/ethnicity). The benefit of using propensity score weighting is that after weighting the empirical distribution of all other factors (e.g., parental biofeatures, socioeconomic characteristics) should be nearly identical across groups. Therefore, the only observed attributes that differ between the 2 groups, by design, should be race/ethnicity and birth outcomes of interest.

For example, by weighting the White–White group, I could examine the birth outcomes of infants born to 2 White parents as though they had exactly the same demographic and socioeconomic characteristics as those born to a White mother and a Black father. All covariates had similar distributions in both groups as a result of the propensity score weighting, so any remaining difference in birth outcomes between groups (i.e., White–White and White–Black), should be attributable to paternal race/ethnicity, assuming most important risk factors were captured.

In this analysis, infants born to White mothers and Black fathers were the reference group because Blacks have long been the focus of birth-outcome disparity research, and all other racial combinations were comparison groups that were individually weighted to match the reference group. For instance, infants born to a White mother and a White father were one of the comparison groups. White–White infants who had background covariates similar to those of White–Black infants received higher propensity scores and weights. Conversely, White–White infants who had characteristics very dissimilar to those of White–Black infants received lower propensity scores and weights. Other comparison groups included White–Mexican, White–American Indian, White–Puerto Rican, White–Central/South American, and White–unreported.

RESULTS

Table 1 presents a summary of average birthweights in a set of biracial births, according to selected combinations of parental race/ethnicity. Infants born to Black mothers had the lowest mean birthweight in each paternal race/ethnicity group, significantly lower than those of infants born to White or Mexican mothers. The unreported paternal race group showed a large disparity between infants of Black mothers, 36.2% of whom had unreported paternal race, and White or Mexican mothers, 8.6% and 12.5% of whom had missing data, respectively. For each maternal race/ethnicity, missing paternal race/ethnicity occurred with the lowest mean birthweight among all paternal groups. Therefore, not considering this group or only using mother's race to predict birth outcomes would yield a biased estimate of the likelihood of birth outcomes in each maternal racial/ethnic group.

Table 2 presents a summary of parental and children's characteristics obtained from birth certificates as part of NCHS. These characteristics varied significantly between paternal groups, and the maternal characteristics for the group of unreported paternal race were the most adverse among all groups. White mothers in this group also had the riskiest behaviors during pregnancy: 39% used tobacco and 2% used alcohol during pregnancy, much more than any other group.

Infants in the White–White group tended to have older parents. Their parents also had higher percentages of college education (61%), marital rates (86%), and proportions receiving adequate prenatal care (81%). This group also had a low prevalence of tobacco and alcohol use during pregnancy.

Infants in the White–Black and White–American Indian groups had several adverse maternal characteristics such as a lower percentage of college education and a higher rate of tobacco use. Maternal characteristics for White–American Indian infants included higher cigarette and alcohol consumption compared with other groups.

Among White–Mexican and White–Puerto Rican infants, maternal characteristics were similar in parental characteristics except for tobacco and alcohol use. Mothers of White–Puerto Rican infants had higher prevalence maternal tobacco (21%) and alcohol (1.3%) use during pregnancy compared with those of White–Mexican infants (16% and 0.8%, respectively). White–Central/South American infants' mothers had more-favorable maternal characteristics than did those with other Hispanic paternal groups. Thus, the White female partners of Mexican, Puerto Rican, and Central/South American men were different in many ways, which probably reflects differences within Hispanic male partners of different origins. (I speculated that the fact that White female partners of Hispanic men of different origins were different was, in part, because they were influenced by their male partners, taking smoking as an example. In other words, the differences among White women probably reflected the differences among their partners. This was not a primary focus of my study, although it supports the argument that Hispanics of different origins are different in many ways, and therefore, in research, they should not be just labeled as Hispanic and be grouped together.)

Consistent with Table 1, infants in the White–unreported group had the worst birth outcomes in each category. Infants in the White–Black group, although they possessed

TABLE 2—Unweighted Parental and Infant Characteristics and Birth Outcomes for Births to White Women, by Paternal Race/Ethnicity: National Center for Health Statistics Linked Birth and Infant Death File, 2001

	Black (Ref)	White	Mexican	American Indian	Puerto Rican	Central/South American[a]	Unreported
Total, No.	42 839	1 759 706	37 961	9 990	9 281	7 048	187 717
Maternal characteristics							
Married, %	44.5	85.6*	66.9*	66.7*	53.9*	74.5*	7.3*
Maternal age, y, %							
<20 y	13.9	6.1*	17.1*	14.0	14.1	9.4*	28.5*
20–34 y	78.0	77.9	74.6*	76.8*	76.0*	75.5*	65.0*
>34 y	8.2	16.0*	8.4	9.2*	9.9*	15.1*	6.5*
Maternal education, y, %							
≤9 y	5.3	3.1*	8.3*	5.6	5.4	5.0*	11.4*
10–12 y	55.3	35.5*	53.7*	53.2*	53.3*	37.9*	65.5*
>12 y	39.4	61.4*	38.0*	41.1*	41.3*	57.1*	23.1*
US born, %	95.6	94.6*	95.2*	97.7*	94.9*	88.7*	97.4*
No. of prenatal care visits, mean	11.6	12.0*	11.6	11.5*	11.3*	11.6	10.7*
Adequacy of care,[b] %							
Adequate	71.9	81.3*	72.9*	71.9	70.6*	74.7*	61.2*
Intermediate	19.1	13.3*	18.8	20.1*	19.9*	17.6*	24.7*
Inadequate	4.8	2.4*	4.3*	4.5	4.6	3.8*	9.6*
Tobacco use, %	23.1	13.1*	15.8*	24.7*	20.5*	9.6*	38.7*
Alcohol use, %	0.9	0.8	0.8	1.2*	1.3*	0.9	2.0*
Paternal characteristic							
Paternal age, y, %							
<20 y	5.5	2.5*	6.8*	6.1*	7.0*	3.3*	. . .
20–34 y	72.6	70.0*	76.8*	74.7*	72.6	71.0*	. . .
>34 y	21.9	27.5*	16.4*	19.3*	20.4*	25.7*	. . .
Infant characteristics							
Gestational age, weeks, mean	38.9	38.9	38.9	38.9	39.0*	38.9	38.8*
Male, %	50.7	51.3*	51.0	50.8	51.9*	51.3	50.9
Live-birth order, %							
First live birth	40.0	40.1	39.1	39.3	45.2*	44.9*	53.0*
Second live birth	32.2	35.0	32.4	32.3	32.0	33.7	24.7*
Third live birth or beyond	27.8	25.0	28.5	28.4	22.8*	21.4*	22.3*
Infant outcome, mean							
Birthweight, g	3343	3413*	3336	3362*	3331*	3373*	3251*
LBW rate (per 100)	6.26	4.64*	5.65*	5.59*	5.68*	5.35*	8.39*
5-minute Apgar score	8.92	8.94*	8.92	8.93	8.94*	8.93	8.88*
Infant mortality (per 1000)	7.07	4.29*	4.90*	6.01	4.20*	5.25*	10.23*

Note. LBW = low birthweight. California data were excluded. The reference group was infants born to White mothers and Black fathers. Ellipses indicate that data are not applicable.
[a]Central or South American may include a couple of ethnicities depending on the definition of ethnicity. However, on October 30, 1997, the Office of Management and Budget published *Standards for Maintaining, Collecting, and Presenting Federal Data on Race and Ethnicity*,[16] which allows federal agencies to collect information that reflects the increasing diversity of our nation's population stemming from growth in interracial marriages and immigration. With respect to ethnicity, the Hispanic or Latino category is defined as, "A person of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin, regardless of race."[16] This subcategory of South or Central American has since been widely used in data collection and publications.
[b]Adequacy of prenatal care was coded according to standard methods to include the month prenatal care began, number of prenatal visits, and gestation period.
*$P < .01$ (2-tailed t test).

slightly higher average birthweight than did infants in the White–Mexican and White–Puerto Rican groups, had higher rates of both LBW and infant mortality than any other group except White–unreported. The differences between infants in the White–White and White–Black groups can be seen in the mean birthweight gap of 70 g, the LBW rate gap of 1.62%, the infant mortality rate gap of 2.78 per thousand, and the 5-minute Apgar score difference of 0.024 (Table 2).

Table 3 presents the percentages for covariates of each weighted comparison group. The joint distribution of covariates of each comparison group is identical to the joint distribution of the reference group's covariates. Each comparison group's covariates were no longer significantly different from those of the reference group. For instance, each racial/ethnic group's "married" marital status rate was around 45%, 14% of mothers were aged younger than 20 years, and 39% had some college education or more. This suggests that the differences in birth outcomes between these hypothetical outcomes of non–White–Black infants' and White–Black infants' outcomes can be attributed to the effect of being in the White–Black group.

Table 3 also presents infant outcomes for the White–Black group and weighted outcomes for the comparison groups. When every comparison group's covariates were distributed in the same manner as the White–Black group, the average birthweight decreased and both LBW rate (except in the White–American Indian group) and infant mortality rate increased in every comparison group except for the White–unknown group, whose mortality rate decreased. The differences in outcomes between infants in the White–Black group and other groups except for the White–unknown group were no longer significant; for example, the difference between infants in the White–Black group and the weighted White–White group was only 7 g in birthweight and 0.19% in LBW rate. When the White–unknown group was matched with the White–Black group by covariates, the average birthweight increased by 65 g, from 3250 g to 3316 g, the LBW rate decreased from 8.39% to 6.85%, the infant mortality rate declined from 10.23 to 7.81 per 1000, and the 5-minute

TABLE 3—Weighted Parental and Infant Characteristics and Birth Outcomes for Births to White Women, by Paternal Race/Ethnicity: National Center for Health Statistics Linked Birth and Infant Death File, 2001

	Black (Ref)	White	Mexican	American Indian	Puerto Rican	Central/South American[a]	Unreported
Effective sample size,[b] No.	42 839	662 700	28 249	8 088	8 769	4 506	42 719
Maternal characteristics							
Married, %	44.5	44.4	45.2	46.2	45.9	47.4	44.2
Maternal age, y, %							
< 20 y	13.9	13.9	14.4	15.3	14.0	14.8	14.1
20–34 y	78.0	77.6	77.2	76.2	77.0	76.2	77.7
> 34 y	8.2	8.6	8.4	8.5	9.0	9.0	8.2
Maternal education, y, %							
≤ 9 y	5.3	5.4	5.7	6.0	5.8	5.9	5.8
10–12 y	55.3	55.0	55.8	56.0	55.6	53.2	56.1
> 12 y	39.4	39.6	38.5	38.0	38.7	40.9	38.1
US born, %	95.6	95.6	95.5	96.4	95.4	95.2	95.4
No. of prenatal care visits, mean	11.6	11.2	11.2	11.2	11.2	11.2	11.2
Adequacy of care,[c] %							
Adequate	71.9	72.2	72.0	71.3	71.4	71.9	71.6
Intermediate	19.1	19.0	19.5	20.0	19.3	19.2	23.4
Inadequate	4.8	4.8	4.8	4.7	4.6	4.8	5.1
Tobacco use, %	23.1	22.9	22.6	24.6	22.6	20.1	20.3
Alcohol use, %	0.9	0.9	0.9	1.1	1.1	1.1	1.0
Paternal characteristic							
Paternal age, y, %							
< 20 y	5.5	5.6	6.0	6.3	6.0	5.7	. . .
20–34 y	72.6	72.7	73.4	73.3	73.4	74.1	. . .
> 34 y	21.9	21.7	20.6	20.4	20.6	20.2	. . .
Infant characteristics							
Gestational age, weeks, mean	38.9	38.8	38.8	38.8	38.9	38.9	38.8
Male, %	50.7	51.3	51.1	50.6	51.6	51.7	51.0
Live-birth order, %							
First live birth	40.0	40.6	40.4	41.7	42.1	42.9	40.0
Second live birth	32.2	32.0	31.5	31.3	31.2	31.5	31.8
Third live birth or beyond	27.8	27.5	28.1	27.0	26.7	25.6	28.2
Infant outcome, mean							
Birthweight, g	3343	3351	3319	3359	3323	3343	3316*
LBW rate (per 100)	6.26	6.07	6.10	5.46	5.88	6.09	6.85*
5-minute Apgar score	8.92	8.93	8.91	8.93	8.94	8.93	8.90
Infant mortality (per 1000)	7.07	6.44	5.41	6.12	4.33	6.25	7.81

Note. LBW = low birthweight. California data were excluded. For each infant in each comparison group (e.g., White mother–White father) propensity scores were estimated with a nonparametric regression technique and then were weighted based on the estimated propensity score to match the reference group (i.e., White–Black). In this approach, an individual more similar to those in the reference group receives a higher propensity score and, thus, higher weight. The propensity score estimation and weighting process were performed for each comparison group independently. Ellipses indicate that data are not applicable.
[a]Central or South American may include a couple of ethnicities depending on the definition of ethnicity. However, on October 30, 1997, the Office of Management and Budget published *Standards for Maintaining, Collecting, and Presenting Federal Data on Race and Ethnicity*,[16] which allows federal agencies to collect information that reflects the increasing diversity of our nation's population stemming from growth in interracial marriages and immigration. With respect to ethnicity, the "Hispanic or Latino" category is defined as, "A person of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin, regardless of race."[16] This subcategory of South or Central American has since been widely used in data collection and publications.
[b]The effective sample size is approximately the number of observations from a simple random sample needed to obtain an estimate with sampling variation equal to the sampling variation obtained with the weighted comparison observations. Therefore, the effective sample size gives an estimate of the number of comparison participants that are comparable to the target group.
[c]Adequacy of prenatal care was coded according to standard methods to include the month prenatal care began, number of prenatal visits, and gestation period.
*$P < .01$ (2-tailed t test).

Apgar score increased from 8.88 to 8.90, but birth outcomes of infants in the weighted White–unknown group were still worse than other groups. The differences in birthweight and LBW rate remained statistically significant.

In summary, most comparison groups' birth-outcome advantages shrank when their covariates were "matched down" against those of the White–Black group, and the White–unknown group's disadvantaged birth outcomes were improved when White–unknown's covariates were "matched up" against those of the White–Black group. These results showed that the disparities in outcomes across groups were largely explained by matched covariates, and the remaining difference that could be attributed to paternal race/ethnicity was small, suggesting that paternal race/ethnicity per se plays a very small role in birth outcomes.

Finally, just to provide a rough sense of the difference between maternal and paternal race/ethnicity influence on birth outcomes, Black–Black infants as a reference group were compared with Black–White and White–Black infants, where the former comparison assessed the paternal effect given Black mothers and the latter comparison estimated the maternal effect given Black fathers. Table 4 shows that the estimated maternal effect was more than 3 times as large as the paternal effect in terms of birthweight, LBW rate, and 5-minute Apgar scores and almost that large for infant mortality rate. However, because of the high rate of unreported fathers for Black mothers, this is a rough assessment and not meant to be conclusive.

DISCUSSION

Maternal Race and Infant Race

In general, I found substantial variation in birth outcomes within the group of infants with White mothers and fathers of different racial/ethnic groups. This is interesting because it shows that the common practice of using maternal race/ethnicity to refer to the infant's race/ethnicity, regardless of father's race/ethnicity, can be problematic. For example, it is not uncommon for a study to refer to infants of White mothers as "White infants," even though "White infants" may imply that the fathers are White. In this

TABLE 4—Comparison of Birth Outcomes, by Parental Race/Ethnicity and Infant Group: National Center for Health Statistics Linked Birth and Infant Death File, 2001

	Black-White Infant Group (n = 9 950)	White-Black Infant Group (n = 40 913)
Birthweight	61.15*	191.20*
LBW rate (per 100)	−2.07*	−7.24*
5-minute Apgar score	0.008	0.051*
1-year mortality (per 1000)	−1.85	−5.21*

Note. LBW = low birthweight. California data were excluded. The Black-Black infant group was the reference group. The value in each cell presents the standardized coefficient of comparison between Black-Black and Black-White infant groups, and between Black-Black and White-Black infant groups, after I controlled for maternal, paternal, and infant characteristics, but covariates are not reported in the table. Infants born to Black mothers and Black fathers (n = 300 731) formed the reference category, after we controlled for the same covariates.
*$P < .01$ (2-tailed t test).

study, I demonstrated that infants of a White mother and a White father, the real "White infants," have the better birth outcomes than do those infants of a White mother and a non-White father. Therefore, the practice of using "White mother" to refer to White infants will yield lower estimation of the birth outcomes because there are infants of non-White fathers in the sample.

The infants in the White–White group had the most-advantaged birth outcomes, followed by infants in the 3 Hispanic-father groups. Infants in the White–Black group had the second-most-disadvantaged birth outcomes; the differences in birth outcomes between White–Black and White–White infants were statistically significant: White–White infants had a 2% (70 g) higher average birthweight, 26% lower LBW rate (4.64% vs 6.26%), and 39% lower infant mortality rate (0.43% vs 0.71%) than did White–Black infants. Infants in the White–unknown group had the most-disadvantaged outcomes in each category. These heterogeneities within White mothers show that the common practice of using maternal race/ethnicity to refer to the race/ethnicity of the infant is problematic: White–White infants had the best birth outcomes among the groups studied, so any other paternal race/ethnicity pulls down the averages for all White mothers. That is, the birth outcomes of White–White infants are actually underestimated by researchers who use mothers' race/ethnicity to refer to infants' race/ethnicity, and thus, the racial/ethnic disparities between White and any other race/ethnicity may be underestimated accordingly as well.

The use of maternal race to refer to infant's race in research has already been recognized as a potential source of problems. In 1997, to reflect "the increasing diversity of our Nation's population that has resulted primarily from growth in immigration and in interracial marriages,"[16] the Federal Office of Management and Budget revised the standards for how the federal government would collect and present data on race/ethnicity. For example, Census 2000 included as many as 63 possible combinations of race.[25] Despite this effort, the use of maternal race/ethnicity to refer to a child's race/ethnicity is quite common in most research and many data-collection efforts, such as the National Center for Health Statistics and research that uses data from the National Center for Health Statistics, because "[the National Vital Statistics System] is based on data collected by the states, [and it] will not be fully compliant with the new standards until all of the States revise their birth certificates to reflect the new standards."[26(p4)] This approach, as discussed previously, may yield underestimation; therefore, before the 1997 Office of Management and Budget standards are widely implemented and accepted, researchers need to be clear and cautious when using maternal race/ethnicity to refer to child's race/ethnicity.

Paternal Racial Effect

I also observed that White women with White partners were different in many ways from those with non-White partners. On the whole, the White–White group had the most advantaged parental and children's characteristics, whereas the White–Black and White–unknown groups had the most disadvantaged parental characteristics. These patterns are consistent with previous studies of intermarriage in United States, such as Fu's 2001 study.[7] Because we did not have socioeconomic characteristic information of fathers in the data, we could not test the status-exchange hypothesis (i.e., we don't know whether White male partners of White women were socioeconomically better off than non-White partners of White women), but this data analysis is consistent with the in-group preference hypothesis. The observed difference implies that, for providers and researchers, knowing male partners may help identify potential risks.

When I compared infants in the weighted groups to those in the White–Black group, only very small differences in outcomes remained across groups that may be attributed to paternal race/ethnicity or omitted variables such as income. These results showed that the disparities in birth outcomes among subgroups of White mothers can largely be attributed to nonracial parental characteristics. The small paternal racial effect on birth outcomes found here is a result, in large part, of the fact that mothers play a more important role than do fathers in the course of pregnancy, and therefore, mother's race and ethnicity has more influence on infant outcomes, as Table 4 shows.

As discussed previously, the White–unknown group is a category of its own. With the most-disadvantaged covariates, we unsurprisingly found that this group's outcomes were the worst. Even after we applied the propensity-score weighting to match the White–unknown group to the White–Black group, which improved all the covariates of the weighted White–unknown group to the same level of the White–Black group, the outcomes of White–unknown infants still remained significantly worse than those of other groups. Clearly, the unreported father is a proxy for more-noteworthy factors, because if unreported fathers were merely missing from certificates, their infants' outcomes should not be so much worse.

Further research is needed to investigate the reasons why the father's information is missing. In particular, we want to distinguish fathers just missing on birth certificates for some reason from those completely missing from the child's life. For example, 7% of mothers were married in the group of unreported fathers, and those fathers are probably not entirely missing from the child's life.

This result confirms findings by Gould et al., who argued that incomplete birth certificates provide an important marker for identifying high-risk women and vulnerable infants. They also pointed out that data "cleaning" in analysis might result in the removal of those mothers and infants at risk.[27] In this study, I found that unreported fathers were perhaps the most vital marker for the identification of infants at risk.

Although the exact pathways of how unreported fathers would affect infant health at birth are not definite, a possibility is that infants in this group are unintended, or even unwanted, births and they are likely to receive less care than intended infants, both during pregnancy and after birth. In this study, female partners of unreported fathers were disproportionately young (29% were younger than 20 years), received less-adequate prenatal care, and had a strikingly high smoking rate (39%), which indicates the mothers may not have been prepared to get pregnant. The 1995 National Survey of Family Growth found that up to 31% of all births had not been intended, including 22% mistimed and 9% unwanted births.[28] Unintendedness itself poses an added and independent risk factor to both women and infants and often precludes people from participating in preconception risk identification.[29,30]

Implications for Public Health

The results of this study have multidimensional implications for public health. First, counter to the common conception that White mothers are at lower risk for poor infant health, I found that there were great variations within the White mother group, especially in education and behaviors. This implies that prenatal interventions need to pay more attention to the disadvantaged mothers within all racial/ethnic groups, even when the particular race/ethnicity is normally not considered at risk. As Hogue and Vasquez argued, it is time for health policymakers to prioritize integration of the concerns of all pregnant women, not just those of minorities.[31]

Secondly, the father deserves more attention from researchers. Not only can the father's characteristics help to identify potential risks, but his behaviors also may affect the mother's behaviors. For example, some previous research has shown that, regardless of marital status, a woman's substance use during pregnancy is highly correlated with both her partner's substance use and the degree of emotional supports he provided.[32] Unfortunately, no information on male partners' behaviors in the data set means that such an analysis is beyond the scope of this study.

Finally, further research is needed to investigate why so many fathers are unreported and how unreported fathers may affect birth outcomes. Identifying the reasons that fathers are missing on the birth certificate is the first step. In parallel with further research efforts, policies and programs need to be carefully designed to address how to improve outcomes of unintended pregnancy. ■

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Human Participant Protection

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