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High Maternal Age and Low Pre-Pregnancy Body Mass Index Correlate with Lower Birth Weight of Male Infants

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In Japan, the percentage of leanness has been increasing in young women, and the percentage of low birth weight infants (< 2,500 g) has increased. Moreover, the average age of primiparas rose 3.5 years during the last 30 years. The purpose of this study was to clarify the relationship between maternal age and the influence of maternal pre-pregnancy physique on the neonatal physique of infants. Questionnaires were issued to the participants and collected when they submitted their gestational notifications at their local ward office in Kyoto Prefecture. After delivery, we obtained information on the course of the pregnancy and the neonatal physique of the infants from the participant's maternal passbooks. A total of 454 mothers (age 20 ≥) were analyzed: 161 young mothers (aged 20 to 29 years), 185 mothers (aged 30 to 34 years), and 108 older mothers (age ≥ 35). Overall, the mean rate of leanness (pre-pregnancy BMI < 18.5) was 23.8%. We found that birth weight was significantly lower in female infants, born to lean young mothers, compared to non-lean young mothers, whereas no significant difference was detected in other mothers (age ≥ 30), irrespective of pre-pregnancy BMI. By contrast, male infants, born to older lean mothers (age ≥ 35), showed significantly lower birth weight. Thus, maternal pre-pregnancy BMI exerts differential effects on the fetal growth (neonatal physique), depending on the maternal age and the sex of infants. We need to improve BMI in pre-pregnancy women, especially those in the twenties and 35 years old or over.

Keywords: birth weight; body mass index; infant; mother; physique
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Introduction

The percentage of low birth weight (LBW, < 2,500g) infants, including premature infants, has risen in Japan, from 5.2% in 1980 to 9.6% in 2010 (Health, Labour and Welfare Statistics Association 2010). It has been reported that the risk of death due to circulatory diseases caused by hypertension or arteriosclerosis, as well as the risk of metabolic syndrome, may show an increase after lower birth weight infants reach adulthood (Barker 1995; Jaquet et al. 2005; Risnes et al. 2009). This theory, known as the "Fetal Origins of Adult Disease" (Barker and Osmond 1986), was proposed by Barker in 1986, and it is considered one of the foremost medical hypotheses of the 20th century. This theory has also drawn a lot of attention in Japan. The results of other reports have suggested the association between infant birth weight and height at birth and abnormal glucose tolerance in adults (Antonisamy et al. 2009), as well as a relationship between the head circumference at birth and the rate of deaths due to heart disease (Barker et al. 1993; Risnes et al. 2009). Accordingly, a method to reduce the lower birth weight of infants is to prevent non-communicable diseases in adulthood.

The increase in the number of lower birth weight

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infants is in part due to maternal pre-pregnancy leanness, smoking, an increase in delivery at a later age, and weight management instructions given by obstetricians intended to prevent pregnancy-induced hypertension and accidents at birth (Murakami et al. 2005; Takimoto et al. 2005; Noguchi 2008). Especially for women, the high educational background and social status factors have improved recently, and their life style has become diversified. The average age of primiparas rose 4.6 years in the last 37 years, from 25.7 years in 1975 to 30.3 years in 2012 (Health, Labour and Welfare Statistics Association 2012), and it is expected that this trend will continue. Previously, we reported that the influence of the mother's physique was stronger in pluriparas, compared with primiparas (Fukuda et al. 2015). There was a possibility that the effect of the older mother's physique on the neonatal physique of the infants was stronger than that in the younger mothers.

In a previous study (Sawada et al. 2010), conducted in the central part of Kyoto Prefecture in 2007, with 195 subjects aged from 16 to 40 years, we found that the percentage of maternal pre-pregnancy leanness was 17.0% for all of the mothers. Several reports have been published on the relationship between maternal pre-pregnancy leanness and the birth of lower birth weight infants (Sebire et al. 2001; Ehrenberg et al. 2003; Watanabe et al. 2010; Ye et al. 2010). However, no studies have focused on the impact of maternal age. Therefore, the purpose of this study was to clarify the influence of a mother's age on the relationship between pre-pregnancy body mass index (BMI) and the neonatal physique of an infant.

Subjects and Methods

Study subjects

We conducted this prospective study in three municipalities in Kyoto Prefecture, Nantan City in the central part of the prefecture, as well as Nagaokakyo City and Seika-cho in the southern part of the prefecture.

As shown in Fig. 1, the subjects of the study were 775 mothers who submitted gestational notifications in a one-year period from September 26, 2009 through August 30, 2010. A total of 642 (82.8%) mothers agreed to participate in the study. We excluded mothers who had their gestational notifications submitted by proxy, either by their husband or another individual, and mothers with polytocous births. We explained to the participants that we would conduct a study of the neonatal physique of infants at the infant health examination, and 474 participants agreed to the examination (73.8% of the original mothers who agreed to participate in the study and 62.1% of the mothers who submitted gestational notifications). We eliminated 2 mothers who did not fill in the age item for the mother in the gestational notifications, 3 mothers under the age 20, and 15 mothers who had premature births (3.2%), leaving 454 participants available for analysis.

Study methods

The study was conducted on an open, volunteer basis. When the subjects submitted their gestational notifications at their local ward office, the ward office clerks explained the main purpose of the study and informed the subjects that there were no disadvantages if they decided to refuse participation. We considered that the participants agreed to participation when they signed an informed consent form. The questionnaires were collected directly from the ward office after submission. There were 10 items in the questionnaires, includ-

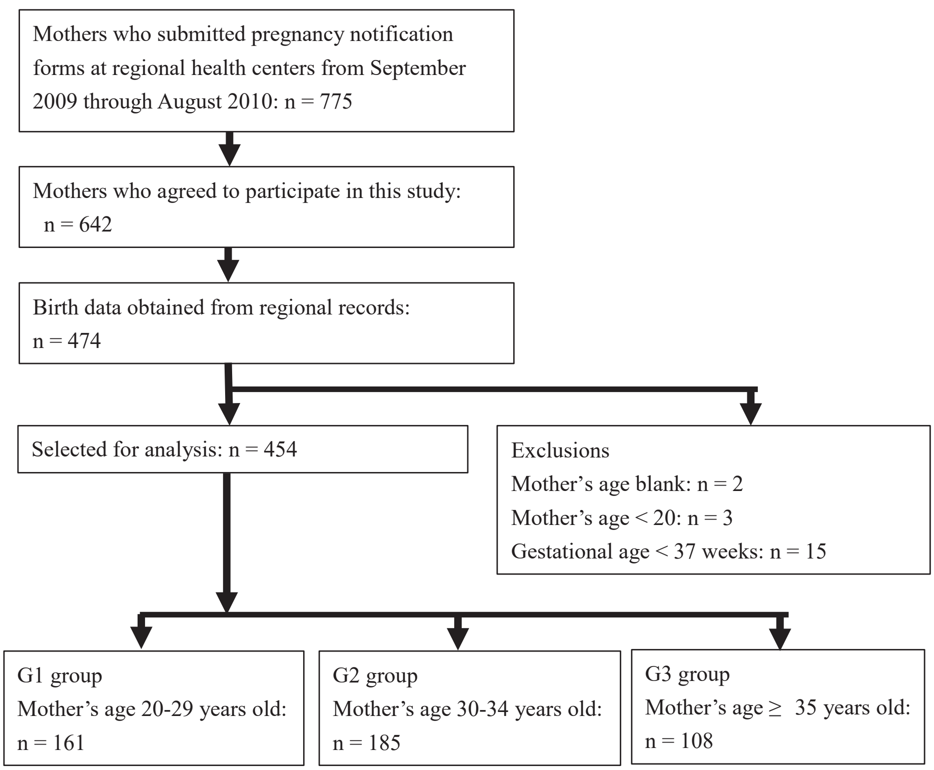

Fig. 1. Study design and subjects.

ing 6 items related to the physical condition of the participants (age, pre-pregnancy height, pre-pregnancy weight, pregnancy history, delivery history, and the number of deliveries) as well as 4 items related to life-style habits (smoking and drinking status, both pre- and during-pregnancy).

After delivery, we obtained information on the course of the pregnancy and conducted by the local municipality. The researchers explained the main purpose of the study. We considered that the participants agree to participation when they signed an informed consent form.

There were 7 items in the questionnaires related to the course of the pregnancy (increase in the body weight of the mother, edema, proteinuria, hypertension, diabetes, anemia, threatened miscarriage and the existence or nonexistence of premature delivery). There were also 3 items related to the delivery status (the health of the mother, infant abnormalities, and the nonexistence of multiple fetation), as well as 5 items related to the status of the infant after delivery (gestational length, weight, height, head circumference, and chest circumference).

Statistical analysis

Based on the definitions published by the Japan Society of Obstetrics and Gynecology and the WHO for birth at an elderly age, the participants were divided into the younger mother's group (age ≥ 20, < 35) and the older mother's group (age ≥ 35). Furthermore, the younger mother's group was divided into the G1 group (age ≥ 20, < 30: aged 20 to 29 years) and the G2 group (age ≥ 30, < 35: aged 30 to 34 years). The elder mother's group was the G3 group (age ≥ 35).

The pre-pregnancy BMI for each participant was calculated by taking the body weight (kg) at the beginning of pregnancy and dividing it by the square of the height (m) of the subject. The subjects were then categorized into lean (BMI < 18.5 kg/m^2) and non-lean (BMI ≥ 18.5 kg/m^2) groups, based on their BMI values. The Kaup index for the infants was calculated by dividing the birth weight by the square of the birth height (g/cm^2 × 10).

We employed the mean and standard deviation of the quantitative data. The Mann-Whitney U test was employed to assess the distribution of the quantitative variables in the two groups. The one-way analysis of variance was employed to assess the distribution of the quantitative variables in the three groups and the χ^2 test was employed to assess the category variables for relativity and independency. Furthermore, for each of the three maternal age groups (G1, G2 and G3), the infant body weight at birth was considered an objective variable and the mother's age, the mother's BMI, the number of births, the gestational length, the total weight gain during the pregnancy and the smoking during pregnancy were taken as explanation variables. Next, with the variable selection standard taken as $P < 0.05$, multiple linear regression models using the backward selection method were employed to assess the effect of maternal pre-pregnancy BMI on the body weight of the infants. When missing values were included in the explanation variables, only the item concerned was treated as having a missing value. P values less than 0.05 were considered significant. The statistical software IBM SPSS Statistics for Windows Version 19.0 (IBM Japan Inc., Tokyo, Japan) was used for the analyses.

Ethical considerations

All of the participants in the study were informed of the purpose of this study. In addition, we confirmed their intention for participation in the study. Each participant signed an informed consent form. This study was approved by the Ethics Committee of Kyoto Prefectural University (Fiscal year 2010, No. 32).

Results

Table 1 shows the characteristics of the infants and

Table 1. Characteristics of the mothers categorized by the mother's age.

	Mother's age				
	Selected sample	G1 group (age ≥ 20, < 30)	G2 group (age ≥ 30, < 35)	G3 group (age ≥ 35)	P value
Number	454	161	185	108	
Mother					
Age^a	31.3 ± 4.2	26.8 ± 2.1	32.0 ± 1.4	36.8 ± 2.0	< 0.001$^{1)}$
Lean group (BMI < 18.5) (%)	23.8	25.0	22.5	11.9	0.034$^{2)}$
Height (cm)^a	158.8 ± 5.3	159.1 ± 5.5	158.6 ± 5.4	158.9 ± 4.9	0.676$^{1)}$
Weight (kg)^a	50.8 ± 8.1	50.3 ± 10.2	50.7 ± 7.0	51.7 ± 6.2	0.396$^{1)}$
BMI (kg/m^2)^a	20.0 ± 2.3	19.6 ± 2.0	20.1 ± 2.5	20.5 ± 2.4	0.016$^{1)}$
Total weight gain (kg)^a	9.4 ± 2.9	10.1 ± 3.0	9.0 ± 3.0	9.0 ± 2.6	0.003$^{1)}$
Gestational length (weeks)^a	39.2 ± 1.1 (39 wk 1d)	39.3 ± 1.1 (39 wk 2d)	39.1 ± 1.2 (39 wk 1d)	39.2 ± 1.1 (39 wk 1d)	0.526$^{1)}$
Cesarean deliveries (%)	16.3	9.9	17.8	23.1	0.012$^{2)}$
Primiparas (%)	42.7	59.6	37.3	26.4	< 0.001$^{2)}$
Drinking before pregnancy (%)^b	27.2	24.8	28.4	28.7	0.742$^{2)}$
Drinking during pregnancy (%)^b	0.8	0.0	0.7	2.3	0.178$^{2)}$
Smoking before pregnancy (%)^c	11.9	17.4	10.8	5.6	0.011$^{2)}$
Smoking during pregnancy (%)^c	3.0	1.9	3.4	3.9	0.607$^{2)}$

^{a}Mean ± SD.
^{b}Drinking: once/week or more.
^{c}Smoking: everyday or more.
$^{1)}$one-way analysis of variance for differences among three groups.
$^{2)}\chi^2$ test for differences among three groups.
BMI, body mass index.

Table 2. Physical characteristics of the infants categorized by the mother's age and characteristics.

Mothers	n	Birth weight (g)	P value	Birth height (cm)	P value	Birth head circumference (cm)	P value	Birth chest circumference (cm)	P value	Kaup index	P value
Age											
G1 group (age ≥ 20, < 30)	161	3,031 ± 348		48.8 ± 1.9		33.2 ± 1.3		31.7 ± 1.6		12.7 ± 0.9	
G2 group (age ≥ 30, < 35)	185	3,077 ± 331	0.397[1)]	49.0 ± 1.8	0.13[1)]	33.6 ± 1.3	0.063[1)]	32.0 ± 1.5	0.177[1)]	12.8 ± 1.0	0.283[1)]
G3 group (age ≥ 35)	108	3,033 ± 376		48.6 ± 1.8		33.4 ± 1.4		32.0 ± 1.7		12.9 ± 1.1	
Physical											
Non lean (BMI ≥ 18.5)	341	3,064 ± 351	0.024	48.9 ± 1.8	0.018	33.5 ± 1.3	0.004	31.9 ± 1.7	0.022	12.8 ± 1.0	0.13
Lean (BMI < 18.5)	90	2,971 ± 335		48.4 ± 1.7		33.0 ± 1.4		31.5 ± 1.5		12.6 ± 0.9	
Parity											
Primiparas	193	3,040 ± 355	0.44[2)]	49.0 ± 1.8	0.09[2)]	33.3 ± 1.5	0.24[2)]	31.7 ± 1.7	0.5[2)]	12.6 ± 1.0	0.006[2)]
Pluripare	259	3,059 ± 342		48.7 ± 1.8		33.5 ± 1.3		32.0 ± 1.5		12.9 ± 1.0	
Drinking before pregnancy											
Yes[a]	102	3,113 ± 346	0.044[2)]	49.1 ± 1.9	0.09[2)]	33.5 ± 1.3	0.24[2)]	32.1 ± 1.7	0.5[2)]	13.0 ± 1.1	0.006[2)]
No	273	3,027 ± 352		48.7 ± 1.9		33.4 ± 1.4		31.8 ± 1.6		12.7 ± 1.0	
Drinking during pregnancy											
Yes[a]	3	2,995 ± 249	0.75[2)]	48.7 ± 1.5	0.89[2)]	33.7 ± 1.0	0.72[2)]	31.3 ± 1.5	0.47[2)]	12.6 ± 0.6	0.78[2)]
No	363	3,052 ± 353		48.8 ± 1.9		33.4 ± 1.4		31.9 ± 1.6		12.8 ± 1.0	
Smoking before pregnancy											
Yes[b]	54	3,027 ± 359	0.5[2)]	48.8 ± 1.8	0.95[2)]	33.2 ± 1.5	0.18[2)]	31.8 ± 1.4	0.67[2)]	12.7 ± 0.9	0.38[2)]
No	400	3,053 ± 347		48.8 ± 1.8		33.4 ± 1.3		31.9 ± 1.6		12.8 ± 1.0	
Smoking during pregnancy											
Yes[b]	13	2,985 ± 425	0.54[2)]	48.5 ± 1.9	0.76[2)]	32.9 ± 1.6	0.09[2)]	31.5 ± 1.6	0.61[2)]	12.7 ± 1.2	0.93[2)]
No	419	3,050 ± 346		48.8 ± 1.8		33.4 ± 1.3		31.8 ± 1.6		12.8 ± 1.0	

[a]Drinking: once / week or more.
[b]Smoking: everyday or sometimes.
[1)]one-way analysis of variance for differences among three groups.
[2)]t test.
BMI, body mass index.

mothers categorized by the mother's age. Among the three age groups, the rate of leanness was highest in the G1 group (aged 20 to 29 years) (P = 0.034). The statistically significant difference was detected in the BMI (P = 0.016) among the three groups. The weight gain was the highest in the G1 group (P = 0.003).

Table 2 shows the physical characteristics of the infants categorized by the mother's age and characteristics. As a result of a comparison of the physical characteristics of the infants at birth classified by the leanness of the mothers, significantly lower values were detected for the birth weight (P = 0.024), the height (P = 0.018), the head circumference (P = 0.004) and the chest circumference (P = 0.022) in the lean group, compared with the non-lean group. The Kaup index showed statistically significant values for parity (P = 0.006) and drinking before pregnancy (P = 0.006). However, no statistically significant differences were detected for the mother's age, or the physical characteristics of the infants at birth classified by the smoking status of the mothers.

Table 3 shows the comparison of the characteristics of the mothers and infants in the lean and non-lean groups. In case of male infants, born to mothers in the G1 group (aged 20 to 29 years), no statistically significant differences were detected between the lean and non-lean groups for any of the items. In the G2 group (aged 30 to 34 years), the significantly higher value was demonstrated in the non-lean group only for the rate of cesarean deliveries (P = 0.025). On the other hand, in the G3 group (age ≥ 35), significantly lower values were demonstrated in the lean group for the total weight gain during pregnancy (P = 0.024), the birth weight (P = 0.044), the chest circumference (P = 0.008) and the Kaup index (P = 0.048). In case of female infants, born to mothers in the G1 group, significantly lower values were demonstrated in the lean group for the birth weight (P = 0.017), the head circumference (P = 0.021) and the Kaup index (P = 0.029). In the G2 group, significantly lower values were demonstrated in the lean group for the birth height (P = 0.042) and the chest circumference (P = 0.024). Furthermore, a significantly higher value was demonstrated in the lean group for the rate of LBW (P = 0.025). In the G3 group, significantly lower values were demonstrated in the lean group for the birth chest circumference (P = 0.004) and the total weight gain during pregnancy (P = 0.005).

To clarify the independent effect of the pre-pregnancy BMI of the mothers at the beginning of pregnancy on the

Table 3. Comparison of the characteristics of the mothers and infants in the lean and non-lean groups of mothers categorized by the mother's age.

		G1 group (age ≥ 20, < 30)			G2 group (age ≥ 30, < 35)			G3 group (age ≥ 35)		
		Lean group (BMI < 18.5)	Non-lean group (BMI ≥ 18.5)	P value	Lean group (BMI < 18.5)	Non-lean group (BMI ≥ 18.5)	P value	Lean group (BMI < 18.5)	Non-lean group (BMI ≥ 18.5)	P value
Male infants (n = 218)	Number	18	64		19	69		5	43	
	Mother									
	Total weigth gain (kg)[a]	10.5 ± 1.9	10.1 ± 3.4	0.219[1)]	9.3 ± 2.9	9.6 ± 2.8	0.805[1)]	6.0 ± 3.1	9.4 ± 2.5	0.024[1)]
	Gestational length (weeks)[a]	39.2 ± 1.0 (39 wk 1d)	39.2 ± 1.1 (39 wk 1d)	0.747[1)]	38.9 ± 1.2 (38 wk 6d)	38.9 ± 1.1 (38 wk 6d)	0.950[1)]	39.0 ± 0.7 (39 wk 0d)	39.1 ± 1.2 (39 wk 0d)	0.819[1)]
	Cesarean deliveries (%)	11.1	14.1	0.549[2)]	5.3	29.0	0.025[2)]	20.0	30.2	0.542[2)]
	Primiparas (%)	72.2	53.1	0.119[2)]	43.5	47.4	0.481[2)]	40.0	25.6	0.413[2)]
	Infants									
	Birth weight (g)[a]	3,114 ± 293	3,065 ± 341	0.423[1)]	3,208 ± 340	3,152 ± 307	0.637[1)]	2,736 ± 275	3,084 ± 423	0.044[1)]
	Birth height (cm)[a]	48.7 ± 1.6	49.3 ± 1.8	0.443[1)]	49.5 ± 1.7	49.4 ± 1.7	0.557[1)]	47.8 ± 1.4	49.0 ± 1.7	0.161[1)]
	Birth head circumference (cm)[a]	33.5 ± 1.4	33.3 ± 1.3	0.811[1)]	33.8 ± 1.6	34.0 ± 1.2	0.650[1)]	32.6 ± 0.5	33.6 ± 1.6	0.107[1)]
	Birth chest circumference (cm)[a]	32.3 ± 1.2	31.9 ± 1.8	0.664[1)]	32.6 ± 1.4	32.4 ± 1.6	0.602[1)]	29.5 ± 1.7	31.9 ± 1.8	0.008[1)]
	Kaup index (g / cm^2 × 10)[a]	13.1 ± 0.8	12.6 ± 1.0	0.079[1)]	13.0 ± 1.0	13.0 ± 1.1	0.755[1)]	12.0 ± 0.8	12.8 ± 1.2	0.048[1)]
	Lower birth weight infants (%)[b]	0.0	1.6	0.780[2)]	0.0	0.0	1.000[2)]	20.0	4.7	0.286[2)]
Female infants (n = 212)	Number	20	50		21	68		7	46	
	Mother									
	Total weigth gain (kg)[a]	10.5 ± 2.7	9.6 ± 3.0	0.149[1)]	8.7 ± 2.4	8.7 ± 3.2	0.784[1)]	7.9 ± 0.6	9.3 ± 2.3	0.050[1)]
	Gestational length (weeks)[a]	39.0 ± 1.2	39.4 ± 1.1	0.305[1)]	39.2 ± 1.1	39.4 ± 1.2	0.468[1)]	38.9 ± 0.7	39.4 ± 1.1	0.198[1)]
	Cesarean deliveries (%)	10.0	6.0	0.444[2)]	9.5	13.2	0.493[2)]	14.3	19.6	0.605[2)]
	Primiparas (%)	72.2	53.1	0.07 [2)]	42.9	26.5	0.125[2)]	28.6	25.0	0.581[2)]
	Infants									
	Birth weight (g)[a]	2,806 ± 218	3,013 ± 374	0.017[1)]	2,898 ± 354	3,022 ± 326	0.149[1)]	2,827 ± 195	3,028 ± 353	0.133[1)]
	Birth height (cm)[a]	47.9 ± 1.6	48.4 ± 1.8	0.184[1)]	48.0 ± 1.7	48.8 ± 1.8	0.042[1)]	47.7 ± 1.7	48.1 ± 1.9	0.528[1)]
	Birth head circumference (cm)[a]	32.4 ± 1.5	33.1 ± 1.2	0.021[1)]	32.8 ± 1.3	33.3 ± 1.2	0.150[1)]	32.9 ± 1.5	33.5 ± 1.2	0.126[1)]
	Birth chest circumference (cm)[a]	31.4 ± 1.3	31.5 ± 1.6	0.652[1)]	31.0 ± 1.2	31.8 ± 1.4	0.024[1)]	30.7 ± 0.6	32.0 ± 1.5	0.004[1)]
	Kaup index (g / cm^2 × 10)[a]	12.2 ± 0.6	12.8 ± 1.0	0.029[1)]	12.5 ± 1.1	12.7 ± 0.9	0.457[1)]	12.5 ± 1.1	13.1 ± 1.0	0.174[1)]
	Lower birth weight infants (%)[b]	5.0	10.0	0.444[2)]	19.0	2.9	0.025[2)]	0.0	6.5	0.648[2)]

[a]Mean ± SD.
[b]Lower birth weight infants: birth weight < 2,500 g
[1)]t test for differences between the lean and non-lean groups
[2)]χ^2 test for differnces between the lean and non-lean groups
BMI, body mass index.

Table 4. Factors associated with the weight of the infants in the multiple regression analysis.

	G1 group (age ≥ 20, < 30)		G2 group (age ≥ 30, < 35)		G3 group (age ≥ 35)	
	β	P	β	P	β	P
Male infants	n = 82		n = 88		n = 48	
Age	-0.109	0.341	0.151	0.204	-0.051	0.731
Pre-pregnancy BMI	-0.003	0.976	0.016	0.886	0.674	< 0.001
Primiparas	0.111	0.35	0.035	0.8	-0.045	0.744
Gestational length	0.327	0.01	0.431	0.004	0.259	0.095
Total weight gain	0.339	0.008	0.126	0.331	0.161	0.294
Smoking during pregnancy	-0.017	0.878	–	–	-0.415	0.007
Female infants	n = 70		n = 89		n = 53	
Age	0.049	0.685	-0.3	0.803	-0.01	0.993
Pre-pregnancy BMI	0.28	0.028	0.204	0.108	0.236	0.081
Primiparas	0.052	0.682	0.181	0.168	0.253	0.072
Gestational length	0.49	< 0.001	0.526	< 0.001	0.633	< 0.001
Total weight gain	0.048	0.704	0.141	0.293	0.203	0.144
Smoking during pregnancy	–	–	-0.045	0.712	0.068	0.616

BMI, body mass index.

infant neonatal physique, multiple regression analysis was conducted using the stepwise method. Table 4 shows the results of factors associated with the weight of the infants in the multiple regression analysis.

For the male infants born to mothers in the G1 group (aged 20 to 29 years), the factors remaining in the last model were the total weight gain during pregnancy and the gestational length, with an attribution rate of 16.1%. In the

G2 group (aged 30 to 34 years), the factors remaining in the last model was the total weight gain during pregnancy, with an attribution rate of 10.8%. On the other hand, in the G3 group (age ≥ 35), the factors remaining in the last model were the pre-pregnancy BMI and the smoking during pregnancy, with an attribution rate of 45.5%.

For the female infants born to mothers in the G1 group, the factors remaining in the last model were the pre-pregnancy BMI and the gestational length, with an attribution rate of 23.5%. In the G2 and G3 groups (age ≥ 30), the factor remaining in the last model was only the gestational length.

Discussion

In Japan, the incidence of LBW infants was 10.7% (maternal age < 20), 9.2% (age ≥ 20, < 34), and 11.1% (age ≥ 35) in 2010 (Japan Child and Family Research Institute 2013). In the USA, the incidence was 3.2% (age < 17), and gradually declined with advancing maternal age to reach 1.3% (age ≥ 25, < 34) at term (Lee et al. 1988). It increased to 1.7% for subjects with a maternal age greater than 35 years. Those data showed clearly the aging effect for birth weight, a maternal U-shaped aging effect to birth weight. Considering the background, in which LBW infants increased in recent years, late child-bearing has increased and LBW infants of mothers aged young under 29 years have also increased (Takatama and Watanabe 2000).

Several reports have been published on maternal pre-pregnancy BMI, one of the factors that cause lower birth weight (Frederick et al. 2008; Nohr et al. 2009; Han et al. 2011). However, no studies have examined the influence of maternal age. Previously, we reported that the influence of the maternal pre-pregnancy physique was stronger in the non-eldest children, compared with the eldest children (Fukuda et al. 2015). The mothers of the non-eldest children were older than the mothers of the eldest children. Therefore, the present study was conducted to examine the influence of the maternal age and pre-pregnancy BMI on the birth weight of full-term infants. As a result, the low maternal BMI was associated with the lower values that reflect the neonatal physique of female infants in the G1 group (aged 20 to 29 years) and the neonatal physique of male infants in the G3 group (age ≥ 35). Especially, for the male infants in the G3 group, the influence of pre-pregnancy maternal BMI on birth weight might be the strongest, compared with the other groups. Furthermore, we analyzed the dependent variables, such as height, head circumference and chest circumference. Similar results were obtained showing that the maternal BMI had a strong influence on the male infants in the G3 group. In our study, the noticeable effect of pre-pregnancy BMI was found in the G1 group for the female infants and also in the G3 group for the male infants. Lee et al. (1988) reported that young mothers apparently reflected their poor sociodemographic and prenatal care status. Advancing maternal age is associated with a decreased potential for fetal growth, possibly reflecting biologic aging of maternal tissues and systems or the cumulative effects of disease. We found that maternal pre-pregnancy BMI affected the fetal growth, in both younger and elder mothers. The strong influence of maternal BMI shown in the G3 male infants in this study was in agreement with the results of our previous study, which showed a strong influence in the non-eldest male infants (Fukuda et al. 2015).

The main limitation of this study was the relatively low response rate, 61.2%, for the total number of gestational notifications in the target regions. That rate was low because many participants moved out of the target regions and some changed their name after the gestational notification. Accordingly, we could not follow up on those cases through the pregnancy period. Therefore, when we analyzed the data by the maternal physique, age groups and infant's sex, the participants decreased in number. It may be difficult to generalize the results. However, several reports have been published on the relationship between maternal pre-pregnancy leanness and the birth of LBW infants, and no studies have focused on the impact of maternal age and infant's sex. The results of this study were also in agreement with the results of our preceding study in terms of the influence of maternal BMI in younger mothers and older mothers (Fukuda et al. 2015). Furthermore, this study was original because it that showed the relationship between the maternal BMI and the infant's sex.

It is necessary to promote an improvement in pre-pregnancy leanness, especially when the woman concerned is in her early twenties or 35 years old or older. It is necessary to aim for the proper birth weight of the infants.

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Conflict of Interest

The authors declare no conflict of interest.

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