Table 4 Percentiles for maternal weight gain (kg) according to gestational length at delivery

	37 weeks N=3561	38 weeks N=8563	39 weeks N=14841	40 weeks N=14259	41 weeks N=5435
25th	6.4	7.0	7.7	8.0	8.1
50th	9.0	9.5	10.0	10.0	10.5
75th	11.0	12.0	12.0	12.5	13.0
90th	13.3	14.0	14.5	15.0	15.5

cantly high in the "high" (1.58, 95% CI: 1.21–2.06) and "very high" (2.26, 95% CI: 1.72–2.97) weight gain groups. A history of prior spontaneous abortions increased the risk of macrosomia (1.49, 95% CI: 1.16–1.92). Pregnancy-induced hypertension was not related to macrosomia. Maternal diabetes was a significant factor increasing macrosomia risk (2.46, 95% CI: 1.49–4.05).

Table 5 Logistic regression analysis for IUGR and macrosomia according to each selected factor

	No. IUGR/total (%)	OR[a]	95% CI[b]	No. macrosomia/ total (%)	OR[a]	95% CI[b]
Total weight gain						
Very low: <25th percentile for gestational length	495/4535 (10.9)	2.87	2.56–3.21	34/4545 (0.7)	0.32	0.21–0.49
Low: 25th–49th	568/7232 (7.9)	1.49	1.35–1.66	39/7243 (0.5)	0.49	0.34–0.70
Moderate: 50th–74th	1312/22315 (5.9)	1		167/22354 (0.7)	1	
High: 75th–89th	281/7507 (3.7)	0.55	0.55–0.72	87/7519 (1.2)	1.58	1.21–2.06
Very high: 90th+	152/4978 (3.1)	0.45	0.45–0.63	83/4989 (1.7)	2.26	1.72–2.97
IVF conception						
Yes	28/455(6.2)	1.09	0.74–1.60	2/457 (0.44)	0.56	0.14–2.27
No	2780/46121 (6.1)	1		408/46202 (0.88)	1	
Past preterm delivery						
Yes	46/585 (7.9)	1.13	0.83–1.54	5/585 (0.9)	0.76	0.30–1.90
No	2762/45991 (6.1)	1		405/46074 (0.9)	1	
Past still birth						
Yes	29/402 (7.3)	1.09	0.74–1.60	5/402 (1.24)	1.11	0.45–2.74
No	2779/46174 (6.1)	1		405/46257 (0.88)	1	
Past spontaneous abortion						
Yes	383/5890 (6.6)	1.10	0.98–1.23	82/5891 (1.39)	1.49	1.16–1.92
No	2425/40686 (6.0)	1		328/40768 (0.8)	1	
Past cesarean delivery						
Yes	68/888 (7.7)	1.20	0.93–1.55	11/888 (1.2)	0.98	0.52–1.82
No	2740/45688 (6.0)	1		399/45771 (0.9)	1	
Pregnancy induced hypertension						
Preeclampsia	42/192 (21.9)	5.25	3.68–7.49	2/192 (1.0)	1.53	0.37–6.35
Gestational hypertension	81/752 (10.8)	2.79	2.19–3.54	11/754 (1.5)	0.85	0.45–1.63
None	2662/45521 (5.8)	1		396/45602 (0.9)	1	
Maternal diabetes						
Yes	36/553 (6.6)	1.55	1.10–2.20	21/554 (3.8)	2.46	1.49–4.05
No	2772/46023 (6.1)	1		389/46105 (0.8)	1	
Maternal Smoking						
Yes	283/2928 (9.7)	1.78	1.56–2.03	20/2930 (0.7)	0.63	0.40–1.01
No	2525/43648 (5.8)	1		390/43729 (0.9)	1	
Maternal Drinking						
Yes	150/2156 (7.0)	1.20	1.02–1.42	18/2158 (0.8)	0.87	0.54–1.42
No	2658/44420 (6.0)	1		392/44501 (0.9)	1	

Adjusted for maternal age, parity, prepregnancy weight, gestational age and infant gender.

[a] OR=odds ratio.

[b] CI=confidence interval.

Table 6 Multivariate logistic regression analysis for IUGR and macrosomia risk

Variables	IUGR			Macrosomia		
	OR[a]	95% CI[b]	p value	OR[a]	95% CI[b]	p value
Total weight gain						
Very low: <25th percentile for gestational age	2.90	2.59–3.25	<0.01	0.31	0.20–0.47	<0.01
Low: 25th–49th	1.52	1.37–1.69	<0.01	0.49	0.34–0.70	<0.01
Moderate: 50th–74th	1	Referent		1	Referent	
High: 75th–89th	0.68	0.52–0.68	<0.01	1.62	1.24–2.12	<0.01
Very high: 90th+	0.55	0.39–0.55	<0.01	2.41	1.83–3.17	<0.01
Pregnancy-induced hypertension						
Preeclampsia	6.89	4.78–9.92	<0.01	1.01	0.23–4.44	1.00
Gestational hypertension	3.15	2.47–4.03	<0.01	0.69	0.36–1.34	0.28
None	1	Referent		1	Referent	
Maternal diabetes (vs. none)	1.30	0.91–1.84	0.15	3.02	1.80–5.06	<0.01
Maternal smoking (vs. none)	2.08	1.80–2.40	<0.01	0.51	0.31–0.83	<0.01
Maternal drinking (vs. none)	0.94	0.79–1.13	0.54	1.04	0.63–1.72	0.86
Past spontaneous abortion (vs. none)	1.10	0.98–1.23	0.12	1.55	1.20–2.00	<0.01

Adjusted for maternal age, parity, prepregnancy weight, gestational length and infant gender.
Preeclampsia=hypertension with proteinuria ≧2 g/l.
[a] OR=odds ratio.
[b] CI=confidence interval.

Multivariate logistic regression analyses adjusted for maternal age, parity, prepregnancy weight, and infant gender, were performed to estimate the risk of IUGR and macrosomia for the selected significant factors from Table 5, as presented in Table 6. All variables were forced into the model. The ORs for IUGR in mothers with "very low" and "low" weight gains were significantly high, compared to the reference group with "moderate" weight gain, and the ORs in the "high" and "very high" weight gain groups were significantly low. The OR for IUGR was significantly high in mothers with preeclampsia (7.07, 95% CI: 4.91–10.2) and gestational hypertension (3.25, 95% CI: 2.55–4.15). The OR for IUGR was significantly high with maternal smoking (2.08, 95% CI: 1.80–2.40), but not with drinking.

The ORs for macrosomia in mothers with "high" and "very high" weight gains were significantly high, compared to the reference "moderate" weight gain group. The OR for macrosomia was significantly higher in mothers with prior spontaneous abortions (1.55, 95% CI: 1.20–2.00) and diabetes (2.99, 95% CI: 1.79–5.01). Pregnancy-induced hypertension was not related to macrosomia. The OR for macrosomia was significantly low with maternal smoking (0.51, 95% CI: 0.31–0.83), but not with drinking.

4. Discussion

This is the first report on fetal growth and maternal weight gain, prior obstetric history, and pregnancy complications using recent multi-centered data in Japan. Our findings on maternal weight gain and fetal size were in accordance with prior studies in predominantly white populations [12]. The observations on fetal macrosomia risk and maternal diabetes or high maternal weight gain was also consistent with other studies [13–15]. However, the association between prior spontaneous abortions and macrosomia in the subsequent pregnancy was uniquely observed in this study. Spontaneous abortions may be due to underlying glucose intolerance in Asian women, a high-risk population for diabetes [16]. A study on Asian women in Australia showed that women with gestational diabetes had more previous miscarriages/stillbirths compared to non-diabetic women [17]. Further research is needed to examine the relationship between a history of spontaneous abortion and maternal glucose intolerance.

There are several limitations due to the data characteristics of the Perinatal Database. First, it covered only a small proportion of Japanese births in 2001–2002, and was biased to "high-risk" pregnancies. As shown in Table 1, proportions of multiple gestations (7.5%) and preterm births (17.5%) were extremely high compared to national data in 2001–2002 which was 2.1% and 5.5% [4], respectively. Cesarean delivery rate was also quite high (27.2%), compared to hospital-based reports ranging from 7% to 10.3% [18,19].

Second, maternal height was not available in our study, and prepregnancy body size could not be considered in estimating the adequate range of weight gain. The referent weight gain range of 9 kg (50th percentile for 37 weeks) to 13 kg (75th

percentile for 41 weeks) used in this study, is close to values recommended for underweight women (10–12 kg) by JSOG [10]. Mean weight gain in the current study was 1–2 kg less compared to studies in the 1970s when LBW prevalence was lowest [20,21]. Taking into account that more women are underweight before pregnancy, higher target weight gains may be needed. Further studies should be conducted to develop weight gain goals specific to maternal prepregnancy BMI categories, especially for underweight women.

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