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Who and how does prenatal care help: "normal" or "compromised" births

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ABSTRACT

Covariate Density Defined mixture of logistic regressions (CDDmlr) is applied to examine the effects of prenatal care of infant mortality in a heterogeneous birth cohort. The data used are the 2001 US non-Hispanic European and African American cohorts by sex with prenatal care utilization defined by the Kessner Index. The size of the "compromised" subpopulation significantly increases by 1.6%-2.5% and 2.4%-5.1% and the mean birth weight of "normal" births significantly decreases by 45-70 and 104-129 grams for intermediate and inadequate care, respectively, compared to adequate care. Prenatal care affects the mortality of "normal" infants directly, indicated by a significant log odds ratio (0.47-1.27) with less care independent of birth weight. Its net effect on the mortality of the "compromised" subpopulation is generally insignificant. Overall, the "direct" effect dominates the observed changes of infant morality by prenatal care. Our results also suggest racial disparities in the benefits of prenatal care.

INTRODUCTION

Many studies have shown that prenatal care is a significant and positive correlate of a better pregnancy outcome, particularly reducing low birth weight and premature births (Gortmaker 1979; Wise, First et al. 1988; Malloy 1992; Lin 2004; Cai, Hoff et al. 2007). Consequently one of the objectives of the current US health policy is to increase the proportion of women who receive adequate prenatal care throughout the pregnancy to improve birth weight and, ultimately, reduce mortality as well as other neurological and developmental problems (US DOHHS 2000). On the other hand, some researchers have found weak, if any, or even conflicting effects of improved prenatal care utilization on infant birth weight, though infant mortality has decreased (Alexander and Korenbrot 1995; Kaestner 1999; Alexander and Kotelchuck 2001; Lu, Tache et al. 2003). These findings, along with the theoretical view that birth weight is not the casue of infant mortality (Mosely and Chen 1984; Wise, First et al. 1988; Wilcox 2001; Haig 2003; Basso, Wilcox et al. 2006), have raised the urgency of re-examining the relationship between prenatal care utilization and infant mortality.

Wilcox and Russell propose a mechanism on how a stressor can affect the birth outcome (i.e. birth weight and mortality) of "normal" infants (Figures 1) (Wilcox and Russell 1983; Wilcox and Russell 1983; Wilcox and Russell 1990; Wilcox 2001; Wilcox 2002). In brief, they argue that birth weight is not on the causal pathway to mortality. So the reverse-J-shaped birth weight specific mortality curve will first shift horizontally to match the shift in the birth weight distribution by a stressor (Figure 1a and 1b), which should not affect the overall death rate. In addition, they argue that the stressor can

have a "direct" effect on mortality, that is, it can move the whole mortality curve vertically (Figure 1b) and thus change the overall mortality. However, if birth weight is somehow causal to mortality, we should observe an "indirect" effect, represented by a discordant horizontal shift of the birth weight specific mortality curve with respect to the shift of the birth weight distribution (Figure 1c). The limitations of the Wilcox-Russell mechanism stem from its simplicity (Gage, Fang et al. In press). However, it can be statistically tested with proper modeling techniques.

Figure 1 about here

Conway and Deb (2005) suggest that the seemingly heterogeneity of birth cohort may contribute to the lack of observed prenatal care effect on infant health. Therefore, the aim of this research is: a) to develop a fully-parametric model that incorporates and extends the Wilcox-Russell definition of causality (Wilcox and Russell 1983; Wilcox and Russell 1983; Wilcox and Russell 1990; Wilcox 2001; Wilcox 2002) while controlling for heterogeneity within the birth cohort, and b) to determine whether prenatal care utilization influences mortality "directly" (i.e. independent of birth weight), or "indirectly" through its influence on birth weight, or both, in each latent subpopulation identified. The analyses are conducted on 2001 US national non-Hispanic European and African American births by sex with prenatal care utilization defined by the Kessner Index.

METHODS

Source of Data

The data for this analysis are obtained from the 2001 US national linked birth-death files. Race and ethnic origin are based on mother's reported race and ethnic origin. Approximately 6.4% and 8.7% of the non-Hispanic European and African American births are excluded from this analysis due to missing information or gestational age <20 weeks or birth weight <500 grams. Summary statistics for the samples used are presented in Table 1.

Table 1 about here

Statistical Model - CDDmlr

The model employed here is an extension of Gage's two-subpopulation birth weight only CDDmlr model of infant mortality, which decomposes the birth weight distribution into two subpopulations by using standard mixtures of Gaussian distributions and simultaneously fits a separate birth weight specific mortality curve to each latent subpopulation (Gage, Bauer et al. 2004; Gage, Bauer et al. 2004).

First, an indicator variable z, which represents the decreased prenatal care utilization (i.e. $z = 1$ for intermediate or inadequate versus $z = 0$ for adequate), is introduced to all five variables of the birth weight density submodel $f_1(x \mid z;\theta)$, that is,

$$f_1(x \mid z;\theta) = f_1(x \mid z;\pi_s,\mu_s(z),\sigma_s^2(z),\mu_p(z),\sigma_p^2(z))$$

$$= \pi_s(z) \times N_{500}(x;\mu_s(z),\sigma_s^2(z)) + (1-\pi_s(z)) \times N_{500}(x;\mu_p(z),\sigma_p^2(z)) \quad \text{(Eq. 1)}$$

$$\pi_s(z) = \text{logit}(\eta_{s0} + z \times \eta_{s1}) \quad \text{(Eq. 2)}$$

$$\mu_i(z) = \mu_{i0} + z \times \mu_{i1} \quad \text{(Eq. 3)}$$

$$\sigma_i(z) = \sigma_{i0} + z \times \sigma_{i1} \quad \text{(Eq. 4)}$$

π_s is the proportion of births belonging to the secondary (s) subpopulation, the minority subpopulation. The majority subpopulation is referred to as the primary (p) subpopulation. For $i = p$ and s, N_{500} represents a Gaussian density, truncated at 500 grams, with the respective mean and variance.

Second, z is introduced to all six variables of the mortality submodel, that is,

$$f_2(y = 1 \mid x, z; \beta_p, \beta_s, \theta)$$

$$= (1 - q_s(x \mid z, \theta)) \times P_p(x_p^* \mid z, \beta_p^*) + q_s(x \mid z, \theta) \times P_s(x_s^* \mid z, \beta_s^*) \quad \text{(Eq. 5)}$$

$$P_i(x^* \mid z, \beta_i) = P_i(x^* \mid z, a_i, b_i, c_i) = \frac{exp(a_i(z) + b_i(z) \cdot x^* + c_i(z) \cdot x^{*}\text{^}2)}{1 + exp(a_i(z) + b_i(z) \cdot x^* + c_i(z) \cdot x^{*}\text{^}2)} \quad \text{(Eq. 6)}$$

$$a_i(z) = a_{i0} + z \times a_{i1} \quad \text{(Eq. 7)}$$

$$b_i(z) = b_{i0} + z \times b_{i1} \quad \text{(Eq. 8)}$$

$$c_i(z) = c_{i0} + z \times c_{i1} \quad \text{(Eq. 9)}$$

For $i = p$ and s, x_i^* is the standardized x using the respective mean and standard deviation of the subpopulation, P_i is the probability of death for an infant with birth weight (x or x_i^*) in subpopulation i given by a quadratic logistic form to allow reverse-J-shaped (standardized) birth weight specific mortality in each subpopulation, and q_s is the conditional probability of that infant belonging to subpopulation s. The birth weight density submodel $f_1(x \mid z; \theta)$ (Eq. 1) determines that

$$q_s(x \mid z; \theta) = \frac{\pi_s(z) \times N_{500}(x; \mu_s(z), \sigma_s^2(z))}{f_1(x \mid z; \theta)} \quad \text{(Eq. 10)}$$

Overall, there are 22 parameters for our model

$$f(y,x \mid z;\theta,\beta) = f_2(y \mid x,z;\theta,\beta) f_1(x \mid z;\theta) \quad \text{(Eq. 11)}$$

with 10 for the birth weight density submodel and 12 for the mortality submodel.

A significant change in the mixing proportion, the mean, or the variance of any subpopulation indicates a prenatal care effect on the birth weight distribution. A significant vertical move of the mortality curve (i.e. the change of the minimal mortality value) shows a "direct" effect of prenatal care utilization. A horizontal shift (i.e. a change of the optimal standardized birth weight) and/or a change in the shape of the standardized birth weight specific mortality curve (i.e. c_{i1}, which is not considered in the Wilcox-Russell hypothesis (Wilcox and Russell 1983; Wilcox and Russell 1983; Wilcox and Russell 1990; Wilcox 2001; Wilcox 2002)), indicates an "indirect" effect of prenatal care that operates through birth weight, suggesting a potential causal role of birth weight on infant mortality. In addition, the change in the mixing proportion may affect the overall observed infant mortality. This is a third pathway that prenatal care utilization affects the mortality, which is also not considered in the Wilcox-Russell hypothesis (Wilcox and Russell 1983; Wilcox and Russell 1983; Wilcox and Russell 1990; Wilcox 2001; Wilcox 2002). Despite a technical difference in identifying the latent components (Gage, Fang et al. In press), our CDDmlr approach provides a reasonable statistical examination of the Wilcox-Russell hypothesis for "normal" births (Wilcox and Russell 1983; Wilcox and Russell 1983; Wilcox and Russell 1990; Wilcox 2001; Wilcox 2002) as well as "compromised" births.

Model Fitting

The model (Eq. 11) is fitted using the method of maximum likelihood to individual level data using ms() in the SPLUS statistical library. Confidence intervals are estimated from 200 bootstrap samples. Each bootstrap sample is composed of 150,000 births with adequate parental care randomly generated from the entire birth cohort (as opposed to the more conventional procedure of re-sampling with replacement from the original sample) and births with either intermediate or inadequate prenatal care re-sampled from the original data with replacement. The bias-adjusted 95% confidence intervals of each parameter are estimated by using the first 100 bootstraps to estimate the bias and the remaining 100 bootstraps to estimate the 95% confidence intervals (Staude and Sheather 1990).

RESULTS

Across 12 births cohorts of interest (i.e. African and European Americans by sex and by three levels of prenatal care utilization), the primary subpopulation (i.e. 86-95% of the cohort) consistently has a higher mean birth weight (i.e. 3088-3524 grams) and a smaller standard deviation (i.e. 449-495 grams) compared to the secondary component (i.e. 1964-2769 grams for mean and 1048-1406 grams for standard deviation, respectively) (Figure 2). As a consequence of the larger variance, the secondary distribution accounts for most births in both the lower and upper tails of the birth weight distribution. Therefore, the primary and the secondary subpopulations are interpreted as births undergoing "normal" and "compromised" fetal development, respectively (Paneth 1995; Gage and Therriault 1998).

Figure 2 about here

Prenatal care utilization has substantial effects on birth weight distribution (Table 2, Figure 2). Across race and sex, with the decrease of prenatal care, the proportion of secondary births increases significantly by 1.6%-2.5% and 2.4%-5.1% for intermediate and inadequate cares as compared to adequate care, respectively. For "normal" births, the mean birth weight is significantly lower by 45-70 and 104-129 grams and the variance generally widens, if they receive intermediate and inadequate prenatal care. However, the effect of less prenatal care on "compromised" births seems to vary by race. Secondary European American births tend to have lower mean birth weights with less care, particularly for mothers with inadequate prenatal care (i.e. a significant decrease by 407 and 154 grams for females and males, respectively). However, secondary African American subpopulations with less care seem to have higher birth weights compared to those with adequate care, particularly for mothers with intermediate prenatal care (i.e. a significant increase of 256 and 302 grams for females and males, respectively). In addition, less prenatal care is associated with a significant reduction in the variance of "compromised" African American births of both genders by more than 160 grams, but the variances of "compromised" African American subpopulations are relatively constant.

Table 2 about here

There are significant prenatal care effects on infant mortality, especially for "normal" births. The subpopulation specific and total mortality cures are presented in Figure 3, while the overall mortality summed across all birth weights are in Table 3. For

primary births, compared to infants born to mothers with adequate prenatal care, infants born to mothers with less care (i.e. intermediate or inadequate care) generally have significantly higher minimal mortality at the respective optimal birth weight except in the case of primary European American males, while the optimal birth weight tends to remain constant. Therefore, integrated across birth weights, the death rate of the primary increases significantly with the decreasing of prenatal care utilization regardless of race and gender. In particular, for intermediate and inadequate care, the mortality increases by 0.9-1.7 and 3.0-5.0 deaths per 1000 births, respectively. As for "compromised" births, except for European Americans of both sexes with inadequate prenatal care, the effect of decreased prenatal care utilization on mortality is not significant. Combining the primary and secondary births, the overall death rate is significantly higher with less prenatal care in seven out of eight comparisons. In particular, compared to infants born to mothers with adequate prenatal care, whose overall mortality ranges from 2.95-8.25 deaths per 1000 births, infants born to mothers receiving intermediate or inadequate prenatal care have overall mortality ranging from 4.64-9.36 or 8.03-15.78 deaths per 1000 births, respectively.

Figure 3 about here

Table 3 about here

The statistical decomposition of the "direct" and the "indirect" effects of prenatal care utilization is presented in Figure 4 and Table 4. In all target birth cohorts, there is a significant direct effect of prenatal care among primary births, indicating a higher mortality across all birth weights with decreased prenatal care. And inadequate care

increases the log odds by approximately two times over intermediate care does. The "indirect" effect of prenatal care is insignificant in seven cases except for European American females born to mothers receiving inadequate care. Note that this result is only marginally significant and the log odd ratio is negative, indicating a potentially protective "indirect" effect. Therefore, the significant higher mortality with less prenatal care in the primary subpopulation is predominately accounted for by the "direct" effect. For "compromised" births, decreases in prenatal care also tend to elevate mortality directly, though this effect is significant only in three African American cases (i.e. African American Females with intermediate or inadequate prenatal care and African American males with intermediate care). The "indirect" effect of prenatal care is significant only in these three African American cases as well, and the negative value of log odds ratio suggests that somehow birth weight plays a protective role when African American mothers with "compromised" birth use intermediate and inadequate prenatal care. The general net result of adding the "direct" and "indirect" effects suggests a lack of significant response on infant mortality with respect to prenatal care utilization in "compromised" birth. Summed across both subpopulations, total log odds ratio, and thus infant mortality, increases significantly with low prenatal care utilization. This change is mainly accounted for by the "direct" effect in the "normal" subpopulation.

Figure 4 about here

Table 4 about here

Finally, the impact of prenatal care utilization on the mixing proportion (i.e. a cohort "composition" effect) influences the total infant mortality, particularly in African

American cohorts. Holding π constant suggests that the effect of the mixing proportion increases the total mortality by 1.5%-4.1% for European Americans and 6.1%-14.6% for African Americans. Compared to the direct effect of prenatal care, this "composition" effect is fairly small.

DISCUSSION

The Kessner Index has been widely accepted as a quantitative measurement of prenatal care utilization to assess the effects of prenatal care on birth outcomes. However, any studies using this index system (including this one) suffer from its inherent limitations due to the lack of information on the content or clinical adequacy of prenatal care and its strong association with gestational age (Kotelchuck 1994; Alexander and Kotelchuck 1996; Alexander and Kotelchuck 2001; Heaman, Newburn-Cook et al. 2008). In particular, this system can not differentiate women with an expected number of prenatal care visits due to a normal pregnancy from women with frequent prenatal care visits due to a higher risk of adverse birth outcomes (e.g. low birth weight or macrosomic). And women who enter prenatal care early might do so because of signs of a potentially troubled pregnancy, and hence they may have more adverse outcomes than those do not. As a consequence, the Kessner Index tends to overestimate the number of women receiving adequate prenatal care and consequently may even mask the true effect of prenatal care. Therefore, it is important to develop a better measurement of prenatal care utilization that defines different recommended visit patterns with respect to various risks of pregnancy outcomes, and use the new

index to reassess the impact of prenatal care. However, in our CDDmlr approach, births with adverse outcomes (e.g. low or high birth weight) are more likely to belonging to the "compromised" subpopulation. Consequently, assessing prenatal care's effects on pregnancy outcomes for "normal" births should be relatively free of error caused by the Kessner Index.

Another limitation of this analysis lies in the reverse-J shape of the (standardized) birth weight specific mortality curve. It is possible that this shape reflects a causal role of birth weight. On the other hand, it may be a result of confounding among three Gaussian subpopulations each with a constant mortality across all birth weights (Basso, Wilcox et al. 2006), or it simply mirrors the reverse-J-shaped gestational age specific mortality curve, which gestation is causally responsible for, because of its strong dependence on gestational age. The latter two hypotheses can be tested by using the CDDmlr approach, but is beyond the scope of the present analysis.

Our results show that the onset of prenatal care does improve both birth weight and infant mortality. However, it mainly helps pregnancies undergoing "normal" fetal growth by a "direct" effect (i.e. lowering the birth weight specific mortality curve with better prenatal care), while its beneficial effects for "compromised" births who have a significantly higher mortality is limited. Nevertheless, there is a trend towards better survival of "compromised" pregnancies if they receive better prenatal care, indicated by a decrease in secondary mortality (Table 3) and a positive secondary log odd ratio combining the "direct" and "indirect" effects of prenatal care utilization (Table 4) across all races and genders. The lack of significant response in "compromised" births may be

a reflection of the imitations of the Kessner Index mentioned earlier, which the secondary subpopulation is more likely to be subject to. Nevertheless, the overall effect of prenatal care on the infant mortality of "normal" births is much larger that its effect on the infant mortality of "compromised" birth. To some extent, this is counterintuitive to the underlying initiative of the current US public health policy (i.e. the impact of prenatal care and infant mortality is restricted to low birth weights (Behrman 1985; US DOHHS 2000), that mostly belong to the secondary in our model).

In general, our results support the Wilcox-Russell hypothesis that birth weight is not on the causal pathway to infant mortality in "normal" births (Wilcox and Russell 1983; Wilcox and Russell 1983; Wilcox and Russell 1990; Wilcox 2001; Wilcox 2002). For "normal" births, the (standardized) birth weight specific mortality appears to move horizontally compensating for the horizontal shift in the birth weight distribution associated with prenatal care utilization. The change in mortality is solely attributed by the direct effect of prenatal care. For "compromised" births, it is less conclusive because of three significant "indirect" effects in the African American births. Additional data will be needed to test whether this is simply Type I error due to relatively small sample size. Since, in these cases, the significant "direct" effect seems to offset the "indirect" effect and, ultimately, maintain a relatively constant mortality, while in the other five cases there is neither a "direct" nor an "indirect" effect.

This analysis also shows some significant racial differences regarding the impacts of prenatal care utilization on the secondary birth outcomes. "Compromised" African Americans of both sexes always have a higher infant mortality than their European

Amecian peers at all three prenatal care levels. But the racial disparity on mortality is the largest (i.e. 14.9 and 28.8 deaths per 1000 births for females and males, respectively) when both African and European Americans receive adequate care, while the difference between African and European Americans with intermediate and inadequate prenatal care is 3.0 and 18.7 deaths per 1000 births for females, and 0.70 and 12.2 deaths per 1000 births for males. This indicates that the benefits of prenatal care may be different between races, in particular "compromised" African Americans of both sex have a smaller improvement on mortality with better prenatal care compared to their European American counterparts. This is may be due to varying/increasing maternal, socioeconomic, demographic, cultural, medical and biological risks of infant death between secondary African and European Americans, while the racial disparity in using prenatal care has been declining (Alexander, Kogan et al. 2002). As to "normal" births, their racial disparity on infant mortality is relatively constant (ranging form 1.3 to 3.1 across sex and prenatal care), suggesting similar improvement in birth outcomes between races. Overall, our finding implies that the conventional strategy of increasing access to prenatal care for African American women doesn't seem to be effective in eliminating racial difference in infant mortality (Rowley 1995), and surprisingly, it might even further increase the racial disparity on birth outcomes. To reduce and eliminate race disparity in infant mortality, an ethnic-specific health policy may need to be developed and adopted.

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Figure Captions

Figure 1. Characteristic changes in mortality with respect to changes in birth weight based on the Wilcox-Russell "causality" theory (Wilcox and Russell 1983; Wilcox and Russell 1983; Wilcox and Russell 1990; Wilcox 2001; Wilcox 2002): (A) no "indirect" effect, shift in birth weight (bold lines, solid to dashed) and corresponding shift in the birth weight-specific mortality curve (thin lines, solid to dashed), no overall change in infant mortality, (B) no "indirect" effect plus a "direct" effect, shift in birth weight (bold lines, solid to dashed) and corresponding shift in the birth weight-specific mortality curve (thin lines, solid to dashed), no overall change in infant mortality resulting from the shift in birth weight but the "direct" effect increases mortality at all birth weights and overall, and (C) "indirect" effect but no "direct" effect, shift in birth weight (bold lines, solid to dashed) not identical to the shift in the birth weight-specific mortality curve (thin lines, solid to dashed), infant mortally changes due to the shift in birth weight. Only panel (C) suggests that birth weight is on the "causal" pathway. See Wilcox's website (Wilcox 2002) for additional details.

Figure 2. Model-estimated birth weight density by prenatal care utilization: European American males.

Figure 3. Model-estimated (standardized) birth weight specific mortality by prenatal care utilization: African American females. The bold lines represent the estimates and the thin lines represent the respective bias-adjusted 95% confidence intervals of the estimates. The observed mortalities are calculated based on binned data (bin size = 500 grams)

Figure 4. Model-estimated birth weight specific log odds ratio (log OR) for "direct", "indirect", and total (i.e. the sum of "direct" and "indirect") effects of decreased prenatal care utilization on infant mortality: European American females with "intermediate" vs. "adequate" prenatal care. The bold lines represent the estimates and the thin lines represent the respective bias-adjusted 95% confidence intervals of the estimates. A positive value of log OR indicates an increased infant death rate due to a decrease in prenatal care utilization (i.e. "intermediate") as compared to "adequate" prenatal care.

Table 1 Descriptive statistics for the sample populations

Prenatal Care (Kessner Index)	Adequate	Intermediate	Inadequate	Adequate	Intermediate	Inadequate
	Non-His. Eur. Am. F.			Non-His. Eur. Am. M.		
# Observation	814,598	148,809	31,714	854,640	158,159	33,722
# Deaths	2,404	690	255	3,251	952	365
Crude death rate (death/1000)	3.0	4.6	8.0	3.8	6.0	10.8
Mean Birth Weight (gram)	3360	3287	3210	3482	3398	3320
	Non-His. Af. Am. F.			Non-His. Af. Am. M.		
# Observation	159,733	60,051	23,099	163,956	62,910	23,912
# Deaths	1,009	429	260	1,354	589	378
Crude death rate (death/1000)	6.3	7.1	11.3	8.3	9.4	15.8
Mean Birth Weight (gram)	3120	3075	2986	3231	3183	3084

Non-His = non-Hispanic; Eur. = European; Af. = African; Mex. = Mexican; Am. = American; F. = females; M. = males

Table 2 Changes in parameter estimates of the birth weight density submodel due to decreased prenatal care utilization

	Intermediate vs. Adequate				Inadequate vs. Adequate				Intermediate vs. Adequate				Inadequate vs. Adequate			
	Est.	LCI	UCI		Est.	LCI	UCI		Est.	LCI	UCI		Est.	LCI	UCI	
	Non-His. Eur. Am. F.								Non-His. Eur. Am. M.							
π_s (%)	2.3	1.4	3.3	#	2.4	1.3	3.8	#	2.5	1.6	3.6	#	4.8	3.6	6.2	#
μ_s (g)	-20	-113	79		-407	-620	-265	#	-17	-89	56		-154	-254	-28	#
σ_s (g)	-48	-90	3		48	-10	140		-56	-94	-3	#	30	-39	88	
μ_p (g)	-61	-65	-56	#	-119	-125	-113	#	-70	-74	-65	#	-129	-135	-119	#
σ_p (g)	10	5	14	#	33	25	42	#	12	7	16	#	25	17	33	#
	Non-His. Af. Am. F.								Non-His. Af. Am. M.							
π_s (%)	1.6	0.7	2.7	#	5.1	3.9	6.3	#	1.7	0.8	2.7	#	4.3	3.2	5.3	#
μ_s (g)	256	86	428	#	172	-6	342		302	156	496	#	62	-133	211	
σ_s (g)	-166	-243	-92	#	-222	-281	-136	#	-204	-265	-133	#	-162	-226	-73	#
μ_p (g)	-45	-50	-40	#	-104	-110	-98	#	-46	-53	-39	#	-113	-120	-107	#
σ_p (g)	-5	-12	0		-6	-14	1		-4	-11	2		7	1	16	#

Non-His = non-Hispanic; Eur. = European; Af. = African; Am. = American; F. = females; M. = males

#: significantly different from 0 based on bias-adjusted 95% confidence intervals

Table 3 Mortality characteristics with respect to prenatal care utilization

Prenatal Care (Kessner Index)	Adequate	Intermediate	Inadequate	Adequate	Intermediate	Inadequate
	Non-His. Eur. Am. F.			Non-His. Eur. Am. M.		
Primary Subpopulation						
OSBW	1.00	1.03	0.66	1.08	1.58	2.56
OBW (g)	3844	3808	3595	4034	4215	4664
Mortality & at OSBW	0.86	1.70 #	3.05 #	1.25	1.90	2.72
Death Rate &	2.0	2.9 #	5.4 #	2.5	4.2 #	6.1 #
percent of total DR (%)	65.1	58.7	61.5	62.4	63.8	50.5
Secondary Subpopulation						
OSBW	0.98	1.55	1.05	1.38	1.04	1.88
OBW (g)	3800	4330	3513	4292	3842	4743
Mortality & at OSBW	0.56	1.55	1.86	0.53	1.54	1.67
Death Rate &	18.8	24.8	39.1 #	23.5	25.3	49.3 #
percent of total DR (%)	34.9	41.3	38.5	37.6	36.2	49.5
Total Population						
Death Rate &	2.95	4.64 #	8.03 #	3.80	6.02 #	10.82 #
	Non-His. Af. Am. F.			Non-His. Af. Am. M.		
Primary Subpopulation						
OSBW	0.75	0.81	0.80	0.76	0.88	0.71
OBW (g)	3535	3512	3449	3672	3677	3540
Mortality & at OSBW	1.83	2.91 #	3.87 #	2.28	3.30 #	5.13 #
Death Rate &	3.8	4.9 #	6.8 #	4.2	5.5 #	9.2 #
percent of total DR (%)	55.3	61.3	52.2	47.2	52.9	50.9

Secondary Subpopulation						
OSBW	1.47	1.09	1.53	1.47	1.07	1.41
OBW (g)	3996	3546	3900	4036	3551	3777
Mortality & at OSBW	0.05	0.62	0.38	0.16	1.92	0.60
Death Rate &	33.7	27.8	39.8	52.3	44.0	61.5
percent of total DR (%)	44.7	38.6	47.8	52.7	47.0	49.0
Total Population						
Death Rate &	6.30	7.14	11.25 #	8.25	9.36 #	15.78 #

Non-His = non-Hispanic; Eur. = European; Af. = African; Am. = American; F. = females; M. = males

OSBW: optimal standardized birth weight, at which minimal mortality occurs

OBW = optimal birth weight, at which minimal mortality occurs

&: death per 1000 births

#: significantly different from adequate care based on bias-adjusted 95% confidence intervals

Table 4 Decomposition of "direct" and "indirect" effects (expressed as log odd ratio of infant mortality, summed across all birth weights) due to decreased prenatal care utilization

	Non-His. Eur. Am. F.		Non-His. Eur. Am. M.		Non-His. Af. Am. F.		Non-His. Af. Am. M.	
	Intermediate vs. Adequate	Inadequate vs. Adequate	Intermediate vs. Adequate	Inadequate vs. Adequate	Intermediate vs. Adequate	Inadequate vs. Adequate	Intermediate vs. Adequate	Inadequate vs. Adequate
Primary Subpopulation								
Direct	0.68 #	1.27 #	0.42 #	0.78	0.47 #	0.75 #	0.37 #	0.82 #
Indirect	-0.12	-0.15 #	0.11	0.22	-0.08	-0.06	-0.04	-0.02
Sum	0.56 #	1.12 #	0.53 #	0.99 #	0.38 #	0.69 #	0.33 #	0.80 #
Secondary Subpopulation								
Direct	1.02	1.20	1.07	1.16	2.57 #	2.08 #	2.48 #	1.31
Indirect	0.02	0.30	-0.50	0.33	-1.98 #	-1.36 #	-2.05 #	-0.83
Sum	1.03	1.50	0.57	1.48 #	0.60	0.73	0.43	0.48
Total Population								
Direct	0.70 #	1.26 #	0.46 #	0.80 #	0.64 #	0.86 #	0.55 #	0.86 #
Indirect	-0.12	-0.12	0.07	0.22	-0.24 #	-0.17 #	-0.21 #	-0.08
Sum	0.58 #	1.14 #	0.53 #	1.02 #	0.40 #	0.69 #	0.34 #	0.77 #

Non-His = non-Hispanic; Eur. = European; Af. = African; Am. = American; F. = females; M. = males

"Sum" = the sum of direct and indirect effects

#: significantly different from 0 based on bias-adjusted 95% confidence intervals

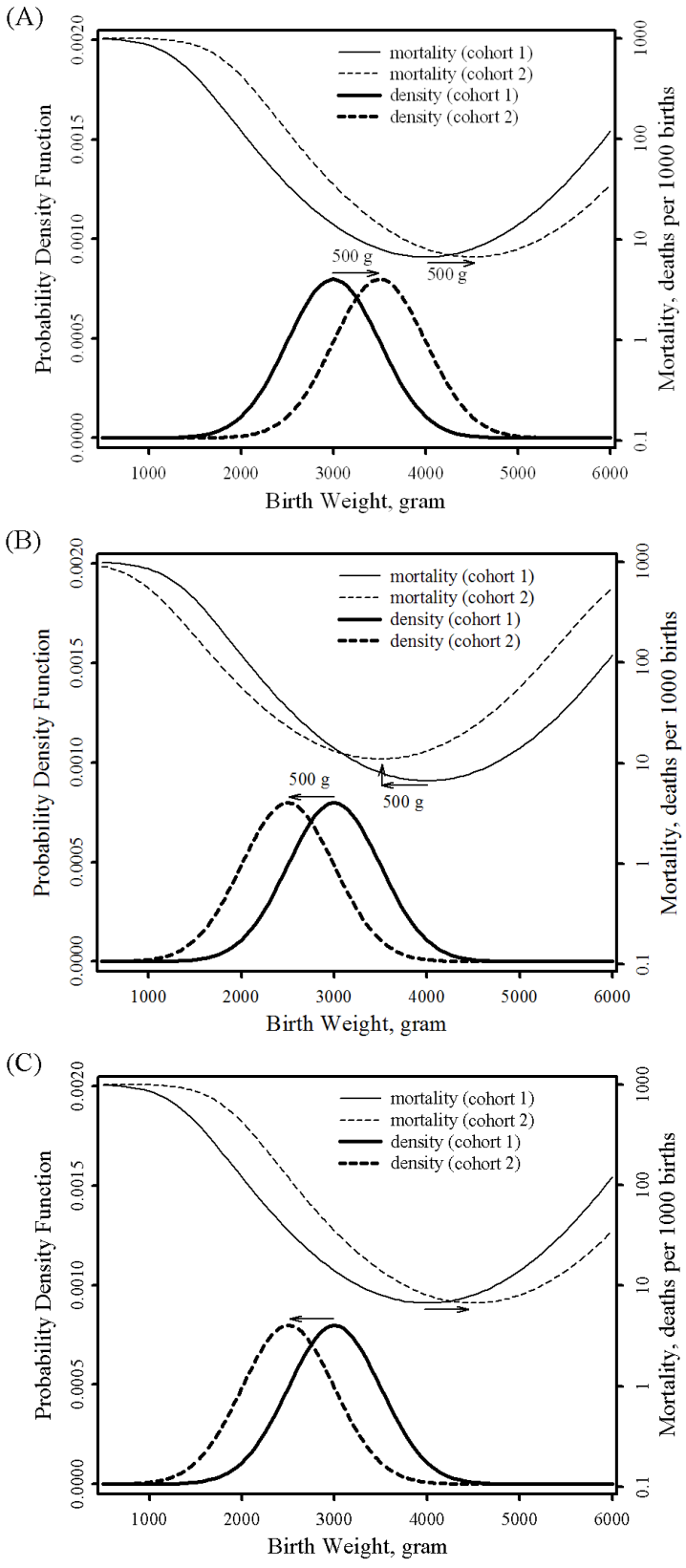
(A)
mortality (cohort 1)
mortality (cohort 2)
density (cohort 1)
density (cohort 2)
500 g
500 g
Probability Density Function
Mortality, deaths per 1000 births
Birth Weight, gram
(B)
mortality (cohort 1)
mortality (cohort 2)
density (cohort 1)
density (cohort 2)
500 g
500 g
Probability Density Function
Mortality, deaths per 1000 births
Birth Weight, gram
(C)
mortality (cohort 1)
mortality (cohort 2)
density (cohort 1)
density (cohort 2)
Probability Density Function
Mortality, deaths per 1000 births
Birth Weight, gram

Figure 1

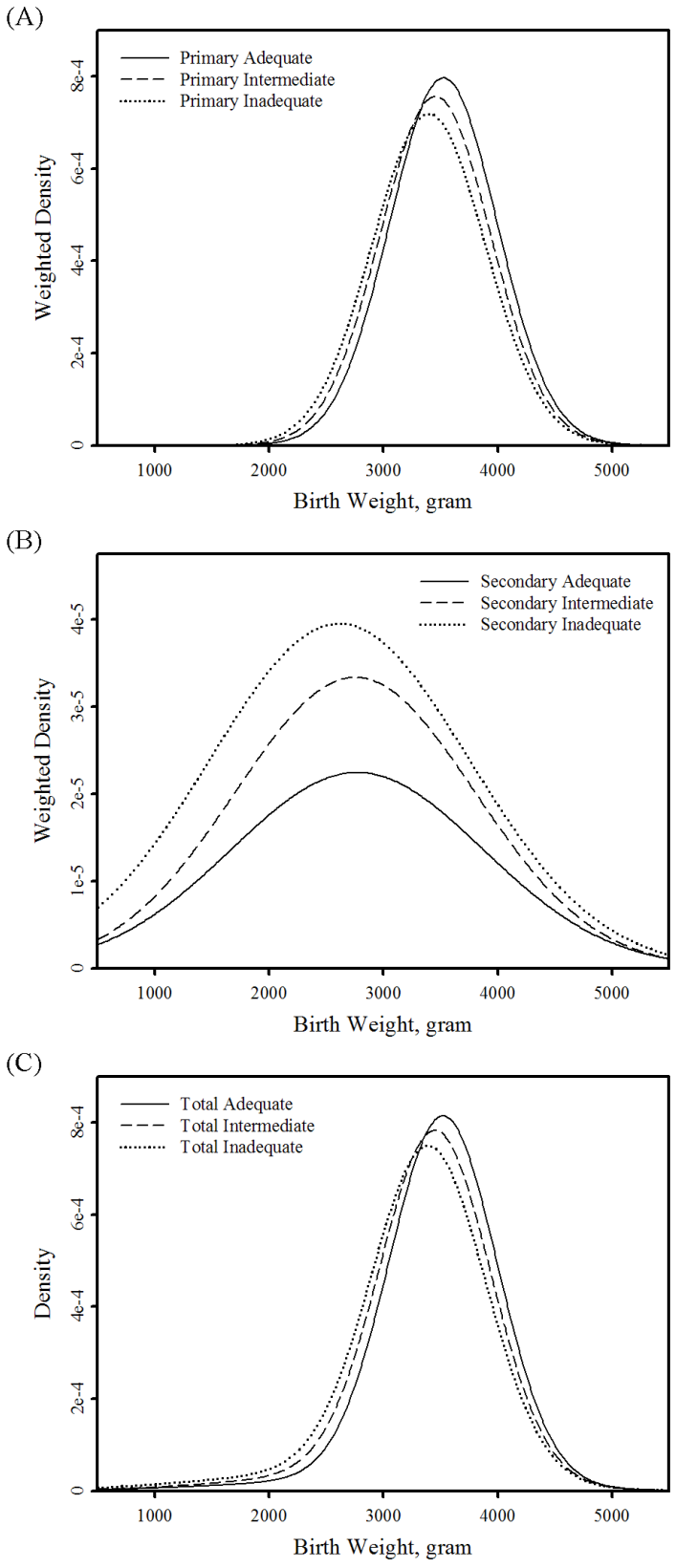
(A)
Primary Adequate
Primary Intermediate
Primary Inadequate
Weighted Density
0
2e-4
4e-4
6e-4
8e-4
1000
2000
3000
4000
5000
Birth Weight, gram
(B)
Secondary Adequate
Secondary Intermediate
Secondary Inadequate
Weighted Density
0
1e-5
2e-5
3e-5
4e-5
1000
2000
3000
4000
5000
Birth Weight, gram
(C)
Total Adequate
Total Intermediate
Total Inadequate
Density
0
2e-4
4e-4
6e-4
8e-4
1000
2000
3000
4000
5000
Birth Weight, gram

Figure 2

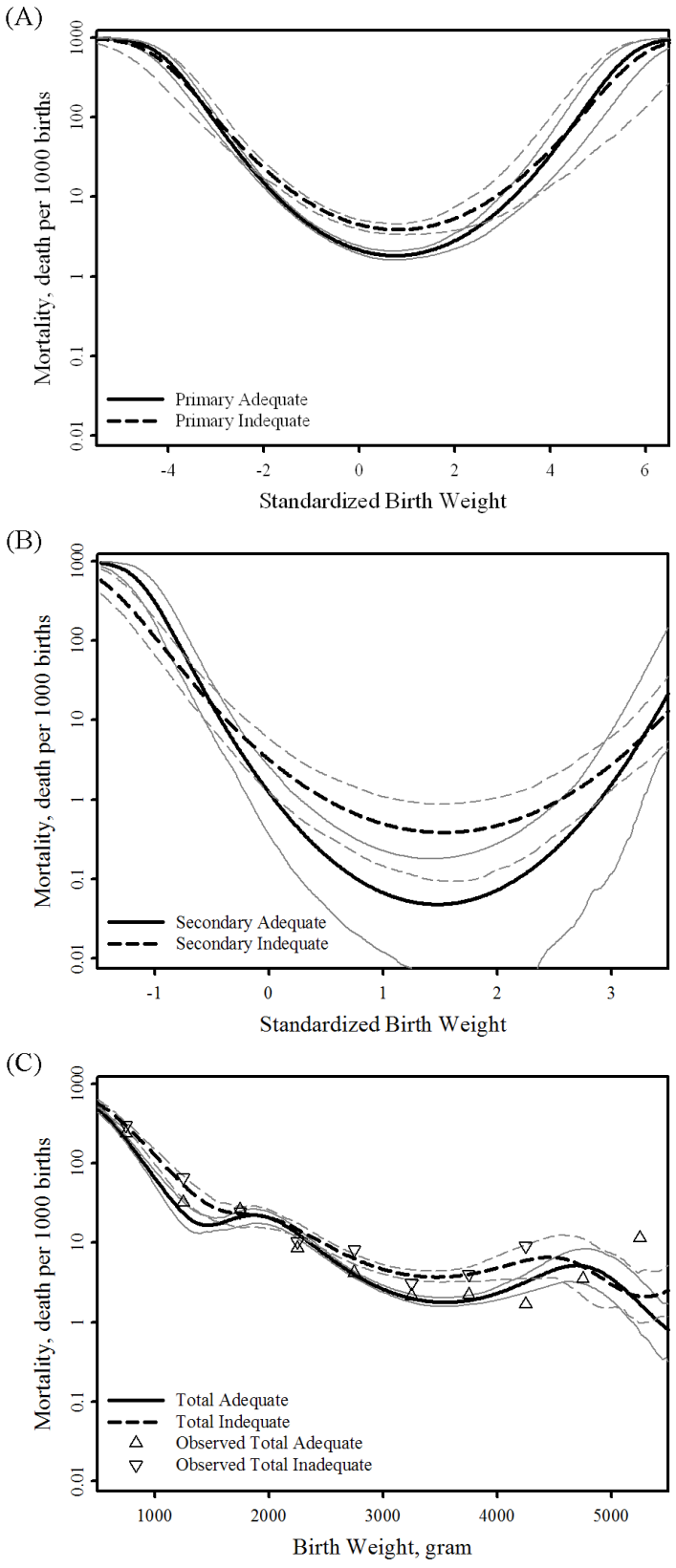
(A)
Mortality, death per 1000 births
0.01
0.1
1
10
100
1000
-4
-2
0
2
4
6
Standardized Birth Weight
Primary Adequate
Primary Indequate
(B)
Mortality, death per 1000 births
0.01
0.1
1
10
100
1000
-1
0
1
2
3
Standardized Birth Weight
Secondary Adequate
Secondary Indequate
(C)
Mortality, death per 1000 births
0.01
0.1
1
10
100
1000
1000
2000
3000
4000
5000
Birth Weight, gram
Total Adequate
Total Indequate
Observed Total Adequate
Observed Total Inadequate

Figure 3

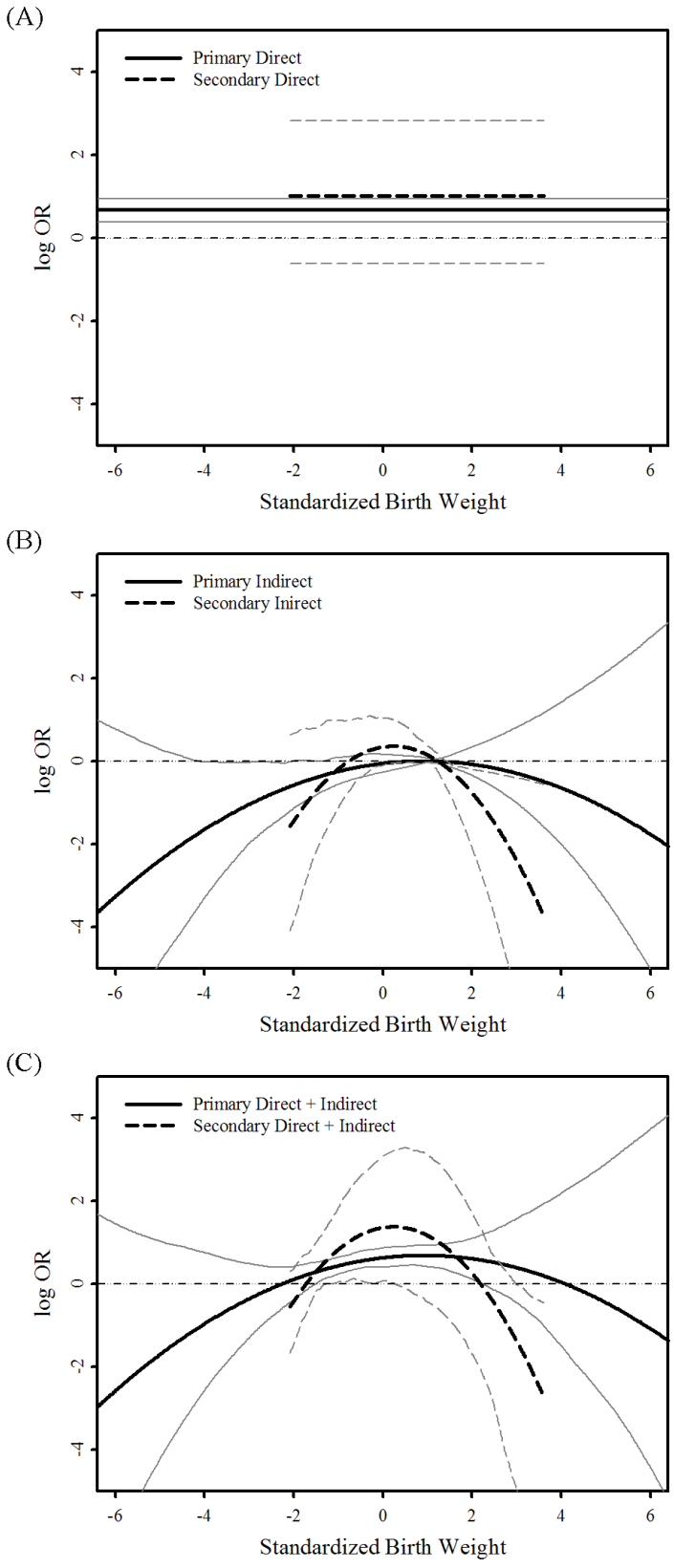
(A)
Primary Direct
Secondary Direct
log OR
4
2
0
-2
-4
-6
-4
-2
0
2
4
6
Standardized Birth Weight
(B)
Primary Indirect
Secondary Inirect
log OR
Standardized Birth Weight
(C)
Primary Direct + Indirect
Secondary Direct + Indirect
log OR
Standardized Birth Weight

Figure 4