In the US, black women bear more than twice the risk of delivering a low birthweight or very low birthweight infant compared with white women. Despite repeated epidemiological assaults, this enigmatic association remains largely impenetrable. Less widely appreciated, and less examined, is the possibility that this racial/ethnic gap in risk of low birthweight varies by maternal age.

Geronimus demonstrated an increasing risk of low birthweight with advancing maternal age among black, but not white, mothers, using 1989 birth certificate data from singleton first births to black and white mothers aged 15–34 in Michigan. More recently, using New York City birth certificate data from 1987 to 1993, Rauh and colleagues also documented markedly increasing risk of delivering low birthweight infants with increasing age among African American women, compared with white women. The age-associated increase in risk of low birthweight was
of maternal age and ethnicity with other factors that are markers of social and economic disadvantage, specifically, maternal education, marital status, and neighbourhood poverty. Maternal age was represented as a continuous variable and multiplicative interactions were assessed by the statistical significance of cross-product terms between maternal age and other variables. In a multivariate model among mothers aged 20–45, the addition of a quadratic term for maternal age (the residual of age² regressed on age), as well as interactions with this term made no material difference to the results (data not shown).

An interaction was retained in the model if it demonstrated a ≤5% probability of occurring by chance alone. The exception to this was the retention in all models of the interaction term between ethnicity and age, as it was of primary interest. First, a ‘Main Effects Model’ was created as the foundation for analysis, which included the ethnicity*age term as well as established predictors of birthweight available from birth certificates: maternal age, ethnicity (black versus white), parity (in three categories), cigarette smoking during pregnancy (smoker versus non-smoker), adequacy of prenatal care (received first trimester care versus later care, no care, or unknown care), maternal education (high school graduate versus not), marital status (married versus not), and neighbourhood poverty. Then, to test whether the ethnic-specific age slopes varied by markers of socioeconomic disadvantage, we tested three-way interactions of maternal age and ethnicity with maternal education, marital status, and neighbourhood poverty (none were retained). Finally, to control for confounding of the maternal age*ethnicity interaction by interactions of other risk factors with age or ethnicity, we tested the effect on the age*ethnicity coefficient of including in the model two-way interactions of maternal education, marital status, parity, prenatal care, smoking, and neighbourhood poverty with maternal age and maternal ethnicity, respectively. The resulting model, which includes several two-way interaction terms, is called the ‘Interaction Model’.

Results
In all, 14% of the 66,495 singleton infants born to black and 5% of the 30,392 singleton infants born to white mothers weighed <2500 g at birth. The distribution of low birthweight (<2500 g) and very low birthweight (<1500 g) births by maternal age for all black and white mothers is shown in Figure 1a. This U-shaped distribution confirms the widespread perception that women at the extremes of the age distribution are at increased risk of delivering small infants. However, this composite picture conceals two markedly diverging trends in the risk of low birthweight by maternal age for black and white mothers (Figure 1b). Although black and white women under 18 years of age shared a similar risk of delivering a low birthweight child, that risk dropped with increasing age for white mothers and climbed for black mothers. A black mother over age 30 had a 20% chance of delivering a low birthweight child, as compared with the 5% chance of a white mother over age 30 delivering an infant <2500 g.

Table 1 presents the distribution of several risk factors for low birthweight, by maternal age and ethnicity. As expected, older women were more likely than younger women to be married, considerably greater for African American mothers receiving public insurance than for whites or for privately insured African Americans. Even after adjustment for multiple risk factors (including an interaction between maternal age and poverty), the risk of poor pregnancy outcome rose faster with age for African American women than for white women.
multiparous, and to receive prenatal care in the first trimester. While black mothers were less likely to be married than white mothers at any age, the relative gap in proportion married narrowed with age. Prevalence of cigarette smoking during pregnancy increased with age among black mothers, while it generally decreased with age among white mothers. Regardless of ethnicity, younger mothers lived in poorer neighbourhoods. Regardless of age, black mothers lived in neighbourhoods that had at least twice as many households in poverty compared with the neighbourhoods in which white mothers lived.

Table 2 presents the results of several models fit to explain the association between maternal age and risk of low birthweight for black and white mothers aged 20–45 years. The ‘Unadjusted’ model demonstrates that the interaction between black ethnicity and age is positive and highly unlikely to have occurred by chance alone ($P < 0.0001$). This indicates that the risk of low birthweight rose more quickly with age among black mothers than it did among white mothers. In this unadjusted model, the odds of delivering a low birthweight infant did not increase with age for white mothers (OR per year of age = 1.00; 95% CI: 0.99–1.01), while the OR per year of maternal age for black women was 1.05 (95% CI: 1.04–1.05). Other models in Table 2 show the effect of adjustment for the main effects of established predictors of low birthweight. Note that addition of
these covariates does little to change the interaction between black ethnicity and age. Even after adjusting for the main effects of all these predictors in the ‘Main Effects Model’, there remains a significant interaction between black ethnicity and age. In this ‘Main Effects Model’, the OR of delivering a low birthweight infant was 1.04 (95% CI: 1.04–1.05) per year of maternal age among black women, compared to 1.02 (95% CI: 1.01–1.03) among white women. This ethnic divergence did not depend on maternal parity (P = 0.99 for the interaction of the ethnicity*age slope with primiparity). The risk of low birthweight rose with age among white women in the ‘Main Effects Model’ because it sets levels of maternal education, parity, smoking status, prenatal care, marital status, and Neighbourhood Poverty equal to those more typical of black mothers. The fact that the age slopes diverge even after adjustment for these variables indicates that their main effects do not fully explain the steeper trajectory of risk with age for black women.

However, interactions between other risk factors and maternal age might explain the steeper age slope among blacks. The ‘Interaction Model’ adds to the ‘Main Effects Model’ terms to represent interactions of maternal age with education, marital status, parity, level of Neighbourhood Poverty, and cigarette smoking, as well as an interaction between maternal ethnicity and marital status. The results of this ‘Interaction Model’ are contrasted to those of the ‘Main Effects Model’ in Table 2. Statistically significant interactions were observed of maternal age with marital status (P < 0.0001), Neighbourhood Poverty level (P = 0.01), adequacy of prenatal care (P = 0.002), and cigarette smoking (P = 0.02). The interaction between maternal education and age approached conventional statistical significance (P = 0.08). Marital status also appeared to interact with ethnicity (P < 0.0001). In this ‘Interaction’ model, the interaction between ethnicity and age was no longer statistically significant (P = 0.61). In this model, the OR of delivering a low birthweight infant was 1.05 (95% CI: 1.04–1.06) per year of age for blacks, and 1.05 (95% CI: 1.04–1.06) per year of age for whites.

Maternal age appeared to interact with marital status, Neighbourhood poverty, adequacy of prenatal care, and cigarette smoking (Table 2; the following OR are derived from the combination of relevant terms from the Interaction Model). At age 20, compared to unmarried women of the same ethnicity, married black women enjoyed an OR of 0.90 (95% CI: 0.79–1.02), and married white women had an OR of 0.67 (95% CI: 0.58–0.79). By age 40, the protective association with marriage was even stronger for both black and white women (OR = 0.55 [95% CI: 0.48–0.64] for 40 year old black women and OR = 0.41 [95% CI: 0.35–0.49] for 40 year old white women). At either age, marriage had a stronger protective association for white women than for black women. The relative risk of low birthweight associated with Neighbourhood poverty also grew with maternal age: the OR for living in a Neighbourhood where 50% of households were in poverty, compared with 1% of households, was 1.00 (95% CI: 0.91–1.10) at age 20, and grew to 1.34 (95% CI: 1.13–1.56) by age 40. Similarly, relative risks of smoking appeared to accelerate with age. At age 20, the OR of low birthweight associated with cigarette smoking during pregnancy was 1.94 (95% CI: 1.76–2.15). At age 40, the OR for smoking was 2.47 (95% CI: 2.18–2.79). Compared with women who received no prenatal care, late prenatal care, or whose prenatal care status was unknown, women who received first trimester care had OR for low birthweight of

<table>
<thead>
<tr>
<th>Maternal Ethnicity</th>
<th>Maternal age (years)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15–17</td>
<td>18–19</td>
<td>20–24</td>
<td>25–29</td>
<td>30–34</td>
<td>35–45</td>
</tr>
<tr>
<td>No. of births &lt;2500 g</td>
<td>White</td>
<td>67</td>
<td>95</td>
<td>275</td>
<td>431</td>
<td>454</td>
</tr>
<tr>
<td>Total births</td>
<td>White</td>
<td>600</td>
<td>1212</td>
<td>4870</td>
<td>8541</td>
<td>9613</td>
</tr>
<tr>
<td>Low birthweight (%)</td>
<td>White</td>
<td>11.2</td>
<td>7.8</td>
<td>5.6</td>
<td>5.0</td>
<td>4.7</td>
</tr>
<tr>
<td>No. of births &lt;2500 g</td>
<td>Black</td>
<td>962</td>
<td>1031</td>
<td>2494</td>
<td>2046</td>
<td>1678</td>
</tr>
<tr>
<td>Total births</td>
<td>Black</td>
<td>8098</td>
<td>9393</td>
<td>20835</td>
<td>13971</td>
<td>9139</td>
</tr>
<tr>
<td>Low birthweight (%)</td>
<td>Black</td>
<td>11.9</td>
<td>11.0</td>
<td>12.0</td>
<td>14.6</td>
<td>18.4</td>
</tr>
<tr>
<td>Married (%)</td>
<td>White</td>
<td>12.2</td>
<td>27.2</td>
<td>58.0</td>
<td>84.5</td>
<td>91.8</td>
</tr>
<tr>
<td>Primiparous (%)</td>
<td>White</td>
<td>83.5</td>
<td>63.1</td>
<td>44.5</td>
<td>42.0</td>
<td>36.2</td>
</tr>
<tr>
<td>Parity &gt;3 (%)</td>
<td>White</td>
<td>0.2</td>
<td>2.7</td>
<td>11.8</td>
<td>14.8</td>
<td>17.6</td>
</tr>
<tr>
<td>1st trimester prenatal care (%)</td>
<td>White</td>
<td>57.2</td>
<td>63.5</td>
<td>72.5</td>
<td>84.0</td>
<td>88.9</td>
</tr>
<tr>
<td>Cigarette smokers (%)</td>
<td>White</td>
<td>15.3</td>
<td>20.4</td>
<td>16.5</td>
<td>11.2</td>
<td>8.7</td>
</tr>
<tr>
<td>Graduated from high school (%)</td>
<td>White</td>
<td>13.0</td>
<td>50.8</td>
<td>73.5</td>
<td>90.2</td>
<td>94.1</td>
</tr>
<tr>
<td>Neighbourhood households in poverty (%)</td>
<td>White</td>
<td>13.1 [0.5]</td>
<td>11.8 [0.3]</td>
<td>10.6 [0.1]</td>
<td>8.4 [0.1]</td>
<td>7.6 [0.1]</td>
</tr>
</tbody>
</table>

Table 1: Distribution of births and risk factors for delivery of a low birthweight child, by maternal age and ethnicity. Singleton births to black and white women, Chicago, 1994–1996

a Percentage of households in the mother’s residential Neighbourhood that had incomes below the federal poverty level, according to 1990 US Census.
<table>
<thead>
<tr>
<th>Feature</th>
<th>Unadjusted Model</th>
<th>Main Effects Model</th>
<th>Interaction Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>1.00 (0.99–1.01)</td>
<td>1.02 (1.01–1.03)</td>
<td>1.00 (0.99–1.01)</td>
</tr>
<tr>
<td>Black</td>
<td>0.87 (0.62–1.22)</td>
<td>0.67 (0.48–0.93)</td>
<td>0.90 (0.65–1.26)</td>
</tr>
<tr>
<td>Married</td>
<td>0.50 (0.47–0.54)</td>
<td>0.65 (0.61–0.70)</td>
<td>1.10 (0.78–1.55)</td>
</tr>
<tr>
<td>Education(^b)</td>
<td>0.62 (0.59–0.66)</td>
<td>0.85 (0.80–0.90)</td>
<td>1.08 (0.81–1.42)</td>
</tr>
<tr>
<td>Parity 2</td>
<td>0.89 (0.82–0.96)</td>
<td>0.83 (0.77–0.90)</td>
<td>0.84 (0.78–0.91)</td>
</tr>
<tr>
<td>Parity 3</td>
<td>0.99 (0.92–1.08)</td>
<td>0.86 (0.79–0.93)</td>
<td>0.87 (0.81–0.94)</td>
</tr>
<tr>
<td>Parity 3+</td>
<td>1.29 (1.21–1.39)</td>
<td>0.93 (0.86–1.00)</td>
<td>0.93 (0.87–1.00)</td>
</tr>
<tr>
<td>Prenatal care(^b)</td>
<td>0.63 (0.60–0.66)</td>
<td>0.75 (0.71–0.78)</td>
<td>1.11 (0.86–1.42)</td>
</tr>
<tr>
<td>Smoking</td>
<td>2.58 (2.45–2.72)</td>
<td>2.17 (2.06–2.30)</td>
<td>1.53 (1.15–2.03)</td>
</tr>
<tr>
<td>Poverty(^c) (1% change)</td>
<td>1.01 (1.01–1.01)</td>
<td>1.00 (1.00–1.00)</td>
<td>0.99 (0.99–1.00)</td>
</tr>
<tr>
<td>Black*age</td>
<td>1.05 (1.04–1.06)</td>
<td>1.04 (1.03–1.06)</td>
<td>1.04 (1.03–1.06)</td>
</tr>
<tr>
<td>Married*age</td>
<td>0.98 (0.97–0.99)</td>
<td>0.99 (0.98–1.00)</td>
<td>0.99 (0.98–0.99)</td>
</tr>
<tr>
<td>Education*age(^a)</td>
<td>0.99 (0.98–1.00)</td>
<td>1.01 (1.00–1.02)</td>
<td>1.00 (1.00–1.00)</td>
</tr>
<tr>
<td>PNC*age(^b)</td>
<td>0.98 (0.98–1.00)</td>
<td>1.01 (1.00–1.02)</td>
<td>1.00 (1.00–1.00)</td>
</tr>
<tr>
<td>Smoking*age</td>
<td>0.99 (0.98–0.99)</td>
<td>1.33 (1.16–1.53)</td>
<td>1.33 (1.16–1.53)</td>
</tr>
<tr>
<td>Poverty*age(^c)</td>
<td>1.00 (1.00–1.00)</td>
<td>1.00 (1.00–1.00)</td>
<td>1.00 (1.00–1.00)</td>
</tr>
</tbody>
</table>

\(^a\) Education denotes a high school degree.

\(^b\) Prenatal care (PNC) denotes receipt of adequate prenatal care (received first trimester care versus later care, no care, or unknown care).

\(^c\) Per cent of households in the mother's residential neighbourhood that had incomes below the federal poverty level, according to 1990 US Census.

\(^\ast\) Asterisks are used to indicate where CI that were rounded to 1.00 excluded 1.00 before being rounded to two decimal places.
and colleagues, who documented ethnic age-divergence in the risk of delivering a low birthweight baby among black and white mothers, confirming Geronimus’ original observations in Michigan that the ethnic birthweight gap was amplified with age.7 Our findings also agree with those of Rauh and colleagues, who documented ethnic age-divergence in the risk of low birthweight in New York City.8 In all three studies, adjustment for markers of maternal social and economic disadvantage diminished the ethnic age divergence.

Although these studies agree in their broad strokes, there are some important differences in their findings. Rauh and colleagues tested all possible interactions between maternal age and risk factors for low birthweight in New York. Only maternal ethnicity and Medicaid status interacted significantly with age. In New York, even after adjustment for main effects of established risk factors and the interaction of maternal age with Medicaid status, there remained a significant interaction between maternal age and ethnicity, such that the OR of having a moderately low birthweight infant for African American women (compared with white) rose from 1.8 at age 20 to 2.6 at age 40, while the OR of having a very low birthweight infant rose from 2.5 to 4.2.

In contrast, in Chicago we found that most markers of socioeconomic status interacted with maternal age. The Chicago birth certificates did not include Medicaid status, so we were unable to test for the interaction between age and Medicaid status detected in New York. Although it is possible that the interactions of maternal age with neighbourhood poverty, marital status, and education might have been explained by Medicaid status, it seems more likely that all these factors capture overlapping, but not identical, facets of socioeconomic position. In Chicago, the age trajectories in risk of low birthweight were significantly steeper for women who were unmarried, smoked, lived in a poor neighbourhood, or who received inadequate prenatal care. Adjustment for these interactions with age eliminated the interaction between maternal ethnicity and age in Chicago. In other words, the risk of delivering a low birthweight child rose with maternal age for both white and black women who were unmarried, smoked, lived in a poor neighbourhood, smoked cigarettes, or received inadequate prenatal care.

Although this analysis in Chicago revealed increasing risk of low birthweight with advancing age among disadvantaged white and black mothers, social disadvantage was disproportionately borne by black women. This explains why the unadjusted data show a steep rise in risk of low birthweight with maternal age particular to black women. It should also be noted that, even after adjustment for multiple risk factors, there remained a twofold OR of low birthweight for black women compared with white women at any age. The failure to explain the overall ethnic birthweight gap with standard measures of current socioeconomic status is consistent with many previous studies.2–6

Several competing hypotheses can be marshalled to explain the apparent amplification of social and economic risk factors with age. First, the interactions could simply reflect a greater impact of recent exposures among older pregnant women. For example, the interaction between smoking and maternal age (which was also reported by Cnattingius et al. in Sweden)12 could indicate that smoking during pregnancy has a more detrimental impact on perinatal outcomes among older mothers. Along the same lines, prenatal care might yield more benefit to older mothers, who carry more risks of complications.

An alternative hypothesis posits that the high risk of poor pregnancy outcome among disadvantaged older mothers is the result of selective social mobility: less healthy women may ‘drift downwards’ into poverty as they age. Thus, it has been argued that poor health causes poverty, rather than poverty causing poor health.13,14 If ill health or other unmeasured risk factors for poor pregnancy outcome caused widespread downward mobility between ages 20 and 45 years, health risk might cluster among older disadvantaged women. Although this could theoretically produce the divergent age gradients observed in this study, selective mobility would have to be quite strong to account for such large social class differentials.15 It seems unlikely that most women bearing children in poor neighbourhoods are trapped there by ill health. In fact, there is evidence that childhood poverty precedes poor pregnancy outcome: low birthweight is better predicted by socioeconomic conditions in childhood than during the pregnancy.16–18

Finally, interactions between maternal age and risk factors could reflect a ‘weathering’ effect of cumulative disadvantage.
as women age. The ‘weathering hypothesis’ was coined by Geronimus, who proposed that health may begin to deteriorate in early adulthood as a physical consequence of cumulative socioeconomic disadvantage. A similar view is promoted by the ‘life course approach’, which emphasizes the cumulative health impact of social, biological, and psychological processes from conception to death. Both the ‘life course approach’ and the ‘weathering hypothesis’ suggest that social inequalities cause premature ageing. According to these approaches, the accumulating burdens of poverty and discrimination compromise a woman’s health and chances of delivering a healthy infant, even before she conceives the pregnancy. Our observation of steep age gradients among the most disadvantaged black and white women is consistent with these approaches. Seen through a ‘weathering’ lens, for disadvantaged populations, maternal age becomes a marker of duration of exposure to hardship. For example, an interaction between poverty and maternal age may capture a degrading impact of long-lasting poverty on health. Likewise, the interaction between prenatal care and maternal age could indicate a deterioration in health resulting from lack of health care throughout childhood and the reproductive years. With similar logic, the interaction between smoking and age could reflect cumulative damage from long-term smoking.

Cross-sectional data such as these collected in Michigan, New York, and Chicago cannot reveal which of these three hypotheses—true interactions with advanced maternal age; downward social mobility among the unhealthy; or ‘weathering’—are responsible for the significant interactions of maternal age with social and economic risk factors. These hypotheses are not mutually exclusive; all three mechanisms may contribute to the very high risk of poor pregnancy outcome among older disadvantaged women. Definitive evidence distinguishing these alternatives will come only from a longitudinal study with multiple observations of the same woman over time, linking changing exposures to sequential pregnancy outcomes. Although vital statistics datasets may be large enough to test such interactions, they typically lack longitudinal exposure information. There are other limitations to data collected for vital statistics purposes, including limited scope and varying degrees of accuracy.

Although it cannot provide proof, this analysis provides supporting evidence that the lifelong tolls of social and economic disadvantage constitute powerful ‘weathering’ forces that age women prematurely by wreaking cumulative physiological damage. If so, efforts to improve birth outcomes must safeguard and enhance the health of disadvantaged women long before they become pregnant. Future longitudinal studies are needed to establish definitively whether, and how, women are ‘weathered’ by socioeconomic disadvantage.

Acknowledgements

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KEY MESSAGES

- In the urban US, the risk of delivering a low birthweight infant generally rises with maternal age for black mothers, while it drops with age for white mothers.
- Some, but not all, of the ethnic divergence in maternal age trends is explained by the main effects of social and economic risk factors for low birthweight. In this analysis, further adjustment for the interaction of maternal age with these risk factors completely explained the ethnic divergence in the risk of low birthweight associated with increasing maternal age.
- Thus, older mothers at social and material disadvantage were at especially high risk of poor pregnancy outcome, regardless of ethnicity. Future longitudinal studies are needed to determine whether this high risk among older disadvantaged mothers indicates a cumulative, ‘weathering’ exposure to hardship.

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mothers were
infant mortality rates for teens were high, but those for older
health show similar patterns. For example, in Harlem in 1990,
and Michigan (1989) 3 Studies using other indicators of infant
Rich-Edwards, Buka, Brennan, and Earls1 analyse citywide birth
certificate data from New York City (1987–1993)2
increase risk of low birthweight with advancing maternal age
behavioural—is not sufficiently rich or reliable. Geocoding birth
certificate data—socioeconomic, health, or
maternal information
suffer from chronic disease. African-American women
20 years old. However, probably little more can be learned from analysing
birth certificate data. Infant health may be used to proxy
maternal health, but it cannot replace direct inspection of the
health of girls and women. Moreover, the maternal information
available on birth certificates—socioeconomic, health, or
is not sufficiently rich or reliable. Geocoding birth
certificate data has enabled description of important geo-
ographical differences, suggesting the role of residential context.
However, for the task of explicating underlying mechanisms
and social processes, geocoding is a grossly insufficient remedy
for the lack of socioeconomic data.5

Population variation in maternal-age patterns of birth out-
come should be placed in the broader investigative contexts
of women’s health and structural health inequality. As Rich-
Edwards et al. suggest, taking a cumulative life-course approach
is likely to be constructive. The theory of ‘weathering’ provides
a model.3,4 The cumulative life-course approach has sparked
interest among social epidemiologists concerned with diseases of middle to old age,6 but there is no reason that it should not
be applicable to the reproductive ages as well. Substantial per-
centages of African-American women in their 20s or early 30s
already suffer from chronic disease. African-American women
in some high-poverty urban areas report rates of health-induced
disabilities at age 35 or 55 that are comparable to the national

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Commentary: Weathering Chicago

Arlene T Geronimus

Rich-Edwards, Buka, Brennan, and Earls1 analyse citywide birth
certificate data from Chicago for 1994 through 1996. They find
increased risk of low birthweight with advancing maternal age
(beginning at age 15) for black mothers in their unadjusted data, and an even steeper increase with maternal age among socio-
economically disadvantaged women, black or white. Previous
researchers taking similar empirical approaches have arrived at generally similar findings for African American mothers,

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