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＜ Original ＞

Early full-term birth is an important factor for the increase in the proportion of low-birth-weight infants between 1980 and 2015 in Japan

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Abstract

Objectives: The proportion of low birth weight (LBW: less than 2,500 g) infants in Japan is increasing consistently. Recent studies have suggested associations between intrauterine development including LBW and an increased risk of chronic diseases, such as obesity, diabetes, and cardiovascular diseases throughout adult life. Further nationwide quantitative analysis is required to clarify the factors that determine the increase in the proportion of LBW infants and the effect on future health outcomes. To address these important issues, we aimed to analyze the factors related to LBW using Vital Statistics of live births between 1980 and 2015 in Japan.

Methods: All birth registry data from 1980, 1985, 1990, 1995, 2000, 2005, 2010, and 2015 (n = 9,743,319), stored in Vital Statistics, a database maintained by the Ministry of Health, Labor, and Welfare of Japan including information from the national census, were analyzed using SAS statistical software version 9.4.

Results: Analysis of the national census in Japan from 1980 to 2015 revealed that the largest risk factor for LBW was an increase in early term birth at 37 gestational weeks. The population attributable risk proportion at 37 weeks showed a two-fold increase from 11% to 22% when adjusted for maternal age, sex, birth order, and number of fetuses. Thus, the gestational duration exhibited a stronger relationship with LBW infants than other evaluated pregnancy-related factors.

Conclusion: While multiple factors could be involved in the increase in the prevalence of LBW, early full-term birth, as likely determined by medical interventions for delivery, such as induction of labor and caesarean sections, constitutes an important factor affecting LBW. A more precise analysis of perinatal medicine for pregnant women is required to reduce the prevalence of LBW.

keywords: low birth weight infants, national census, vital statistics, early term birth, perinatal medicine

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I. Introduction

After World War II, maternal and child health (MCH) in Japan gradually improved, and at present, Japan is one of the countries with the lowest infant mortality rates and lowest maternal mortality rates worldwide. However, Japan is now faced with a highly aged population with the lowest percentage of children, showing low fertility rates and an elevated rate of low birth weight (LBW) infants [1]. Considering these trends, the Healthy Parents and Children 21, the national MCH policy in Japan, has added "an increase in the proportion of healthy-weight children" as one of the specific goals among the many efforts to promote MCH in 2000 [2]. However, the Development Assistance Committee, an Organization for Economic Cooperation and Development committee, has reported that the LBW prevalence in Japan is still higher than that of other developed countries [3]. Kato et al. [4] have reported factors associated with birth weight decline from 1980 to 2004 in Japan. As it is difficult to fully explain recent decreases in birth weight among

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Japanese neonates by trends in gestational age, sex, birth order, multiple gestations, and fathers' age, pre-pregnancy maternal BMI and maternal diet should be considered as additional factors. Takemoto et al. [5] have reported mother age higher than 35 years and preterm birth as risk factors for LBW. Birth weight, perinatal and infant mortality largely depends on the socio-economic factors in developed countries [6]. The factors why LBW infants increased after 1980 in Japan have not fully examined yet. To clarify the characteristics of childbirth in Japan is an urgent task.

Recent epidemiological studies have added ideas of LBW being a risk factor for non-communicable diseases as the fetal programming hypothesis, which is now supported by evidence from research in areas of evolutionary biology and maternal physiology, to be integrated into the theory known as the developmental origins of health and disease. The fetal origins of adult disease theory (the Barker hypothesis) [7] have claimed that adulthood diseases are attributable to malnourishment experienced during fetal, neonatal, or infantile periods. Moreover, it has also become a concern in Japan that the decreased average of birth weight would result in a future increase in the incidence of various diseases. For instance, Ogawa et al. [8] reported that the risk of gestational diabetes mellitus was significantly higher among women born with a weight between 1,500–2,499 grams.

In order to explore directions for health promotion, and to discuss MCH policies in Japan, it is important to clarify the cause, background, and the possible measures on the issues regarding birth weight decline. Therefore, we aimed to analyze the factors related to LBW using Vital Statistics of live births from 1980 to 2015 in Japan.

II. Methods

We obtained birth registry data from the Vital Statistics (definite number) of the Ministry of Health, Labor, and Welfare [9~11]. Vital Statistics data files from the national census, including total live births in Japan, are robust tools for analyzing the factors causing LBW infants in Japan. The data was provided by the Statistics and Information Department of the Minister's Secretariat at the Ministry of Health, Labor, and Welfare, with permission from the Ministry; data could only be obtained if claimed and permitted.

In total, 9,743,319 birth certificate files were retrieved (data from 1980, 1985, 1990, 1995, 2000, 2005, 2010, and 2015). The data was tabulated by the number of children according to birth weight (100 g category), maternal age (every 5 years), sex, gestational age (every week between 23 and 42 weeks), birth order (first, second, and third or more), and number of fetuses (single, multiple). Every 5 years from 1980 to 2015, distribution, prevalence, relative risk (RR) of LBW, and population attributable risk proportion (PARP) of LBW were calculated for maternal age, sex, gestational age, birth order, and number of fetuses. Using the tabulated data, the percentage of each category and RR was calculated using the Poisson regression model. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC, USA). The protocol of the present study was approved by the Ethics Committee of the National Institute of Public Health (approval no. NIPH-IRBA #12010).

III. Results

Table 1 shows the average birth weight of boys and girls, and the proportion of LBW infants, weighing less than 2,500 g at birth, from 1951 to 2020 in Japan. After World War II, the average birth weight of all live births gradually increased from 3.14 kg (boy) and 3.06 kg (girl) in 1951 to 3.23 kg (boy) and 3.14 kg (girl) in 1980. Subsequently, they started to decrease; in 2020, the average birth weights were 3.05 kg (boy) and 2.96 kg (girl), showing 170 g and 180 g decreases, respectively. The rate of LBW has gradually increased from 4.8% (boy) and 5.6% (girl) in 1980 to 8.3% (boy) and 10.6% (girl) in 2020.

Table 2 shows the rate of live births in each gestational week every 5 years from 1980 to 2015. Although slight increase of live births was observed at 35 and 36 weeks, most of the increase occurred at full-term (37 weeks to 41 weeks). Figure 1 shows the change in the rate of live births at 36, 37, 38, 39, 40 and 41 gestational weeks from 1980 to 2015. In 1980, 5.26 % of live births occurred at 37 weeks gestation, whereas this rate increased to 10.65% in 2015 showing a two-fold increase, whereas at 38 weeks, the rate of live births increased from 15.29 % in 1980 to 21.75 % in 2015, showing only a 1.4-fold increase.

The proportion of LBW infants in each gestational week from 1980 to 2015 is shown in Figure 2. LBW infants constantly increased at the preterm period especially from 31 to 37 gestational weeks.

The proportion of LBW infants at 36 to 41 gestational weeks to the total number of LBW infants in each year from 1980 to 2015 is shown in Figure 3. From 1980 to 1995, the proportion of LBW infants was high at 38 weeks, while the peak moved to 37 weeks after year 2000. The highest proportion of LBW infants gradually shifted from 38 weeks to 37 weeks, indicating that the increase in the rate of LBW is prominent at 37 weeks in 2000, 2005, 2010, and 2015. The detailed data on the proportion of LBW infants in each gestational week were shown in Table 3.

The relative risk (RR) of LBW infants at full term from 1980 to 2015 adjusted for all known factors (maternal age, birth order, sex, and multiple pregnancies) is shown

Table 1 Average birth weight and low birth weight (LBW) rate in Japan from 1951 to 2020

Year	Average birth weight (kg)		LBW infant rate (%)		Number of birth
	boy	girl	boy	girl	
1951	3.14	3.06	6.4	8.3	2137689
1960	3.14	3.06	6.5	7.7	1606041
1970	3.22	3.13	5.2	6.1	1934239
1980	3.23	3.14	4.8	5.6	1576889
1990	3.16	3.08	5.7	7.0	1221585
2000	3.07	2.99	7.8	9.5	1190547
2010	3.04	2.96	8.5	10.8	1071304
2020	3.05	2.96	8.3	10.6	840832

Table 2 Distribution of birth rate in each gestational week from 1980 to 2015 (%)

Week	Year							
	1980	1985	1990	1995	2000	2005	2010	2015
<23	0.01	0.02	0.02	0.02	0.03	0.04	0.04	0.04
24	0.01	0.02	0.03	0.03	0.03	0.04	0.04	0.04
25	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.05
26	0.03	0.04	0.05	0.05	0.05	0.06	0.06	0.06
27	0.05	0.05	0.06	0.06	0.07	0.07	0.07	0.06
28	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.08
29	0.07	0.08	0.08	0.09	0.10	0.10	0.10	0.10
30	0.10	0.10	0.10	0.11	0.12	0.13	0.12	0.12
31	0.13	0.13	0.13	0.15	0.19	0.17	0.16	0.15
32	0.20	0.19	0.19	0.20	0.21	0.23	0.22	0.22
33	0.30	0.27	0.28	0.30	0.30	0.32	0.33	0.31
34	0.48	0.47	0.45	0.50	0.52	0.54	0.53	0.54
35	0.83	0.82	0.87	0.92	1.02	1.04	1.04	1.00
36	1.81	1.89	2.16	2.37	2.62	2.82	2.87	2.80
37	5.26	5.79	6.92	7.65	8.60	9.44	10.62	10.65
38	15.29	16.45	18.37	18.89	19.21	19.38	20.31	21.75
39	27.87	28.86	30.01	29.65	29.08	28.25	28.06	28.02
40	30.24	29.09	27.74	27.18	26.67	26.6	25.82	25.36
41	12.79	12.47	10.76	10.54	10.23	10.08	9.14	8.42
42w<	4.43	3.15	1.68	1.18	0.83	0.57	0.33	0.22

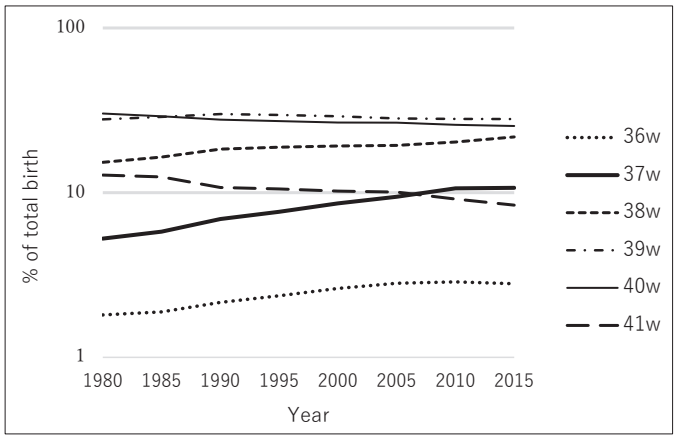

Figure 1 Change in the rate of live birth at 36, 37, 38, 39, 40 and 41 gestational weeks from 1980 to 2015 in logarithmic display

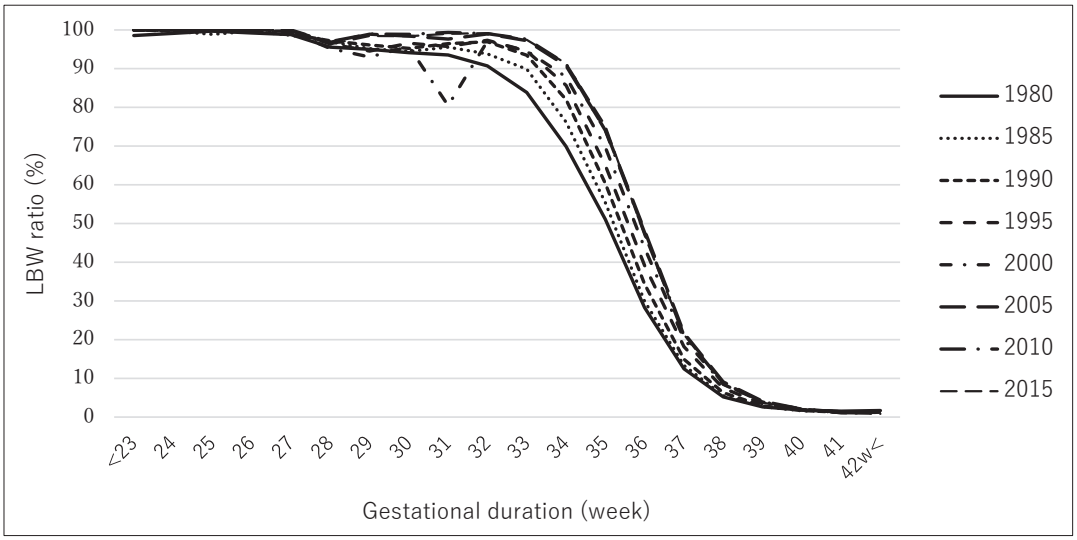

Figure 2 Proportion of LBW infants in each gestational week from 1980 to 2015
LBW: Low birth weight

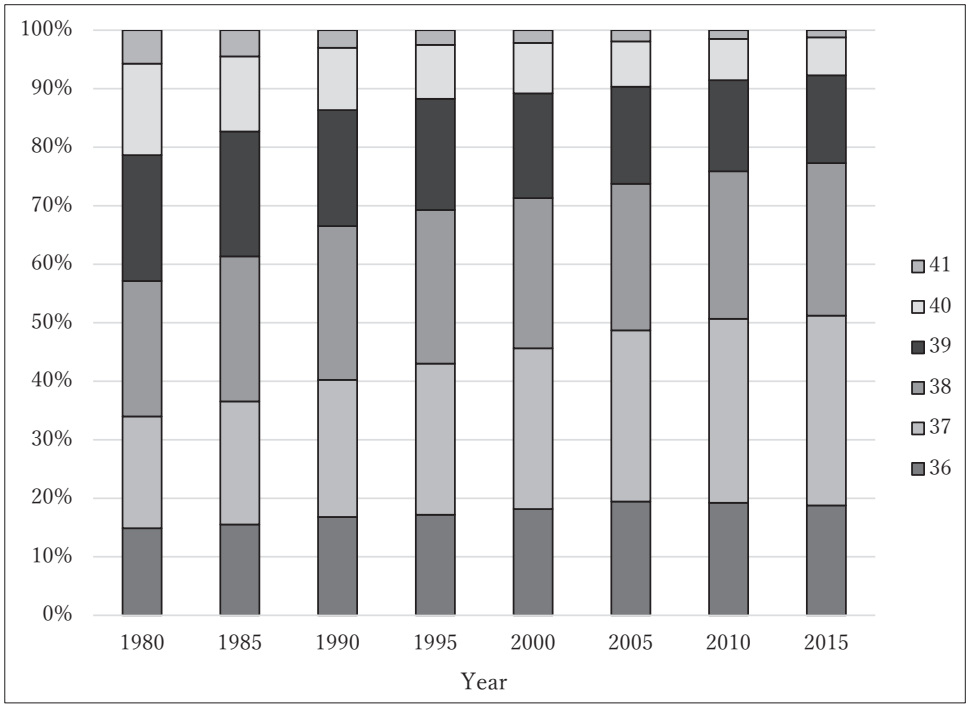

Figure 3 Proportion of LBW infants to total number of LBW infants at 36, 37, 38, 39, 40, and 41 gestational weeks from 1980 to 2015 (%)
LBW: Low birth weight

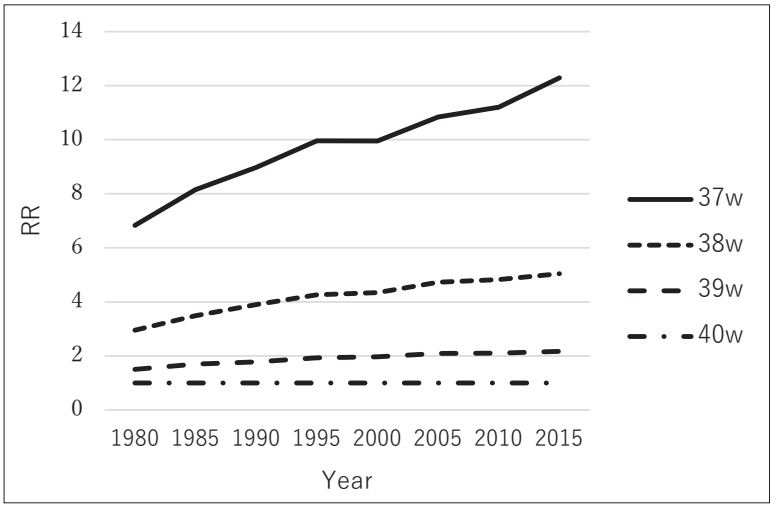

Figure 4 Relative risk (RR) of LBW infants at term pregnancy (37–40 gestational weeks) from 1980 to 2015 adjusted for all known factors (maternal age, birth order, sex, and multiple pregnancies)
LBW: Low birth weight
Reference = 40 weeks of gestation

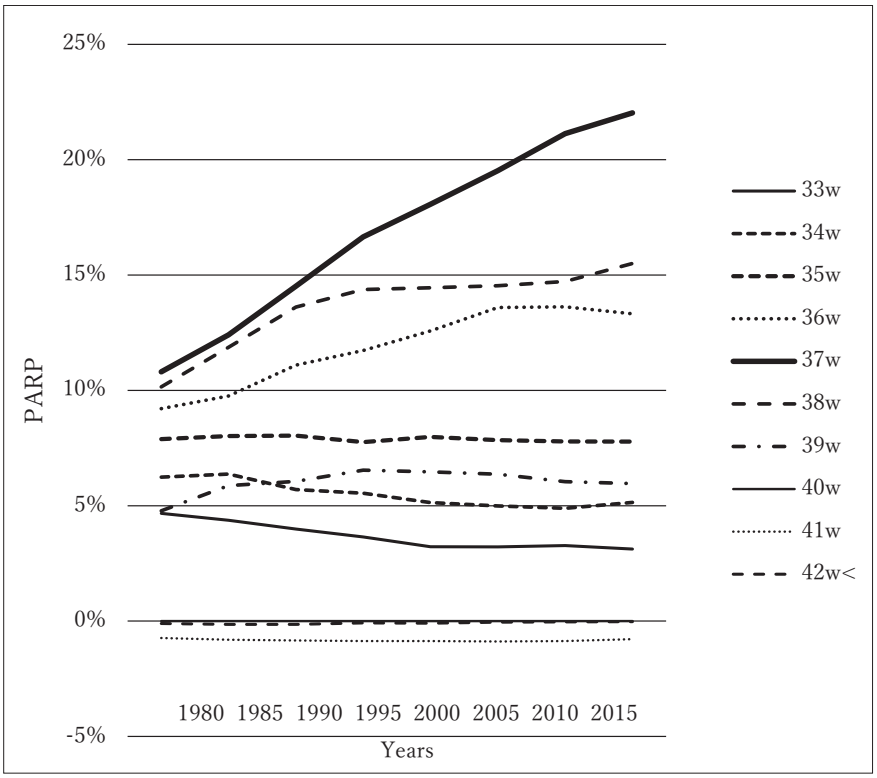

Figure 5 PARP of LBW infants at 33, 34, 35, 36, 37, 38, 39, 40, 41, and 42 gestational weeks between 1980 and 2015 adjusted for all known factors (maternal age, birth order, sex, and multiple pregnancies)
LBW: Low birth weight, PARP: Population attributable risk proportion
Reference = 40 weeks of gestation

Table 3 Proportion of LBW infants in each gestational week to total number of LBW infants in each year from 1980 to 2015 (%)

LBW: Low birth weight

Week	Year							
	1980	1985	1990	1995	2000	2005	2010	2015
<23	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.5
24	0.3	0.4	0.5	0.4	0.4	0.4	0.4	0.4
25	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
26	0.6	0.8	0.7	0.7	0.6	0.6	0.6	0.6
27	0.9	0.9	1.0	0.8	0.8	0.7	0.7	0.7
28	1.2	1.3	1.1	1.0	0.9	0.9	0.9	0.8
29	1.4	1.4	1.2	1.1	1.1	1.1	1.0	1.0
30	1.9	1.8	1.5	1.5	1.3	1.4	1.3	1.3
31	2.4	2.3	2.0	1.9	1.8	1.7	1.7	1.6
32	3.4	3.2	3.0	2.6	2.3	2.4	2.3	2.3
33	4.8	4.5	4.1	3.7	3.3	3.3	3.3	3.2
34	6.4	6.5	5.8	5.7	5.3	5.1	5.0	5.3
35	8.2	8.3	8.3	8.0	8.3	8.1	8.0	8.0
36	9.9	10.4	11.7	12.3	13.3	14.3	14.2	13.9
37	12.7	14.1	16.3	18.5	20.1	21.5	23.2	24.0
38	15.4	16.6	18.3	18.8	18.8	18.4	18.6	19.3
39	14.3	14.3	13.8	13.6	13.1	12.2	11.5	11.1
40	10.4	8.6	7.4	6.6	6.3	5.7	5.2	4.8
41	3.8	3.0	2.1	1.8	1.6	1.4	1.1	0.9
42<	1.5	0.8	0.3	0.2	0.1	0.1	0.0	0.0

Table 4 Relative risk (RR) of LBW infants in each gestational week between 1980 and 2015 adjusted for all known factors (maternal age, birth order, sex, and multiple pregnancies)

LBW: Low birth weight, Reference=40 weeks of gestation

Week	Year							
	1980	1985	1990	1995	2000	2005	2010	2015
<23	43.9	56.1	50.8	44.3	41.7	45.0	48.8	52.2
24	45.4	54.9	50.9	45.4	43.5	44.7	48.1	51.6
25	49.2	52.9	49.9	49.4	42.6	43.6	48.5	53.7
26	51.0	57.0	52.3	46.5	42.8	45.2	48.3	52.0
27	48.5	52.5	49.5	48.2	41.5	44.1	47.2	49.6
28	46.1	54.1	50.6	45.7	39.5	42.8	45.9	49.3
29	45.6	52.5	50.7	45.2	39.1	42.2	45.9	50.1
30	46.5	50.5	50.7	44.0	41.4	43.2	45.6	49.3
31	43.9	51.3	49.4	44.7	35.8	41.8	46.3	50.1
32	42.6	51.0	49.9	45.3	40.6	42.9	46.0	49.9
33	40.2	48.5	48.9	44.6	40.2	41.4	45.5	49.1
34	33.6	42.1	43.0	40.6	37.4	38.9	43.0	47.2
35	25.0	30.7	32.7	31.7	30.3	32.5	35.1	39.2
36	14.6	17.4	19.3	20.1	19.7	21.6	23.2	25.1
37	6.8	8.2	9.0	10.0	10.0	10.8	11.2	12.3
38	3.0	3.5	3.9	4.3	4.3	4.7	4.8	5.0
39	1.5	1.7	1.8	1.9	2.0	2.1	2.1	2.2
40	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
41	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.5
42<	0.9	0.9	0.7	0.7	0.5	0.6	0.5	0.4

Table 5 PARP of LBW infants in each gestational week from 1980 to 2015 adjusted for all known factors (maternal age, birth order, sex, and multiple pregnancies) (%)

LBW: Low birth weight, PARP: Population attributable risk proportion, Reference=40 weeks of gestation

Week	Year							
	1980	1985	1990	1995	2000	2005	2010	2015
<23	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.5
24	0.3	0.4	0.5	0.4	0.4	0.4	0.4	0.4
25	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
26	0.6	0.8	0.7	0.6	0.5	0.6	0.6	0.6
27	0.9	0.9	0.9	0.8	0.7	0.7	0.7	0.7
28	1.2	1.2	1.1	0.9	0.9	0.9	0.9	0.8
29	1.3	1.4	1.2	1.1	1.0	1.0	1.0	1.0
30	1.8	1.7	1.5	1.4	1.3	1.3	1.3	1.3
31	2.4	2.3	2.0	1.8	1.7	1.7	1.6	1.6
32	3.4	3.2	2.9	2.5	2.3	2.3	2.2	2.2
33	4.7	4.4	4.0	3.7	3.2	3.2	3.3	3.1
34	6.2	6.4	5.7	5.5	5.1	5.0	4.9	5.1
35	7.9	8.0	8.0	7.8	8.0	7.8	7.8	7.8
36	9.2	9.8	11.1	11.7	12.6	13.6	13.6	13.3
37	10.8	12.4	14.5	16.7	18.1	19.5	21.1	22.0
38	10.2	11.9	13.6	14.4	14.4	14.5	14.7	15.5
39	4.8	5.9	6.1	6.5	6.5	6.4	6.0	6.0
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	-0.7	-0.8	-0.8	-0.9	-0.9	-0.9	-0.9	-0.8
42<	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0

in Figure 4. Multivariate adjusted RR of LBW by gestational week, using 40 weeks of gestation as the reference (RR=1.0), is shown. The RR adjusted for all known factors (maternal age, birth order, sex, and multiple pregnancies), increased as the gestational duration shortened (35–38 weeks) in these 35 years. In term pregnancy at 37, 38, 39, and 40 weeks, the RR at 37 weeks increased from 6.8 to 12.3. The detailed data of RR in each gestational week are shown in Table 4.

Figure 5 shows the PARP of LBW infants at 33～42weeks of gestation from 1980 to 2015, adjusting for all the known factors (maternal age, birth order, sex, and multiple pregnancies). The PARP peaked at 37 weeks of gestation and increased from 10.8 % in 1980 to 22.0 % in 2015. This indicates that the increase in the number of births at 37 weeks has mainly influenced the increase in the proportion of LBW infants. The detailed data on the PARP of LBW infants in each gestational week are shown in Table 5.

IV. Discussion

In the present study, analysis of the PARP of gestational week adjusted by the factors (sex, gestational duration, single/multiple, birth order, and maternal age) obtained from Vital Statistics has shown that shortened gestational duration at 37 weeks has been prominent in Japan over the past 35 years (Figure 5). As full-term gestation is defined as 37 to 40 gestational weeks, 37 weeks of gestation indicates an early stage of maturity, called early full-term. The birth at 37 weeks is the most influential factor for the increase in the rate of LBW in Japan. However, it does not indicate the increases of preterm birth nor early neonatal deaths [12], showing no difficulty in surviving outside the womb, which is supposedly attributed to the increase in the rates of multiple pregnancies [13]. There has been little change in the distribution of birth weight at 37 weeks over the past 35 years, which indicates that there has not been much deterioration in the intrauterine environment at 37 weeks despite the increase in the proportion of LBW infants.

Changes in maternal nutrient intake and slimming trends among women are some of the causes of increased rate of LBW in Japan [14]. A chart for optimal maternal weight gain used in Japan adopts strict body weight restrictions compared to those used in other countries [15, 16]. It is said that the possibility of its influence on LBW infants cannot be denied. Moreover, Okui et al. [17] have reported an association between maternal occupations and LBW infants in Japan from 1995 to 2015, which revealed that the standardized LBW ratio for manual workers was the highest among all occupations from 2000 to 2015.

It is assumed that after 2000, a medical incident by an obstetrician triggered a decrease in obstetrician involvement in perinatal care in Japan [18]. The deficiency in human resources in the field of perinatal medicine has brought about the inevitable choices of cesarean section [19]. Early interruption of gestation caused shortened gestational duration

and increased the proportion of LBW infants [20]. These factors resulted in the need for neonatal medicine, leading to an additional healthcare burden.

The strength of this study is that we used the whole population data from Vital Statistics of all births between 1980 and 2015. However, there are limitations of the original data resources lacking in important variables. To clarify the cause of the increase in LBW infants at 37 gestational weeks, more detailed variables are needed, such as information on their delivery method, weight gain during pregnancy and smoking status of parents.

Also, there should be included risks of lifestyle-related diseases, infertility treatments and the burden on perinatal medicine of the parents in the database. In the future, it will be necessary to track the prognosis of children through a large-scale survey that includes information on the method of delivery of pregnant women and the course of pregnancy. Continuous follow-up on health and diseases of LBW children is essential.

Further investigations are needed to identify risk factors to be applied in effective health instructions by analyzing existing databases, including Vital Statistics. We should develop a nationwide cohort study that can help predict the risk of LBW infants in the field of perinatal medicine. More detailed demographic surveys of LBW infants, including cohort studies on long-term follow-up of the post-growth health status of LBW infants are needed for further research in the field.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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＜原著＞

我が国における低出生体重児増加（1980 ～ 2015 年）におよぼす早期正期産増加の影響

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抄録

目的：日本では，低出生体重（LBW：2,500g未満）児の出生割合が増加している．近年の研究では，胎児の子宮内発育と，成育後の肥満，糖尿病，心血管疾患などの慢性疾患のリスク増加との関連が示唆されており，LBW児の増加はこの点からも危惧される．我が国におけるLBW児の増加の要因やLBW児の生育後の健康状態への影響を明らかにする全国規模の分析が必要である．今回，1980年から2015年までの出生児の人口動態統計という全数調査データを用いて，LBW児の増加の要因を解析した．

方法：人口動態統計特別集計データの1980年から2015年におけるLBW児割合の変遷を５年おきに分析した（n＝9,743,319）．統計解析にはSAS ver 9.4（Windows版）を用いた．

結果：1980年から2015年まで35年間の人口動態調査の全数把握データを用い，妊娠週数，母体年齢，性別，出生順位，胎児数などの要因で調整した人口寄与危険割合（Population attributable risk proportion：PARP）を分析したところ，妊娠37週における変化が最も大きく11％から22％へと２倍に増加した．これにより，妊娠37週での出生は他の要因よりもLBW児増加と強い相関のあることが示された．

結論：やせや母親の勤務環境などLBW児増加に影響を与える要因は数多くあるが，陣痛誘発や帝王切開などの医療的介入によって妊娠期間が早まるものの正期産の週数以内でとどまっており，早期正期産の増加が集団全体としてLBW児の増加に最も寄与することが示唆された．今後は，妊婦の分娩方法や妊娠経過に関する情報も含めた大規模調査によりLBW児の増加要因ならびに児の予後を追跡していく必要があると考えられた．

キーワード：低出生体重児，国勢調査，人口動態統計，早期正期産，周産期医療