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

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Low birth weight often results in infant death, particularly during the neonatal period, and causes severe developmental hardships and life-long disabilities for the survivors. In recent years, more than two-thirds of all infant deaths in the United States occurred to the slightly less than eight percent of infants born at low birth weight. The long-term trend of increase in low birth weight infants has finally halted the reduction of infant mortality at present and further it is triggering a national alert: a century-long trend of decline in infant mortality was reversed when the infant mortality rate rose for the first time in more than three decades to 7.0 in 2002 from 6.8 in 2001 (6.9-preliminary in 2003). The authors conducted wide and deep research on low birth weight using the national birth data for all the years from 1950 to 2003, recent infant mortality statistics, and a number of existing research results to (1) study its distributions, investigate its impacts on infant mortality, and explore its relations to other primary indicators including gestational age, plurality, maternal age, fertility rate, birth rates, and birth percentages by maternal age; (2) estimate its treatment costs, analyze its medical causes and risk factors, and propose prevention strategies; and (3) recognize its patterns of change, establish its mathematical and statistical models, and predict its trends for the 21st century using these models. Research results for the topics under (2) and (3) above will be included in subsequent papers.

Keywords: Low birth weight, distribution, impact, infant mortality, gestational age, plurality, maternal age, fertility rate, birth rates, birth percentages by maternal age, cause, risk factor, prevention, treatment cost, pattern, Fourier analysis, regression, mathematics/statistical model, prediction, trend of low birth weight

1. INTRODUCTION

The Infant Mortality Rate (IMR), Neonatal Mortality Rate (NMR) and Postneonatal Mortality Rate (PMR) are the number of infant deaths under 1 year, less than 28 days, and from 28 to 364 days,

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respectively, relative to 1000 live births. The Maternal Mortality Rate (MMR) is the number of maternal deaths due to pregnancy-related complications, relative to 100,000 live births. From 1940 to 2001, the U.S. national IMR reduced exponentially from 47.0 to 6.8 (60 to 100 between 1900 and 1935), but then rose to 7.0 in 2002; from the beginning of the 20th century to 2002, the U.S. MMR also declined exponentially, from 850 to 8.9 (600 to 850 between 1900 and 1935) (Guyer and Freedman, 2000; Wei, 2003). The declines in IMR and MMR are more likely to be the results of dramatically improved medical technologies. Yet, in contrast with the nation's competitiveness in science, technology and high quality perinatal care systems, the national IMR ranks around 30th in recent years (Sweden (rank 1) has the lowest, 3.5, and Angola has the highest, 193.7). Within industrialized countries, the U.S. IMR and MMR remain higher than many others. Racial, ethnic and geographical disparities are widespread. For example, Minority IMR is still about twice of White IMR and Black IMR is still more than twice of White IMR; in 2002 or from 1999-2001 linked files, Alabama, Delaware, District of Columbia, Louisiana, Mississippi, South Carolina, Tennessee and Puerto Rico had 9.1 IMR or higher; Georgia, North Carolina and Virgin Islands had IMRs between 8.7 and 9.0; Maine, Massachusetts and Vermont had IMRs below 5.0 (Mathews and MacDorman, 2002; Mathews and Menacker, 2002a, 2003b; Kochanek and Murphy, 2004).

Throughout the last century, many efforts were made to improve or advance the environmental conditions, nutrition, clinical medicine, access to health care, surveillance and monitoring of disease, education particularly health education, and living standards (Centers for Disease Control and Prevention, 1999). Nevertheless, each year in the U.S., there are still about 28,000 infant deaths and 360 maternal deaths (International Classification of Diseases (ICD), 10th Revision) due to pregnancy-related complications (Mathews and Menacker, 2002a, 2003b; Kochanek and Murphy, 2004).

Low birth weight is a major cause of infant death and an internationally recognized important measure of infant and maternal health (of population health in general). This research is a comprehensive study of low birth weight including its distributions, impacts on infant mortality, relations to other primary health indicators including gestational age, multiple births and maternal age, treatment costs, medical causes, risk factors, prevention, patterns of change, mathematical/statistical models, and a prediction of the trends for the 21st century.

The Low Birth Weight (LBW) rate, Very Low Birth Weight (VLBW) rate and Moderate Low Birth Weight (MLBW) rate are the number of infants whose weights at birth are below 2500 grams, below 1500 grams and between 1500 and 2499 grams, respectively, relative to 100 live births. Though LBW accounts for approximately 16% of the total infant deaths according the ICD (10th Revision), it is a fact that more than two-thirds of all infant deaths in the U.S. occurred to the slightly less than eight percent of infants born at LBW; approximately two-thirds of neonatal deaths (which is about twice of postneonatal deaths) were LBW infants born preterm; and more than half of these infants were VLBW (MacDorman and Martin, 2005) for each year since 1950, which was probably an earliest year when the national annual birth weight data was completely recorded. As such, LBW is widely recognized as one of the most significant causes contributing substantially to infant mortality, severe childhood handicap and life-long disabilities; and LBW remains a major public health problem in the U.S. (and in fact for all the nations in the world).

Like infant and maternal mortalities, racial, ethnic and geographical disparities on LBW are widespread. Unlike infant and maternal mortalities, it appears that improved medical technologies do not directly reduce the incidence of LBW babies. In fact, the LBW rate substantially has been changing periodically (partially caused by the periodic changes of total fertility, birth rates, and birth percentages by maternal age) since 1950 with an average rate of 7.47% (from 1950 to 2003), increased almost in every year since 1980 (6.8%) (7.8% in 2002, 7.9% in 2003, 8.1%-preliminary in 2004) (Martin and Hamilton, 2002a, 2002b, 2003c, 2005d). The long-term trend of increase in low birth weight infants has finally halted the reduction of infant mortality at present and further it is triggering a national alert: a century-long trend of decline in infant mortality was reversed when the IMR rose for the first time in more than three decades to 7.0 in 2002 from 6.8 in 2001 (6.9-preliminary in 2003) (MacDorman and Martin, 2005; Hoyert and Kung, 2005).

This research also found that the LBW rate varies significantly by maternal age, it is lowest for the mothers ages 25-29 and 30-34, and it is highest for teen mothers and older mothers (35+); the High Birth Weight (HBW, birth weight ≥ 4000 grams) rate is positively proportional to maternal age. Moreover, LBW is often a result of short gestation or multiple births, and vice versa. Decline of LBW is essentially a problem of prevention and requires improvements in the practices and behavior of the women themselves during and before their pregnancy.

The total medical cost to care for LBW babies in their first year is conservatively estimated as high as 5.7 billion dollars for the United States, and the subsequent cost of LBW infants is even higher as many of these LBW babies will need to be re-hospitalized in order to keep them alive after they could survive their first year. In addition, long-term medical, social services and special education expenses can continue throughout their lifetime.

Particularly, the authors proposed frameworks including mathematical/statistical methods and four LBW models to discover the patterns of change for the U.S. national LBW from 1950 to 2003 and to identify significant factors that contribute to these patterns. The contents and methods are outlined as follows.

First, focus on the 2002 U.S. birth and infant death data to analyze the relations between LBW and relevant health indicators such as infant mortality, prematurity, multiple births, total fertility, and birth rates and birth percentages of individual maternal age groups, by using comparisons among relevant groups classified by birth weight, gestational age, plurality, maternal age and time. Also study the long-term patterns of change for these indicators (except mortality) using 1950 to 2002 data. Racial and geographic disparities on LBW and infant mortality are briefly discussed.

Second, estimate the first year treatment costs for the care of LBW infants using the 2002 birth data and describe the lifetime expenses. Then introduce the global LBW status to emphasize the importance of LBW problem, explore major medical causes of LBW (nationally and globally), and propose prevention recommendations.

Third, apply Fourier analysis to the annual LBW rates from 1961 to 2002 to recognize the patterns of change in LBW during this time period. The resulting model for LBW vs time shows that the LBW rate changes periodically (close to a sine curve) from 1961 to 2002. The model is then compared to the similar patterns of change for total fertility, birth rates and birth percentages by maternal age. By using this method, similar models can be established for LBW by racial/ethnic group, and for other measures such as VLBW, MLBW, and prematurity as well. Further, use the 1950 to 2002 birth data to analyze the correlations between the LBW rate and total fertility, birth rates and birth percentages of individual maternal age groups, respectively. Three multiple regression models on the LBW rate are established, which can be used to predict future LBW rates for the entire 21st century, where explanatory variables are the birth rates and birth percentages of the eight standard maternal age groups for which the U.S. Census Bureau has birth projections for all the years of the 21st century. These models may produce different estimations, but they are consistent overall. By applying these models along with the U.S. Census Bureau's projected birth data, predictions of the U.S. LBW rates for selected years between 2005 and 2100 are calculated.

2. BIRTH, LOW WEIGHT BIRTH AND INFANT DEATH DISTRIBUTIONS

According to the United States 2000 Census, Minority and African Americans were 24.86% and 12.32% of the total population, respectively. From the 2002 national birth and death data (Martin and Hamilton, 2003c; Kochanek and Murphy, 2004), the minority group had 846,966 or 21.06% of the total births (4,021,726), however accounted for 31.29% of the total LBW births with a LBW rate of 11.60% (1.71 times that of White, 6.80%), and for 34.48% of the total infant deaths with an IMR of 11.41 per 1,000 live births (1.97 times that of White, 5.97). Such a racial disparity was primarily resulted by the African American group, which had 14.76% of the total births in 2002, but accounted for 25.09% of the total LBW births with a LBW rate 13.28% (1.95 times that of White), and for 30.41% of the total infant deaths with an IMR of 14.36 (2.48 times that of White). The VLBW rates for African American and minority group were as high as 3.12% and 2.53%, or 2.7 and 2.2 times that of White, 1.17%. Additional details are summarized in Table 1 below.

The racial disparity between Minority (especially African American) and White was a significant factor for high LBW rates and high infant mortality in 2002. Caused by larger proportions of African American population, LBW and infant mortality rates were generally higher for states in Southeast and lower for states in the West and Northeast. Notice that New York, Texas, Georgia, Florida, California, Illinois and North Carolina have the largest Black populations (1.7 millions or more);

District of Columbia, Mississippi, Louisiana, South Carolina, Georgia, Maryland, Alabama and North Carolina have the largest percentages of Black population (21% or more). Thus, special attentions should be given to these states if they are not highlighted by IMRs, LBW rates and other primary health indicators. Rate declines in these states will significantly reduce the national rates. In general, geographical disparities are largely caused by racial disparities. Table 1 below gives the detailed birth, LBW and infant mortality distributions for the year of 2002.

Table 1: Distributions of Births, Infant Deaths and LBW infants by Race: United States, 2002
Data Source: National Center for Health Statistics[1]

		Total	White	Minority	Black
Population[2]	No	281421906	211460626	69961280	34658190
	%		75.14	24.86	12.32
Births	No	4021726	3174760	846966	593691
	%		78.94	21.06	14.76
Infant Deaths	No	28034	18369	9665	8526
	%		65.52	34.48	30.41
	Rate	6.97	5.79	11.41	14.36
LBW[3] Infants	No	314077	215799	98278	78813
	%		68.71	31.29	25.09
	Rate	7.81	6.80	11.60	13.28
VLBW Infants	No	58544	37092	21452	18542
	%		63.36	36.64	31.67
	Rate	1.46	1.17	2.53	3.12
MLBW Infants	No	255533	178707	76826	60271
	%		69.93	30.07	23.59
	Rate	6.35	5.63	9.07	10.15

[1] Data can be found in (Martin and Hamilton, 2003c) and (Kochanek and Murphy, 2004)
[2] This is the U.S. 2000 Census population for the 50 states and District of Columbia. 6,826,228 individuals of two or more races are included in the Minority Group.
[3] Birth weights for 2,992 (0.07%) infants classified as Not Stated not included.

In 2003, LBW, VLBW and MLBW rates continued to increase to 7.92, 1.45 and 6.48, respectively (Martin and Hamilton, 2005d). In 2004, the comparable figures were further up to (preliminary) 8.1, 1.47 and 6.6, respectively.

3. BIRTH WEIGHT VS INFANT MORTALITY

Birth weight is a most significant predictor of infant survival probabilities. In 2002, two-thirds (68.0%) of all infant deaths in the U.S. occurred to the 7.8% of infants born at LBW, and more than half (53.9%) of all infant deaths occurred to the 1.5% of infants born at VLBW. The infant mortality rates for above two groups of infants were as high as 59.5 and 250.8, or 25 and 105 times the rate 2.4 for infants born at normal weights (2500 grams or more) (Kochanek and Murphy, 2004). Figure 1 indicates the association of IMR with birth weight: IMR drops sharply as birth weight increases.

Table 2 provides more detailed associations between various ranges of birth weight and first year, neonatal and postneonatal survival chances (1999-2002 linked files). For infants born at normal weights, their IMR was as low as 2.4, and one-third (0.8/2.4=33.3%) deaths occurred in the neonatal period (less than 28 days after birth). However, for infants born at LBW, their IMR was as high as 59.5, and more than four-fifths (48.6/59.5=82%) deaths occurred in the neonatal period. More specifically, for MLBW and VLBW infants, their IMRs were as high as 15.1 and 250.8, and 58.3% and 87.8% deaths occurred in the neonatal period, respectively. Hence, LBW (MLBW, VLBW) critically threatens the infant neonatal survival. Similarly, LBW also critically reduces the survival probability during postneonatal period (between 28 and 364 days) for infants who could survive the neonatal period, as shown in the last column of Table 2.

Figure 1: Infant Mortality Rates by Birth Weight: United States, 2002
Figure Source: (Kochanek and Murphy, 2004)

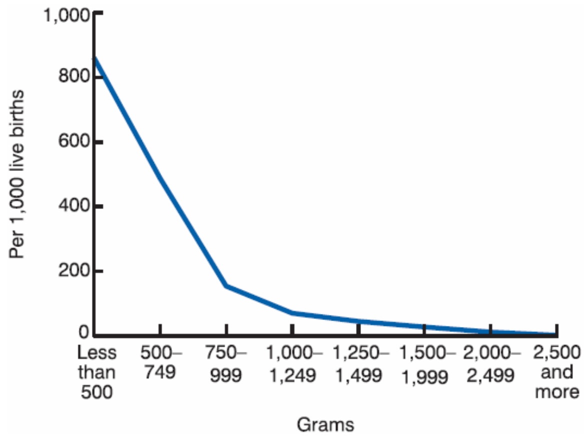


Table 2: United States Infant, Neonatal and Postneonatal Mortality (IMR, NMR, PMR) Rates by Birth Weight, 1999-2002 Liked Files
Data Source: National Center for Health Statistics[1]

	Birth Weight	IMR	NMR	PMR
	All Weights	7.0	4.7	2.3
	All LBW	59.5	48.6	10.9
VLBW	All VLBW	250.8	220.3	30.5
	< 500g	862.0	839.0	23.0
	500-749g	489.6	424.5	65.1
	750-999g	155.1	116.4	38.7
	1000-1249g	70.3	52.4	17.9
	1250-1499g	45.7	32.2	13.5
MLBW	All MLBW	15.1	8.8	6.3
	1500-1999g	26.5	17.3	9.2
	2000-2499g	11.5	6.1	5.4
Normal	≥ 2500g	2.4	0.8	1.6

[1] Data can be found in (Kochanek and Murphy, 2004).

Remark: Internationally (Lawn and Cousens, 2005; Wardlaw and Blanc, 2004), about two-thirds of all infant deaths occurred in the neonatal period and the remaining one-third of deaths occurred during the postneonatal period in 2000. The average daily mortality rate during the neonatal period was close to 30-fold higher than during the postneonatal period. The highest risk of death was on the first day of life (25-45% of all neonatal deaths). Some three-quarters of neonatal deaths happened in the first week after birth (early neonatal deaths). In general, the first month is critical for an infant to survive. During the first month, approximately 27% infant deaths occur from Prematurity, 36% from Infections (26% from Blood infection/Pneumonia, 7% from Tetanus and 3% from Diarrhea), 23% from Asphyxia, 7% from Congenital and 7% from other causes. Globally, some 60-80% of these infants were born at LBW in 2000. For the U.S., these percentages vary from year to year according to the ICD (10th Revision), and can be found from the National Center for Health Statistics' annual publications, Deaths: Final Data (or annual infant mortality statistics).

4. BIRTH WEIGHT VS GESTATIONAL AGE

The length of the gestation period (gestational age) is a most significant factor in determining infant birth weight, and the patterns of change for gestational age are generally similar to those for birth weight (Martin and Hamilton, 2003c; also see bottom portion of Table 3 below). In 2002, nearly two-thirds (66.0%) of LBW infants were born prematurely (P, before 37 completed weeks of gestation), and 80.7% of VLBW infants and 94.8% of infants with birth weights less than 1000 grams were born very prematurely (VP, less than 32 completed weeks of gestation) (Calculated from Table 43 of Martin and Hamilton, 2003c). Like LBW, the preterm birth rate increased in more than 20 years, from 9.4% in 1981 to 12.1% in 2002 (480,812 preterm births in 2002), and the very preterm birth rate increased from 1.81% to 1.96% (77,845 very preterm births in 2002) during the same period of time. The association and similarity between gestational age and birth weight are summarized in Tables 3 and 4 below. With the increase of gestational age, the chance of LBW decreases sharply. The long-term trends of gestational age are given at the lower portion of Table 3. Table 4 compares birth weight and gestational age for all plurality groups.

Table 3: Birth Weight vs Gestational Age: United States, 1984 and 2002 (top portion), and Live Birth Percentages by Gestational Age: United States, 1966, 1974, 1984, 1990 and 2002 (bottom)
Data Source: National Center for Health Statistics[1]

		Gestational Age (in weeks)			
		Total	< 37	37-39	40 or more
LBW Rate	2002	7.8%	43.2%	3.9%	1.6%
	1984	6.7%	40.1%	4.8%	1.8%
	Gestational Age (in weeks)				
	VP < 32	P < 37	Term & Postterm		
			37-39	40	> 40
2002	1.96	12.1	51.0	20.3	16.6
1990	1.90	10.5	40.9	22.3	25.1
1984	1.83	9.4	37.6	22.4	30.7
1974	1.61	8.5	33.1	22.7	35.7[2]
1966	1.90	10.3	38.9	22.6	28.1[3]

[1] 2002 data can be found in (Martin and Hamilton, 2003c); 1984, 1974 and 1966 Birth data files can be obtained by searching CDC and NCHS Internet Sites http://www.cdc.gov/ and http://www.cdc.gov/nchs/Default.htm, or by request.
[2] In 1974, 26.5% of all infants were born at 41-42 weeks of gestation, 9.2% at 43 or more weeks. Data can be found in NCHS, (1976), *Final Natality Statistics (1974)* (Monthly Vital Statistics Report, Vol. 24, No. 11, Supplement 2), Rockville, Maryland.
[3] In 1966, these figures were estimated as 21.8% and 6.3%. Data can be found in Health Services and Mental Health Administration, NCHS, (1970), *Natality Statistics Analysis: United States, 1965-1967* (Vital and Health Statistics, Series 21, No. 19). Rockville, Maryland.

In 2003, preterm and very preterm rates continued to increase to 12.3 and 1.97, respectively (Martin and Hamilton, 2005d). In 2004, the comparable figures were further up to (preliminary) 12.5 and 2.00, respectively.

Like LBW, preterm birth accounts for a majority of infant deaths and more than two-fifths (43.2% in 2002 and 40.1% in 1984) of these infants are LBW (Table 3). In 2002, the infant mortality rate for term infants was as low as 2.5, but as high as 37.9 and 186.4 for preterm infants and very preterm infants (15 and 75 times the rate of term infants); 67.4% of all infant deaths occurred to the 12.1% of infants born preterm and 53.7% occurred to the 2.0% of infants born very preterm (Kochanek and Murphy, 2004). In 2001, 41% of all infants born earlier than 28 weeks of gestation did not survive their first year, compared to the 5% for infants born at 28-31 weeks, 1% for infants delivered at 32-35 weeks, and 0.3% for term infants (Martin and Hamilton, 2003c).

Table 4: Birth Weight and Gestational Age by Plurality: United States, 2002

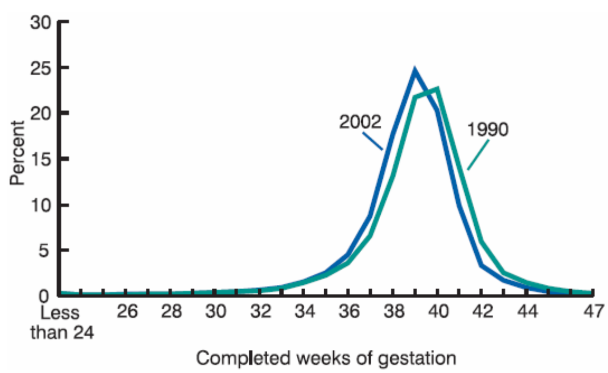
Data Source: National Center for Health Statistics[1]

Plurality	Live Births	Gestation Age			Birth Weight		
		VP (%)	P (%)	Mean Age (weeks)	VLBW (%)	LBW (%)	Mean Weight (grams)
Singleton	3889191	1.6	10.4	38.8	1.1	6.1	3332
Twin	125134	11.9	58.2	35.3	10.2	55.4	2347
Triplet	6898	36.1	92.4	32.2	34.5	94.4	1687
Quadruplet	434	59.9	96.8	29.9	61.1	98.8	1309
Quintuplet	69	78.3	91.3	28.5	83.8	94.1	1105

[1] Data can be found in (Martin and Hamilton, 2003c)

As shown in Figure 2 below, the mean gestational age reduced from 39.2 weeks in 1990 to 38.8 weeks in 2002 among singletons (in 2002, 35.3 for twins, 32.2 for triplets, 29.9 for Quadruplets, and 28.5 for Quintuplets and higher). In addition, Table 3 above shows a long trend shift toward earlier term delivery, indicated by the facts that more infants are delivered at 37-39 weeks of gestation (from 37.5% in 1984 up to 51.0% in 2002) and concurrently fewer infants are delivered at 41 weeks or later (from 30.7% in 1984 down to 16.6% in 2002). The decline in postterm births (42 or more weeks) was particularly striking, from 11.3% in 1990 to 6.7% in 2002 (down 40%). Figure 2 below shows such a shift toward early delivery from 1990 to 2002. The shift toward earlier term delivery suggests the use of delivery management techniques such as cesarean delivery and induction of labor (Martin and Hamilton, 2003c), and the significantly increased multiple births (usually large chances of shorter gestation and LBW) primarily delivered by mothers older than 30. Notice that from 1984 to 2002, birth rates and birth percentages had risen extraordinarily for mothers older than 30 while these rates continued to decrease for younger mothers aged 15-24; mothers aged 25-29 produced the best birth outcomes and for this age group, although the birth rate increased, the birth percentage decreased, (Table 5 in next section). This caused a maternal age delay, resulted in more multiple births and partially contributed to the high LBW rate.

Figure 2: Birth Distributions by Gestational Age: United States, 1990 and 2002
Figure Source: (MacDorman and Martin, 2005)



5. BIRTH WEIGHT VS MULTIPLE BIRTHS AND MATERNAL AGE

Plurality rate is proportional to the maternal age and old mothers are more likely to give multiple births, which often result in LBW and preterm infants (Table 4 above and Table 5 below). While total multiple birth rate and multiple birth rates by maternal age group were stable from 1965 to the early

1980s, these rates significantly climbed up from 1984 to 2002, particularly for older mothers. The total multiple birth rate (per 1,000 live births) soared to 32.9 in 2002 from 19.3 in 1980 (and 20.4 in 1984), in almost a linear increase and over 61% rise during this period, and thus caused a large increase for the total LBW rate.

Table 5: Total Fertility Rates, Total LBW Rates, Birth Rates and LBW Rates by Maternal Age[1]: United States, 1950, 1965, 1980, 1984 and 2002 (with comparisons for 1965, 1984 and 2002) Data Source: National Center for Health Statistics[2]

Year	Total Fertility Rate	Birth Rates by Maternal Age					
		15-19	20-24	25-29	30-34	35-39	40-44
1950	3090.5	81.6	196.6	166.1	103.7	52.9	15.1
1965	2912.6	70.5	195.3	161.6	94.4	46.2	12.8
1980	1839.5	53.0	115.1	112.9	61.9	19.8	3.9
1984	1806.5	50.6	106.8	108.7	67.0	22.9	3.9
2002	2013.0	43.0	103.6	113.6	91.5	41.4	8.3
1950	Birth %	11.8	31.8	28.8	16.8	8.3	2.1
1965, year of highest LBW rate	LBW Rate (Total 8.3%)	10.6	7.8	7.3	8.0	9.2	9.7
	Plurality Rate (Total 2.01%)	1.27	1.78	2.23	2.68	2.94	2.23
	Birth %	13.6[3]	36.1	25.6	14.5	7.8	2.3[4]
1984, year of lowest LBW rate	LBW Rate (Total 6.7%)	9.3	6.9	5.9	5.9	6.7	8.3
	Plurality Rate (Total 2.04%)	1.31	1.80	2.19	2.49	2.69	2.20
	Birth %	12.8	31.1	31.8	17.8	5.3	0.7
2002	LBW Rate (Total 7.8%)	9.6	7.9	6.9	7.2	8.6	10.4
	Plurality Rate (Total 3.29%)	1.61	2.29	3.05	4.19	5.18	5.64
	Birth %	10.6	25.4	26.4	23.7	11.3	2.4

[1] Total fertility rates are sums of birth rates for the 9 five-year age groups multiplied by 5 (age groups under 15, 45-49 and 50-54 not shown in this table, together had 0.32% of the total births in 2002). Birth rates are live births per 1,000 women in specified group. Infants classified as Not Stated are excluded in calculating 2002 LBW rates.
[2] See note 1 under Table 3 for the methods to obtain these old data.
[3] Under 20
[4] 40 and older

The top left portion of Table 5 shows total fertility rates for the indicated years, with a sharp decrease from 3090.5 in 1950 to 1806.5 in 1984 (41.5% decrease) and then an increasing trend to 2013.0 in 2002 (10.3% increase). The top right portion shows long-term trends of birth rates from 1950 to 2002 by age group. From 1950 to early 1980s, birth rates sharply decreased for all age groups. From 1984 to 2002, birth rates for younger mothers continuously decreased but slower (17.7% and 3.1% drops for age groups 15-19 and 20-24) implying that the lowest rates will soon be achieved and for those aged 20-24, the birth rate will rise in the next few years; for other mothers, birth rates increased abruptly (4.5%, 36.6%, 80.8% and 112.8% increases for age groups 25-29, 30-34, 35-39 and 40-44). Notice that the long-term trends of LBW rates by total and by age group appeared in similar patterns during this time period: rapidly going down from 1965 to 1984 and then quickly rising up from 1984 to 2002 (bottom portion of Table 5). Hence, a positive correlation between total LBW rate and total fertility (as well as between LBW rates and birth rates for mothers aged 25 or older, see Figure 3) exists, which will be calculated later. For younger age groups (15-24), such a correlation has not been observed as their birth rates continue to decrease reaching the lowest levels.

The bottom portion of Table 5 shows long-term trends of LBW rates, plurality rates and birth percentages by total and by maternal age group. 1965 was the year of highest total LBW rate (and high LBW rates by age group) ever recorded, compared to 1984 when the lowest LBW rate (and low LBW rates by age group) was achieved. The year 1984 is of great interest because in this year all the LBW, VLBW, Preterm, and Very Preterm rates were the lowest ever recorded, 6.7%, 1.19%, 9.4 and 1.83, respectively (6.8%, 1.16%, 9.4 and 1.81 for 1981). In contrast, in 1965, the LBW rate was highest, 8.3%. From 1965 to 1984, total plurality rate and plurality rates by age group were all stable, while total fertility rate and birth rates by age group sharply decreased to their lowest levels and birth percentages of mothers aged 25-34 increased significantly (decreased for other age groups), resulting in large decreases of LBW rates by total and by age group. In contrast, from 1984 to 2002, total fertility rate and birth rates for mothers aged 30 and older increased to high levels, plurality rates for older mothers nearly tripled (ages 40-44) or doubled (ages 35-39) or increased by 68% (ages 30-34), and at the same time birth percentages of these older mothers increased in similar scales (maternal age delay), resulting in large number of multiple births which partially contributed to the fast increases of LBW rates by total and by age group (and fast increase of preterm rate, from 9.4% in 1984 to 12.1% in 2002). In addition, the decreased birth percentage of those aged 25-29 and the increased plurality rates for mothers aged 25-59, 20-24 and 15-19 since 1984 also contributed to the increases of LBW rates by total and by age group.

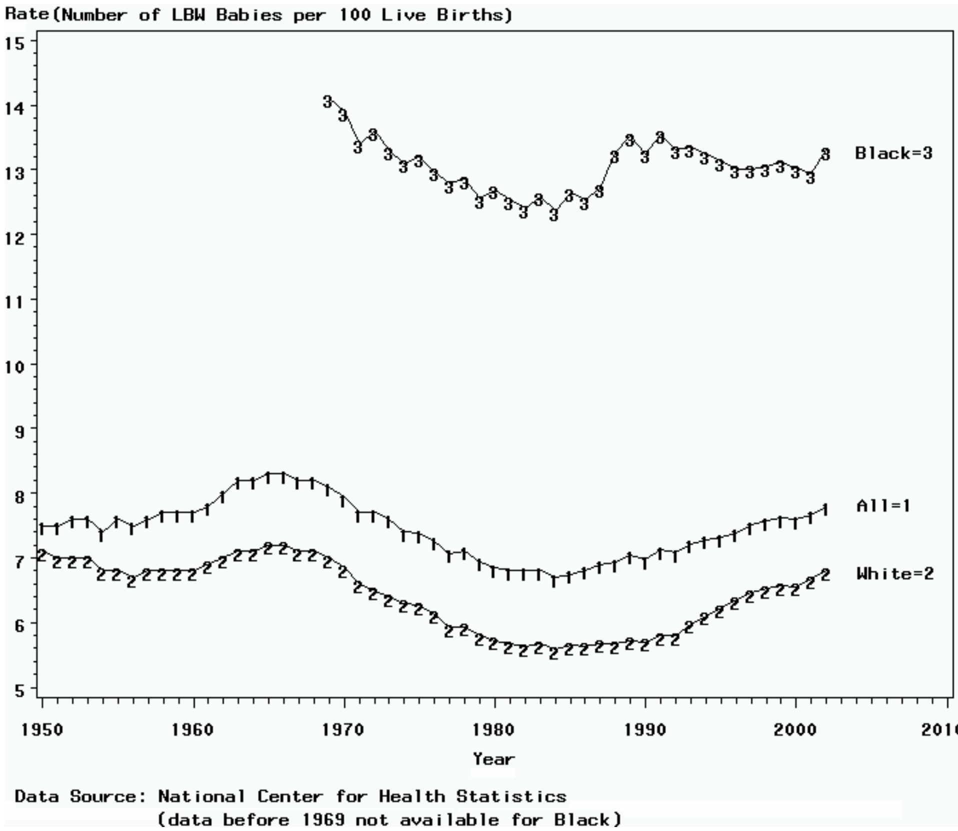
Particularly, Table 5 indicates that LBW rates vary significantly among maternal age groups in each individual year (see Figure 4 also) but relatively less within each age group for different years; LBW rates of individual maternal age groups changed periodically, comparable to the patterns of change for their birth rates and percentages of births (except for youngest mothers aged 15-24 whose birth rates are approaching their lowest levels). These long-term trends of change for birth rates, plurality rates and LBW rates by age group suggest that high plurality rate is a significant cause for the increase of LBW rate since 1984 and strong positive correlations between plurality rates and birth rates (birth percentages, respectively) by age group exist for all mothers except those aged 15-24.

As a note, plurality rate is higher for Non-Hispanic (White: 37.3 and Black: 35.7 in 2002) and lower for Hispanic (21.5 in 2002). The upsurge in multiple births over the past two decades, especially in triplet/+ births, has been associated with two related trends: fertility therapies and older age of childbearing (Martin and Hamilton, 2003c).

Within the multiple births, twinning births are particularly important since they represent the majority of multiple births. In 2002, there were 125,134 live births in twin deliveries (almost doubled from 68,339 in 1980), which was 94.4% of all multiple births, compared to 6,898 triplet, 434 quadruplet, and 69 quintuplet and higher order multiple births (together 5.6% of all multiple births). In 2002, the twin birth rate was 31.1 per 1,000 live births, a 37.6% increase since 1990 (22.6) and 64.6% increase since 1980 (18.9) (Martin and Hamilton, 2003c). Table 5 illustrates that increases of multiple births occurred for all age groups since early 1980s, and particularly for older mothers. The number of twin births to women aged 45–49 years has soared from only 39 to 991 between 1990 and 2002, and the twin birth rate from 23.8 to 189.7 per 1,000 live births (Martin and Hamilton, 2003c). Since 1998, the rate of triplet and other higher order multiple births declined slightly to 1.84 in 2002 per 1,000 live births, and this ended a long-term upswing in the triplet/+ rate since 1980 (more than 400% increase from 1980 to 1998 with an average annual increase of 13%, from 0.37 to 1.94).

If multiple births for 2002 could be reduced by 50% in each plurality category to the levels of year 1984 (see Table 5), the LBW rate for 2002 would be reduced to 6.96% (calculated from Table 4), close to the rate in 1984. Hence, the increased rate of multiple births, significantly due to maternal age delay, largely accounted for the increase of LBW rate since 1984. On the other hand, the preterm rate increased from 9.4% in 1984 to 12.1% in 2002 (28.7% increase, Table 3), but a similar calculation would still result in a preterm rate as high as 11.23% for 2002 even if the plurality rates of multiple births could be reduced 50% as assumed above. Therefore, the influence of high plurality on LBW is more significant than on preterm birth. In fact, the ratio of LBW rates between twins and singletons was 9.08 (55.4 : 6.1) and the ratio of preterm rates between these two groups was 5.60 (58.2 : 10.4) in 2002 (Table 4). As a consequence, LBW is a high risk for all pregnancies particularly for multiple births, and preterm delivery is a risk for all pregnancies including singletons. The increased multiple births (primarily caused by maternal age delay and increased birth rates of older mothers) contributed to greater increases for LBW births than for preterm births since 1984. Notice that from 1965 to 1984 (stable plurality rate), the steeply declined total fertility, birth rates of individual age group, and shift of births to maternal ages 25-34 contributed to the decreases in the LBW rate.

Figure 3: Low Birth Weight and Racial Disparities – Periodic Changes, United States, 1950-2002



These long-term patterns of periodic change in total fertility rate, birth rates, birth percentages by maternal age, and plurality rates by maternal age, together with the yet not complete patterns of periodic change for birth percentages by age group, largely contributed to similar patterns of periodic change in LBW (see Figure 3 above and Figures 4 and 5 below). Notice that information of gestational age is implicitly contained in Table 5 as the gestational age is closely associated with birth weight and plurality, and patterns of change for gestational age are generally similar to that of birth weight (Martin and Hamilton, 2003c).

In 2000, the average American woman having her first baby was approximately 25 years old. In 1970, it was 21.4. The mean age of mothers for all births rose from 24.6 to 27.2 over the past three decades. Over one-half of all births still occur to women in their twenties - the peak childbearing years, but the average age in this group has shifted steadily upward since 1970. The increase in the average age of women having a baby also reflects the sharp declines in teen birth rate (since 1950) and fast rise in birth rates for women in thirties and forties (since 1980) (Mathews and Hamilton, 2002).

Figure 4: Total Low Birth Weight and Birth Rates by Maternal Age Group, United States, 1950-2002

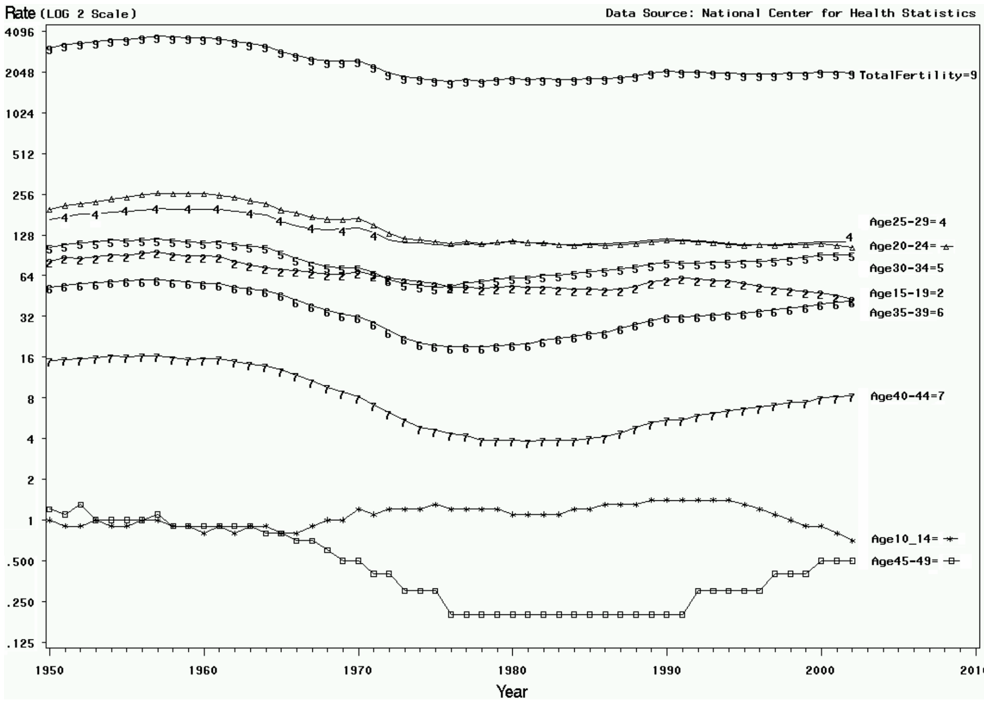


Figure 5: Total Low Birth Weight and Birth Percentages by Maternal Age, United States, 1950-2002

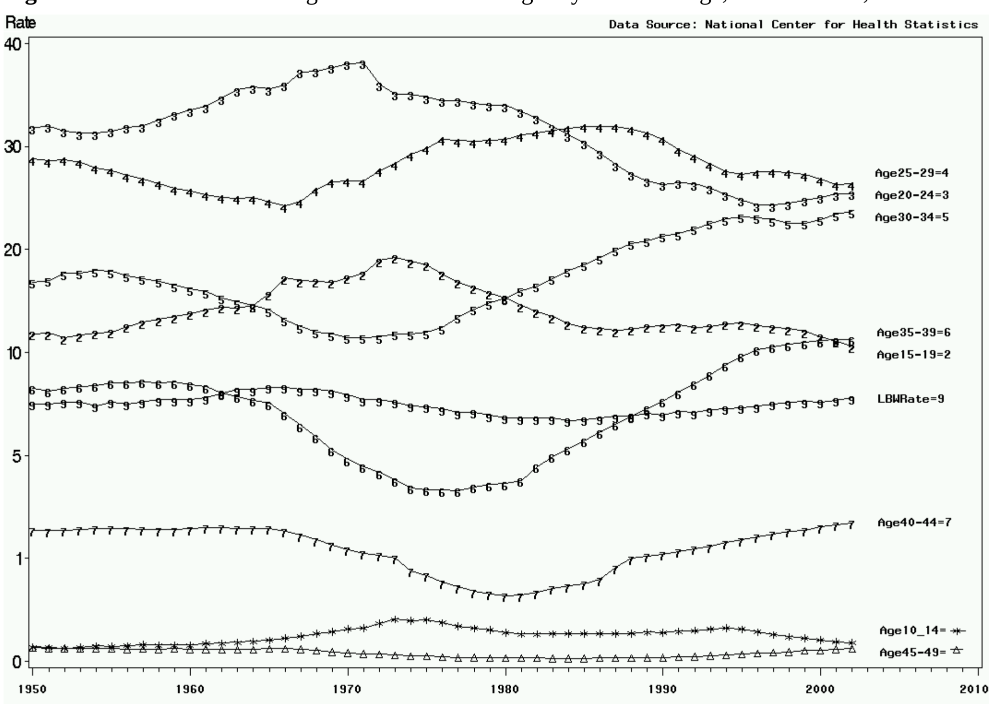
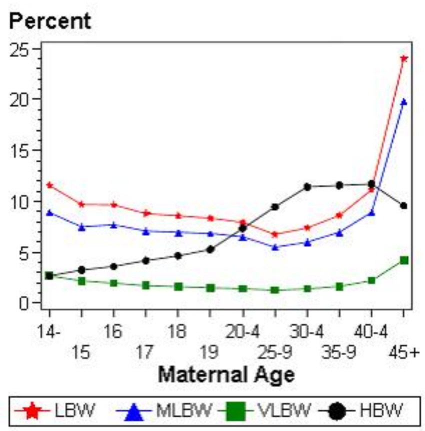


Figure 6 below shows U-shape distributions of LBW, VLBW and MLBW by maternal age (2002 data). A similar figure for 1999 LBW for singletons and for all pluralities can be found from (Ventura and Martin, 2001). The graph for preterm rates by maternal age has a similar pattern (omitted).

Figure 6: VLBW, MLBW, LBW and HBW by Maternal Age, United States, 2002
Data Source: National Center for Health Statistics



Notice in Figure 6, older mothers are also likely to deliver high birth weight infants (HBW, birth weight at 4000 grams or higher), however, this will not be further studied in this research.

In conclusion, LBW is highly correlated to (and vary greatly by) gestational age, plurality, maternal age, total fertility, birth rates, and birth percentages by maternal age. Based on these correlations and regression analyses, statistical models characterizing the total LBW rate will be established in our subsequent papers.

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