Association of Dietary Change during Pregnancy with Large-for-Gestational Age Births: A Prospective Observational Study

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Summary Being born with large birthweight is considered as a disadvantage due to risk of non-communicable diseases later in life. However, it is not fully understood what kind of maternal dietary intake during pregnancy affect large birthweight. Therefore, we examined the association of dietary intakes and its changes during pregnancy with large-for-gestational-age (LGA) births in Japanese pregnant women. In the prospective study, 245 pregnant women who visited Kyoto Medical Center were enrolled. Nutrition survey using brief-type self-administered diet history questionnaire (BDHQ) at all trimester was completed in 171 pregnant women. Based on birthweight and gestational age, participants were divided into three groups, such as small-for-gestational-age (<10th, SGA, n=17), appropriate-for-gestational-age (≥10th and <90th, AGA, n=144), and LGA (≥90th, n=10) groups. Compared with those without LGA births, mothers with LGA births showed: 1) greater weight gain during pregnancy (LGA: 14.0±3.2 kg, AGA: 9.9±3.9 kg, SGA: 8.4±3.1 kg, p<0.05); 2) higher energy intake throughout pregnancy (LGA: 310±368 kcal, AGA: 7±490 kcal, SGA: −97±293 kcal, p trend<0.05); 3) larger changes in plant oil and sucrose consumptions from the 1st to 2nd trimester, probably due to the results of greater consumption of bread, Western confectionery, Japanese confectionery, and mayonnaise and dressing during the same period (p trend<0.05, respectively). Our results suggest that higher energy intake throughout pregnancy, as well as greater consumption of plant oil and sucrose from the first to second trimester could be associated with LGA births.

Key Words pregnant women, maternal nutrition, birth weight, gestational weight gain, energy intake, plant oil, sucrose

The growing prevalence of non-communicable diseases (NCDs) has a negative impact on society, including an increased financial burden on the medical and nursing care systems (1), as well as on individuals, such as a shorter healthy life expectancy and impaired quality of life (2). The conditions generally develop because of long-term unhealthy lifestyle habits and genetic predispositions. Recently, numerous epidemiological and experimental studies have supported the Developmental Origins of Health and Disease (DOHaD) hypothesis (3, 4), which proposes that the nutritional environment during prenatal period is another key factor influencing the risk of NCDs during adulthood. One indicator of prenatal nutritional environment is birthweight.

Birthweight has a U-shaped relation with later-life risk of NCDs (5, 6). Low birthweight (LBW, <2,500 g) and small-for-gestational-age (SGA, <10th percentile) births is considered as a disadvantage due to risk of development of obesity, type 2 diabetes, and hypertension in adulthood (7). Meanwhile, high birthweight (HBW, ≥4,000 g) and large-for-gestational-age (LGA, ≥90th percentile) births is recognized as a risk of development of obesity, hypertension, cardiovascular diseases, and hepatic steatosis in childhood and adulthood (8, 9). Birthweight reflects causal effects of maternal nutrition, which affects placental functions and fetal growth. Moreover, gestational weight gain is related to birthweight in mothers with underweight or normal weight before pregnancy (10). Therefore, achieving normal range of birthweight through adequate maternal diet and weight gain during pregnancy may contribute to reduce adverse health outcomes in later life.

Regarding the association between maternal dietary pattern and birthweight, it has been reported that mothers with LBW or SGA births had some typical dietary patterns during pregnancy. For example, a high
consumption of bread, confectionery, soft drinks (11), low-carbohydrate diet (12), or ‘high prudent diet’ that was high in vegetables, fruit, and whole-grain products (13) during pregnancy. On the other hand, a European cohort demonstrated that mothers with LGA births consumed greater amount of artificially sweetened beverages during pregnancy (14). Moreover, a Chinese cohort showed that greater birthweight was associated with the greater consumption of fruit, nuts, and Cantonese desserts during pregnancy (15). However, such relationship has not been fully clarified in Japan. Probably, thinness has been highly prevalent among Japanese reproductive aged women (16). Such situation might generate more interest in low birthweight studies. Therefore, a limited number of studies regarding the relationship between HBW or LGA births and gestational dietary patterns in Japan. Moreover, almost all studies analyzed dietary data collected from a single stage of pregnancy. Thus, it remains unclear the impact of maternal diet during each trimester (e.g., from the first to second, the second to third, or the first to third trimester) on birthweight. In particular, there are few reports regarding the relationships between gestational energy, nutrients, and foods and birthweight.

Accordingly, the aim of present study was to examine the association of dietary change during pregnancy with LGA births among Japanese pregnant women.

MATERIALS AND METHODS

Study design. This prospective cohort study was conducted in National Hospital Organization Kyoto Medical Center from May 2015 to July 2017. Participants were recruited among pregnant women attending the Department of Obstetrics and Gynecology in the first trimester and followed up to delivery.

The inclusion criteria were participants 1) who were less than 16 wk of gestation, 2) who were more than 20 y old, and 3) who planned to receive entire prenatal care and delivery at Kyoto Medical Center, and 4) who were permitted to participate in this study by their obstetricians, taking into account the patient’s health conditions and treatment status.

The exclusion criteria were participants 1) who did not read or write Japanese, 2) who was unable to obtain birth data (e.g., change hospital, miscarriage, abortion, and withdrawal of consent for this study), and 3) who were judged by their obstetricians to be ineligible (e.g., the patients who need medical treatment of malignancy or urgent hospitalization).

As shown in Fig. 1, 788 pregnant women visited to this hospital during the study period. Of those, 245 women met inclusion criteria and they were enrolled in this cohort. Twenty-nine participants were lost to follow-up. To avoid maternal factors affecting birthweight, we excluded 45 participants who had following factors: multiple gestation, gestational diabetes, type 1 or type 2 diabetes, hepatitis virus carrier and insufficient dietary data. Also, these participants received dietary counseling by a dietician or doctor, which may lead to changes of their dietary habit. Finally, we analyzed 171 participants who completed all nutrition assessments at each trimester.

All study procedures were conducted as per the Declaration of Helsinki and were approved by the Ethics Committee of National Hospital Organization Kyoto Medical Center (approval number: 15-020). We obtained written informed consent from all participants after a full explanation of the study.

Psychological and biochemical assessment. All participants underwent the pregnancy checkup, such as
anthropometric measurements, blood pressure measurement, and laboratory tests as routine practice. Laboratory tests include total protein, albumin, hemoglobin, and blood glucose to assess the pregnancy complications. Maternal and newborn characteristics, obtained from their clinical records, are shown in Table 1. Maternal biochemical data we used were measured in the third trimester. Pre-pregnancy smoking history was checked by using a questionnaire.

**Nutrition assessment.** To estimate maternal dietary intakes during pregnancy, we used a brief-type self-administered diet history questionnaire (BDHQ) (17, 18) at three time points: the first, second, and third trimester. The BDHQ is a four-page fixed-portion questionnaire that can assess the consumption of selected foods to estimate the dietary intakes of 58 food and beverage items for the past month. The validity and reliability of the BDHQ for measuring energy, protein, sodium, and potassium intake among pregnant Japanese women have been reported (19). Details of the BDHQ, including list of food items and methods have been reported elsewhere (17, 18). The participants took 15 to 20 min to complete this questionnaire in a waiting room of the hospital.

**Statistical analysis.** Participants were divided into three groups according to the birthweight for gestational age (20): 1) SGA (<10th percentile); 2) appropriate-for-gestational-age (AGA) (≥10th and <90th percentile); and 3) LGA (≥90th percentile). According to Japan Society for the Study of Obesity (JASSO) criteria, pre-pregnancy weight status was classified as underweight (BMI<18.5 kg/m²), normal (18.5–24.9 kg/m²), or obese (≥25.0 kg/m²). We calculated the mean daily nutrient or food intakes at all three trimesters. We then calculated the changes in means from the first to second trimester, the second to third trimester, and the first to third trimester. All dietary data was adjusted for total energy intake in each trimester.

Shapiro-Wilk tests were used to assess the normal distribution of the data. According to the normality, the difference of maternal and newborn characteristics and changes in maternal dietary intakes among three groups were investigated. To compare the qualitative three group data, chi-square test or Fisher’s exact test was conducted. All other group comparisons were made with Kruskal-Walls using a post-hoc Bonferroni test. The Jonckheere-Terpstra test (21) was used to assess trends between birthweight and nutrient or food intakes. Logistic regression analyses were performed to assess the changes in dietary intakes associated with LGA births. The dependent variable was LGA births which included AGA and SGA births as reference groups. The indepen-

### Table 1. Maternal and newborn characteristics.

| Characteristics          | SGA  | AGA  | LGA  | p    |
|--------------------------|------|------|------|------|
| Age, y                   |      |      |      |      |
| Height, cm               |      |      |      |      |
| Pre-pregnancy weight, kg |      |      |      |      |
| Pre-pregnancy BMI, kg/m² |      |      |      |      |
| Gestational weight gain, kg | 8.4±3.1 |      |      |      |
| Underweight (<18.5 kg/m²) | 10.9±1.2 |      |      |      |
| Normal (18.5–24.9 kg/m²) | 8.0±3.1 |      |      |      |
| Obese (≥25.0 kg/m²)     | 5.3±3.7 |      |      |      |
| Systolic blood pressure, mmHg | 110.4±12.7 | 113.3±10.6 | 116.8±11.7 | 0.286 |
| Diastolic blood pressure, mmHg | 68.5±10.0 | 68.2±7.7 | 69.0±6.9 | 0.893 |
| Total protein, g/dl      | 6.1±0.4 | 6.2±0.4 | 5.8±0.6 | 0.384 |
| Albumin, g/dl            | 3.2±0.3 | 3.1±0.2 | 2.9±0.3 | 0.420 |
| Hemoglobin, g/dl         | 11.1±0.9 | 11.0±1.0 | 10.8±0.8 | 0.732 |
| Blood glucose, mg/dl     | 81.3±8.8 | 88.7±14.2 | 93.0±28.7 | 0.418 |
| Pre-pregnancy smoking    | 3 (17.6%) | 19 (13.6%) | 2 (20.0%) | 0.787 |
| Primipara                | 7 (41.2%) | 64 (44.4%) | 4 (40.0%) | 0.937 |
| Cesarean delivery        | 4 (23.5%) | 25 (17.4%) | 2 (20.0%) | 0.813 |
| Male gender              | 10 (58.8%) | 74 (51.4%) | 3 (30.0%) | 0.335 |
| Gestational weeks, wk    | 39.1±1.1 | 38.8±1.2 | 38.8±1.8 | 0.534 |
| Birthweight, g           | 2.489±0.217 | 2.966±0.285 | 3.589±0.356 | <0.001 |

Values represent mean±SD or n (%). BMI, body mass index.

* p<0.05 SGA group vs. LGA group. b p<0.05 AGA group vs. LGA group (by Kruskal-Walls test combined with post hoc Bonferroni test).
Table 2. Changes in energy and energy-adjusted nutrient intakes during pregnancy among the SGA, AGA, and LGA groups.

| Variable                                      | SGA n=17 | AGA n=144 | LGA n=10 | p for trend |
|-----------------------------------------------|----------|-----------|----------|-------------|
| **Energy, kcal/d**                            |          |           |          |             |
| Baseline                                      | 1,444±452| 1,500±465 | 1,506±482| 0.826       |
| $\Delta_1$ (1st–2nd)                          | 173±455  | 21±456    | 273±302  | 0.701       |
| $\Delta_1$ (2nd–3rd)                          | -270±486 | -14±373   | 38±302   | 0.045       |
| $\Delta_1$ (1st–3rd)                          | -97±293  | 7±490     | 310±368  | 0.013       |
| **Protein, g/1,000 kcal/d**                   |          |           |          |             |
| Baseline                                      | 34.5±7.7 | 35.4±6.3  | 35.8±2.9 | 0.369       |
| $\Delta_1$ (1st–2nd)                          | 1.2±7.0  | 2.3±6.2   | -0.1±5.0 | 0.899       |
| $\Delta_1$ (2nd–3rd)                          | 0.7±6.2  | -0.3±6.1  | -0.4±3.4 | 0.582       |
| $\Delta_1$ (1st–3rd)                          | 1.9±6.6  | 2.0±7.3   | -0.5±3.5 | 0.402       |
| **Fat, g/1,000 kcal/d**                       |          |           |          |             |
| Baseline                                      | 30.5±7.3 | 30.6±6.3  | 29.4±3.5 | 0.559       |
| $\Delta_1$ (1st–2nd)                          | 0.2±6.5  | 1.6±7.0   | 4.6±6.7  | 0.126       |
| $\Delta_1$ (2nd–3rd)                          | 2.0±3.5  | 0.2±5.2   | -2.6±3.4 | 0.079       |
| $\Delta_1$ (1st–3rd)                          | 2.2±6.0  | 1.8±7.2   | 2.0±6.2  | 0.833       |
| **Carbohydrate, g/1,000 kcal/d**              |          |           |          |             |
| Baseline                                      | 144.6±23.1| 143.0±18.3| 145.0±9.6| 0.995       |
| $\Delta_1$ (1st–2nd)                          | -2.8±21.0| -5.9±19.5 | -10.2±17.6| 0.301       |
| $\Delta_1$ (2nd–3rd)                          | -4.8±18.1| -0.2±15.4 | 5.8±12.7 | 0.143       |
| $\Delta_1$ (1st–3rd)                          | -7.6±21.2| -6.2±21.5 | -4.5±18.3| 0.546       |
| **Plant oil, g/1,000 kcal/d**                 |          |           |          |             |
| Baseline                                      | 17.1±3.9 | 16.2±4.4  | 13.7±4.3 | 0.019       |
| $\Delta_1$ (1st–2nd)                          | -1.1±3.0 | 0.6±5.2   | 5.1±5.7  | 0.005       |
| $\Delta_1$ (2nd–3rd)                          | 1.3±3.6  | -0.1±3.9  | -2.4±6.2 | 0.060       |
| $\Delta_1$ (1st–3rd)                          | 0.2±3.2  | 0.5±5.0   | 2.8±5.9  | 0.297       |
| **Animal fat, g/1,000 kcal/d**                |          |           |          |             |
| Baseline                                      | 13.4±5.0 | 14.4±4.6  | 15.6±4.2 | 0.167       |
| $\Delta_1$ (1st–2nd)                          | 1.3±4.4  | 1.0±4.9   | -0.5±3.3 | 0.307       |
| $\Delta_1$ (2nd–3rd)                          | 0.7±5.1  | 0.2±4.2   | -0.2±2.4 | 0.617       |
| $\Delta_1$ (1st–3rd)                          | 2.0±4.9  | 1.3±5.3   | -0.7±3.5 | 0.148       |
| **Saturated fatty acid, g/1,000 kcal/d**      |          |           |          |             |
| Baseline                                      | 8.7±2.5  | 8.6±2.3   | 9.0±2.1  | 0.988       |
| $\Delta_1$ (1st–2nd)                          | 0.2±2.2  | 0.5±2.4   | 0.6±2.3  | 0.968       |
| $\Delta_1$ (2nd–3rd)                          | 0.6±2.9  | 0.3±2.0   | -0.7±1.1 | 0.137       |
| $\Delta_1$ (1st–3rd)                          | 0.8±2.4  | 0.8±2.4   | -0.2±1.8 | 0.354       |
| **n-6 PUFA, g/1,000 kcal/d**                  |          |           |          |             |
| Baseline                                      | 5.8±1.6  | 5.9±1.5   | 5.4±1.0  | 0.353       |
| $\Delta_1$ (1st–2nd)                          | 0.1±1.5  | 0.2±1.6   | 1.2±1.8  | 0.149       |
| $\Delta_1$ (2nd–3rd)                          | 0.2±1.4  | -0.1±1.2  | -0.5±1.5 | 0.286       |
| $\Delta_1$ (1st–3rd)                          | 0.3±1.5  | 0.1±1.6   | 0.6±1.7  | 0.667       |
| **n-3 PUFA, g/1,000 kcal/d**                  |          |           |          |             |
| Baseline                                      | 1.3±0.5  | 1.3±0.4   | 1.1±0.2  | 0.442       |
| $\Delta_1$ (1st–2nd)                          | 0.1±0.4  | 0.1±0.5   | 0.4±0.3  | 0.162       |
| $\Delta_1$ (2nd–3rd)                          | 0.1±0.3  | -0.1±0.4  | -0.1±0.4 | 0.102       |
| $\Delta_1$ (1st–3rd)                          | 0.2±0.5  | 0.1±0.5   | 0.3±0.5  | 0.893       |
| **Total dietary fiber, g/1,000 kcal/d**       |          |           |          |             |
| Baseline                                      | 6.3±2.2  | 6.3±1.8   | 6.7±1.9  | 0.427       |
| $\Delta_1$ (1st–2nd)                          | -0.2±1.4 | 0.3±1.5   | -0.4±1.3 | 0.717       |
| $\Delta_1$ (2nd–3rd)                          | -0.1±2.1 | -0.1±1.5  | -0.2±1.2 | 0.717       |
| $\Delta_1$ (1st–3rd)                          | -0.2±1.9 | 0.2±1.4   | -0.5±1.5 | 0.624       |
| **Sucrose, g/1,000 kcal/d**                   |          |           |          |             |
| Baseline                                      | 6.9±3.4  | 6.4±4.3   | 6.3±5.9  | 0.279       |
| $\Delta_1$ (1st–2nd)                          | -1.6±2.4 | 0.5±5.0   | 2.5±2.2  | 0.002       |
| $\Delta_1$ (2nd–3rd)                          | 1.4±3.1  | 0.1±3.6   | -0.2±4.3 | 0.232       |
| $\Delta_1$ (1st–3rd)                          | -0.2±3.3 | 0.6±4.6   | 2.3±4.0  | 0.073       |

Values represent mean±SD.
Baseline, 1st trimester. $\Delta_1$, changes from the 1st to 2nd trimester. $\Delta_2$, changes from the 2nd to 3rd trimester. $\Delta_3$, changes from the 1st to 3rd trimester.
PUFA, polyunsaturated fatty acid. 1st, the 1st trimester. 2nd, the 2nd trimester. 3rd, the 3rd trimester. p for trend was determined using Jonckheere-Terpstra’s test among three groups.
dent variables included were changes in plant oil or sucrose intakes from the first to second trimester which showed significant difference among three groups. In addition, multiple regression analysis was performed to assess determination coefficient for plant oil or sucrose intakes with foodstuffs as independent variables.

All data are expressed as mean ± SD. All dietary intakes were adjusted for total energy intake in each trimester. All of the statistical analyses were performed with the Statistical Package (SPSS for Windows™, version 24, IBM Inc., Tokyo, Japan). A value of p < 0.05 was considered statistically significant.

**RESULTS**

Table 1 represents maternal and newborn characteristics. We identified 17 (9.9%) mothers with SGA births, 144 (84.2%) mothers with AGA births, and 10 (5.9%) mothers with LGA births. The birthweight in LGA (3,589 ± 356 g) group was, as expected, higher than SGA (2,489 ± 217 g) and AGA (2,966 ± 285 g) groups (p < 0.05), while gender and gestational weeks were no significant differences among the three groups.

Maternal age, height, and pre-pregnancy weight or BMI did not significantly differ among the three groups. Concerning gestational weight gain, the LGA group had a significantly higher value compared with other two groups (p < 0.05). As regard to pre-pregnancy weight status, such as underweight, normal, and obesity, we noted that significantly higher gestational weight gain was observed (p < 0.05) only in the mothers with normal weight before pregnancy. In addition, obese mother who had weight gain of 16.7 kg (mean) delivered LGA infants. Clinical characteristics including blood pressure and biochemical measurements, and pre-pregnancy smoking history were no significant differences among the three groups. Moreover, the rate of primipara and cesarean delivery were similar in the three groups.

Table 2 shows the changes in energy-adjusted nutrient intakes at second (from 1st to 2nd) and third trimester (from 1st to 3rd, from 2nd to 3rd) among the three groups. At baseline, no significant difference was shown in energy and macro-nutrients; however, significant changes in energy intake with the LGA group during pregnancy (1st to 3rd and 2nd to 3rd trimester). With respect to the food intakes, significantly greater changes in energy-adjusted plant oil and sucrose from the first to second trimester were shown in the LGA group. At the same period, no significant changes were observed in remaining nutrients and foodstuffs. Logistic regression analysis revealed that changes in plant oil intakes (from

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**Table 3. Changes in maternal daily food intakes from 1st to 2nd trimester among the SGA, AGA, and LGA groups.**

| Category                        | SGA (n=17) | AGA (n=144) | LGA (n=10) | p for trend |
|---------------------------------|------------|-------------|------------|------------|
| **Cereals, g/1,000 kcal/d**     |            |             |            |            |
| Δ1 Rice                         | 40.4±79.4  | 0.3±82.9    | -11.5±52.5 | 0.060      |
| Δ1 Bread                        | -5.8±15.9  | -2.6±21.9   | 8.3±15.1   | 0.023      |
| Δ1 Buckwheat noodles            | 0.8±8.0    | -1.1±11.5   | -0.3±6.2   | 0.181      |
| Δ1 Japanese wheat noodles      | -7.1±17.1  | -4.8±16.9   | -22.0±52.5 | 0.758      |
| Δ1 Chinese noodles             | -5.1±17.7  | -1.6±11.1   | -2.2±13.7  | 0.458      |
| Δ1 Spaghetti and macaroni      | -1.2±13.3  | 0.3±11.4    | -2.3±8.1   | 0.701      |

**Confectioneries, g/1,000 kcal/d**

| Category                        | SGA (n=17) | AGA (n=144) | LGA (n=10) | p for trend |
|---------------------------------|------------|-------------|------------|------------|
| Δ1 Western confectionery        | -5.9±9.3   | 2.3±15.3    | 7.0±12.2   | 0.003      |
| Δ1 Japanese confectionery       | -0.9±1.9   | 0.5±5.4     | 1.2±3.0    | 0.026      |
| Δ1 Rice crackers               | -2.7±5.7   | -1.2±8.3    | -4.3±9.3   | 0.699      |
| Δ1 Ice cream                    | 5.3±16.5   | -0.1±28.1   | -6.8±20.6  | 0.449      |

**Beverages, g/1,000 kcal/d**

| Category                        | SGA (n=17) | AGA (n=144) | LGA (n=10) | p for trend |
|---------------------------------|------------|-------------|------------|------------|
| Δ1 Green tea                    | 4.8±79.2   | 2.4±69.6    | -10.9±35.9 | 0.185      |
| Δ1 Black and oolong tea         | 16.9±27.9  | -0.2±76.5   | 17.7±40.6  | 0.280      |
| Δ1 Coffee                       | 0.9±17.9   | 10.3±67.4   | -7.6±37.5  | 0.938      |
| Δ1 Cola and sweetened soft drinks | -30.3±122.9 | -37.6±93.1 | 20.6±42.7  | 0.687      |
| Δ1 100% juice                   | -24.7±77.6 | -11.6±80.4  | 3.1±41.8   | 0.614      |

**Meat, g/1,000 kcal/d**

| Category                        | SGA (n=17) | AGA (n=144) | LGA (n=10) | p for trend |
|---------------------------------|------------|-------------|------------|------------|
| Δ1 Chicken                      | 1.8±14.0   | 1.1±11.4    | -1.9±8.4   | 0.638      |
| Δ1 Pork and beef                | 1.2±10.5   | 0.9±11.5    | -2.0±8.3   | 0.678      |
| Δ1 Processed meat               | -0.3±3.8   | -0.2±4.5    | 1.8±5.4    | 0.313      |
| Δ1 Liver                        | -0.2±0.8   | -0.1±2.8    | 0.2±0.5    | 0.568      |

**Oils, g/1,000 kcal/d**

| Category                        | SGA (n=17) | AGA (n=144) | LGA (n=10) | p for trend |
|---------------------------------|------------|-------------|------------|------------|
| Δ1 Mayonnaise and dressing      | -0.8±1.9   | -0.4±3.8    | 2.3±2.5    | 0.004      |
| Δ1 Oil used during cooking      | 0.7±3.1    | 0.6±3.1     | 1.8±3.3    | 0.375      |

Values represent mean ± SD.

Δ1: changes from the 1st to 2nd trimester.

p for trend was determined using Jonckheere-Terpstra’s test among three groups.
1st to 2nd trimester) were positively associated with the LGA births compared with the AGA and SGA births (OR: 1.21, 95% CI: 1.06–1.39, p<0.05). At the same period, no significant changes were observed in sucrose intakes.

Table 3 represents changes in energy-adjusted daily food intakes from the first to second trimester of pregnancy. Focusing on some foodstuffs as source of plant oil and sucrose, significant trends in bread, Western confectionery, Japanese confectionery, and mayonnaise and dressing were observed among three groups.

Furthermore, multiple regression analysis with increased plant oil or sucrose intakes from the first to second trimester as the dependent variable was performed in all 171 participants (Table 4). Independent variables included were foodstuffs, which showed positive association with increased plant oil or sucrose intakes from the first to second trimester. As for increased plant oil intake, the contribution rate of increase in consumption of Western confectionery, Japanese confectionery, and mayonnaise and dressing was determined using multiple regression analysis.

Table 4. Multiple regression analysis for plant oil or sucrose from 1st to 2nd trimester in all participants.

| Variable                        | β   | Standardized β | p     |
|---------------------------------|-----|----------------|-------|
| Δ1 Plant oil                    |     |                |       |
| Δ1 Mayonnaise and dressing      | 0.801 | 0.563          | <0.001|
| Δ1 Oil used during cooking      | 0.846 | 0.501          | <0.001|
| Δ1 Western confectionery        | 0.164 | 0.467          | <0.001|
| Δ1 Sucrose                      |     |                |       |
| Δ1 Western confectionery        | 0.192 | 0.601          | <0.001|
| Δ1 Japanese confectionery       | 0.368 | 0.389          | <0.001|
| Δ1 Sugar                        | 0.982 | 0.336          | <0.001|
| Δ1 Bread                        | 0.078 | 0.348          | <0.001|

Δt: changes from the 1st to 2nd trimester.

p was determined using multiple regression analysis.

DISCUSSION

We obtained three main findings. Compared with those without LGA births, mothers with LGA births showed: 1) greater weight gain during pregnancy; 2) higher energy intake throughout pregnancy; 3) larger changes in plant oil and sucrose consumptions from the 1st to 2nd trimester, probably due to the results of greater consumption of bread, Western confectionery, Japanese confectionery, and mayonnaise and dressing during the same period.

Birthweight is a common proxy of fetal growth. In Japan, due to higher prevalence of underweight among young women, many studies focused on low birthweight as an unfavorable outcome. It is certainly important, however, high birthweight has also conditions associated with obesity and NCDs during childhood or later in life. From a preventive standpoint, dietary advice to prevent and reduce the LGA birth may contribute to not only mother’s health condition but also well-being of next generation.

Regarding a cause of high birthweight, some studies demonstrated that high birthweight is associated with gestational weight gain in women with underweight (10) or normal weight (10, 22). In addition, recent systematic review and meta-analysis suggested that excessive gestational weight gain over the recommendation was associated with high odds ratio of 1.85 for LGA births and 1.95 for HBW births (23). The study among Japanese women also found a relationship between gestational weight gain and the risk of HBW (24). Above findings are good accordance with our results, in that high gestational weight gain is associated with high birthweight and the relationship was observed only in women with pre-pregnancy normal weight. The present study included only 10 mothers with LGA births; however, their gestational weight gain (14.0±3.2 kg) was similar level to that reported in Thai women who delivered LGA births (16.3±4.9 kg) (25). In addition, the present participants with LGA births and Thai women with LGA births had a similar pre-pregnancy BMI (Japanese, 21.6±3.1 kg/m²; Thai, 22.6±4.0 kg/m²), indicating that body size of this group may be normal as Asian. Furthermore, in this study, obese pregnant women with excessive weight gain (mean: 16.7 kg) delivered LGA infants; therefore, to prevent LGA births, appropriate weight management may be more important in obese pregnant women.

As to energy intake, it is reasonable that high energy intake is related to greater birthweight. In the present study, we found that the mothers with LGA births had a higher energy intake throughout pregnancy. Moreover, mothers with LGA births had a higher energy intake from the second to third trimester of pregnancy, but not more early pregnancy period. Excessive energy intake from the second to third trimester of pregnancy, in which the physiological demand for energy increases due to rapid fetal growth (26, 27), may have facilitated fetal weight gain.

The present study provides intriguing finding that increase in consumption of plant oil and sucrose may
The main sources of plant oil intakes were regarded as mayonnaise and dressing, oil used during cooking, and Western confectionery. The consumption levels of mayonnaise and dressing are presented in combination, because they are grouped together as a single item in the BDHQ. In general, high energy-density food, such as high-fat foods could contribute to a high birthweight (32). Focusing on the type of fat, maternal monounsaturated (33) and polyunsaturated (34) fatty acids are both positively correlated with birthweight. In this study, it should be noted that the risk of LGA births was increased by changes in plant oil intakes from the first to second trimester of pregnancy (OR: 1.21, 95% CI: 1.06–1.39). Moreover, our results imply that the changes in maternal dietary intakes in the mothers with LGA births from the first to second trimester of pregnancy may have consisted of sucrose-rich confectionery and fried foods (probably including fast food or fried snacks). Maternal weight gain in the first and second trimesters of pregnancy may be determinants of birthweight than in the third trimester of pregnancy (35). It is also the time when dietary intakes often change due to sickness such as nausea and vomiting during pregnancy (36).

Therefore, it is meaningful to clarify the changes in detail of dietary intakes during this period.

The limitations of this study include: 1) the results were obtained from a single-center cohort of mothers and their children; 2) the results were obtained from advanced medical care hospital where had many high-risk pregnant. Such situation may lead to lower rate of LGA births (5.9%); 3) the BDHQ was employed to avoid additional burden to respondents, but it is less accurate than weighed food record method; 4) despite its large cohort size, complete data from first, second and third trimester of pregnancy were available for 171 mothers, including only 10 with LGA births, resulting in the small sample size. On the other hand, the strength of this study include: 1) this study conducted as prospective observational design; 2) nutritional data were obtained from all three trimesters: 3) the participants were single-race. Due to above limitations, the results should be carefully interpreted; however, our study may provide useful information for promoting healthy development of the fetus and favorable birthweight.

In conclusion, the present results suggest that higher energy intake throughout pregnancy, as well as greater consumption of plant oil and sucrose from the first to second trimester could be associated with LGA births. Further study using larger samples is needed to support the present issues.

**Authorship**

Research conception and design: SM-I, NS and NN; data collection and database creation: SM-I and III; statistical analysis of the data: SM-I and SN; interpretation of the data: SM-I, KY, KT, NS, and NN; writing of the manuscript: SM-I and NN.

**Disclosure of state of COI**

All authors declare no conflicts of interest.

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