Predicting Birth Weight: Relative Importance of Sociodemographic, Medical, and Prenatal Care Variables

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This study uses the 1980 National Natality Study to examine the relative importance of sociodemographic factors, medical-risk factors, and prenatal care in predicting birth weight. Findings indicate that both sociodemographic and medical-risk factors are important in predicting birth weight, with medical risks accounting for slightly more variance (after accounting for social variables) in birth weight. Although prenatal care accounts for only 1 percent of the variance, a statistical interaction between prenatal care and labor complications accounts for an additional 1 percent.

Low birth weight is defined as a birth weight of less than 2,500 grams. The hazards associated with low birth weight include excess mortality, morbidity, and handicaps that may continue well into the school years. Although the United States has made great progress in this century in infant survival, decreasing the infant mortality rate by over 90 percent to the 1991 rate of 8.9 deaths per 1,000 live births, the same
cannot be said for low birth weight. The 1988 low-birth-weight rate of 6.9 percent represents no decrease since 1980. Indeed, improvement in infant mortality has resulted largely from improved survival of low-birth-weight infants (particularly those of moderately low birth weight, i.e., between 1,500 and 2,500 grams, delivered at full term) and not from a reduction in low-birth-weight births.

There are two components to low birth weight: prematurity, which is defined as delivery of the fetus before 37 weeks of gestation, and intrauterine growth retardation, or small size for gestational age. At a given birth weight, mature babies are more likely to survive than premature babies, and at a given gestational age, heavier babies are more likely to survive. Much of the attention to low birth weight in this country has tended to focus on prematurity, although in developing countries and among American nonwhites, the majority of low-birth-weight births may be due to intrauterine growth retardation. Indeed, Selma Taffel reported that only 55 percent of all low-birth-weight infants were premature; the other 45 percent were full-term.

The purpose of this article is to examine the predictors of birth weight, with particular attention paid to a model that has implications for intervention. For this reason, we examine both aspects of birth weight, that is, length of gestation and intrauterine growth (as measured by weight, controlled for length of gestation). The constructs in the model represent variables that have been found to be predictive of low birth weight in previous studies.

Because of our interest in factors that are amenable to intervention, we examine variables in order of increasing amenability to intervention. We thus hypothesize that sociodemographic variables, health status, and prenatal care are related to birth weight both directly and indirectly, through length of gestation. We group these variables in three blocks. Sociodemographic variables, that is, traits that are not responsive to client-level intervention during the prenatal period and must thus be considered a “given,” are entered first in the analysis. Health status is then entered as block 2. Finally, prenatal care, which is most likely to be responsive to intervention, is entered as block 3. It should be noted that our purpose is not to explain the greatest amount of variance in the outcome variable, which would require including a number of variables that are excluded here, such as gender of the fetus. Rather, we seek to compare certain factors included in our model for their relative effect on birth weight. Our model is comparable to a model of neonatal mortality proposed by Paul Wise that suggests that poverty influences mortality in two ways: by elevating risk and by reducing access to interventions (both prenatal and perinatal) that might reduce that risk.
Method

Data Source

The data presented in this study are from the 1980 National Natality Survey (NNS), which includes a probability sample of 9,941 live births in the United States in 1980. The NNS is a nationally representative survey conducted by the National Center for Health Statistics and provides data on social demographic, health, and behavioral characteristics of childbearing women and on pregnancy outcomes. Sample weights are provided in the NNS public-use tape for estimating values for the entire population of 3,612,258 live births in 1980. We used only the unweighted data in these analyses because our interest lies in the relationships among the variables rather than in making population estimates.9

The current study is based on singleton births with gestation of 41 weeks or less with no congenital malformations. Multiple births, postdate deliveries, and births involving congenital malformations were eliminated since those conditions are related to birth weight in ways that would distort our analyses.10 The NNS includes data derived from birth certificates, as well as data from questionnaires that were administered to married mothers and their health care providers. We restricted our analyses to data from the birth certificates and the hospitals in order to avoid sample loss. (The self-report questionnaires were not administered to unmarried mothers.) Only cases with complete information on all study variables are included. It should be kept in mind that the sample is composed only of cases with complete data on these variables, and they are likely to be at lower risk for poor pregnancy outcomes than the sample as a whole. Women with missing data on vital statistics records have been found to have poorer pregnancy outcomes than those with complete data.11

Variables

The variables selected for each construct have been used in previous studies as indicators of that construct. For example, income may be the most direct measure of poverty, but income was asked only of married mothers in this survey. However, other authors have used race, maternal age, education, and marital status as indicators of socioeconomic status among pregnant women, so we used these variables as proxies for socioeconomic status.12 Whites made up 81.4 percent of the NNS sample, African Americans composed 15.6 percent, and other groups made up the remainder (3%). We coded race as “black” versus all others due to the small number of other races.
For the medical risk block of variables, we used the three categories of maternal risk as defined by the NNS: chronic (or “underlying”) illnesses (including heart disease, diabetes, asthma, and other previously existing conditions), pregnancy complications (including pregnancy-induced conditions such as urinary infections, placental problems, hypertension, inadequate or excessive weight gain), labor complications (including inadequate pelvis, toxemia, hemorrhage, etc.), and previous pregnancy losses.

Maternal behavior during pregnancy is strongly related to pregnancy outcome. The major health behavior variables that have been found to be related to birth outcomes include prenatal care and drug, tobacco, or alcohol use. Only prenatal care is available for the complete sample in the NNS (questions regarding smoking and drinking were part of the mothers’ questionnaire, which was administered only to married mothers).

Prenatal care, the third block of variables, is the most widely recognized measure of maternal health behavior in the literature on low birth weight. In these analyses, data on prenatal care were collected from the birth certificate and included month of initiation of care and total number of visits. We used an ordinal variable that combines these two aspects of prenatal care into an index of adequacy of care, with correction for length of gestation, that is, to correct for low numbers of visits due to early delivery. Previous studies often have measured prenatal care as either present or absent or have set some arbitrary cutoff point, such as George Ryan and colleagues’ comparison of women with four or more visits to those with fewer than four. We believe that the loss of information caused by such a truncation may distort the true effect of prenatal care.

Statistical Methods

Hierarchical multiple regression was used to estimate the independent effects of several correlated variables as they were added. This method controls for the multicollinearity among the independent variables that is a major problem in studies of birth weight, and, in particular, in studies that attempt to assess the effect of prenatal care on birth weight. Previous studies that have relied on determination of numerous bivariate associations between risk factors and birth weight may be informative regarding certain gross relationships, but they are likely to be seriously distorted by correlations among the independent variables.

Gestational length was entered as the final step of the analysis, allowing us to examine changes in the regression coefficients for each variable and thus to evaluate the effects of variables on weight through both reduced gestational length and impaired intrauterine growth.
The variables within each of the three blocks (socioeconomic status, medical complications, and prenatal care) were entered simultaneously within the blocks because we had no theoretical reasons for selecting among variables within blocks. Thus, variables that are highly correlated with each other and also with birth weight may not add a great deal to the variance individually, but we were able to compare their importance to the dependent variables by comparing the standardized coefficients.

Finally, we tested for statistical interactions, that is, where the effects of a variable on another variable may differ according to the level of a third variable.

Results

A number of steps were performed to build the appropriate model. First, we performed a multiple regression, entering the three blocks in turn, with the variables within each block entered simultaneously. We examined the coefficients for the individual variables and discovered that, due to the correlations among the variables, some were contributing little unique variance to the dependent variable. As a result, we eliminated maternal age and education (which had been treated as continuous variables) from the socioeconomic status block and pregnancy complications from the medical block. These deletions resulted in no change in the amount of variance explained and only slight changes in the regression coefficients.

Table 1 shows the final model, with the unstandardized and standardized coefficients for each variable in the model. Medical risk variables accounted for the greatest amount of variance in birth weight (7%) after controlling for sociodemographic factors, with sociodemographic factors second (5%, uncontrolled for medical risks). Prenatal care accounted for 1 percent of the variance after the other factors were entered. All of the main-effect variables exerted approximately equal influence on gestational length and weight controlling for gestation, with the exception of underlying medical conditions, which affected mostly gestational length (results are not shown).

Because of research indicating that the benefits of prenatal care are greatest for women at high risk of poor outcomes, we tested for significant statistical interactions between prenatal care and each of the other significant independent variables. Only the interaction with labor complications was significant, revealing that each increase in the level of prenatal care improved infants’ birth weights by approximately 58.4 grams. For example, the infants born to women who had no labor complications had a mean birth weight of 3,520 grams. Among women with labor complications, mean birth weights were reduced by 280.6 grams for those with no prenatal care, 222.2 grams for those
Table 1

**Regression Results ($N = 7,877$)**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Distribution in Sample (%)</th>
<th>Cumulative $R$</th>
<th>$R^2$ Change</th>
<th>$F$ Change (df)</th>
<th>$B$</th>
<th>$\beta$</th>
<th>$t^*$</th>
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<td>Black</td>
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<td>.05</td>
<td>220.40 (2; 7,875)</td>
<td>$-296.35$</td>
<td>$-0.15$</td>
<td>$-12.41$</td>
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<tr>
<td>Intensive</td>
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<tr>
<td>Prenatal care $\times$ labor complications</td>
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<td>.37</td>
<td>.01</td>
<td>204.14 (6; 7,871)</td>
<td>113.29</td>
<td>.12</td>
<td>10.77</td>
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<tr>
<td>Gestation</td>
<td></td>
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</tbody>
</table>

*Race was used as dichotomous variable, black vs. others.

* All t-tests are significant at $p < .0001$, except the interaction between prenatal care and labor complications, for which $p < .002$. 
with inadequate care, 163.9 grams for those with intermediate-level care, 105.5 grams for those with adequate care, and only 47.1 grams for those with intensive care.\textsuperscript{18}

**Discussion**

Several of the findings of this study have important implications. In what follows, we first discuss findings regarding the socioeconomic variables, followed by those related to medical conditions. Finally, we discuss prenatal care and the interaction. This is followed by a discussion of some limitations of the study and its implications.

**Socioeconomic Variables**

We found that race and marital status were the only two socioeconomic variables that were apparently necessary to represent this construct, although it should be noted that if reliable and valid data on income were available for all women, it is likely that this variable would be important. Nonetheless, the persistent 2:1 ratio of low birth weight between African-American and white infants lends particular importance to the findings on race.\textsuperscript{19} With the exception of labor complications (which was entered after accounting for race), race had the most powerful influence on birth weight of any variable in our model. Contrary to the findings of Jeffrey Levin, Kyriakos Markides, Joan Richardson, and A. Harold Lubin, race affected about equally both length of gestation and intrauterine growth.\textsuperscript{20} Because race was entered first in the model (given our interest in variables amenable to intervention), we did not examine the effects of race with other, more modifiable variables controlled, as did Levin and colleagues.

Notably, unlike some other studies, we did not observe a significant interaction between race and prenatal care. This may be because, unlike the other studies, we chose to test the interaction after entering all the main effects; most of the variance associated with a race/prenatal care interaction may have been accounted for by medical risk factors. That is, African-American pregnancies are complicated by more medical problems than their white counterparts' pregnancies.

These findings on the importance of race should not be interpreted as an indication of biologic predisposition to lower birth weight among African Americans, however. Indeed, race is more properly interpreted as a social phenomenon rather than a biological one since race acts as a proxy variable for income, education, quality of housing, and other "quality of life" variables.\textsuperscript{21}

**Medical Risk Variables**

It is certainly not surprising that maternal medical risk factors are related to birth weight. However, the positive relationship we found
between underlying medical conditions and birth weight is puzzling, yet it held up in the face of various methods of testing. We explored the possibility that women with previously identified medical conditions might obtain earlier and better prenatal care and thus have superior outcomes. However, the distribution of prenatal care was similar for women with and without such underlying medical conditions (the comparison is not shown).

A likely explanation for this finding is that several of these medical conditions (most notable, diabetes and obesity) may act to increase birth weight without improving infant health. The effects of a number of other categories may be negligible or may be due to many different conditions that act in competing ways on birth weight in this diverse group of women. For example, among women with underlying conditions, over one-third were categorized as “other.” This category included a wide range of dissimilar conditions, such as orthopedic problems and asthma. The confusion in interpreting the effects of underlying conditions suggests the importance of breaking down such combinations of conditions into more refined categories when sample size permits or at least being aware of the possibility of competing effects on birth weight by different conditions within categories.

A second surprise about medical risk factors is that pregnancy complications did not exert an important independent influence on birth weight. We surmise that some of the conditions in this category (such as excessive weight gain and obesity) may be subject to bias in diagnosis, depending on individual physicians’ perceptions, and also may be operating in competing ways, as we discussed above. In addition, possible pregnancy complications are likely to be detected and addressed earlier and more thoroughly for women who obtain early and frequent prenatal care. Similar conditions among women who obtained less care might not have been identified. Jon Tyson and colleagues note that this reduced likelihood of identifying risk factors among women with less prenatal care may bias findings against the benefits of prenatal care.

Prenatal Care

The findings of the effects of prenatal care on birth weight are perhaps the most interesting. Although the main effect of prenatal care on birth weight was small (accounting for 1% of the variance), the interaction with labor complications contributed another 1 percent, and the presence of the interaction is consistent with previous findings that prenatal care is most important for women at high risk for poor outcomes. Moreover, given the relative intractability of the other variables in the model, this variable appears to be one of the few avenues for reducing low birth weight. Thus, although the amount of variance
associated with prenatal care is small, it may represent a large proportion of the potential for successful intervention.

Four explanations are possible for the interaction between labor complications and prenatal care on birth weight. First, labor complications may be acting as a proxy for some other underlying disease that is poorly understood but that is amenable to prenatal care intervention, for example, eclampsia as a severe form of hypertension. Second, many potential types of labor complications (such as inadequate pelvis and toxemia) may be identified in prenatal care and managed through induction of labor or cesarean section as appropriate, resulting in better outcomes than would otherwise occur. Third, prenatal care may compel women to take better care of themselves and provide a context for seeking immediate assistance when complications do develop so that other complications, such as premature rupture of membranes, are identified and managed earlier.

Finally, it is possible that socially disadvantaged women, who are more likely to receive their prenatal care in a clinic setting, may benefit especially from the auxiliary services associated with prenatal care in a clinic. Social work assessment and intervention, nutritional supplementation through the Special Supplemental Food Program for Women, Infants, and Children (WIC), and referrals for other services may all reduce the negative effects of labor complications for these women.

These explanations are consistent with Tyson and colleagues’ finding of a more positive effect of prenatal care late in pregnancy on birth weight, as opposed to prenatal care received earlier. Their study of indigent women who delivered at a Texas hospital found that prenatal care late in pregnancy (especially by 38 and 42 weeks, but to some degree by 34 weeks) reduced the risk of having an infant below the tenth percentile in weight. They did not find an effect of prenatal care on duration of pregnancy, although they note that their methods would not have identified such an effect associated with early prenatal care.

In this regard, it is notable that the results of our study provide a proxy for examining the dose-response effect of prenatal care. That is, it allows us to examine whether there are increasing improvements in birth weight with increasing amounts of prenatal care. This issue is difficult to address, given the channeling of women (both by themselves and by their physicians) into more intensive care when they have identified medical problems. By measuring prenatal care as an ordinal variable while simultaneously controlling for important medical risk factors, we were able to address this issue. Although we found women with labor complications to have infants of significantly lower birth weights than women without those complications, the negative effect was reduced with increasing levels of care.
and was least when prenatal care was intensive (i.e., greater than the number of visits recommended by the American College of Obstetricians, given gestation). Clearly, additional research is needed to determine whether prenatal care has a dose-response effect on birth weight and whether that effect is primarily through interaction with various risk factors. More sophisticated measures of prenatal care will be necessary to make that determination. In particular, instruments should be developed that measure the "auxiliary" services that are often part of prenatal care in public health clinics. Those services are likely to be particularly important for poor women, who are also most likely to experience poor pregnancy outcomes. The statistical interaction we have noted would suggest that the content of prenatal care is critical.

Study Advantages and Limitations

The methods of this study offer a number of advantages in examining the major influences on birth weight. First, the NNS provides a large and diverse sample of U.S. births with extensive information on the important independent variables. The size of the sample of the NNS and the completeness of the data, in combination with multiple regression techniques that allow for simultaneous testing of many variables, permitted testing for interactions, which is essential for a better understanding of the effects of prenatal care on birth weight and other outcomes.

It is also important to note the limitations of the study. Perhaps most important in terms of the usefulness for designing interventions is the exclusion from our model of some variables that are likely to be important in the prediction of birth weight, including maternal health behaviors such as smoking and drug use. Such variables exert independent effects on birth weight; indeed, smoking is the most important determinant of low birth weight. These variables also might be regarded as mechanisms through which lower social class results in reduced birth weight, for example, if lower-class women are more likely to smoke and thus to reduce their infants' birth weights. These behaviors might be amenable to intervention carried out in the course of prenatal care, so they are critical to the question we address in this study. Herbert Miller, Khatab Hassanein, Tom D. Y. Chin, and Paul Hensleigh's study of 1,211 white mothers is a case in point. Women in the lowest social class group had the highest incidence of low birth weight; the prevalence of "medical" risk variables (including smoking, drug use, low weight gain, and inadequate prenatal care) was inversely related to social class. Miller et al. note the importance of this finding, but they did not analyze the effect of these variables controlling for social class.
A number of other important variables were unavailable to us from the NNS. Some of those variables are available in the 1988 Maternal and Infant Health Survey (as the latest administration of the NNS is named). These important variables include issues related to social support and use of social services. These variables are particularly important as we consider the implications of increasing access to and use of prenatal care, as well as what should be the content of prenatal care for disadvantaged women.

Implications

In view of the well-known methodological difficulties of assessing the effects of prenatal care, the findings of this study merit additional comment. Prenatal care has been found consistently to be positively associated with pregnancy outcome, including birth weight, although the effects have tended to be small. Methodological problems inherent in studying the effects of prenatal care must be acknowledged but should not be used to discount the findings of a large body of work.

Of primary concern are the dichotomous measures of prenatal care typically used, for example, any prenatal care versus no prenatal care or “inadequate” versus “adequate” levels of care. Such methods are bound to be less sensitive to effects of prenatal care than more refined measures, particularly if the benefits of prenatal care tend to accrue to small groups of women. Although it is true that we must move away from simple quantitative measures of prenatal care and toward a better understanding of the content of care, there is still a great deal to be done in refining our quantitative measures.

Second, it has not been possible to control adequately for the enormous differences in risk between women who seek out quality prenatal care and those who do not. Women who fail to receive adequate prenatal care tend to have lower education and income and tend to be unmarried and younger than is ideal for childbearing; they probably also differ in other ways, such as tendency to comply with medical advice. Studies that control for such factors might demonstrate less dramatic effects of prenatal care than those that do not, particularly when relatively insensitive measures of prenatal care are used. (See, e.g., Jeffrey Harris’s sophisticated analysis using proportional hazards models.) The use of hierarchical regression, entering some of the self-selection variables first, provides one means (albeit not wholly satisfactory) of dealing with the serious problem of correlated independent variables.

Finally, we have attempted to examine the relative contributions of the two aspects of birth weight (length of gestation and growth during gestation) by entering gestational length as the last variable in the hierarchical regression and examining the effects on the regression
coefficients. Our findings of effects on both paths to lowered birth weight for most of the independent variables are intriguing and inconsistent with Harris's findings of effects for prenatal care only on weight.35 This inconsistency may be due to Harris's sophisticated methods of controlling for fetal selection (i.e., the natural process by which less fit fetuses are lost over time), but this is unclear. It is probably correct that such complicated processes cannot be addressed using cross-sectional birth certificate data, but Harris's work is based on some assumptions that require further testing.

Given that half of all low-birth-weight births in low-income and minority groups may be due to shortened gestation, it seems important to pursue the effects of both impaired growth and shortened gestation, particularly since there is a dearth of interventions that have proved successful in improving intrauterine growth.36

In conclusion, despite some limitations, this study provides support for prenatal care as a predictor of birth weight. Although the absolute effects were relatively small, the control for certain, largely unmodifiable factors and the indication that women at high risk of delivering low-birth-weight babies due to medical problems show particular benefit from prenatal care suggest that it can be important. Further research is required to investigate the relative effects of prenatal care on length of gestation and intrauterine growth and particularly to define the most important components of prenatal care for women who are at high risk of poor pregnancy outcomes.

Notes

This work was supported in part by project MCJ-000106 from the Maternal and Child Health Bureau (Title V, Social Security Act), Health Resources and Services Administration, Department of Health and Human Services.


21. There is considerable controversy over whether the persistent black-white difference in low birth weight is an inherent biological difference. See Cooper and David (n. 12 above).


24. Ibid.


26. Tyson et al. (n. 23 above).


30. Eisner et al. (n. 16 above); Greenberg (n. 16 above); Ryan, Sweeney, and Solola (n. 16 above).


35. Ibid.

36. Ibid.