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Original Article

Gestational Outcomes and Birth Weight in Japanese Women at the Upper and Lower limits of the Normal BMI range

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To examine the outcome of gestational blood pressure and birth weight in women with normal pre-pregnancy BMI (18.5-25 kg/m^2) who are at the lower and upper limits of this range, *i.e.*, slightly underweight or slightly overweight. Overall, 2,038 Japanese women with low -risk who had delivered during January 2014–December 2016 were classified according to their pre-pregnancy BMI: underweight (< 18.5 kg/m^2), slightly underweight (18.5 ≤ BMI < 21 kg/m^2), normal (21 ≤ BMI < 23 kg/m^2), slightly overweight (23 ≤ BMI < 25 kg/m^2) and overweight (≤ 25 kg/m^2). Their blood pressure during each trimester and birth weight was evaluated. The slightly overweight group showed a significantly higher blood pressure than the underweight and slightly underweight groups. Birth weight was lower in the slightly underweight than in the slightly overweight group ($p < 0.01$). The incidence rate of "heavy for dates" (HFD) infants was significantly higher in the slightly overweight and overweight groups than in the other groups ($p < 0.05$ and $p < 0.01$, respectively). Weight gain of < 7 kg significantly increased the rate of "light for dates" (LFD) infants, while a weight gain of ≥ 13 kg significantly increased the rate of HFD infants ($p < 0.05$ and $p < 0.01$, respectively). Blood pressure during pregnancy was associated with pre-pregnancy BMI. The birth weight of infants of low-risk pregnant women is affected by both pre-pregnancy BMI and gestational weight gain.

Key words: birth weight, blood pressure, normal body weight, pregnancy pre-pregnancy BMI

In Japan, the mean birth weight has decreased from 3.24 kg for boys and 3.15 kg for girls in 1975 to 3.05 kg for boys and 2.96 kg for girls in 2016 (Vital Statistics Overview. https://www.mhlw.go.jp/toukei/list/dl/81-1a2.pdf. cited 2020 Aug 28). Accordingly, the rate of low-birth-weight babies (LBW) has increased since 1975; the proportion of LBW was 8.3% for boy and 10.6% for girls in 2016 (Vital Statistics Overview. https://www.mhlw.go.jp/toukei/list/dl/81-1a2.pdf. cited 2020 Aug 28). These percentages rank second-highest among the 38 countries in the OECD (OECD Health Status Infant Health. Low Birthweight. https://stats.oecd.org/Index.aspx?QueryId=30118. cited 2020 Aug 28). The birth weight of newborns is associated with pre-pregnancy body weight of the mother [1, 2]. The mean body mass index (BMI) of Japanese women in their 20s is 21.0 and for those in their 30s is 21.7 (National Health and Nutrition Survey in Japan 2019. https://www.mhlw.go.jp/content/000710991.pdf cited 2021 Feb 7)

In overweight women with a BMI of ≥ 25 kg/m^2,

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there is an increase in the incidence rate of macrosomic babies [3], whereas in underweight pregnant women with a BMI of < 18.5 kg/m^2, there is a high incidence rate of LBW [4,5]. Furthermore, the rate of underweight women in their 20s and 30s has increased, respectively, from 13.4% and 7.7% in 1981 to 20.7% and 16.4% in 2019 (National Health and Nutrition Survey in Japan 2019. https://www.mhlw.go.jp/content/000710991.pdf https://www.mhlw.go.jp/content/10904750/000351576.pdf cited 2021 Feb 7).

The increased incidence of LBW in Japan may be associated with the trend among Japanese women of having a thin body.

To prevent perinatal complications, there are four groups for managing the body weight of pregnant women in Japan, depending on whether they have an underweight, normal, or obesity I, II BMI before pregnancy.

However, the normal body weight in the guideline is given as 18.5 ≤ BMI < 25 kg/m^2. For an individual whose height is 160 cm, this implies that their body weight is anywhere within 47.4-63.7 kg, which is a range of 16 kg.

The appropriateness of managing all pregnant women with such a wide range of body weight in a uniform manner is questionable. The relationship between weight gain and perinatal prognosis is unclear in slightly underweight pregnant women with a BMI close to 18.5 kg/m^2 and in slightly overweight women with a BMI close to 25 kg/m^2. We hypothesized that their outcomes would be worse despite their having a normal pre-pregnancy BMI.

The present study examined the outcomes of pregnancy and state of neonates in pre-pregnancy BMI in Japanese women with uncomplicated pregnancies who had slightly underweight and slightly overweight pre-pregnancy BMI.

Materials and Methods

In total, 2,100 Japanese women with singleton pregnancies who gave birth at three maternity clinics managing low-risk deliveries between January 2014 and December 2016 were recruited for this study. Among these women, we excluded 31 women with premature deliveries, 4 women with gestational hypertension who were transported to the hospital in the course of their pregnancies, 17 women who were transported to hospital during labor (including nine women with arrested labor, five women with non-reassuring fetal status, two women with malrotation, and one woman with eclamptic attack) and 10 women with incomplete data records. As such, 2,038 women were ultimately included in our analysis.

We extracted the subjects' age, height, pre-pregnancy weight, pre-pregnancy BMI, smoking habit, drinking habit, amount of weight gained during pregnancy, and complications, such as threatened abortion, preterm labor, and gestational diabetes mellitus (GDM). Further, we extracted the highest blood pressure recorded in the three trimesters from the start of pregnancy to 13 weeks of pregnancy, from 14 to 27 weeks of pregnancy and from 28 weeks of pregnancy until delivery. Moreover, we extracted the number of gestational weeks at delivery, labor duration, estimated blood loss at delivery and up to two h postpartum, mode of delivery, neonate gender, and birth weight.

BMI categories were classified based on Healthy Parents and Children 21 and Japan Society for The Study of Obesity. BMI categories were as follows. The pregnant women included in the study were divided into an underweight (BMI < 18.5) and overweight group (BMI ≥ 25) based on their pre-pregnancy height and weight, whereas other pregnant women with normal body weight pregnancies were divided into three groups: a normal group (21 ≤ BMI < 23), centered on a BMI of 22, which was expected to have the lowest prevalence of illness [6,7], and slightly underweight (18.5 ≤ BMI < 21) and slightly overweight groups (BMI 23 ≤ BMI < 25) for the women near the limits of the "normal" BMI range. In this study, BMI ≥ 25 (obesity) is defined as overweight. The optimal BMI was taken from the Japan Society for the Study of Obesity, which advocates a BMI of 22 for low morbidity. As a result, we subdivided women of normal weight into 3 groups: slightly underweight (BMI 18.5 to 20.9), normal weight (BMI 21.0 to 22.9), and slightly overweight (BMI 23 to 24.9). When these BMI are converted to the body weight of a female with a height of 160 cm, each group covers a range of approximately 5 kg.

With regard to birth weight, infants weighing less than the 10th percentile were defined as light for dates (LFD), infants weighing between the 10th and 90th percentile were defined as appropriate for date, and infants weighing more than the 90th percentile were defined as heavy for date(HFD).

It is possible that birth weight was affected by gestational age. To examine whether low birth weight was caused by fetal growth restriction or gestational age, we evaluated the degree of fetal development according to birth weight alone as well as according to birth weight adjusted to the standard birthweight for gestational age, as indicated by the Japan Pediatric Society (Japan Pediatric Society. https://www.jpeds.or.jp/uploads/files/saisin_100924.pdf. cited 2019 Jan 8).

Age, which showed a normal distribution, was subjected to one-way ANOVA. For the second-trimester diastolic blood pressure, the Welch test was performed, followed by multiple comparisons with the Bonferroni test.

For items with non-normal distribution, including height, weight, pre-pregnancy BMI, systolic and diastolic blood pressure of the first trimester, systolic blood pressure of the second trimester, systolic and diastolic blood pressure of the third trimester, labor duration, estimated blood loss at delivery, birth weight, and birth weight according to infant gender, we conducted an intergroup comparison using the Kruskal–Wallis test. Bonferroni was used for multiple comparisons after the Kruskal–Wallis test.

The relationship between body weight gain in the pregnant mothers and physical constitutions of the infants was examined using the $\chi 2$ test or Fisher's exact test.

Weight gain was divided into four groups: < 7 kg, 7-9.9 kg, 10-12.9 g, and ≥ 13 kg. Residual analysis was used after chi-square test.

A comparison according to background factors was performed by the chi-square test and residual analysis. All statistical tests were performed using the statistical software IBM Statistics SPSS Version 24 for Windows. p value of < 0.05 were considered to indicate significant difference.

Data were collected from three maternity clinics based on medical and delivery records. All data were anonymized using a data sheet so that individuals could not be identified. As this was a retrospective study based on encrypted data analysis, informed consent was not needed. The present study was performed with the approval of the Ethical Review Board of Okayama University Graduate School of Health Sciences (approval number: D16-04) and conforms to the provisions of the Declaration of Helsinki (as revised in Tokyo 2004).

Results

Subject background. Overall, there were 358 women (17.6%) in the underweight group, 871 women (42.7%) in the slightly underweight group, 427 women (21.0%) in the normal group, 177 women (8.7%) in the slightly overweight group, and 205 women (10.1%) in the overweight group (Table 1). The mean weight gain during pregnancy was 10.3 ± 3.6 kg overall and was significantly lower in the overweight group than in the other four groups. The overweight group had a significantly higher rate of multiparous women than the other

Table 1 Characteristics of study population

	Underweight[I] BMI < 18.5 n = 358 (17.6%)	Slightly underweight[II] 18.5 ≦ BMI < 21 n = 871 (42.7%)	Normal[III] 21 ≦ BMI < 23 n = 427 (21.0%)	Slightly overweight[IV] 23 ≦ BMI < 25 n = 177 (8.7%)	Overweight[V] BMI 25 ≧ n = 205 (10.1%)	*P*-value	Multiple comparisons	
Age at delivery (years)	29.4 ± 5.2	29.7 ± 5.3	29.8 ± 5.5	30.4 ± 4.8	30.2 ± 5.1	0.222†		
Primipara, n (%)	158 (44.1%)	387 (44.4%)	173 (40.5%)	77 (43.5%)	59 (28.8%)	< 0.01‡		
Multipara, n (%)	200 (55.9%)	484 (55.6%)	254 (59.5%)	100 (56.5%)	146 (71.2%)			
Hight (cm)	158.1 ± 5.3	158.0 ± 5.3	157.6 ± 5.2	158.0 ± 5.3	157.6 ± 5.3	0.454§		
Weight (kg)	44.0 ± 3.4	49.3 ± 3.7	54.3 ± 3.7	59.2 ± 4.2	68.0 ± 7.4	< 0.001§	I vs. II, III, IV, V	***
							II vs. III, IV, V	***
							III vs. IV, V	***
							IV vs.V	**
Body weight gaint (kg)	11.0 ± 3.3	11.0 ± 3.4	10.9 ± 3.6	11.0 ± 4.1	9.3 ± 4.4	< 0.001§	V vs. I, II, III, IV	***
BMI (kg/m^2)	17.6 ± 0.7	19.7 ± 0.7	21.9 ± 0.5	23.7 ± 0.5	27.4 ± 2.1	< 0.001§	I vs. II, III, IV, V	***
							II vs. III, IV, V	***
							III vs. IV, V	***
							IV vs. V	*
Smoking during pre pregnancy, n (%)	40 (11.2%)	85 (9.8%)	38 (8.9%)	25 (14.1%)	22 (10.7%)	0.364‡		
alcohol use in pre pregnancy, n (%)	23 (6.4%)	34 (3.9%)	20 (4.7%)	10 (5.6%)	10 (4.9%)	0.417‡		
Antenatal occupation, n (%)	138 (38.5%)	369 (42.4%)	170 (39.8%)	59 (33.3%)	87 (42.4%)	0.200‡		

Value is mean ± standard deviation or number (percentage); †, ANOVA; ‡, Chi-squared test; §, Kruskal–Wallis test and post hoc test by Bonferroni multiple comparison.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
Body mass index: BMI.

four groups ($p<0.01$) (Table 1).

Pre-pregnancy BMI and blood pressure during the trimesters. The slightly overweight and overweight groups had significantly higher blood pressure than the underweight and slightly underweight groups (Table 2).

Pre-pregnancy BMI and infant birth weight. Birth weight was significantly lower in the underweight and slightly underweight groups than the slightly overweight and overweight group (underweight vs. slightly overweight / overweight $p<0.001$, slightly underweight vs. slightly overweight / overweight $p<0.01$) (Table 3). There was no significant difference in birth weight between the slightly underweight and underweight groups or between the slightly overweight and overweight groups. Among the primiparous women, birth weight was significantly lower for women in the slightly underweight group than for those in the slightly overweight group ($p<0.05$). Among the multiparous women, birth weight was lower in the slightly underweight group, but this difference was not significant.

The incidence rate of LFD was significantly higher in the underweight group than in the other four groups ($p<0.01$). The incidence rate of HFD was significantly higher in the slightly overweight and overweight groups than in the other three groups ($p<0.05$ and $p<0.01$, respectively).

Maternal weight gain and infant birth weight. we evaluated the degree of fetal development according to birth weight alone and according to birth weight adjusted to the standard birth weight for gestational age, as indicated by the Japan Pediatric Society. Overall, the slightly underweight group ($100.3\pm10.8\%$) had significantly lower values than the slightly overweight ($103.4\pm11.3\%$) and overweight groups ($104.1\pm11.1\%$) ($p<0.01$). However, there was no significant difference between the underweight and slightly underweight groups.

As shown in Table 4, the incidence of LFD infants increased significantly when the body weight increase was <7 kg, while HFD infants increased significantly when the body weight increase was ≥13 kg ($p<0.05$ and $p<0.01$, respectively). In the underweight group, pregnant women with a weight gain of 7-9.9 kg had LFD infants at a significantly higher rate of than the other three groups ($p<0.01$).

In the slightly underweight group and normal weight group, pregnant women with a weight gain of less than 7 kg during pregnancy had LFD infants at a significantly higher rate than those who gained more than 7 kg ($p<0.01$ and $p<0.05$ respectively). In the slightly overweight and overweight groups, there was no significant difference in rate of LFD or HFD among weight-gain groups.

Factors affecting perinatal prognosis. To examine factors affecting birth weight, a multiple regression analysis with 2,038 pregnant women was conducted.

Table 2 Non-pregnant BMI and blood pressure during the trimesters

		Underweight[I] BMI <18.5 n=358	Slightly underweight[II] 18.5≦BMI<21 n=871	Normal[III] 21≦BMI<23 n=427	Slightly overweight[IV] 23≦BMI<25 n=177	Overweight[V] BMI 25≧ n=205	*P*-value	Multiple comparisons	
1st trimester	SBP (mmHg)	108.4±11.4	110.8±12.0	113.3±12.4	116.0±11.3	119.6±13.2	<0.001†	I vs. II, III, IV, V	**
								II vs. III, IV, V	**
								III vs. V	***
	DBP (mmHg)	60.4±8.7	61.0±9.0	62.4±8.5	64.8±9.0	65.4±10.2	<0.001†	I vs. III, IV, V	**
								II vs. III, IV, V	*
								III vs. V	**
2nd trimester	SBP (mmHg)	107.6±11.6	109.2±11.3	112.1±11.1	114.5±11.6	117.5±11.3	<0.001†	I vs. III, IV, V	***
								II vs. III, IV, V	**
								III vs. V	***
	DBP (mmHg)	58.8±7.7	59.4±8.1	60.9±7.7	64.0±9.0	64.1±8.8	<0.001‡	I vs. III, IV, V	**
								II vs. III, IV, V	*
								III vs. IV, V	***
3rd trimester	SBP (mmHg)	112.5±12.5	114.5±12.0	116.8±12.1	118.7±12.5	122.6±12.7	<0.001†	I vs. III, IV, V	***
								II vs. III, IV, V	*
								III vs. V	***
	DBP (mmHg)	62.2±9.1	63.9±9.1	65.3±9.6	67.4±9.4	68.8±10.2	<0.001†	I vs. II, III, IV, V	*
								II vs. IV, V	***
								III vs. V	***

Value is mean±standard deviation; †, Kruskal–Wallis test and post hoc test by Bonferroni multiple comparison; ‡, Welch test. and post hoc test by Bonferroni multiple comparison.
*$p<0.05$, **$p<0.01$, ***$p<0.001$.
SBP, systolic blood pressure; DBP, diastolic blood pressure.

Table 3 Non-pregnant BMI and birth weight

	Underweight I BMI < 18.5 n = 358	Slightly underweight II 18.5 ≦ BMI < 21 n = 871	Normal III 21 ≦ BMI < 23 n = 427	Slightly overweight IV 23 ≦ BMI < 25 n = 177	Overweight V BMI 25 ≧ n=205	*P*-value	Multiple comparisons	
Infant Sex, n (%)								
Boys	192 (53.6%)	454 (52.1%)	236 (55.3%)	88 (49.7%)	95 (46.3%)	0.271†		
Girls	166 (46.4%)	417 (47.9%)	191 (44.7%)	89 (50.3%)	110 (53.7%)			
Birth weight	3,014.5 ± 366.1	3,075.5 ± 346.5	3,152.5 ± 374.3	3,186.2 ± 362.9	3,220.1 ± 383.0	< 0.001‡	I vs. III, IV, V	***
							II vs. III, IV, V	**
Boys	3,069.4 ± 377.2	3,096.4 ± 348.2	3,200 ± 383.1	3,208.7 ± 349.6	3,287.8 ± 431.2	< 0.001‡	I vs. III, IV, V	*
							II vs. III, IV, V	*
Girls	2,951.0 ± 343.1	3,052.7 ± 343.7	3,093.9 ± 355.5	3,164 ± 376.1	3,161.6 ± 326.7	< 0.001‡	I vs. II, III, IV, V	*
							II vs. V	*
Primipara (n = 854)	2,980.8 ± 330.9	3,054.0 ± 341.6	3,095.5 ± 346.7	3,172.6 ± 380.6	3,112.1 ± 369.5	< 0.01‡	I vs. III, IV	*
							II vs. IV	*
Multipara (n = 1184)	3,014.2 ± 390.4	3,092.7 ± 349.8	3,191.3 ± 387.9	3,196.7 ± 350.1	3,263.7 ± 380.9	< 0.001‡	I vs. III, IV, V	**
							II vs. III, V	**
Birth weight < 2500g, n (%)	25 (7.0%)**	31 (3.6%)	12 (2.8%)	5 (2.8%)	7 (3.4%)	< 0.001†		
Birth weight 2500–2999, n (%)	153 (42.7%)**	358 (41.1%)**	140 (32.8%)	50 (28.2%)*	48 (23.4%)**			
Birth weight 3000–3500, n (%)	148 (41.3%)	383 (44.0%)	207 (48.5%)	91 (51.4%)	95 (46.3%)			
Birth weight 3500–4000, n (%)	29 (8.1%)**	92 (10.6%)	59 (13.8%)	28 (15.8%)	49 (23.9%)**			
Birth weight ≧ 4000g, n (%)	3 (0.8%)	7(0.8%)	9 (2.1%)	3 (1.7%)	6 (2.9%)*			
Birth weight/standard birth weight for gestational age (%)	98.9 ± 10.7	100.3 ± 10.8	102.0 ± 11.4	103.4 ± 11.3	104.1 ± 11.1	< 0.001‡	I vs. III, IV, V	**
							II vs. IV, V	**
Light for dates	42 (11.7%)**	68 (7.8%)	27 (6.3%)	11 (6.2%)	12 (5.9%)	< 0.001†		
Appropriate for dates	293 (81.8%)	726 (83.4%)	348 (81.5%)	139 (78.5%)	155 (75.6%)*			
Heavy for dates	23 (6.4%)*	77 (8.8%)*	52 (12.2%)	27 (15.3%)*	38 (18.5%)**			

Value is mean ± standard deviation or number (percentage); †, Chi-squared test followed by residual analysis; ‡, Kruskal–Wallis test and post hoc test by Bonferroni multiple comparison.
*$p<0.05$, **$p<0.01$, ***$p<0.001$.

Table 4 Maternal weight gain during pregnancy and birthweight

		I 7 kg<	II 7–9.9 kg	III 10–12.9 kg	IV 13 kg ≧	*P*-value
Total (n = 2038)	LFD	31 (11.6%)*	51 (9.4%)	58 (8.5%)	20 (3.6%)	< 0.001†
	AFD	221 (82.8%)	455 (84.3%)	548 (80.2%)	437 (79.7%)	
	HFD	15 (5.6%)	34 (6.3%)	77 (11.3%)	91 (16.6%)**	
Underweight (n = 358)	LFD	5 (13.9%)	19 (20.7%)**	14 (11.1%)	4 (3.8%)	< 0.01‡
	AFD	30 (83.3%)	72 (78.3%)	101 (80.2%)	90 (86.5%)	
	HFD	1 (2.8%)	1 (1.1%)	11 (8.7%)	10 (9.6%)	
Slightly underweight (n = 871)	LFD	14 (15.9%)**	22 (9.1%)	24 (7.8%)	8 (3.4%)	< 0.001‡
	AFD	72 (81.8%)	209 (86.7%)	258 (83.5%)	187 (80.3%)	
	HFD	2 (2.3%)	10 (4.1%)	27 (8.7%)	38 (16.3%)**	
Normal (n = 427)	LFD	8 (15.1%)*	7 (6.3%)	10 (6.7%)	2 (1.8%)	< 0.001‡
	AFD	41 (77.4%)	98 (88.3%)	121 (81.2%)	88 (77.2%)	
	HFD	4 (7.5%)	6 (5.4%)	18 (12.1%)	24 (21.1%)**	
Slightly 0verweight (n = 177)	LFD	1 (3.4%)	1 (2.4%)	5 (10.4%)	4 (6.8%)	ns
	AFD	26 (89.7%)	35 (85.4%)	33 (68.8%)	45 (76.3%)	
	HFD	2 (6.9%)	5 (12.2%)	10 (20.8%)	10 (16.9%)	
Overweight (n = 205)	LFD	3 (4.9%)	2 (3.6%)	5 (9.8%)	2 (5.3%)	ns
	AFD	52 (85.2%)	41 (74.5%)	35 (68.6%)	27 (71.1%)	
	HFD	6 (9.8%)	12 (21.8%)	11 (21.6%)	9 (23.7%)	

number (percentage); †, Chi-squared test followed by residual analysis; ‡, Fisher's test followed by residual analysis.
LFD, Light for dates; AFD, Appropriate for dates; HFD, Heavy for dates.
*$p<0.05$, **$p<0.01$.

Birth weight was the objective variable; and pre-pregnancy BMI, amount of weight gain, parity, presence or absence of GDM, presence or absence of prepregnant drinking habit, presence or absence of prepregnant smoking habit, and infant gender were explanatory variables. We found that pre-pregnancy BMI, weight gain during pregnancy, and prepregnant smoking habit correlated with infant birth weight ($p < 0.001$, $p < 0.001$, and $p < 0.01$, respectively).

Discussion

The BMI status of underweight in women of reproductive age has been a concerning trend in Japan. Furthermore, it is, estimated that there are a large proportion of women with a low-normal body weight, whose BMI is categorically normal but still close to 18.5. While the prevalence of underweight of women in their reproductive age has increased the rate of overweight women has not decreased; rather, it has remained stable. It is possible that low-normal weight women (*i.e.*, women of BMI near 18.5) have the same or similar risks in pregnancy as underweight women, and that women with high-normal weight (*i.e.*, women of BMI near 25) have the same or similar risks in pregnancy as overweight women.

One impetus for this study is the fact that, for an 160-cm individual, there is an approximate 16-kg weight gap between high and low weights within the "normal" weight range of BMI > 18.5 and < 25. We thus classified women in the normal range into 3 groups by roughly 5-kg increments, and investigated the pregnancies of normal-weight women with BMIs near 18.5 (slightly underweight group) and near 25 (slightly overweight group) in comparison to those of their mid-normal ($21 \leq$ BMI < 23) peers.

Proportion of pregnant women by pre-pregnancy BMI. We examined body types of over 2,000 Japanese pregnant women and found that those with pre-pregnancy underweight (BMI ≤ 18.5) comprised a relatively high proportion, 17.6%. Studies from other countries have reported proportions of underweight women of 3.1~6.0% in North American countries and [8-10] 3.0~12.1% in European countries [11-14], making Japan's rate exceedingly high by comparison. In part, this may reflect the Asian body type, as the proportion of underweight women in South Korea is also high, at 15.6~16.28% [15-16]; however, the percentage among the Japanese subjects of the present study was even higher than that.

Furthermore, when added to the predominant "slightly underweight" ($18.5 \leq$ BMI < 21) group in Japan, with a proportion of 42.7%, the underweight group comprised well over half the subjects. According to the World Health Organization's statistics (WHO. Mean body mass index trends among adults, age-standardized (kg/m^2) Estimates by country https://apps.who.int/gho/data/view.main.CTRY12461?lang=en.cited 2020 Oct 14), the mean BMI of Japanese adult women is among the lowest in developed countries. Such high proportions of underweight and slightly underweight women of reproductive age are unique to Japan and not seen in other advanced countries.

Pre-pregnancy BMI and blood pressure. In the present study, blood pressure was examined during each trimester. Results showed that among pregnant women in the normal BMI rang, the slightly overweight group had significantly higher BP values than the slightly underweight group, with values comparable to those of the overweight group. Overweight and obese pregnant women are at a higher risk of preeclampsia [17, 18] and gestational hypertension than pregnant women with normal body weight [17]. However, according to a previous study in Japanese women, the pre-pregnancy BMI was reported to be 22.7 ± 4.5 kg/m^2 in the group, of women with preeclampsia and 23.6 ± 5.0 in the group of women with gestational hypertension [19]. Such findings suggest that the incidence of gestational hypertension affects overweight pregnant women and many slightly overweight pregnant women with the normal BMI range. In the present study, we could not evaluate the incidence of hypertensive disorders during pregnancy (HDP) in slightly overweight pregnant women because all subjects had a normal course of pregnancy.

Further studies are necessary to determine the relationship between obesity-prone groups as well as gestational hypertension nephropathy and gestational hypertension.

Pre-pregnancy BMI and birth weight. Birth weight affects the prognosis of a child. Underweight and overweight infants have an increased risk of developing diseases, such as ischemic heart disease and diabetes mellitus in adulthood [20, 21]. Therefore, preventing LBW and macrosomia is important to protect the health of future generations. We categorized

pre-pregnancy BMI into five groups, and the slightly overweight and slightly underweight groups were analysed to evaluate the relationship with birth weight. The percentage of HFD of the slightly overweight group, like the overweight group, was significantly higher than that of the normal group.

Our results were consistent with those of a previous study reporting that underweight pregnant women are at a higher risk of giving birth to LBW [4] and LFD infants than normal-weight pregnant women [22]. The birth weights of infants of the underweight and slightly underweight groups were significantly lower than that of the normal group. However, no significant difference in the percentage of LFD infants between the slightly underweight group and the normal weight group was observed.

Weight gain during pregnancy was 11.0 ± 3.4 kg in the slightly underweight group, almost the same as that of the normal group at 10.9 ± 3.6kg. It is possible that the sufficient weight gain of the mothers prevented a significant difference in the percentage of LFD infants.

Pregnant women with normal weight can be at a high risk of having LFD if insufficient weight is gained, as in the case of underweight pregnant women [22]. In this report, in both the slightly underweight group and the normal group, the rate of LFD infants significantly increased when the weight gain of the mothers was below 7 kg. Similarly, the rate of HFD infants significantly increased when the weight gain was above 13 kg. In this study, the normal group was defined as $21 \leq \mathrm{BMI} < 23$. There was no difference in the percentage of LFD infants between the slightly underweight group and the normal group. On the other hand, the percentage of neonates with HFD was higher in the slightly overweight group than in the normal group. Thus, both pre-pregnancy BMI and the weight gain of pregnant mothers affect the birth weight of infants in low-risk pregnant women, and management with a focus on both pre-pregnancy BMI and weight gain is considered important.

In the present study, different trends were observed in blood pressure and birth weight between the normal group and the slightly underweight or slightly overweight group. However, pregnant women at risk of HDP and perinatal complications could not be examined because this study was conducted at an institution dealing with low-risk pregnancies. In the future, it is necessary to include high-risk pregnant women, and further investigate the appropriate pre-pregnancy BMI from the perspective of birth weight, on the one hand and gestational blood pressure on the other. In addition, the elucidation of the effects of weight gain during pregnancy on blood pressure and infant weight according to pre-pregnancy BMI category could be useful for providing guidance to pregnant women.

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