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Best practice guidelines

# Association of maternal pre-pregnancy weight, weight gain during pregnancy, and smoking with small-for-gestational-age infants in Japan

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ABSTRACT

*Aim:* The aim of this study was to evaluate the associations of maternal pre-pregnancy body mass index (BMI), weight gain during pregnancy, and smoking, with small-for-gestational-age (SGA) births among Japanese women.
*Materials and methods:* Subjects were pregnant women who gave birth to single, term infants (37–42 weeks) at a clinic and hospital in the Nagasaki area between 2012 and 2013. To examine associations with SGA, 49 underweight (BMI < 18.5 kg/m$^2$) and 579 normal-weight (18.5 ≤ BMI < 25.0 kg/m$^2$) Japanese women with either appropriate-for-gestational-age or SGA infants were selected and analyzed.
*Results:* The prevalence of SGA infants was 6.8%. Seven percent of women were current smokers. Prevalence of pre-pregnancy underweight and gestational weight gain less than recommendation were 20.8% and 16.7%, respectively. Multivariate logistic regression was performed to assess factors affecting SGA infants in the pregnant women. After adjusting for covariates, the amount of maternal weight gain below recommendation (odds ratio (OR), 2.72; 95% confidence interval (CI), 1.37–5.39) and maternal smoking status (OR, 2.80; 95% CI, 1.14–6.91) were significantly and independently associated with SGA births. Pre-pregnancy maternal weight status showed a borderline association (OR, 1.91; 95% CI, 0.96–3.83, $p = 0.067$).
*Conclusion:* To prevent SGA births, education regarding the adequate nutrition and the adverse effect of maternal smoking is important for the women of reproductive age.



**Contents**



## 1. Introduction

Although the total number of births in Japan is decreasing, low-birth-weight births are increasing. This increase in low-birth-weight infants seems mainly attributable to the increasing frequency of small-for-gestational-age (SGA) infants [1]. SGA infants are recognized as carrying an increased risk of developing chronic diseases in adulthood, such as hypertension, type-2 diabetes, and coronary heart disease [2,3]. In addition, SGA infants reportedly show higher rates of neonatal mortality and morbidity than normal birth weight infants [4,5]. This increase in SGA infants thus represents a serious health problem for modern society.

Low pre-pregnancy body mass index (BMI) has been identified as a risk factor for low-birth-weight births [6,7]. Several studies have

*Abbreviations:* BMI, body mass index; SGA, small-for-gestational-age; OR, odds ratio; CI, confidence interval; AGA, appropriate-for-gestational-age; WHO, World Health Organization; CRL, crown rump length.

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suggested that a low pre-pregnancy BMI and low weight gain during pregnancy are associated with the incidence of SGA infants [8–10]. Unfortunately, the proportion of underweight individuals among women of childbearing age in Japan has doubled compared with 20 years ago [11].

Maternal smoking habits increase the risk of SGA births [10,12]. Suzuki et al. [12] conducted a questionnaire survey among 1100 mothers registered at Koshu City, Japan, and showed that maternal smoking was associated with SGA infants. Watanabe et al. [10] surveyed hospital records of 3661 women in the Tokyo metropolitan area, Japan, and showed that maternal smoking more than 10 cigarettes per day was associated with an increased risk of having an SGA infant.

An insufficient number of studies have described or evaluated the influences of pre-pregnancy BMI, weight gain during pregnancy, and maternal smoking on perinatal outcomes in Japan [10]. The aim of the present study was therefore to evaluate the associations of pre-pregnancy BMI, weight gain during pregnancy, and maternal smoking with SGA infants in Japanese pregnant women.

## 2. Subjects and methods

Subjects were identified using data from 915 pregnant women who gave birth to single, term infants (37–42 weeks) at a clinic and a hospital in the Nagasaki area between 2012 and 2013. A total of 294 pregnant women were excluded due to: pregnancy-induced hypertension in 58 women; pre-pregnancy hypertension in 7 women; renal disease in 7 women; gestational diabetes mellitus in 61 women; diabetic pregnancy in 9 women; placenta previa in 17 women; threatened premature delivery in 61 women; overweight status (BMI ≥ 25.0 kg/m$^2$) that might affect fetal growth in 67 women; and missing information in 1 woman. To examine associations with SGA infants, 49 underweight (BMI < 18.5 kg/m$^2$) and 579 normal-weight (18.5 ≤ BMI < 25.0 kg/m$^2$) Japanese women with appropriate-for-gestational-age (AGA) or small-for-gestational-age (SGA) infants were finally selected and analyzed. Pre-pregnancy BMI categories were defined according to the standards of the World Health Organization (WHO). The definition of SGA was defined as an infant with a birth weight less than the 10th percentile of the intrauterine growth curves of Japan in 2010, according to the workshop meeting of the committee on Fetus and Newborn and Consultants in 1966.

Gestational age was determined according to the last menstrual period and confirmed by ultrasound examination, in which crown rump length (CRL) of the fetus was measured at 8–9 weeks of gestation. Maternal and infant birth data were extracted retrospectively from hospital records. Information from the maternal records included age, parity, medical history, pre-pregnancy weight, weight gain during pregnancy, current smoking status, and pregnancy complications. Information extracted from the infant records included birth weight, length, and sex. Total gestational weight gain was defined as the difference between measured weight at the prenatal visit closest to the delivery and self-reported pre-pregnancy weight. Maternal weight gain during pregnancy was classified into the three categories of the recommended levels of the Maternal and Child Health Division, Ministry of Health, Labour and Welfare, Japan: below (<9 kg), within (9–12 kg), and above (>12 kg) for underweight (BMI < 18.5 kg/m$^2$) women; and below (<7 kg), within (7–12 kg), and above (>12 kg) for normal-weight (BMI 18.5–25 kg/m$^2$) women [13].

### 2.1. Statistical analysis

Student's *t*-test for continuous variables and the chi-square test for categorical variables were used to determine differences between women with SGA and AGA infants. Multivariate logistic regression analysis was performed to explore the associations of pre-pregnancy BMI, recommended weight gain, and maternal smoking status with SGA infants. Only those variables showing a significant association in univariate analyses ($p < 0.05$, chi-square test) were included in the model. Adjusted odds ratio (OR) and 95% confidence interval (95% CI) were then estimated. A value of $p < 0.05$ was considered significant. Analyses were performed using SPSS for Windows version 14.0 (SPSS, Chicago, IL). This study was approved by the Ethics Committees of Nagasaki University Hospital.

## 3. Results

Table 1 summarizes the characteristics of subjects. The prevalence of SGA infants was 6.8%. Seven percent of women were current smokers. The prevalence of pre-pregnancy underweight women and maternal gestational weight gain below recommendation were 20.8% and 16.7%, respectively.

Table 2 compares variables between women with SGA and AGA infants according to univariate analysis. Women with SGA infants showed significantly lower pre-pregnancy weight ($p = 0.02$), pre-pregnancy BMI ($p = 0.04$), maternal gestational weight gain ($p < 0.01$), and birth weight of infants ($p < 0.01$). In Fig. 1, the prevalence of factors were shown among women with SGA infant and those of women with AGA infant. Women with SGA infants also showed a significantly more frequent pre-pregnancy underweight ($p = 0.04$) and smoking ($p = 0.03$) status compared to women with AGA infants.

Multivariate logistic regression was performed to assess factors affecting SGA births (Table 3). After adjusting for covariates, maternal gestational weight gain below recommendation (OR, 2.72; 95% CI, 1.37–5.39) and maternal smoking status (OR, 2.80; 95% CI, 1.14–6.91) were significantly and independently associated with SGA infants.

**Table 1**
Participant characteristics.

| Variable | (N = 621) | |
|---|---|---|
| | Mean ± SD | Range |
| Age (years) | 31.6 ± 5.2 | 16–44 |
| Height (cm) | 158.4 ± 5.4 | 140–176 |
| Pre-pregnancy weight (kg) | 51.0 ± 6.3 | 31–72 |
| Pre-pregnancy BMI[a] (kg/m$^2$) | 20.3 ± 2.1 | 14.1–25.0 |
| Maternal gestational weight gain (kg) | 10.6 ± 3.6 | −8.0–26.5 |
| Gestational age at delivery (weeks) | 38.7 ± 1.2 | 37–41 |
| Fetal birth weight (g) | 2972.9 ± 337.4 | 1582–3852 |
| | N | % |
| *Prevalence of AGA[b] or SGA[c]* | | |
| AGA[b] | 579 | 93.2 |
| SGA[c] | 42 | 6.8 |
| *Pre-pregnancy BMI[a] (kg/m$^2$)* | | |
| 18.5 ≤ BMI < 25.0 | 492 | 79.2 |
| BMI <18.5 | 129 | 20.8 |
| *Maternal smoking status* | | |
| Non-smoker | 576 | 92.8 |
| Smoker | 45 | 7.2 |
| *Recommended gestational weight gain[d]* | | |
| Below | 104 | 16.7 |
| Within | 316 | 50.9 |
| Above | 201 | 32.4 |
| *Parity* | | |
| Primiparous | 275 | 44.3 |
| Multiparous | 346 | 55.7 |
| *Infant sex* | | |
| Male | 327 | 52.7 |
| Female | 294 | 47.3 |

[a] Body mass index.
[b] Small-for-gestational-age.
[c] Appropriate-for-gestational-age.
[d] Below (<9 kg), within (9–12 kg), and above (>12 kg) for underweight (BMI < 18.5 kg/m$^2$) women, and below (<7 kg), within (7–12 kg) and above (>12 kg) for normal weight (BMI 18.5–25 kg/m$^2$) women.

**Table 2**
Comparison between women with small-for-gestational-age (SGA) and appropriate-for-gestational-age (AGA) infants.

| Variable | SGA | AGA | (N = 621) |
|---|---|---|---|
| | Mean ± SD | | p |
| Age (years) | 30.6 ± 5.2 | 31.6 ± 5.3 | 0.24 |
| Height (cm) | 157.6 ± 4.9 | 158.4 ± 5.5 | 0.35 |
| Pre-pregnancy weight (kg) | 48.6 ± 4.9 | 51.2 ± 6.3 | 0.02 |
| Pre-pregnancy BMI [a] (kg/m$^2$) | 19.7 ± 2.1 | 20.4 ± 2.1 | 0.04 |
| Maternal gestational weight gain (kg) | 8.9 ± 3.8 | 10.8 ± 3.6 | <0.01 |
| Gestational age at delivery (weeks) | 38.6 ± 1.2 | 38.9 ± 1.2 | 0.10 |
| Fetal birth weight (g) | 2329.5 ± 301.1 | 3019.5 ± 288.8 | <0.01 |
| | Number (%) | | |
| *Parity* | | | |
| Primiparous | 21 (50.0) | 254 (43.9) | |
| Multiparous | 21 (50.0) | 325 (56.1) | 0.44 |

[a] Body mass index.

Pre-pregnancy underweight status tended to show a borderline association (OR, 1.91; 95% CI, 0.96–3.83; p = 0.067).

## 4. Discussion

According to a WHO report [14], the prevalence of underweight women in developed countries is 3.3% in the United States, 5.9% in the United Kingdom, and 4.1% in Canada. In Asian countries, the prevalence is 8.5% in China and 6.5% in Korea. The National Health and Nutrition Survey Japan reported in 2012 the prevalence of underweight women as 11.4% [11]. Furthermore, the prevalence was 21.8% among 20- to 29-year-old women. This phenomenon has been reported to reflect an overestimated body size and 'desire for a thin body image', unnecessary weight control, fasting diets, self-reported eating disorders, and low dietary intake [15]. The prevalence of underweight women was 20.8% in the present study. Watanabe et al. [10] reported the prevalence of underweight women as 15.8% among women who gave birth to single, term infants, similar to our result. The relatively high proportion of thinness in young women may thus be problematic in Japan.

We have shown that maternal weight gain below the recommended level was associated with having a SGA infant. Previous studies have also reported that poor weight gain increases the risk of a SGA birth [16–18]. In addition, poor maternal nutritional status during pregnancy has been associated with reduced placental weight and surface area, which could limit nutrient transfer from the maternal circulation to the fetus, even if dietary intake increased later in pregnancy [19]. Furthermore, our results from multivariate logistic regression analysis suggested that adequate weight gain during pregnancy might decrease the risk of SGA births, regardless of pre-pregnancy BMI. These findings suggest the importance of adequate maternal weight gain during pregnancy to avoid having SGA infants.

Maternal smoking status has been reported as a risk factor for the incidence of SGA infants [10,20]. Prenatal cigarette smoking caused symmetrical fetal growth impairment, such as lower birth weight, length, and head circumference [21], and SGA infants [20]. Our results also showed that the odds of an SGA birth were increased by 2.8 times in current smokers, relative to non-smokers.

We have shown that low pre-pregnancy BMI was significantly associated with SGA births in univariate analysis, and showed a borderline association in multivariate analysis (p = 0.067). These results are similar to those of previous studies [8–10]. Watanabe et al. [10] suggested that the decrease in birth weight may be caused by the low body weight of women before conception in Japan. Tsukamoto et al. [18] suggested that low maternal BMI could result from chronically poor energy intake, which would reduce fat stores and compromise visceral and somatic protein status. Finucane et al.

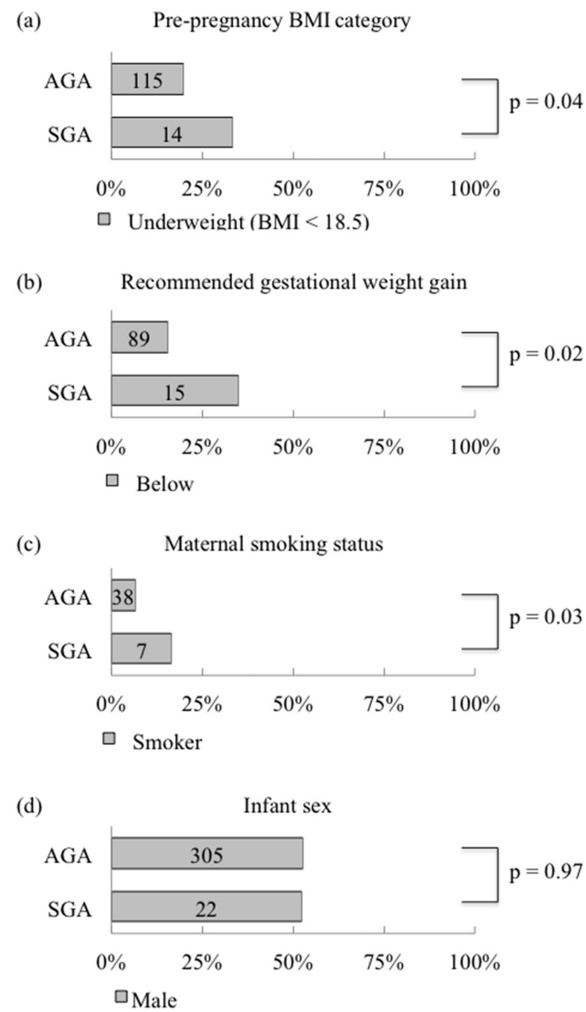


**Fig. 1.** A comparison between factors of women with SGA infant and those of women with AGA infant. (a) The prevalences of pre-pregnancy BMI category were represented among women with SGA infant (lower) and women with AGA infant (upper). The prevalence of underweight was shown in filled box. The numbers of women were presented in the box. (b) The prevalences of recommended gestational weight gain were represented among women with SGA infant (lower) and women with AGA infant (upper). Each category was defined as below (<9 kg), within (9–12 kg), and above (>12 kg) for underweight (BMI < 18.5 kg/m$^2$) women, and below (<7 kg), within (7–12 kg), and above (>12 kg) for normal weight (BMI 18.5–25 kg/m$^2$) women, respectively. The prevalence of below was shown in filled box. The numbers of women were presented in the box. (c) The prevalences of pre-pregnancy maternal smoking status were represented among women with SGA infant (lower) and women with AGA infant (upper). The prevalence of smoker was shown in filled box. The numbers of women were presented in the box. (d) The prevalences of infant sex were represented among women with SGA infant (lower) and women with AGA infant (upper). The prevalence of male was shown in filled box. The numbers of women were presented in the box.

**Table 3**
Odds ratio (OR) and 95% confidence interval (CI) for small-for-gestational-age (SGA) infants according to maternal status.

| | Unit | OR (95% CI) | (N = 621) p |
|---|---|---|---|
| Pre-pregnancy underweight[a] | Underweight/normal | 1.91 (0.96–3.83) | 0.067 |
| Recommended gestational weight gain[b] | Below/within, above | 2.72 (1.37–5.39) | 0.004 |
| Maternal smoking status | Smoker/non-smoker | 2.80 (1.14–6.91) | 0.025 |

[a] Body mass index < 18.5 kg/m$^2$.
[b] Below (<9 kg), within (9–12 kg), and above (>12 kg) for underweight (BMI < 18.5 kg/m$^2$) women, and below (<7 kg), within (7–12 kg), and above (>12 kg) for normal weight (BMI 18.5–25 kg/m$^2$) women.

[22] reported that the BMI of Japanese women was more similar to that of women in low-income countries than in high-income countries. These results suggest that in Japanese women, maintaining adequate BMI before conception is an important factor for preventing SGA births.

Based on our findings, one of the conundrums regarding the SGA infant is whether being simply small, as opposed to growth restricted, carries the risks of metabolic disease in adulthood. There is no evidence on infant with malnutrition or signs of growth restriction compared to the small but apparently healthy infant. Further studies are needed to assess the long-term risks among SGA infant in order to understand the benefits of improving the maternal nutrition.

Several limitations must be considered when interpreting the results of this study. First, pre-pregnancy weight was self-reported, and some women underreport their weight [23,24]. However, several studies have found that self-reported pre-pregnancy weight or BMI correlates highly with measured values [25,26]. Second, data on maternal socioeconomic and nutritional status during pregnancy, both of which are associated with infant growth [27], were not available in our study. Further study including maternal socioeconomic and nutritional status is needed.

In conclusion, low maternal weight gain during pregnancy and maternal smoking habits appear significantly associated with SGA births. Pre-pregnancy underweight showed a tendency toward a borderline association. To prevent SGA births, education regarding the adequate nutrition and the adverse effect of maternal smoking may be important for the women of reproductive age.

## Conflict of interest

The authors have no conflict of interest to disclose.

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