Original Article

Effect of individualised dietary education at medical check-ups on maternal and fetal outcomes in pregnant Japanese women

Reiko Tajirika-Shirai MD[1], Hidemi Takimoto MD, PhD[2], Tetsuji Yokoyama MD, PhD[3], Hitoshi Kaneko MD[4], Toshiro Kubota MD, PhD[1], Naoyuki Miyasaka MD, PhD[1]

[1]*Department of Comprehensive Reproductive Medicine, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, Bunkyo-ku, Tokyo, Japan*
[2]*National Institute of Health and Nutrition, National Institutes of Biomedical Innovation, Health and Nutrition, Shinjuku-ku, Tokyo, Japan*
[3]*National Institute of Public Health, Wako-shi, Saitama, Japan*
[4]*Department of Obstetrics and Gynecology, Nissan Tamagawa Hospital, Setagaya-ku, Tokyo, Japan*

Background and Objectives: An increased prevalence of low maternal weight and insufficient pregnancy weight gain may be responsible for an increase in low birthweight infants in Japan. We aimed to examine the effects of individualised dietary education at medical check-ups on maternal/fetal outcomes in Japanese women. **Methods and Study Design:** Four hundred and six underweight and normal weight singleton pregnant women, who attended check-ups at an obstetric facility until ≥30 weeks gestation and delivered at 36-41 weeks gestation, were selected for analyses. Weight gain was assessed at each check-up based on the official "Dietary Guidelines for Pregnant and Lactating Women". Individual dietary advice was provided by dieticians to those with insufficient or excess weight gain status around 28 weeks gestation. The medical records from uncomplicated singleton deliveries (36-41 weeks gestation) at the same facility from 2008-2010 were used (n=792) to examine the effect of dietary education on maternal/fetal outcomes. **Results:** Pre-pregnancy underweight was present in >24% of women in both the intervention and non-intervention groups. Adequate weight gain occurred more frequently in the intervention group ($p<0.01$). There were no significant differences in mean birthweight or the proportion of low birthweight infants. However, the proportion of extremely small for gestational age infants (birthweight <3rd percentile) was lower in the intervention group ($p=0.011$). There were no differences in the frequency of caesarean delivery, pregnancy induced hypertension, or infant Apgar scores <7. **Conclusions:** Dietary education during pregnancy check-ups promotes adequate maternal weight gain and helps prevent extreme fetal growth restraint.

Key Words: dietary education, infant, pregnancy outcomes, weight gain, BMI

INTRODUCTION

Weight gain in pregnancy has long been used as a proxy for assessing maternal nutritional status. Because of the increasing prevalence of overweight and obesity in pregnant women and related complications such as gestational diabetes mellitus (GDM) and fetal macrosomia, many recent intervention studies have been conducted to prevent excess weight gain during pregnancy. Based on these studies, the United States Institute of Medicine (IOM) revised its pregnancy weight gain guidelines in 2009.[1] These guidelines stressed the importance of avoiding excess weight gain during pregnancy to reduce the risk of complications during labour and delivery, reduce postpartum weight retention, and reduce the risk of pregnancy-induced hypertension (PIH), including preeclampsia and eclampsia.

In contrast to other developed countries, in Japan, obesity among reproductive age women is not endemic. The national data in 2012 shows that obesity (BMI ≥25) rates are quite low: 7.8% for women aged 20-29 years and 12.1% for women aged 30-39 years.[2] Moreover, the proportion of adult women with BMI ≥30 is only 3.7%, which is extremely low compared to the Organisation for Economic Co-operation and Development (OECD) average of 19.0%.[3] Although maternal obesity is a risk factor for hypertensive disorders of pregnancy, caesarean deliveries, and maternal mortality,[4] rising maternal underweight combined with insufficient pregnancy weight gain may be a larger problem in Japan affecting fetal growth, as evidenced by a recent increase in the frequency of low

Corresponding Author: Dr Hidemi Takimoto, National Institute of Health and Nutrition, National Institutes of Biomedical Innovation, Health and Nutrition, 1-23-1 Toyama, Shinjuku-ku, Tokyo 1628636, Japan.
Tel: +81-3-3203-5721; Fax: +81-3-3202-3278
Email: thidemi@nibiohn.go.jp
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birthweight infants.[5] The prevalence of low birthweight among singleton pregnancies rose from 4.6% in 1975 to 8.4% in 2010 and has changed only marginally over the last 5 years.[6-13] Prior studies suggest that lower weight at birth is associated with the future development of chronic diseases such as heart disease and diabetes mellitus.[14] However, the proportion of underweight (BMI <18.5) adult women in Japan (11%) is more than twice that of the OECD average (4%),[15] and it is especially high in women aged 20-29 years (21.8%).[2] In order to address the increasing frequency of low birthweight, the Japanese Ministry of Health, Labour, and Welfare (MHLW) issued "Dietary Guidelines for Pregnant and Lactating Women" in 2006. These guidelines include official weight gain recommendations in order to promote the birth of term singleton infants weighing 2500 to 4000 g (Table 1).[16]

However, results from both the National Growth Survey of Preschool Children conducted in 2010 and the Vital Statistics survey showed that despite national efforts to promote fetal growth, neither average birthweight nor prevalence of low birthweight improved.[9,17] This suggests that dissemination of maternal health information, mainly through the Maternal and Child Health Handbook, has had limited effects on the general population. This handbook is distributed free of charge to all pregnant women who register with their local government, and the results of their prenatal check-ups are recorded by obstetricians or midwives. Maternal health information including the official guidelines are introduced in the handbook.

A systematic review conducted by Ota et al suggested that nutrition education provided to malnourished pregnant women may increase birthweight.[18] In Japan, pregnant women are given financial support from their local government for their prenatal check-ups, where they have the opportunity to consult not only an obstetrician, but also a midwife or dietician, who provide individual advice to the women. We speculated that this prenatal check-up program might be an appropriate setting to conduct a dietary intervention. The aim of this study was to examine the effect of individualised dietary education on maternal and child outcomes in a developed country with elevated low birthweight prevalence. As part of this study, we devised an intervention project to provide dietary advice at the time of prenatal medical check-ups.

METHODS

Study subjects

The current study protocol was approved by the Institutional Review Board of Nissan Tamagawa Hospital (No.11-13) and the National Institute of Health and Nutrition (No. 20120723-02).

Intervention group

Women with 15-20 weeks gestation singleton pregnancies, who attended prenatal medical check-ups at the research facility from July 2012 to August 2013, were selected as possible participants for this study. Women who planned to continue to return for medical check-ups until at least 30 weeks gestation, and without any pre-pregnancy complications that might affect pregnancy outcomes, such as hypertension, diabetes mellitus, or lymphangioleiomyomatosis (n=447), were recruited. Each woman was given detailed oral and written information regarding the study protocol and provided informed consent. A total of 30 women were excluded. Specifically, one woman refused further participation, another had a pregnancy ending in stillbirth, 20 moved to another obstetric facility prior to 30 weeks gestation, one delivered an infant with major birth defects, and seven delivered before 36 weeks gestation or after 42 weeks gestation. Delivery record data and information regarding post-delivery one-month health examinations were obtained for 38 women who delivered at another obstetric facility from the women themselves or from the other facility. Eleven women who were overweight (pre-pregnancy BMI ≥25) were excluded. After applying exclusions, 406 women were included in the final analyses (Figure 1).

Non-intervention group

Because this study was conducted at a single facility, it was difficult to select a control group during the same study period. To address this difficulty, we selected data from past medical records (2008-2010) of births at 36-41 weeks gestation at the same facility, without any pre-pregnancy complications which might affect pregnancy outcomes. Among the 994 records, we excluded data for cases with major birth defects (n=4), those lacking information on pre-pregnancy body weight, weight measurements around 28 weeks gestation, or delivery (n=116), and women who participated in the intervention study (n=50). For women who had multiple deliveries from 2008-2010, only the most recent delivery was included (n=21). After excluding women with a pre-pregnancy BMI ≥25, 792 records were included (Figure 2). We selected 2008-2010 for the comparison because the official

Table 1. Weight gain targets applied in this study and official weight gain recommendations in Japan and United States

Pre-pregnancy BMI categories (kg/m^2)	Weight gain targets at 28 weeks (kg)	Official recommendations (throughout pregnancy)	
		Japan (kg)	US (IOM) (kg)
<18.5	5–9†	9–12†	12.7–18.1
18.5-25	4–9†	7–12†‡	11.3–15.9
25-30	-	Individual advice§	6.8–11.3
≥30			5.0–9.1

†Weight gain targets applied in this study.
‡Women with pre-pregnancy BMIs close to the lower range are recommended to target the higher range of weight gain, and women close to the higher range are recommended to target the lower range of weight gain.
§Women who have pre-pregnancy BMIs slightly exceeding 25.0 are recommended to gain about 5 kg, while those markedly exceeding a BMI of 25.0 need individual advice from their obstetricians, considering other pre-existing risks.

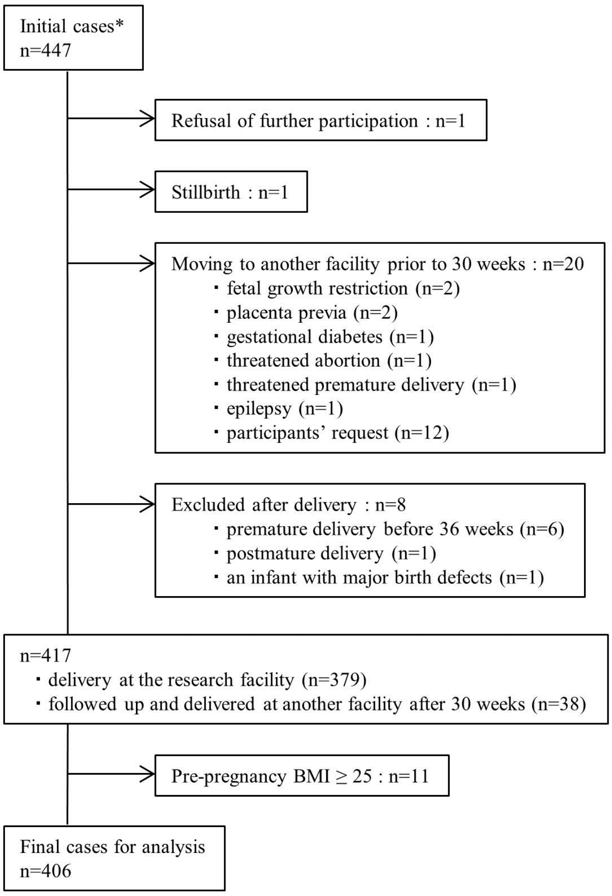


Figure 1. Patient selection process for the intervention group. *Women with singleton pregnancies who visited the research facility to attend prenatal check-ups from 20 to 30 weeks gestation without any pre-pregnancy complications which may affect the outcomes.

national weight gain guidelines were introduced in the Maternal and Child Health Handbook in 2008,[16] and we wanted to make sure that women in both the non-intervention and intervention groups had an opportunity to refer to the official guidelines.

Dietary education methods

We employed the weight gain targets (Table 1) and food balance guide (Figure 3[19]) for pregnant women included in the 2006 "Dietary Guidelines for Pregnant and Lactating Women", issued by the MHLW.[16] An outline of the intervention is shown in Figure 4.

Women who agreed to participate in the intervention were first informed of their optimal weight gain according to their pre-pregnancy BMI category (Table 1), calculated from the self-reported height and pre-pregnancy weight at 15-20 weeks gestation. At the same time, a leaflet regarding a healthy diet during pregnancy was provided to them. After that, midwives recorded the subject's weight using the weight gain charts according to BMI categories and gave brief dietary advice to each woman based on their weight gain status at the time of the medical check-up.

According to the "Guidelines for Obstetrical Practice in Japan", issued by the Japan Society of Obstetrics and Gynecology (JSOG), it is recommended that prenatal check-ups with weight measurement be carried out every 4 weeks during gestational weeks 12-23, every 2 weeks during gestational weeks 24-35, and every week during gestational weeks 36-40.[20] Following these guidelines, women who delivered at the research facility were provided dietary education intervention until the last medical check-up. Women who delivered at another facility were involved in the intervention until the last check-up before moving. The intervention was discontinued if the woman was diagnosed with GDM.

The weight gain charts and criteria for providing individual dietary advice were developed with reference to our previous study.[21] To be specific, our criteria were based on the 90th percentile of weight gain at 28 weeks gestation in women with uncomplicated singleton pregnancies, whose total weight gain during pregnancy met the recommended values shown in Table 1, and who delivered babies weighing 2500 g to 3999 g.

In cases of 'insufficient' or 'excess' weight gain status around 28 weeks gestation, women were requested to keep three-day dietary records. Dieticians gave individual dietary advice based on these records, referring to the "Dietary Guidelines for Pregnant and Lactating Women".[16] Concomitantly, the dieticians reviewed the subject's food intake for one of the three days in detail. They later calculated the woman's servings intake (SVs) according to the food balance guide, together with energy and nutrient intakes using the software "Komamawashi ver. 3".[22] Calculation of energy and nutrient intakes were undertaken according to the Standard Food Composition Tables (2010),[23] published by the Japanese Ministry of Education, Culture, Sports, Science, and Technology.

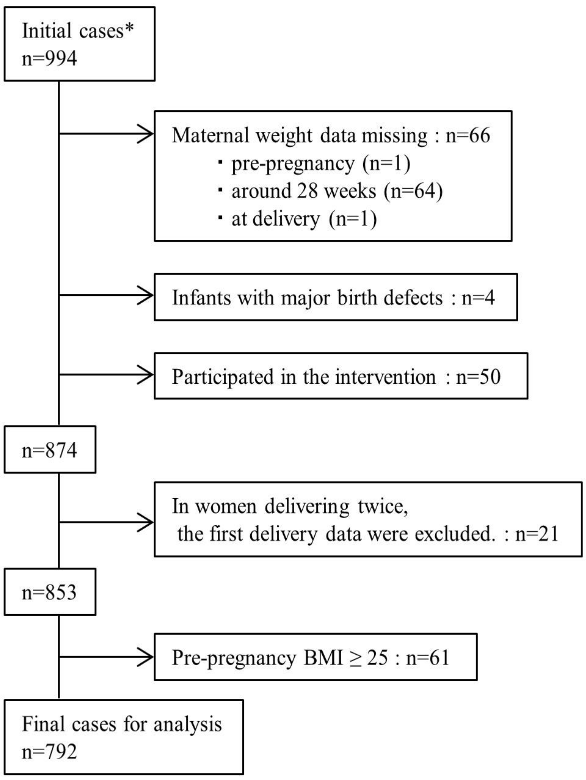
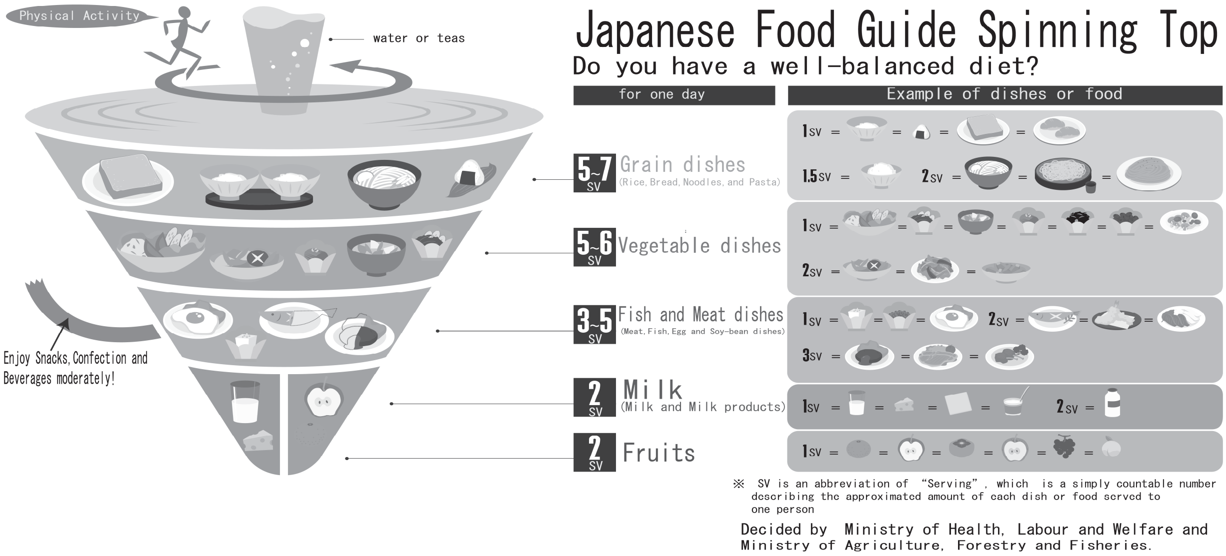


Figure 2. Case selection process for the non-intervention group. *Past medical records (2008-2012) of deliveries (36-41 weeks gestation) at the research facility without any pre-pregnancy complications which may affect the outcomes.



	Ideal SVs in one day	Additional SVs in pregnancy	
		Second trimester	Third trimester
Grain dishes	5-7	-	+1
Vegetable dishes	5-6	+1	+1
Fish and Meat dishes	3-5	+1	+1
Milk	2	-	+1
Fruits	2	+1	+1

Figure 3. Food balance guide employed for dietary education.

Women who met with the dietician received the calculated results with individual dietary advice two weeks later.

Evaluation of pregnancy outcomes

We compared pregnancy outcomes (maternal outcomes, infant outcomes, and maternal and infant outcomes at one month after delivery) between the intervention group and the non-intervention group. Regarding maternal outcomes, the frequency of complications including caesarean delivery, PIH, and GDM, mean weight gain at 28 weeks gestation and at delivery, and weight gain status according to BMI categories (Table 1) were evaluated. We could not compare the proportion of GDM between the intervention and non-intervention groups because the diagnostic methods and criteria for GDM were changed in Japan in 2010.[20] With regard to infant outcomes, sex, mean gestational days, mean birth weight, frequency of low birthweight (<2500 g), macrosomia (≥4000 g), small for gestational age (SGA) (<10th percentile), and large for gestational age (LGA) (≥90th percentile) were selected. We also categorised infants with birthweights below the 3rd percentile as extremely SGA and those with birthweights above the 97th percentile as extremely LGA. Infant birthweights were categorised using the "New Japanese Neonatal Anthropometric Charts for Gestational Age at Birth",[24,25] published by the Japan Paediatric Society in 2010. All available data from one month after delivery regarding maternal and infant weights and the proportion of mothers breastfeeding were analysed.

Additionally, to evaluate the effect of individual dietary advice by dieticians to women who were identified with 'insufficient' or 'excess' weight gain status at 28 weeks gestation, we compared their weight gain statuses and infant birthweights between the intervention and non-intervention groups.

Statistical analysis

Data were expressed as mean±SD where appropriate. Unpaired t-tests were used to compare normally distributed continuous variables between the intervention and non-intervention groups, and Mann-Whitney U-tests were used to analyse non-normally distributed continuous variables. To compare categorical variables, either chi-squared tests or Fisher's exact tests were used. A p value of <0.05 was considered statistically significant. All analyses were performed using IBM SPSS Statistics 20 (Armonk, New York).

RESULTS

Subject characteristics

General characteristics of the study subjects in both the intervention and non-intervention groups are shown in Table 2. Mean maternal age was significantly higher in the intervention group, but maternal pre-pregnancy BMI, proportion of primiparas, and proportion of smokers were not significantly different. The proportion of pre-pregnancy underweight (BMI <18.5) was >24% in both groups. The mean pre-pregnancy BMI was 19.9 kg/m^2 in all subjects.

Pregnancy outcomes

Pregnancy outcomes for both groups are shown in Table 3. With regard to maternal outcomes, there were no significant differences in the proportion of caesarean deliver-

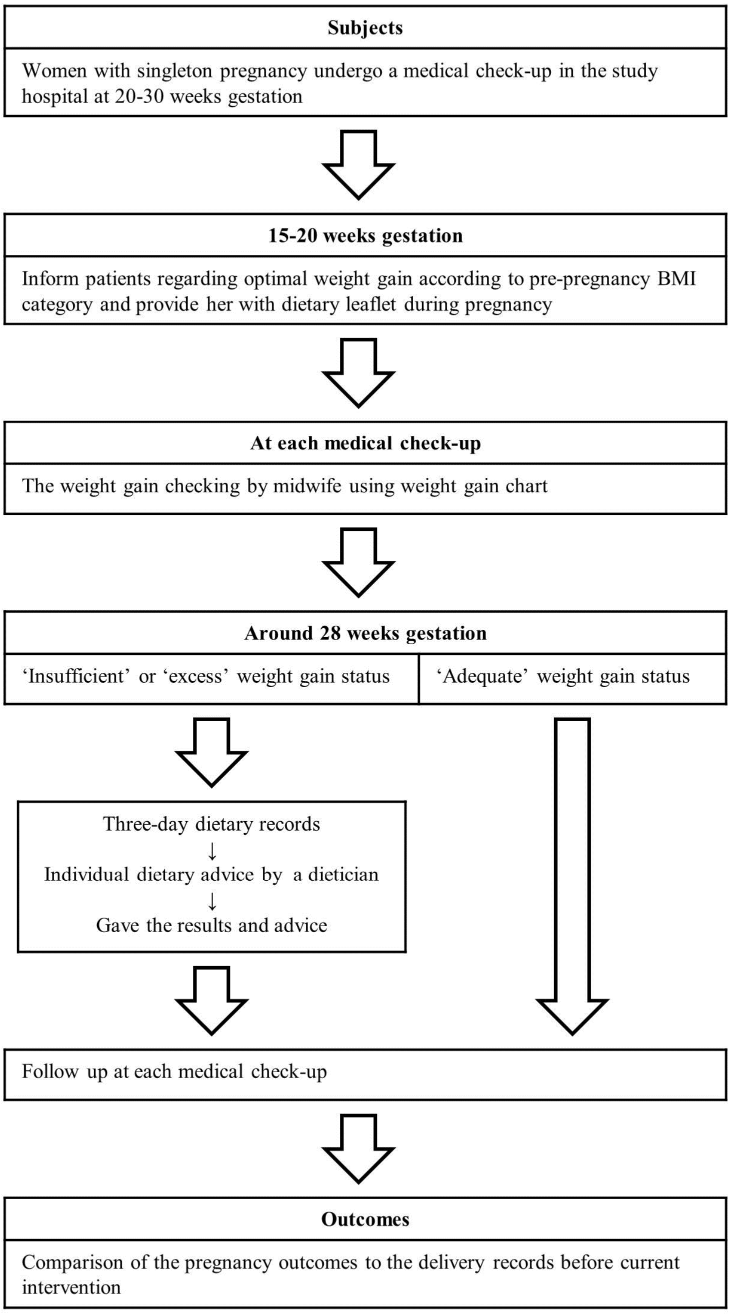


Figure 4. Dietary education methods

Table 2. Subject characteristics in both groups

	Intervention group (n=406)	Non-intervention group (n=792)	*p* value
Age at delivery (yrs)	33.4±3.8 (33.0)	32.4±4.5 (33.0)	<0.01
Height (cm)	159±5 (158)	159±5 (159)	0.84
Pre-pregnancy weight (kg)	50.2±5.4 (50.0)	50.4±5.6 (50.0)	0.54
Pre-pregnancy BMI (kg/m^2)	19.8±1.9 (19.5)	19.9±1.9 (19.7)	0.41
Underweight (BMI <18.5) (%)	25.1	24.2	0.74
Primiparas (%)	48.0	48.5	0.88
Smoking during pregnancy (%)	1.7	2.0	0.72

Continuous variables were expressed as the mean±SD (median) and compared using unpaired t-tests.
Categorical variables were compared using chi-squared tests.

ies or PIH. Differences in weight gain status at both 28 weeks and delivery were observed. The mean weight gain at 28 weeks was significantly lower (p=0.027), and the proportion of 'excess' weight gain at 28 weeks was significantly lower (p<0.01) in the intervention group, compared to the non-intervention group. The mean weight gain from 28 weeks to delivery was significantly larger (p<0.01), the proportion of 'adequate' weight gain status at delivery was significantly higher (p<0.01), and the proportion of 'insufficient' and 'excess' weight gain status were significantly lower (p<0.05) in the intervention group, compared to the non-intervention group. Total weight gain during pregnancy was similar between both groups.

Regarding infant outcomes, there were no significant differences in gestational age and the proportion of infants with an Apgar score <7. Mean birthweight was 3.07 kg in both groups (p=0.76). The proportion of low birthweight infants was similar between both groups, and the proportion of SGA (birthweight <10th percentile) was lower in the intervention group compared to the non-intervention group, but the difference was not statistically significant (p=0.27). However, the proportion of extremely SGA (birthweight <3rd percentile) was significantly lower in the intervention group (p=0.011). The proportion of LGA (birthweight ≥90th percentile) was similar between both groups, and the proportion of extremely LGA (birthweight ≥97th percentile) and macrosomia were lower in the intervention group compared to the non-intervention group, but the differences were not statistically significant.

At one month after delivery, there were no differences in maternal weight retention or BMI between the two groups. Infant body weight was slightly higher in the intervention group, but the difference was not significant (p=0.20). The proportion of women breastfeeding was higher in the intervention group, but the difference between the two groups was not significant (p=0.25).

For women identified as having 'insufficient' weight gain at 28 weeks gestation, there were no differences in maternal pre-pregnancy BMI status or infant gestational age at delivery between the intervention and non-intervention groups (Table 4). Weight gain from 28 weeks to delivery and the proportion of women with 'adequate' weight gain status at delivery were significantly higher (both p<0.01) in the intervention group. However, there were no significant differences in mean infant birthweight or the proportion of low birthweight, SGA,

Table 3. Pregnancy outcomes in both groups

	Intervention group (n=406)	Non-intervention group (n=792)	p value
Maternal outcomes			
Caesarean delivery (%)	15.5	16.7	0.61
Gestational diabetes mellitus (GDM) (%)	4.7	—	—
Pregnancy-induced hypertension (PIH) (%)	2.0	2.7	0.47
Weight gain at 28 weeks (kg)	6.4±2.2 (6.5)	6.7±2.5 (6.6)	0.027
Weight gain from 28 weeks to delivery (kg)	4.1±1.6 (4.1)	3.8±1.7 (3.8)	<0.01
Total weight gain during pregnancy (kg)	10.5±2.6 (10.4)	10.5±3.1 (10.5)	0.98
Weight gain status at 28 weeks (%)			
Insufficient	15.8	17.4	0.47
Adequate	74.9	65.7	<0.01
Excess	9.4	16.9	<0.01
Weight gain status at delivery (%)			
Insufficient	12.1	18.2	<0.01
Adequate	62.3	50.8	<0.01
Excess	25.6	31.1	0.0498
Infant outcomes			
Male infant (%)	52.5	53.5	0.73
Gestational age (days)	276±8 (277)	276±8 (277)	0.37*
Birthweight (kg)	3.07±0.34 (3.07)	3.07±0.36 (3.06)	0.76
Low birthweight (%)	4.4	4.2	0.83
SGA† (%)	4.2	5.7	0.27
Extremely SGA‡ (%)	0	1.5	0.011**
Macrosomia (%)	0.2	0.8	0.43**
LGA§ (%)	10.8	10.4	0.80
Extremely LGA¶ (%)	3.0	3.9	0.40
Apgar score <7 (1 min) (%)	1.3 (n=393)	0.6	0.31**
Maternal and infant outcomes at one month after delivery	(n=403)	(n=740)	
Maternal weight retention†† (kg)	3.4±2.4 (3.5)	3.2±2.6 (3.2)	0.18
Maternal BMI (kg/m^2)	21.2±2.1 (20.9)	21.2±2.1 (20.9)	0.90
Infant body weight (kg)	4.22±0.50 (4.20)	4.18±0.53 (4.17)	0.20
Infant weight gain (kg)	1.15±0.36 (1.12)	1.10±0.37 (1.11)	0.18*
Breastfed infants (%)	49.9	46.4	0.25

SGA: small for gestational age; LGA: large for gestational age; —: unavailable.
Continuous variables were expressed in mean±SD (median) and compared using unpaired t-tests.
Categorical variables were compared using chi-squared tests.
†Birthweight <10th percentile.
‡Birthweight <3rd percentile.
§Birthweight ≥90th percentile.
¶Birthweight ≥97th percentile.
††Maternal weight retention: the difference between maternal weight at one month after delivery and pre-pregnancy weight.
*Mann-Whitney U-test.
**Fisher's exact test.

extremely SGA, macrosomia, LGA, or extremely LGA infants. Regarding women who were identified as having ‘excess’ weight gain at 28 weeks gestation, there were also no differences in maternal pre-pregnancy BMI status or infant gestational age at delivery between the intervention and non-intervention groups. In contrast, while the proportion of women with weight gain from 28 weeks to delivery and weight gain status at delivery were not significantly different between the two groups, the proportion of women with ‘adequate’ weight gain at delivery was slightly higher in the intervention group than in the non-intervention group.

DISCUSSION

No previous studies in Japan have examined dietary education at prenatal medical check-ups in order to reduce the prevalence of low birthweight. Our dietary intervention program, implemented in the prenatal medical check-up setting, proved feasible and promoted adequate weight gains during pregnancy. The Japan Society for the Study of Hypertension in Pregnancy has previously published weight gain recommendations for pregnant women,[26] but we chose to use guidelines recommended in the Maternal and Child Health Handbook. Japanese women are more familiar with this official and up-to-date handbook, and the handbook includes a food balance guide for a desirable diet (Table 1, Figure 3). All women in both groups received this handbook, which is provided free of charge by the local government at the time of pregnancy registration. However, there are no data available regarding the degree to which the handbook influences a woman’s dietary behaviours.

Our study proved that an intervention program using the contents of the official guideline for individualised dietary education can influence the weight gain status during pregnancy, as shown by the higher proportion of ‘adequate’ weight gain status in the intervention group compared to the non-intervention group (Table 3). There was no significant difference in infant birthweight between both groups. However, there was a significantly lower frequency of extremely SGA birthweight infants in the intervention group, suggesting that dietary education intervention may be effective for preventing fetal growth restraint due to undernutrition. Additionally, the proportion of ‘excess’ weight gain was lower in the intervention group. In addition, there were no significant differences among the groups regarding the proportion of complications such as macrosomia, caesarean delivery, and PIH. This was probably due to the low proportion of macrosomia and PIH in our study population. A limitation of our study is that we could not exclude caesarean cases performed because of previous caesarean deliveries or a breech presentation. Therefore, we could not compare the number of caesarean cases that were attributable to excess weight gain. Second, it was impossible to compare the proportion of GDM between the two groups because the diagnostic criteria for GDM were changed in 2010, and prior to this, GDM screening had not been fully conducted. However, the incidence of GDM is expected to be approximately 8.5% according to the new criteria,[27] and the proportion of GDM in the intervention group was 4.7%. Our interventions had no adverse effects on either maternal or infant outcomes.

Individual dietary advice by dieticians was effective, particularly for women with ‘insufficient’ weight gain at 28 weeks gestation, as shown by the higher proportion of women with ‘adequate’ weight gain status at delivery in the intervention group compared to the non-intervention group (Table 4). However, there was no difference in infant birthweight between the groups. We scheduled individual dietary advice to be given around 28 weeks gestation in our study, because prenatal check-ups were conducted at 4-week intervals until 23 weeks gestation,[20] and it was impossible to give frequent dietary advice, furthermore, we also intended to provide advice after the screening for GDM. Moreover, regarding women who had ‘excess’ weight gain at 28 weeks, there was no difference in total weight gain status. Starting dietary advice earlier may influence infant birthweight.

Because our study was conducted at a single facility, we selected a non-intervention group using past medical records (2008-2010) of births at the same facility. Although it is desirable to conduct a randomised controlled trial by selecting a control group in the study facility, this was not feasible during the intervention period. However, we consider our selection of the non-intervention group to be adequate, because mean infant birthweight and prevalence of low birthweight in Japan were similar between 2008-2010 and 2012-2013. Mean birthweight was 3.02 kg from 2008 to 2013, and prevalence of low birthweight was 8.2-8.4% from 2008 to 2013.[7-12] In addition, according to the National Health and Nutrition Survey Japan, dietary intake of young women showed few changes in energy, nutrient, and salt intakes from 2008 to 2013. Especially, among women aged 30-39 years, who formed the majority of this study, mean energy intake remained stable at nearly 1700 kcal, and further, intakes of carbohydrates, protein, and salt also remained stable.[2,28-32] These nationwide data suggest that changes in dietary intakes of pregnant women are likely minimal, with negligible effect on weight gain or infant birthweight.

The maximum weight gain recommendation for underweight and normal weight Japanese women is 12 kg, less than that recommended in the United States (IOM) (Table 1).[1] This was based on evidence that showed a higher risk of caesarean deliveries for underweight women and higher risks of macrosomia and massive haemorrhage during delivery for normal weight women who had gained more than 12 kg. Among those gaining more than 15 kg, the risk of caesarean deliveries also increased in normal weight women.[16] In contrast, the perinatal mortality rates (per 1,000 live births) by birthweight categories were 30.4 for infants under 2.5 kg, 1.2 for 2.5-3.0 kg infants, 0.5 for 3.0-3.5 kg infants, and 0.6 for 3.5-4.0 kg infants, according to 2014 Japanese vital statistics.[13] It is notable that perinatal mortality was higher in the 2.5-3.0 kg category than in the 3.0-3.5 kg and 3.5-4.0 kg categories. Therefore, the ideal birth weight for healthy Japanese infants may be in the 3.0-4.0 kg range. When considering the upper limit of weight gain recommendations, further study with regard to perinatal mortality may be necessary.

Table 4. Pregnancy outcomes for women who were identified as having 'insufficient' or 'excess' weight gain at 28 weeks gestation

	'Insufficient' weight gain at 28 weeks			'Excess' weight gain at 28 weeks		
	Intervention (n=64)	Non-intervention (n=138)	*p* value	Intervention (n=38)	Non-intervention (n=134)	*p* value
Pre-pregnancy BMI (kg/m^2)	19.9±2.2 (19.4)	19.8±2.1 (19.6)	0.83*	20.1±1.9 (19.9)	19.9±2.0 (19.8)	0.78*
Underweight (BMI <18.5) (%)	31.3	34.8	0.62	18.4	27.6	0.25
Weight gain at 28 weeks (kg)	2.9±1.2 (3.2)	3.2±1.2 (3.4)	0.18*	10.1±1.1 (9.7)	10.5±1.5 (10.0)	<0.01*
Weight gain from 28 weeks to delivery (kg)	4.2±1.8 (4.3)	3.5±1.8 (3.4)	<0.01*	4.1±1.6 (3.8)	4.0±1.9 (4.1)	0.82*
Total weight gain during pregnancy (kg)	7.2±2.1 (7.6)	6.7±2.1 (6.7)	0.033*	14.2±2.0 (14.0)	14.5±2.3 (14.4)	0.33*
Weight gain status at delivery (%)						
Insufficient	51.6	69.6	0.013	0	0.7	1.00**
Adequate	48.4	29.7	<0.01	13.2	10.4	0.64
Excess	0	6.5	1.00**	86.8	88.8	0.74
Gestational age (days)	275±7 (275)	274±8 (274)	0.49*	276±8 (277)	276±9 (278)	0.75*
Infant birthweight (kg)	2.96±0.34 (2.95)	2.93±0.32 (2.96)	0.55	3.16±0.34 (3.20)	3.17±0.37 (3.15)	0.87
Low birthweight (%)	7.8	6.5	0.74	2.6	2.2	1.00**
SGA† (%)	6.3	10.9	0.30	2.6	1.5	0.53**
Extremely SGA‡ (%)	0	1.4	1.00**	0	0.7	1.00**
Macrosomia (%)	0	0	-	0	3.0	0.58**
LGA§ (%)	10.9	3.6	0.055**	23.7	18.7	0.49
Extremely LGA¶ (%)	0	0	-	5.3	8.2	0.74**

SGA: small for gestational age; LGA: large for gestational age.
Continuous variables were expressed as the mean ± SD (median) and compared using unpaired t-tests.
Categorical variables were compared using chi-squared tests.
†Birthweight <10th percentile.
‡Birthweight <3rd percentile.
§Birthweight ≥90th percentile.
¶Birthweight ≥97th percentile.
*Mann-Whitney U-test.
**Fisher's exact test.

In addition to the limitations regarding caesarean deliveries and GDM noted above, our study had several other limitations. First, the mean maternal age was significantly higher in the intervention group. However, we did not adjust the results for maternal age, because the main focus of our study was infant birthweight, and we observed no correlation between birthweight and maternal age in either group (R=0.016). Although it is possible that women in the intervention group were better informed regarding diet and weight gain recommendations during pregnancy prior to the intervention, we did not examine for this possibility. Second, pre-pregnancy BMI calculations were based on self-reported height and weight. We followed recommendations from the JSOG "Guidelines for Obstetrical Practice in Japan" stating that pre-pregnancy body categories be estimated from BMI calculated from self-reported height and weight.[20] Previous studies showed that self-reported height and weight highly correlated with measured values in adult Japanese women,[33,34] so we believe that this did not affect the results. Third, we could not assess the dietary intake of all women in the intervention group, and could not determine whether the women with an adequate weight gain followed a well-balanced diet. Nevertheless, we regard our intervention as effective because of the positive results regarding maternal weight gain status and the prevention of extremely SGA infants.

Few developed countries have issues similar to those of Japan, where maternal underweight combined with insufficient pregnancy weight gain is prevalent, and maternal undernutrition may be a risk factor for the future development of chronic diseases in their offspring.[14] It is important to note that underweight is prevalent among Japanese women of reproductive age, occurring in 21.8% of women aged 20-29 years and 17.1% of women aged 30-39 years in a 2012 study.[2] Most previous intervention studies were conducted to improve only short-term maternal or infant outcomes and have not focused on adopting life-long modifications to improve dietary habits.[18] The present results suggest that individualised dietary education provided during prenatal medical check-ups might influence maternal dietary behaviour. Future larger long-term intervention studies with improved methods of dietary education are needed to improve fetal undernutrition and help women maintain a healthy diet throughout their entire lives.

AUTHOR DISCLOSURES

The authors declare no conflict of interest or financial relationship (within the past 12 months) with a biotechnology manufacturer, pharmaceutical company, or other commercial entity that has an interest in the subject matter or materials discussed in the manuscript.

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