UNITED STATES LOW BIRTH WEIGHT SINCE 1950: DISTRIBUTIONS, IMPACTS, CAUSES, COSTS, PATTERNS, MATHEMATICAL MODELS, PREDICTION AND PREVENTION (II)

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This is the second part of a series of studies on the United States national low birth weight. The focus of this part includes: estimating the first year treatment costs associated with the care of low birth weight infants, describing the long-term expenses, analyzing medical causes and risk factors which can result in low birth weight, and proposing preventive strategies that may reduce the chances of low birth weight. Global low birth weight status will be briefly discussed. For definitions, terms and abbreviations, please refer to our previous work (same title) with the Scientific Inquiry, where a number of existing research papers on low birth weight are also listed in the references.

Keywords: Low birth weight, infant mortality, cause, prevention, treatment cost, lifetime expense, global low birth weight

1. LOW BIRTH WEIGHT: THE FIRST YEAR TREATMENT COSTS AND LIFETIME EXPENSES

In 1998, Rogowski (1998) studied the cost-effectiveness of care for VLBW infants, and calculated the medical costs for 887 California single VLBW weight infants for the time period 1986-1987. The average treatment cost for the first year per such infant was estimated as $59,700 (1987 dollars) and the aggregate treatment cost per first year survivor was $93,800. For the 20% of VLBW infants born in multiple births in the state, no cost estimation was made, which could be higher or lower depending on the timing of death.

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On the other hand, in 2005, Almond and Chay, et al. studied the treatment cost for LBW infants born in twin births between 1983 and 2000 (Almond and Chay, 2005). The data used were linked birth and infant death micro data (1983-1997) produced by the United States National Center for Health Statistics and the Healthcare Cost & Utilization Project (HCUP) State Inpatient Database (1995-2000) produced by the U.S. Department of Health and Human Services (New York, New Jersey and Maryland data only). Although twins represent a small subpopulation of all infants born in the U.S., they are of great interest in health and biomedical literature for several reasons. First, while constituting about 3% of all births in recent years in the nation, twins accounted for more than 30% of all LBW births, 14% of preterm births, and 13% of all infant deaths. Further, twin births have accounted for an increasing share of all LBW infants over the past 20 years. In general, twins tend to be lighter, with a mean birth weight about 950 grams lower than singleton newborns. Table 1 below summarizes the excess hospital costs associated with LBW, which, together with Rogowski's estimates, will be used to estimate the national costs for caring LBW infants in their first year.

### Table 1: Implied Excess Hospital Costs Associated with Low Birth Weight

<table>
<thead>
<tr>
<th>Birth Weight (g)</th>
<th>Percent of Singleton</th>
<th>Excess Hospital Cost$^1$</th>
<th>Pooled ($)</th>
<th>Fixed Effects ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 600</td>
<td>0.18</td>
<td></td>
<td>51803</td>
<td>61213</td>
</tr>
<tr>
<td>600-800</td>
<td>0.16</td>
<td></td>
<td>131589</td>
<td>67816</td>
</tr>
<tr>
<td>800-1000</td>
<td>0.19</td>
<td></td>
<td>127190</td>
<td>36846</td>
</tr>
<tr>
<td>1000-1500</td>
<td>0.55</td>
<td></td>
<td>74706</td>
<td>22309</td>
</tr>
<tr>
<td>1500-2000</td>
<td>1.11</td>
<td></td>
<td>25137</td>
<td>6806</td>
</tr>
<tr>
<td>2000-2500</td>
<td>3.95</td>
<td></td>
<td>3417</td>
<td>604</td>
</tr>
</tbody>
</table>

$^1$ The entries represent the average reduced hospital costs (in 2000 dollars) associated with increasing an infant's birth weight from the given birth weight category to above 2500 grams.

In 2002, the numbers of LBW infants with birth weights < 500g, 500-999g, 1000-1499g, 1500-1999g and 2000-2499g were 6,268, 22,845, 29,431, 61,652, 193,881, respectively. The total number of VLBW infants was 58,544 with an estimated total first year medical costs 58,544 × $59,700 = 3.5 billion (1987 dollars) from Rogowski's estimation method; for MLBW infants, the figure was 255,533 with an estimated total first year medical costs 61,652 × $25,137 + 193,881 × $3,417 = 2.2 billion (2000 dollars) from Almond and Chay's polled estimation, which may be lower or higher than the actual costs since the treatment might have to be continued when an infant's weight reached 2500 grams or the treatment might stop when an infant died before reaching 2500 grams. Therefore, the total first year treatment costs for LBW infants born in 2002 are estimated as 3.5 + 2.2 = 5.7 billion dollars (2000 dollars).

As for the validity of above estimates, Medicaid alone paid $19.5 million dollars in 2000 for the treatment of all 2740 LBW infants of Kansas State (which was 36% of the 54.1 million dollars spent by Kansas Medicaid for first-year-of-life treatment for all babies born in 2000). In the same year, the total number of LBW infants in the U.S. was 307,030, which was 112.06 times that of Kansas. Hence, nationwide, Medicaid alone paid approximately 112.06 × $19.5 million = 2,185 million or 2.185 billion dollars in 2000 (The Medicaid population in 2000 was 33,690,364 or 12.0% of the total population, and had higher LBW rate). For Kansas in 2000, the average treatment costs ($16,000) for LBW and premature babies were about 5 times more expensive during the first year of life than normal birth weight babies ($3,100), as given in "A Report to the Legislative Post Audit Committee By the Legislative Division of Post Audit State of Kansas" in June 2003). Hence, the treatment costs for the U.S. LBW infants in 2000 may be estimated as 307,030 × $16,000 = 4.91 billion dollars, compared to the previously estimated 5.7 billion. The LBW rates of Kansas were lower but close to the national averages in years since 1990.

Above estimations are more conservative, compared to a bill (below) introduced in the U.S. Senate.
LBW birth, as well as preterm birth, is a significant financial burden in health care. According to a bill introduced in the U.S. Senate, PREEMIE Act, 109th CONGRESS, S. 707, the estimated charges for hospital stays for infants with any diagnosis of LBW/prematurity were as high as $15.5 billion dollars in 2002. On average, LBW babies were in the hospital 12 days, or 6 times longer than normal birth weight babies at 2 days. The differences are even more dramatic between normal birth weight babies and VLBW babies, who averaged 28 days in the hospital.

Compared to the first year treatment costs, long-term expenses of LBW infants are even higher. Many of these LBW babies will have to be re-hospitalized in order to keep them alive after they survive their first year. In addition, medical, social services and special education expenses can continue throughout their lifetime. The average lifetime medical costs of a premature baby are conservatively estimated at $500,000. Decreasing the LBW rate requires improvements in the practices and behavior of the women themselves during and before pregnancy. Risk-taking behaviors or inattention to healthy practices while pregnant is a documented cause of LBW. An effective way to change these behaviors is to engage women in making lifestyle changes when becoming sexually active and/or early in pregnancy.

Babies who are born below normal birth weight are at a greater risk of experiencing vision and hearing impairment, hyperactivity, cerebral palsy, poor concentration, developmental delays, school failure, and mental retardation. In addition, they are almost 50% more likely to require special education services. Recent research also indicates a link between LBW and adult conditions such as hypertension, diabetes and cardiovascular disease. Some researchers indicate that common genetic factors may underlie both birth weight and cardiovascular disease and a child’s birth characteristics can serve as an indicator of not only a mother’s health, but also a father’s. Some studies suggest a lifecycle: women who are underweight at birth are more likely to deliver underweight infants. In general, all researchers agree that the smaller the newborn, the more developmental hardships the infant will experience.

2. LOW BIRTH WEIGHT: A GLOBAL PROBLEM

The Lancet Neonatal Survival Steering Team, composed of researchers at many universities and charitable organizations, estimated that four million neonatal deaths (approximately two-thirds of all infant deaths) occur among the 130 million babies born worldwide each year (and another four million stillborns) (Zupan and Aahman, 2005; Lawn and Cousins, 2005).

In 2004, a publication by the United Nations Children’s Fund (UNICEF) and World Health Organization (WHO) estimated the worldwide LBW rates by country and by region for 2000 or years around 2000 (Wardlaw and Blanc, 2004): The number of live births was 132,882 (in thousands), the number of LBW infants was 20,629 (in thousands) and the LBW rate was 15.5%. LBW rates for more developed, less developed, and least developed countries were 7.0%, 16.5%, and 18.6%, respectively. Asia had the highest rate (18.3%), Europe had the lowest (6.4%), and Northern America had the second lowest (7.7%) (the U.S. national rate for 2000 was 7.6%). A number of countries had rates between 4% and 7%, and there were a few countries which had 3%. Approximately 1% of infant deaths occurred in industrialized countries. Two-thirds occurred in 10 countries: India, China, Pakistan, Nigeria, Bangladesh, Ethiopia, Congo, Indonesia, Afghanistan and Tanzania. Among the new information was the calculation that at least 41% of the four million deaths, and possibly as much as 72%, could be prevented if current knowledge were put to use.

Worldwide, the incidence of LBW appears not to have changed significantly from 1990 to 2000. During this period, more than 20 million infants were born with LBW each year, and this was a major reason for the four million infant deaths each year. More than 95% of LBW babies were born in developing countries, and the number of LBW babies is concentrated in two regions of the developing world: Asia and Africa. 72% of LBW infants in developing countries were born in Asia where most births also take place, and 22% were born in Africa. India alone accounted for 40% of low weight births in the developing world and more than half of those in Asia. There were more than one million infants born with LBW in China (1.146 millions in 1999) and nearly eight millions in India (7.837 millions). Latin America and the Caribbean, and Oceania had the lowest number of LBW infants, with 1.2 million and 27,000, respectively. Among the more developed regions, North America averaged

8%, while Europe had the lowest regional average (6%). The level of LBW in developing countries (16.5%) was more than double the level in developed regions (7%) (Wardlaw and Blanc, 2004; Bang and Reddy, 2002). At present, the LBW and infant mortality remain at similar levels.

3. LOW BIRTH WEIGHT: THE CAUSES

Prematurity and intrauterine growth retardation, a condition where foetal growth has been constrained, are the two main causes of LBW. LBW is closely associated with foetal and neonatal mortality and morbidity, inhibited growth and cognitive development, and chronic diseases later in life (Pojeta and Kelley, 2000; Barker, 1992). The majority of LBW infants in developing countries are due to intrauterine growth retardation, while most LBW infants in industrialized countries are due to preterm birth. In the U.S., for White population, preterm birth seems to be the major cause of LBW, for minority particularly African Americans, the major causes seem to be both preterm birth and intrauterine growth retardation. In addition, the delayed maternal age since 1980’s (Greaver and Wei, 2006) resulted in significant increases for multiple births which in turn resulted in large number of LBW infants.

In many cases, the exact causes of prematurity are unknown; they may include high maternal blood pressure, acute infections, hard physical work, multiple births, stress, anxiety, other psychological factors, maternal age, and behavior risk-factors. Causes of intrauterine growth retardation are complex and multiple, but center on the foetus, the placenta, the mother, and combinations of all three (Pojeta and Kelley, 2000). The maternal environment is the most important determinant of birth weight, and factors that prevent normal circulation across the placenta cause poor nutrient and oxygen supply to the foetus, restricting growth. These factors may include maternal malnutrition, malaria (where it is endemic), anaemia, and acute and chronic infections (such as sexually transmitted diseases and urinary tract infections). Foetal, genetic or chromosomal anomalies, first-time births, multiple births, as well as maternal disorders such as renal diseases and hypertension, are also associated with intrauterine growth retardation. Cigarette smoking (a most significant and modifiable risk factor for LBW incidence) and preeclampsia cause the highest relative risks for intrauterine growth retardation in industrialized countries, while alcohol and drug use may also restrict foetal growth. A WHO research found that LBW that results from suboptimal intrauterine growth is associated with three major risk factors: cigarette smoking during pregnancy, low maternal weight gain, and low pre-pregnancy weight. These three risk factors account for nearly two-thirds of all growth-retarded infants (Kramer, 1987a).

Maternal smoking during pregnancy, considered the most important modifiable cause of LBW in the U.S., is believed to reduce birth weight by about 200 grams on average. In 2002, LBW rate for maternal Smokers was 12.2%, compared to 7.5% for Non-Smokers (Martin and Hamilton, 2003). The median twin would be considered a LBW baby (2417 grams), and also born prematurely (36.0 weeks). For singletons, these figures were 3,369 and 39.3 (Almond and Chay, 2005; Kramer, 1987b).

4. LOW BIRTH WEIGHT: THE PREVENTION VS CARE

The weight of an infant at birth is an important indicator of maternal health and nutrition prior to, and during pregnancy, and a powerful predictor of infant growth and survival. Infants born with LBW suffer from extremely high rates of morbidity and mortality from infectious disease, and underweight, stunting or wasting beginning in the neonatal period through childhood (Pojeta and Kelley, 2000). The impact of LBW is very complex and may even pass from one generation to the next - a lifecycle. As such, LBW remains a major public health concern for the nation (and for the world).

Like infant mortality, Minority LBW rate (11.60% in 2002) is close to twice of White LBW rate (6.80% in 2002) and Black LBW rate (13.28% in 2002) is still twice of White LBW rate (Martin and Hamilton, 2003). As a result of such racial disparities, LBW rates vary geographically due to the high percentages of Black population: Alabama, Delaware, District of Columbia, Louisiana, Mississippi, South Carolina, Puerto Rico and Virgin Islands had highest LBW rates (9.9 to 11.8) in 1999-2002.
Notice that these states also had highest infant mortality rates between 1999 and 2002 (Greaver and Wei, 2006).

Dramatically improved medical technologies greatly improved the infants' survival chances and maternal health since the middle of last century (Table 2 below). Particularly, these technologies could keep many LBW infants alive and, as a consequence, have significantly reduced infant mortalities since last century. However, it seems that improved medical technologies do not directly help much to reduce the incidence of LBW. In fact, there was no drop in the rate of LBW since 1980 (6.8% in 1980, 7.8% in 2002 and averaging 7.4% since 1962), and the long-term patterns of periodic change for LBW rates (by Total, White and Black) since the middle of last century are given in Figure 3 of our previous research (Greaver and Wei, 2006).

Table 2: One-Year Survival Rates of Singleton Low Birth Weight Infants by Birth Weight, United States, 1960, 1980 and 2000
Table Source: (Reichman, 2005)

<table>
<thead>
<tr>
<th>Birth Weight Range</th>
<th>1960</th>
<th>1980</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1000 grams</td>
<td>9%</td>
<td>27%</td>
<td>57%</td>
</tr>
<tr>
<td>1500-1499 grams</td>
<td>45%</td>
<td>79%</td>
<td>93%</td>
</tr>
<tr>
<td>1500-2499 grams</td>
<td>91%</td>
<td>97%</td>
<td>98%</td>
</tr>
</tbody>
</table>

Recently, some researchers proposed a theory on LBW lifecycle - a ripple effect: Women who are underweight at birth are more likely to deliver underweight infants. Skjaerven and Wilcox found that A mother's birth weight was strongly associated with the weight of her baby (Skjaerven and Wilcox, 1997). Maternal birth weight was associated with perinatal survival of her baby only for mothers with birth weights under 2000 grams. These mothers were more likely to lose a baby in the perinatal period (odds ratio, 2.3, 95% confidence interval 1.4 to 3.7). Among mothers with a birth weight over 2000 grams there was no overall association between mother's weight and infant survival. There was, however, a strong interaction between mother's birth weight, infant birth weight, and infant survival. Mortality among small babies was much higher for those whose mothers had been large at birth. For example, babies weighing 2500-2999 grams had a threefold higher mortality if their mother's birth weight had been high (≥ 4000 grams) than if the mother had been small (2500-2999 grams). Mothers who weighed less than 2000 grams at birth have a higher risk of losing their own babies. For mothers who weighed ≥ 2000 grams their birth weight provides a benchmark for judging the growth of their offspring. Babies who are small relative to their mother’s birth weight are at increased risk of mortality (Pojda and Kelley, 2000).

Many health experts and researchers believe up to 75% of LBW can be preventable (Darmstadt and Bhutta, 2005), and hence up to 50% of infant deaths could be avoided because approximately 68% infant deaths occur to LBW infants. However, there is an immediately need for the action (Martines and Paul, 2005). Prenatal care has long been endorsed as a means to identify mothers at risk of delivering a preterm or growth-retarded infant and to provide an array of available medical, genetic, psychosocial (smoking, substance use, stress etc), environmental, nutritional (pre-pregnancy weight and weight gain), and educational interventions intended to reduce the determinants and incidence of LBW and other adverse pregnancy conditions and outcomes. Lifestyle behaviors such as cigarette smoking, weight gain during pregnancy, and use of other drugs play an important role in determining fetal growth. The relationship between lifestyle risk factors and LBW is complex and is affected by psychosocial, economic, and biological factors. Of these risk factors, cigarette smoking is a largest known risk factor for LBW. Approximately 20% of all LBW could be avoided if women did not smoke during pregnancy. Reducing heavy use of alcohol and other drugs during pregnancy could also reduce the chances of LBW. As studied in our previous work (Greaver and Wei, 2006), LBW is closely associated with maternal age, gestational age, multiple births, total fertility rate, birth rates and birth percentages by maternal age (to be studied in a subsequent paper). Racial, ethnic and geographic disparities are also significant reasons of high LBW rates but this will not be further studied in this research.
Acknowledgments

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References