# Neighborhood Risk Factors for Low Birthweight in Baltimore: A Multilevel Analysis

## ABSTRACT

*Objectives.* Past research on low birthweight has focused on individual-level risk factors. We sought to assess the contribution of macrolevel social factors by using census tract–level data on social stratification, community empowerment, and environmental stressors.

*Methods.* Census tract–level information on social risk was linked to birth certificate records from Baltimore, Md, for the period 1985 through 1989. Individual-level factors included maternal education, maternal age, medical assistance health insurance (Medicaid), and trimester of prenatal care initiation. Methods of multilevel modeling using two-stage regression analyses were employed.

*Results.* Macrolevel factors had both direct associations and interactions with low birthweight. All individual risk factors showed interaction with macrolevel variables; that is, individual-level risk factors for low birthweight behaved differently depending upon the characteristics of the neighborhood of residence. For example, women living in high-risk neighborhoods benefited less from prenatal care than did women living in lower-risk neighborhoods.

*Conclusions.* Multilevel modeling is an important tool that allows simultaneous study of macro- and individual-level risk factors. Multilevel analyses should play a larger role in the formulation of public health policies. (*Am J Public Health.* 1997;87:1113–1118)

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## Introduction

Low birthweight remains a significant public health problem in the United States. Low birthweight (defined as a weight of less than 2500 g at birth for a live-born infant) has declined very little over the past several decades and is even on the rise among some high-risk groups.[1] Much research has focused on individual-level risk factors for low birthweight; individual-level models, however, have been able to explain only a small proportion of the overall variability seen for birthweight.[2] Moreover, it is increasingly being recognized that environmental factors contribute to the risk of low birthweight.[3–7]

Previous studies of low birthweight have been limited to individual factors in their conceptualization of social risk.[8,9] Social risk, however, should also include environmental stressors, which shape individual vulnerability and resistance to risk factors for health.[4,10–20]

Analyses that include both individual-level and macrolevel data—referred to as contextual or multilevel models—have several advantages.[21] First, multilevel analytic methods are more consistent with social theories than are traditional methods of analysis (e.g., ordinary regression) in that they explicitly accommodate the multiple levels of data.[22] Second, multilevel methods can contribute new knowledge to our current understanding of public health issues by allowing for the inclusion of macrolevel factors in our current explanatory models, thereby bridging the micro–macro gap by increasing our understanding of how contextual factors translate into differences in individual-level risk.[23–25] Further, these methods may eliminate potential confounding of individual-level explanatory models

due to the omission of macrolevel factors.[23,26] Finally, by improving our understanding of how contextual factors influence individual health outcomes, we will be better equipped to design effective intervention strategies.[19,20]

The analysis presented here is part of a larger study looking at indicators of neighborhood and social risk for poor pregnancy outcome in Baltimore, Md. We were specifically interested in answering the following questions about multilevel analyses and the study of risk factors for low birthweight: (1) Are neighborhood-level variables directly related to an increase or decrease in risk of low birthweight? (2) Do individual-level risk factors for low birthweight behave differently depending on the characteristics of the neighborhood in which a woman resides? (3) What are the intervention design or policy implications of including macrolevel variables in research on low birthweight?

## Methods

### Data

*Individual-level variables.* Computerized birth certificates with nonmissing information on birthweight and maternal characteristics were obtained for the

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## TABLE 1—Variables Used in Multilevel Analysis of Risk for Low Birthweight, Baltimore, Md, 1985 through 1989

| Variable | Type | Distribution, Mean (SD) |
| --- | --- | --- |
| Individual-level | | |
| Low birthweight[a] | Binary | .12 (.32) |
| Maternal age, y | Continuous | 24.2 (5.7) |
| Maternal education, y | Continuous | 12.0 (3.5) |
| Trimester of prenatal care initiation[b] | Categorical | Median is 2 |
| Health insurance status[c] | Binary | .27 (.44) |
| Census tract–level | | |
| Ratio of home owners to renters | Continuous | 1.4 (1.3) |
| No. of community groups | Continuous | 3.0 (2.7) |
| Unemployment rate, % | Continuous | 7 (4.3) |
| Rate of housing violations, % | Continuous | 9 (7) |
| Per capita crime rate, % | Continuous | 11 (18) |
| Average wealth, $000 | Continuous log | 99 (53) |
| Per capita income, $000 | Dummy | 12 (7) |

[a]<2500 g = 1, ≥2500 g = 0.
[b]For women who received no prenatal care, the value of this variable was 4. Therefore, higher numbers represent less adequate prenatal care.
[c]Medicaid = 1, non-Medicaid = 0.

dummy variables were created. Because of non-normality, a log transformation of the wealth was used to more closely approximate a normal distribution.

The study variables are summarized in Table 1.

### Analytic Method

Models that include two or more levels of information should be analyzed by means of appropriate statistical methods that accommodate the different levels of data.[15,29–32] The analytic method we used is based on the two-stage regression method proposed by Wong and Mason[31] and Bryk and Raudenbush[23] for the analysis of multilevel models. We chose to use a two-stage regression method because it gives consistent estimators of risk factors when sample sizes are as large as our data set, which has hundreds of observations per census tract or census tract cluster. In performing two-stage regression, we wanted to obtain information on two types of relationships: direct effects of individual-level and macrolevel factors on low birthweight and interaction effects between micro- and macrolevel factors and low birthweight.

The first stage of the analysis involved the generation of 180 census tract–specific regression models on individual-level data. (There are 198 residential census tracts in Baltimore City. However, because of low frequencies of low birthweight for 18 of the census tracts, individual-level regressions yielded unstable parameter estimates. Therefore, data from these 18 census tracts were combined with those of adjacent census tracts with similar sociodemographic information, which improved estimation and allowed for data on all births in the city to be used.) In these models, low birthweight was regressed on the four individual-level variables: maternal age, maternal education, prenatal care, and health insurance status. We had approximately 200 to 900 observations per census tract. We refer to the first stage of the analysis as the microlevel analysis. Although the macrolevel attributes are ignored at this stage, context is accounted for because a regression equation is generated for each census tract separately. For the second stage of the two-stage regression analysis, the macrolevel analysis, we consider only the 180 census tracts. The distributions of the five estimates obtained in the first stage (the intercept and the regression coefficients for the four individual-level variables) were each regressed on the census tract–level variables separately. Thus, at

calendar years 1985 through 1989 from the city health department's Bureau of Biostatistics (n = 50 757). The health department routinely codes data with census tract identifiers. A program such as Map Info for Windows (200 Broadway, Troy, NY 12180) can then be used to link these geocoded data with data that describe census tract–level characteristics.[27]

We had wanted to examine how macrolevel social factors contributed to racial differences in low birthweight. However, we were not able to get census tract–specific risk of low birthweight by race for the majority of the census tracts. Although births in Baltimore during the study period were predominantly (73%) to African-American women, very few census tracts had enough Black and White births to make reliable estimates; the majority of Baltimore census tracts have either predominantly White or predominantly Black births, making estimation difficult.

*Census tract–level variables.* Data on census tract characteristics were obtained from several sources. Decisions about which variables to use to characterize the census tracts were based on several considerations. First, census tract–level variables had to be readily available from a routinely collected data source. Ready availability of these data will facilitate use of the analytic techniques reported here in future research and intervention planning. Second, census tract–level variables were chosen to represent a wide spectrum of characteristics of neighborhoods, includ-

ing socioeconomic indicators and physical and social characteristics.

The Community Planning Division of the City of Baltimore's Department of Planning makes available data on a variety of neighborhood characteristics at the census tract level, including home ownership, numbers of housing violations issued, per capita crime rates, and numbers of active neighborhood community groups (which we used as a measure of community empowerment). We obtained unemployment statistics for Baltimore City for 1988 and 1989 from the Maryland Department of Employment and Economic Development.

There are sources of commercially available data that yield profiles of census tracts. Per capita income and information on household wealth (e.g., equity in homes, vehicles, assets, mortgages, and other debts and real estate ownership) at the census tract and block group level can be obtained through Claritas/NPDC (PO Box 610, Ithaca, NY 14851-0610). This information is updated annually on the basis of census data, marketing surveys, and projections.

We wanted more than one indicator of social class, as previous researchers have called for the use of more than one indicator to capture the complexity of this risk factor.[28] Per capita income and household wealth were thought to be nonlinearly related to low birthweight. Per capita income was therefore categorized into quartiles, based on the distribution of this variable for the city as a whole, and

this stage the attributes of the contexts are brought into the model. Also at this stage, we can use model-building techniques whereby "best fit" models can be obtained. Multicollinearity was not a problem in our analysis; the range of correlations between neighborhood-level variables was from .009 to .625, with only 2 of 40 correlation pairs at the .60 or higher level and 30 of the 40 pairs at .30 or lower. All continuous variables were centered at the mean.[23] Therefore, the reference group for each continuous variable is those individuals who had an average value for the variable in question or census tracts at an average level of that variable. A detailed account of the methods and rationale behind the statistical technique used here can be obtained from the authors.

## Results

The final multilevel model is shown in Table 2. Although nonsignificant variables were retained for adjustment purposes (see Table 2 footnotes), only statistically significant predictors are shown in the table.

### Direct Effects of Individual and Census Tract Variables

The estimated odds ratios and their corresponding confidence intervals for the direct effects of the individual-level and census tract-level variables are displayed in Table 2. Because all continuous variables were centered at the mean, the reference groups for the odds are those individuals with an average value for the continuous variable. All individual-level variables were significantly related to the risk of low birthweight and therefore were retained in the final model. Higher maternal education had a protective effect for low birthweight. Prenatal care was significantly related to the risk of low birthweight. Later initiation of prenatal care was related to an increased risk of low birthweight. Mothers enrolled in Medicaid were at a higher risk for low birthweight than other women. Finally, maternal age was related to a slight increase in risk of low birthweight, a finding that is consistent with some previous research but not all.[6,9,33,34] For example, some previous studies have shown that for African-Americans, perhaps because of high-risk environments, risk of low birthweight increases with maternal age.[1,6,9,33] Our sample consisted predominantly of African Americans and contained a high proportion of low-

**TABLE 2—Parameter Estimates from the Final Two-Level Logistic Model for Risk of Low Birthweight, Baltimore, Md, 1985 through 1989**

| | β | SE (β) | Odds Ratio | 95% Confidence Interval |
|---|---|---|---|---|
| **Direct effects** | | | | |
| Maternal age | .022 | .004 | 1.02 | 1.01, 1.03 |
| Maternal education | −.129 | .018 | .87 | .85, .91 |
| Prenatal care | .227 | .025 | 1.25 | 1.19, 1.32 |
| Health insurance status | .401 | .068 | 1.49 | 1.31, 1.70 |
| Per capita income < $8000 | .103 | .049 | 1.11 | 1.02, 1.22 |
| **Interaction effects via maternal age[a]** | | | | |
| Unemployment | .002 | .001 | . . . | . . . |
| **Interaction effects via maternal education** | | | | |
| Per capita crime rate | −.769 | .329 | . . . | . . . |
| **Interaction effects via prenatal care[b]** | | | | |
| log(average wealth) | −.118 | .054 | . . . | . . . |
| Unemployment | −.017 | .007 | . . . | . . . |
| **Interaction effects via health insurance status** | | | | |
| Per capita income < $8000 | −.439 | .090 | . . . | . . . |
| Per capita income $8000–$11 000 | −.302 | .092 | . . . | . . . |

*Note.* Parameter estimates are for individual-level, neighborhood-level, and interaction effects.
[a]The interaction effects via maternal age are adjusted for number of community groups.
[b]The interaction effects via prenatal care are adjusted for crime rate and rate of housing violations.

income women. We would have liked to investigate interactions between age and race/ethnicity but could not with our data.

Of the census tract–level variables, per capita income had a significant direct relationship to risk of low birthweight. Residents of census tracts with a per capita income of less than $8000 had a significantly higher risk of low birthweight than did women in census tracts with a per capita income of more than $8000.

### Interaction Effects of Census Tract Variables

Our second study question was whether individual-level risk factors for low birthweight behave differently depending on the neighborhood in which a woman resides. The results indicate that the census tract–level variables did indeed modify the associations between the individual-level factors and the risk of low birthweight. The coefficients and corresponding standard errors of these interaction effects of the macrolevel variables are displayed in Table 2. A few examples will be used to demonstrate how these coefficients are interpreted.

*Medicaid health insurance status.* Per capita income modified the relationship between health insurance status and low birthweight. Having Medicaid as

health insurance increased the risk for low birthweight (odds ratio [OR] = 1.49). The Medicaid health insurance odds ratio for low birthweight is smaller for women living in neighborhoods with a per capita income of less than $8000 than for women living in neighborhoods with a per capita income of $11 000 or more. The Medicaid health insurance odds ratio is diminished by an amount equal to the β for the interaction effect of per capita income less than $8000 (−.439). The low-birthweight odds ratio decreases to 1.07 ($e^{.103 + .401 - .439}$) for Medicaid as health insurance when a woman lives in a neighborhood with a per capita income of less than $8000. Similarly, the negative β for per capita income of $8001 to $11 000 also indicates a diminished odds ratio; for women living in those neighborhoods compared with women living in neighborhoods with a per capita income of more than $11 000, the low-birthweight odds ratio is 1.10 ($e^{.401 - .302}$).

*Prenatal care initiation.* Regarding trimester of prenatal care initiation and risk of low birthweight, the log odds of low birthweight increases by .227 for every trimester after the first that prenatal care is initiated. However, this association is modified by the unemployment rate and the level of wealth in a woman's neighborhood. For every percentage point increase
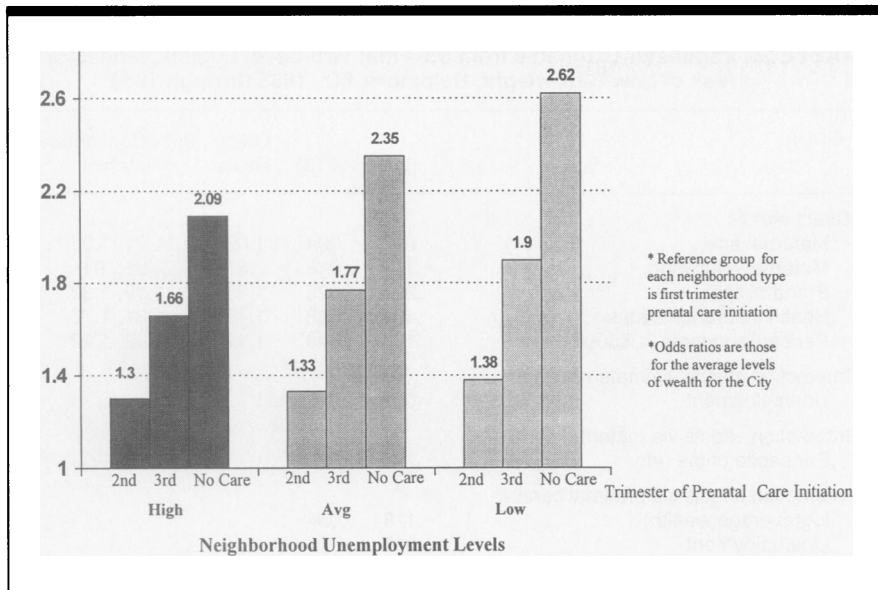
**FIGURE 1—Odds ratios for risk of low birthweight, Baltimore, Md, 1985 through 1989, by trimester of prenatal care initiation within neighborhoods with high, average, and low levels of unemployment, illustrating the interaction between unemployment levels and timing of prenatal care initiation.**



*Note.* Heavy arrows represent direct effects on low birthweight; odds ratios (ORs) for these direct effects are shown in parentheses. Interaction effects are indicated by broken-line arrows. These interaction effects modify the relationship between individual-level variables and low birthweight. For example, the increased risk of low birthweight for women with low levels of education (OR = 1.15 in neighborhoods with average crime rates) is stronger (+) in high-crime than in low-crime neighborhoods; the increase in risk with increasing maternal age (OR = 1.02 in neighborhoods with average unemployment levels) is stronger (+) in high-unemployment than in low-unemployment neighborhoods.
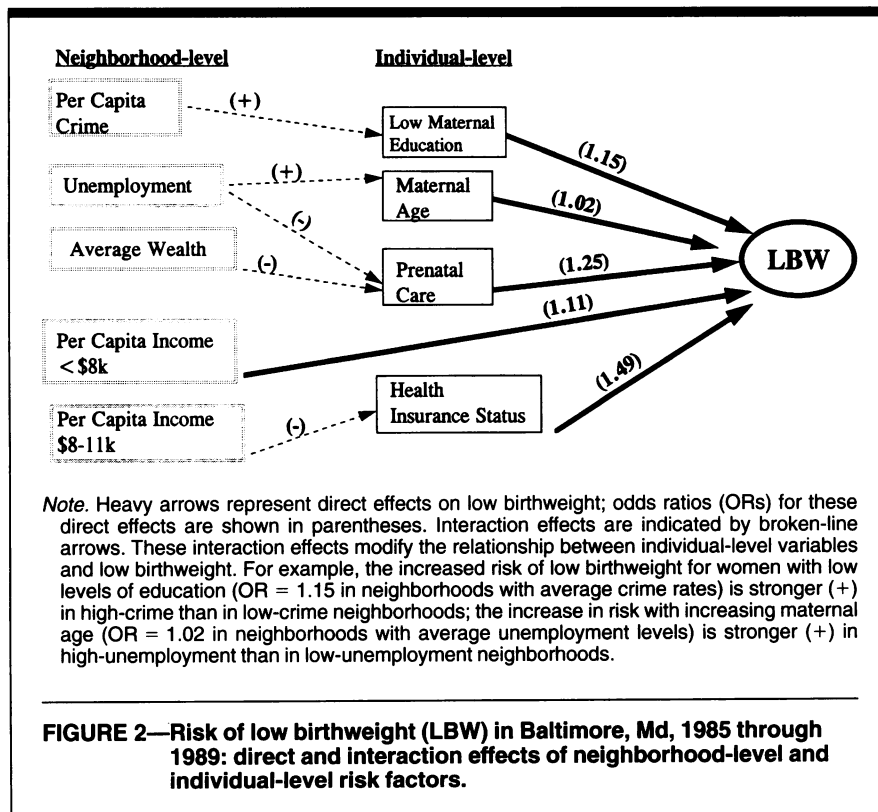
**FIGURE 2—Risk of low birthweight (LBW) in Baltimore, Md, 1985 through 1989: direct and interaction effects of neighborhood-level and individual-level risk factors.**

in the unemployment rate over the city average, the log odds of low birthweight associated with trimester of prenatal care initiation decreases by .017 (see the beta for the interaction effect of unemployment for prenatal care, −.017, in Table 2). That

is, as unemployment increases, the protective effect of early prenatal care initiation diminishes. Therefore, for neighborhoods with an unemployment rate of 9%, which is 2 percentage points above the city average, the log odds of low birthweight

associated with later prenatal care initiation is 0.193 ($e^{2(-.017) + .227}$) (OR = 1.21). (Because unemployment is centered at the city mean of 7%, we multiply the unemployment beta by 2 rather than 9 to obtain the unemployment effect of 9%.) In contrast, for neighborhoods with an unemployment rate of 5%, or 2 percentage points below the city average, the log odds of low birthweight associated with later prenatal care initiation is 0.261 ($e^{-2(-.017) + .227}$) (OR = 1.30). These numbers suggest that in low-risk neighborhoods, as measured by low unemployment, the protective effect of early initiation of prenatal care is stronger than it is in higher-risk neighborhoods. The association between prenatal care initiation and risk of low birthweight for three neighborhoods with different unemployment rates is displayed in Figure 1. Trimester of prenatal care initiation is not as strongly related to the risk of low birthweight in neighborhoods that have a higher unemployment rate. A summary of the direct and interaction relationships of the macro- and individual-level risk factors for low birthweight is presented in Figure 2.

## Discussion

Public health researchers and professionals should be as much concerned with social risk factors as they are with individual-level risk factors. Until more research is dedicated to the study of individuals within the contexts in which they live and work, the relative importance of targeting individual or contextual factors to improve health will remain unknown. Past studies have suggested that larger social factors may be more important than individual-level risk factors in producing adverse health outcomes.[35]

Our findings indicate that including macrolevel social factors in studies of low birthweight is useful for obtaining better explanatory models. We found that indicators of social stratification, particularly per capita income, were directly related to the risk of low birthweight in Baltimore. This finding suggests that future efforts aimed at reducing low birthweight might be more effective if efforts are made to target macrolevel social factors rather than, or in addition to, the usual individual-level factors (e.g., health behaviors, early initiation of prenatal care).

Our indicator of community empowerment, the number of community groups per census tract, was not associated with

low birthweight. While the number of active community groups is a crude indicator of community empowerment, we had expected this factor to have a protective effect against low birthweight.

Our analyses indicate that there is substantial interaction between macrolevel factors and individual-level risk factors for low birthweight. Indicators of social class, and environmental stressors such as poor housing conditions and high crime and unemployment rates, were found to modify the relationship between individual-level risk factors and low birthweight. This finding has implications for the design of policies and interventions for improving pregnancy outcomes. For example, previous policy and intervention recommendations were based primarily on individual-level analyses alone.[36,37] Such analyses may overestimate the importance of changing individual-level risks as a strategy to reduce low birthweight. Our analyses support this idea. For example, although our findings agree with previous studies that show that early initiation of prenatal care reduces the risk of having a low-birthweight infant, our findings indicate that this protective effect varies by residential context. In high-risk neighborhoods, as indicated by average wealth or unemployment rates, the protective effect of prenatal care was diminished. In lower-risk neighborhoods, the benefits of early initiation of prenatal care were more substantial. Thus, when the design of policies or interventions is based only upon individual-level analyses, the benefits of interventions aimed at increasing earlier initiation of prenatal care, which are usually targeted toward high-risk populations, may be overestimated.

Although with most of our interaction effects higher-risk environments diminished the protective effects of individual attributes, not all macrolevel factors behaved consistently. For example, the protective effect of early initiation of prenatal care was greatest for women living in neighborhoods with high levels of housing violations. This suggests that the mechanisms of macrolevel risk factors for low birthweight and possibly other adverse health outcomes are complex. Consideration of a wide variety of environmental stressors and characteristics would be important in future studies.

Future studies might include both individual- and neighborhood-level variables of the same social factors (e.g., mother's income and average income of families in a census tract). These variables do not necessarily measure the same

construct.[21] For example, high levels of persistent neighborhood poverty or unemployment may indicate a lack of political and economic empowerment and resources that affects all persons living in that neighborhood, independent of their own poverty or unemployment status.

Our study used routinely available data as sources for our indicators of social risk. The rationale behind the use of routinely available data was to develop useful indicators that might easily be incorporated into future studies of maternal and child health. However, researchers should not overlook the possibility of developing and using a more comprehensive set of social indicators. For example, to investigate community empowerment we might have included other indicators that are not necessarily routinely available. Such indicators might include satisfaction with neighborhoods, social cohesion, voting patterns, presence of social programs, intervention programs targeting pregnant women and new mothers (e.g., Healthy Start), and churches or church-based programs. A more comprehensive set of indicators for housing conditions might include crowding,[38,39] proportion of abandoned housing, age of dwellings, presence of lead paint, and other specific housing violations. Such data can be collected by a variety of methods, and several researchers have developed systematic means of collecting such information on context.[40–42] Future multilevel studies of low birthweight and very low birthweight might investigate the ability of macrolevel social factors to explain the low-birthweight gap between different racial and ethnic groups.[1] Although previous studies have attempted to explain the gap by looking at individual-level social factors,[8,9] recent studies of segregation[43] and African-American political empowerment[44] suggest that multilevel models may facilitate further explanation of the reasons for the gap. Finally, future studies should adjust for and look for interaction effects with a more comprehensive list of individual-level risk factors, such as presence of pregnancy-related or preexisting medical complications, health behaviors (e.g., smoking during pregnancy), and a better indicator of adequacy of prenatal care. The availability or quality of data in Maryland's vital records registration system precluded us from including such information in our analyses.

We have shown that multilevel models should be used in future analyses of maternal and child health outcomes;

software is becoming accessible and data on contexts are routinely available. Such modeling methods can not only facilitate the development of better explanatory models but can form the basis of better policy and intervention design. □

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