Journal of Preventive Medicine and Public Health
May 2011, Vol. 44, No. 3, 111-117
This article is available at http://jpmph.org/.

doi: 10.3961/jpmph.2011.44.3.111
pISSN 1975-8375
eISSN 2233-4521

Original Article

Changes in the Distribution of Maternal Age and Parity and Increasing Trends in the Low Birth Weight Rate in Korea Between 1995 and 2005

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Objectives: This study measured the impact of shifts in maternal age and parity on the increase in the low birth weight (LBW) rate in Korea.
Methods: We obtained raw data for all 6 397 945 live births registered at the Korea National Statistical Office between 1995 and 2005. We calculated the proportion of increment in the LBW rate due to changes in the distribution of maternal age and parity (AP-dis) and the proportion due to changes in the age- and parity-specific LBW rate (AP-spe).
Results: The LBW rate increased from 3.02% in 1995 to 4.28% in 2005. The multiple birth rate increased from 1.32% to 2.19% during the same period. Of the 1.26% points increment in the LBW rate, 0.64% points occurred among singleton births and 0.62% points occurred among multiple births. Changes in the AP-dis accounted for 50% of the increase in the LBW rate among singleton births, but did not contribute to the increase in the LBW rate among multiple births. The remainder of the total increment in the LBW rate was explained by the increase in the AP-spe.
Conclusions: This study demonstrated that shifts in maternal age and parity among singleton births and increased multiple births were important contributors to the increment in the LBW rate. This study also revealed that the increase in the AP-spe was an equally important contributor as the shifts in maternal age and parity to the increment in the LBW rate among singleton births and was a major contributor among multiple births.

Key words: Infant, Low birth weight, Maternal age, Parity, Korea
J Prev Med Public Health 2011;44(3):111-117

INTRODUCTION

The total fertility rate in the Republic of Korea (ROK) steadily declined from 4.53 in 1970 to 1.08 in 2005, reflecting delayed marriage and more couples having fewer children [1]. The mean maternal age for all births increased from 28.0 in 1995 to 30.2 in 2005 [1]. A more concerning national statistic, however, is the decline in the mean birth weight from 3.34 kg in 1995 to 3.26 kg in 2005. The percentage of babies born with a low birth weight (LBW), defined as a birth weight < 2500 g [2], increased from 3.0% to 4.3% during the same period [1].

The mother's age at delivery and parity are associated with infant birth weight. Women < 20 years and ≥ 30 years of age have a higher LBW rate than women 20-29 years of age [1,3-5]. The LBW rate is higher for first births than second and third births, then increases as the birth order increases beyond four [1,6]. Advanced maternal age and the proportion of first-born infants in women ≥ 30 years of age may have contributed to the increase in the LBW rate in the ROK [1,3-6]. There was also a steady increase in the rate of multiple births, from 1.3% in 1995 to 2.2% in 2005 [1]. The increase in the multiple birth rate may also have contributed to the increase in the preterm birth and LBW rates [1,4].

Birth weight is one of the most sensitive and accessible indicators of newborn health and is directly related to the gestational age. Birth weight has a great significance because it is strongly associated with infant mortality, developmental problems in childhood, and the risk of various diseases in adulthood, including diabetes, hypertension, and cardiovascular conditions [7-10]. Therefore, the identification of factors related to the increase in the LBW rate and the prevention of LBW births are important and urgent public health issues.

Although the association of maternal age and parity with the LBW rate is well-established, to our knowledge, only one study that measured the impact of

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Received : 12 July 2010, Accepted : 20 December 2010

shifts in maternal age and parity on the increase in the LBW rate has been published [11]. Yang et al. [11] evaluated the effects of changes in the distribution of maternal age and parity (AP-dis) and changes in the age- and parity-specific LBW rate (AP-spe) on the LBW trends in the United States between 1980 and 2000 using a decomposition method; however, one of the limitations of the study was that the analysis was restricted to singleton births.

If the AP-spe remains constant over time, increasing trends in the LBW rate may be predominantly attributed to changes in the AP-dis. On the contrary, if the AP-spe changes over time, increasing trends in the LBW rate may be attributed to changes in such risk factors for LBW births as personal lifestyles, environmental factors, and obstetrical practices [11-16]. Thus, we evaluated these two components of changes in the LBW rate for singleton and multiple births separately between 1995 and 2005 in the ROK.

MATERIALS AND METHODS

I. Research Data

We obtained raw data for all live births registered at the National Statistical Office of the ROK for the period between 1995 and 2005. There were 6 397 945 registered births, and the analysis was conducted for 6 361 162 births after excluding 36 783 births that had recorded a birth weight < 500 g or missing data for birth weight, birth plurality, maternal age, and/or parity. Although both the gestational age and birth weight were recorded on the birth certificate, we used the birth weight data alone because it was more accurately recorded than the data on gestational age.

II. Data Analysis

The LBW rate was calculated for each year between 1995 and 2005. The Cochran-Armitage trend test was used to test the significance of trends in the LBW rate over a 10-year period. Differences in the AP-dis or AP-spe between 1995 and 2005 were tested by a chi-square test or Fisher's exact test. To evaluate statistical significance, a two-sided significance level of 0.05 was used. Statistical analysis was performed using SAS version 9.1 (SAS Inc., Cary, NC, USA).

To partition the increase in the LBW rates between 1995 and 2005 into the increase due to changes in the AP-dis and the increase due to changes in the AP-spe, we used the following standardization method, as modified by the authors [17-19].

The standard population is cross-tabulated by age, where $i=1, 2, \cdots, i$ (≤ 19, 20-24, 25-29, 30-34, 35-39, and ≥ 40), and parity, where $j=1, 2, \cdots, j$ (1, 2, and ≥ 3). The AP-spe is

$$m^*_{ij} = \frac{l^*_{ij}}{b^*_{ij}}$$

where m_{ij} is the LBW rate of ij-th cells, l_{ij} the number of LBW births in the ij-th cells, and b_{ij} the number of births in the ij-th cells. The asterisk denotes the standard population. The overall LBW rate, M, is

$$M^* = \frac{L^*}{B^*} = \sum_{ij} m^*_{ij} \frac{b^*_{ij}}{B^*}$$

where L is the total number of LBW births, and B the total number of births. The ratio of m^*_{ij} to M^*, k^*_{ij} is

$$k^*_{ij} = \frac{m^*_{ij}}{M^*} = \frac{\frac{l^*_{ij}}{b^*_{ij}}}{\frac{L^*}{B^*}}$$

If the AP-spe did not change since 1995 (standard population) and remained the same in 2005 (study population), but the AP-dis of births changed over the time period, then the changes in the risk of LBW births in the study population due to changes in the AP-dis can be given by

$$K = \sum_{ij} k^*_{ij} \frac{b_{ij}}{B} = \sum_{ij} \frac{m^*_{ij}}{M^*} \frac{b_{ij}}{B} = \frac{\sum_{ij} m^*_{ij} \frac{b_{ij}}{B}}{M^*}$$

$$= \frac{\text{Expected LBW rate in 2005}}{\text{LBW rate in 1995}}$$

where $\frac{b_{ij}}{B}$ is the proportion of births in 2005 in the ij-th cells. K is named the age-parity score, which can be directly interpreted as the percentage difference in the LBW rate with reference to the standard population.

In our analysis, the expected LBW rate in 2005 was K multiplied by the LBW rate in 1995. Subsequently, changes in the LBW rate due to changes in the AP-dis

Table 1. All live births, singleton and multiple births, singleton and multiple birth rates, and low birth weight (LBW) rate from 1995 to 2005 in the Republic of Korea

	Year										
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
All live births	712 750	657 388	644 103	639 011	636 389	634 438	554 581	489 999	487 849	471 225	433 429
Singleton births	703 374	648 602	635 439	629 376	626 440	623 741	544 596	480 322	478 015	461 305	423 943
Multiple births	9376	8786	8664	9635	9949	10 697	9985	9677	9834	9920	9486
Singleton birth rate (%)*	98.68	98.66	98.65	98.49	98.44	98.31	98.20	98.03	97.98	97.89	97.81
Multiple birth rate (%)*	1.32	1.34	1.35	1.51	1.56	1.69	1.80	1.97	2.02	2.11	2.19
LBW rate (%)											
All live births*	3.02	3.07	3.22	3.46	3.55	3.80	3.93	3.96	4.06	4.13	4.28
Singleton births*	2.57	2.58	2.69	2.80	2.84	3.02	3.08	3.03	3.13	3.15	3.25
Multiple births*	36.70	38.91	42.20	46.95	47.72	49.19	50.28	50.19	49.32	49.86	50.33

Live births with a birth weight < 500 g and missing data for birth weight, birth plurality, maternal age, and/or parity were excluded from the analysis.
*p_{trend} < 0.001 calculated by the Cochoran-Armitage trend test.

Table 2. Distribution of maternal age and parity of births in 1995 and 2005 by plurality in the Republic of Korea

n (%)

Maternal age (y)	1995			2005			p-value[1]
	Birth order			Birth order			
	First	Second	≥ Third	First	Second	≥ Third	
Singleton births							< 0.001
- 19	6134 (0.87)	692 (0.10)	18 (< 0.01)	1966 (0.46)	160 (0.04)	6 (< 0.01)	
20 - 24	102 049 (14.51)	31 465 (4.47)	1685 (0.24)	24 564 (5.79)	6522 (1.54)	567 (0.13)	
25 - 29	191 487 (27.22)	173 663 (24.69)	16 682 (2.37)	112 293 (26.49)	53 164 (12.54)	6037 (1.42)	
30 - 34	33 887 (4.82)	84 000 (11.94)	28 584 (4.06)	68 731 (16.21)	85 121 (20.08)	19 736 (4.66)	
35 - 39	7253 (1.03)	11 547 (1.64)	10 672 (1.52)	11 466 (2.70)	16 559 (3.91)	11 540 (2.72)	
40 -	1139 (0.16)	981 (0.14)	1436 (0.20)	1833 (0.43)	1558 (0.37)	2120 (0.50)	
Multiple births							< 0.001
- 19	23 (0.25)	20 (0.21)	1 (0.01)	5 (0.05)	5 (0.05)	0 (-)	
20 - 24	471 (5.02)	803 (8.56)	149 (1.59)	171 (1.80)	206 (2.17)	43 (0.45)	
25 - 29	1221 (13.02)	2804 (29.91)	887 (9.46)	1289 (13.59)	1609 (16.96)	370 (3.90)	
30 - 34	447 (4.77)	1191 (12.70)	701 (7.48)	1490 (15.71)	2095 (22.09)	835 (8.80)	
35 - 39	114 (1.22)	267 (2.85)	217 (2.31)	374 (3.94)	539 (5.68)	348 (3.67)	
40 -	12 (0.13)	17 (0.18)	31 (0.33)	31 (0.33)	44 (0.46)	32 (0.34)	

[1]p-value calculated by a chi-square test.

(AP-dis_⊿LBW) and AP-spe (AP-spe_⊿LBW) can be calculated as follows:

AP-dis_⊿LBW =
expected LBW % in 2005 - LBW % in 1995
AP-spe_⊿LBW =
observed LBW % in 2005 - expected LBW % in 2005

We calculated these two components for singleton and multiple births separately. This study was approved by the Institutional Review Board of Daegu Catholic University Medical Center.

RESULTS

Between 1995 and 2005, the total number of live births decreased by 39.2%, from 712 750 births in 1995 to 433 429 births in 2005. The multiple birth rate steadily increased from 1.32% in 1995 to 2.19% in 2005, which was statistically significant (p_{trend} < 0.001). During the same period, the LBW rate increased by 1.26% points, from 3.02% to 4.28% (p_{trend} < 0.001). When the LBW rate was calculated for singleton and multiple births separately, statistically significant trends were also observed (p_{trend} < 0.001). The LBW rate for singleton births increased from 2.57% in 1995 to 3.25% in 2005. The LBW rate for multiple births was 14-16 times higher than that for singleton births and increased from 36.70% to 50.33% during the same period (Table 1).

Table 2 shows changes in the AP-dis by plurality between 1995 and 2005. Among both singleton and multiple births, there was a statistically significant shift in the AP-dis to the ≥ 30-year age groups in 2005 (p < 0.001). Table 3 shows the AP-spe by plurality in 1995 and 2005. Among singleton births in 1995, the rates for the first and second babies of mothers 20 - 29 years of age, the third babies of mothers 25-29 years of age, and

Table 3. Maternal age- and parity-specific low birth weight rate (%) in 1995 and 2005 by plurality in the Republic of Korea

Maternal age (y)	1995			2005		
	Birth order			Birth order		
	First	Second	≥ Third	First	Second	≥ Third
Singleton births						
- 19	3.77	4.34	16.67	5.80*	3.75	16.67
20 - 24	2.61	2.42	2.97	3.47*	2.74	5.11*
25 - 29	2.60	2.00	2.13	3.08*	2.34*	3.58*
30 - 34	3.81	2.59	2.38	3.77	2.77*	2.87*
35 - 39	5.46	4.02	3.35	5.82	4.08	4.21*
40 -	5.88	6.32	4.81	6.82	5.58	6.32
Multiple births						
- 19	56.52	65.00	-	80.00	60.00	-
20 - 24	45.86	38.85	35.57	48.54	51.94*	53.49*
25 - 29	41.61	32.95	38.11	49.65*	54.88*	38.92
30 - 34	36.91	33.17	32.67	49.46*	52.79*	43.83*
35 - 39	42.98	40.07	41.01	45.19	53.62*	45.98
40 -	41.67	58.82	48.39	54.84	63.64	46.88

Differences in the age- and parity-specific low birth weight rate for the same age-parity groups by plurality between 1995 and 2005 were tested by a chi-square test or Fisher's exact test.
*$p < 0.05$ calculated by a chi-square test.

the second and third babies of mothers 30-34 years of age were near to or lower than 2.57% (the LBW rate among all singleton births in 1995), while the rates for the remainder of the age-parity groups were much higher than 2.57%. Among multiple births in 1995, the rates for the maternal age between 20 and 39 years were not as variable as the rates for the same maternal age groups among singleton births. Statistically significant increases in the AP-spe in 2005 were observed in 9 of 18 age-parity groups among singleton births and 8 of 17 age-parity groups among multiple births ($p < 0.05$).

The calculation process to separate out the contribution of changes in the AP-dis and AP-spe to the total increment in the LBW rate is summarized in Table 4. Among singleton births, the absolute LBW rate increased by 0.64% points, from 2.54% points in 1995 to 3.18% points in 2005 (25.2% increment). The absolute percentage points of the increase in the LBW rate due to changes in the AP-dis were 0.32 (50.0% of the increase). Among multiple births, the absolute LBW rate increased by 0.62% points, from 0.48% points to 1.10% points during the same period (129.2% increment) and accounted for nearly one-half of the LBW rate increase among all live births. The age-parity score of multiple births for 2005 was 0.999, which means no contribution of changes in the AP-dis to changes in the LBW rate. All of the LBW rate increment among multiple births was attributed to the increase in the AP-spe.

Consequently, a total of 0.32% points, which accounted for 25.4% of the overall increase of 1.26% points, were attributed to changes in the AP-dis, and occurred only among singleton births. The absolute percentage points of the increase in the LBW rate due to changes in the AP-spe were 0.32 (50.0% of the increase) among singleton births, 0.62 (100.0% of the increase) among multiple births, and a total of 0.94, which accounted for 74.6% of the overall increase of 1.26% points.

DISCUSSION

In this study, we evaluated the effects of changes in the AP-dis and the AP-spe on the LBW trends in the ROK between 1995 and 2005 for singleton and multiple births separately. Our study revealed that nearly one-half of the total increase in the LBW rate during the time period occurred among singleton births and the other half occurred among multiple births.

When the impact of the shifts in maternal age and parity on the increase in the LBW rate was evaluated by calculating the age-parity score, one-half of the increase in the LBW rate among singleton births was attributed to changes in the AP-dis, primarily the shift in maternal age to the ≥ 30 - year age groups. The remainder of the

Table 4. Calculation process of changes in the low birth weight (LBW) rate due to changes in the distribution of age and parity (AP-dis) and changes in the age- and parity-specific LBW rate (AP-spe) among singleton and multiple births between 1995 and 2005 in the Republic of Korea

	All live births		Singleton births		Multiple births	
	1995	2005	1995	2005	1995	2005
Observed absolute % points of LBW rate	3.02	4.28	2.54[a]	3.18[b]	0.48[c]	1.10[d]
Changes in the LBW rate (% points)	1.26 (e+f)		0.64[e] (b-a)		0.62[f] (d-c)	
Age-parity score (K) for 2005			1.126[g]		0.999[h]	
Expected absolute % points of LBW rate in 2005 when there were no changes in the AP-spe			2.86[i] (a×g)		0.48[j] (c×h)	
Absolute % points of increase in the LBW rate due to changes in the AP-dis	0.32 (k+l)		0.32[k] (i-a)		0.00[l] (j-c)	
Absolute % points of increase in the LBW rate due to changes in the AP-spe	0.94 (m+n)		0.32[m] (b-i)		0.62[n] (d-j)	

increase in the LBW rate among singleton births was attributed to changes in the AP-spe.

Given recent trends in delayed marriage and childbearing in the ROK and the association of maternal age and parity with the LBW rate, the noticeable impact of the shifts in maternal age and parity on the increase in the LBW rate among singleton births was what we had expected. The impact of the shifts in maternal age and parity observed in our study was greater than that reported in the United States [11]. In a study conducted in the United States [11], among white, singleton, live-born infants, 32.5% of the increased rate of very LBW (VLBW) and 7.4% of the increased rate of LBW between 1980 and 1990 were associated with changes in the AP-dis. Among black infants, 15.9% of the increased rate of VLBW and 38.2% of the increased rate of LBW were associated with changes in the AP-dis during the same period. The difference in the contribution of the shifts in maternal age and parity to the increase in the LBW rate between the current study and the study in the United States may be related with racial difference, and degree of a shift in age and parity distribution.

Although the multiple birth rate increased by 0.87% points, from 1.32% in 1995 to 2.19% in 2005, nearly one-half of the total increment in the LBW rate during this time period occurred among multiple births. This was because the LBW rate for multiple births was very high (36.70% in 1995 and 50.33% in 2005).

When the impact of the shifts in maternal age and parity on the increase in the LBW rate was evaluated by calculating the age-parity score, changes in the AP-dis did not contribute to the increase in the LBW rate among multiple births because even though there was a statistically significant shift in the AP-dis between 1995 and 2005, the AP-spe for the mothers 20 - 39 years of age, where the majority of multiple births was distributed, showed a minor variation. In contrast, the AP-spe for these age groups increased significantly in 2005. As a result, the total increment in the LBW rate among multiple births was attributed to changes in the AP-spe.

The increase in the multiple birth rate was most likely associated with increased utilization of assisted reproduction techniques (ART) for infertile couples. The cause of infertility among these couples might be partly associated with advanced maternal and paternal ages. The Korean Society of Obstetrics and Gynecology reported in their annual report on ART that 15 619 treatment cycles were performed in 2000 and 19 149 treatment cycles were performed in 2005. In 2005, the proportion of multiple embryo transfers was 90.0%. The twin rate of *in vitro* fertilization and intracytoplasmic sperm injection was 34.9% and the triplet rate was 0.5% [20]. The twin and triplet rates are directly related to the number of transferred embryos [21]. It is desirable to regulate the number of transferred embryos that had shown a remarkable impact on reducing the multiple birth rate in Sweden [22]. In addition, advances in embryo selection techniques and other techniques relevant to ART are essential to improve the clinical pregnancy rate in single embryo transfers.

The reasons for the increase in the AP-spe among singleton and multiple births could not be determined from the birth registry data. However, there have been several studies that suggest possible explanations for the increase in the AP-spe among singleton and multiple births. First, the distribution of the body mass index of young women in the ROK was shifted to two tails, overweight and underweight [23,24]. Epidemiologic studies have revealed that underweight women, as well as overweight and obese women, have an increased risk of preterm and LBW births [25-28]. Second, maternal occupation during pregnancy has been reported to be associated with pregnancy outcomes, including preterm and LBW births [29]. Increased economic activity in the service sector among young women [30] might have been associated with the LBW rate. Third, lifestyle factors, including maternal cigarette smoking, have been proposed to be associated with an increased risk of preterm and LBW births. Although there is limited evidence on trends in maternal cigarette smoking during pregnancy, increasing trends in cigarette smoking among young women were observed in the national survey data in the ROK [23,24]. Fourth, ambient air pollution has also been suggested as a contributor to the increase in the LBW rate in the ROK [16].

Recent advances in medical technology and changes in obstetrical practices might be associated with a decrease in fetal deaths, which consequently lead to increased rates of LBW or preterm births. Furthermore, obstetrical practices, such as labor induction and cesarean delivery at preterm gestation, may be associated with increased rates of LBW or preterm births. However, the rate of cesarean section in the ROK decreased from 40.5% in 2001 to 37.1% in 2005 [31]. The impact of health care practices, including obstetric interventions, on the LBW rate needs to be explored in future studies.

The limitations of this study include the possibility of inaccurate recording of birth weights in the birth certificates and subsequent misclassification of LBW. However, there is no basis for suspecting changes in the accuracy of birth weight recording over the study period. By using the data regarding the groups of registered births in each year from 1995 to 2005, we attempted to show the relative contribution of the two components, changes in the AP-dis and AP-spe, to the increase in the LBW rate.

In conclusion, this study demonstrated that shifts in maternal age and parity among singleton births and increased multiple births were important contributors to the increment in the LBW rate between 1995 and 2005 in the ROK. This study also revealed that the increase in the AP-spe was an equally important contributor as the shifts in maternal age and parity to the increment in the LBW rate among singleton births and was a major contributor among multiple births. Further studies are warranted to define the causes of the AP-spe increase. In terms of policy implications of our study, considering the worldwide trends in delayed marriage and childbearing, increasing trends in the LBW rate is not likely to be reversed by medical interventions alone. To reduce the LBW rate, public health services and social interventions to facilitate pregnancy at a physiologically optimal age and quality control of ART are recommended.

ACKNOWLEDGEMENTS

This work was supported by the Medical Science Research Institute of the Catholic University of Daegu.

CONFLICT OF INTEREST

The authors have no conflicts of interest with the material presented in this paper.

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