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Maternal diet quality during pregnancy and its influence on low birth weight and small for gestational age: a birth cohort in Beijing, China

Wangxing Yang[1], Na Han[2], Mingyuan Jiao[2], Xinlei Chang[1], Jue Liu[3], Qianling Zhou[1]* and Hai-Jun Wang[1]

[1]*Department of Maternal and Child Health, School of Public Health, Peking University, Beijing, People's Republic of China*
[2]*Tongzhou Maternal and Child Health Care Hospital of Beijing, Beijing, People's Republic of China*
[3]*Department of Epidemiology and Biostatistics, School of Public Health, Peking University, Beijing, People's Republic of China*

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Abstract

This study aimed to describe diet quality of pregnant women and explore the association between maternal diet and the prevalence of low birth weight (LBW) and small for gestational age (SGA). A total of 3856 participants from a birth cohort in Beijing, China, were recruited between June 2018 and February 2019. Maternal diet in the first and second trimesters was assessed by the Chinese diet balance index for pregnancy (DBI-P), using data collected by the inconsecutive 2-d 24-h dietary recalls. Logistic regressions were performed to explore the independent effects of DBI-P components on LBW and SGA. The prevalence of LBW and SGA was 3·8% and 6·0%, respectively. Dietary intakes of the participants were imbalanced. The proportions of participants having insufficient intake of vegetables (87·3% and 86·6%), dairy product (95·9% and 96·7%) and aquatic foods (80·5% and 85·3%) were high in both trimesters. The insufficiency of fruit intake was more severe in the second (85·2%) than that in the first trimester (22·5%) ($P < 0·05$). After adjusting for potential confounders, the intake of fruits and dairy in the second trimester was negatively associated with the risk of LBW (OR = 0·850, 95% CI: 0·723, 0·999) and SGA (OR = 0·885, 95% CI: 0·787, 0.996), respectively. Sufficient consumption of fruits and dairy products in pregnancy may be suggested in order to prevent LBW and SGA.

Key words: Diet balance index: Pregnant women: Low birth weight: Small for gestational age: Diet quality: China

Maternal nutrition is important for the growth and development of the fetus *in vivo*. Malnutrition during pregnancy may increase the risks of adverse pregnancy outcomes and affect children's health in childhood and/or adulthood[1,2]. Diet quality during pregnancy is critical to maternal nutrition; therefore, it is important to evaluate maternal diet during pregnancy[3]. However, the traditional dietary evaluation represented by a single nutrient or multiple nutrients cannot comprehensively reflect dietary intake, while dietary patterns appear to be more comprehensive in illustrating one's dietary intake structure and composition. An investigation into maternal dietary patterns can directly explore issues related to food consumption and diet composition. The results of the investigation would be useful to guide the development of nutrition education and intervention during pregnancy[4,5].

Diet indexes are one of the methods for dietary pattern evaluation. Globally, a number of dietary evaluation indexes have been used among different populations. In China, the Chinese diet balance index (DBI-07), released in 2007 by the Chinese Nutrition Society, was developed based on the dietary guidelines of the general population, to reflect both deficits and surpluses in food intake and to evaluate diet quality as a whole[6]. The Chinese diet balance index for pregnancy (DBI-P) was developed to specifically evaluate the diet quality of pregnant Chinese women[7]. The DBI-P was based on the healthy dietary pattern in pregnancy recommended by the Chinese Nutrition Society in 2007[8] and the Chinese Dietary Reference Intakes (recommended daily intake of nutrients and energy in three different trimesters)[9]. The indicators and scoring method of DBI-P were designed on the basis of DBI-07. The DBI-P has been used to evaluate the diet of pregnant women in Chengdu[7], Shanghai[10] and Lanzhou[11] and been considered as an easy-to-implement tool to assess diet quality of pregnant women in China.

Low birth weight (LBW) indicates a birth weight below 2500 ***g***[12]. Small for gestational age (SGA) indicates an infant having birth weight below the 10th percentile for infants of the same gestational age[13]. LBW and SGA are both adverse birth outcomes that may lead to perinatal complications[14,15] and long-term diseases[16–19]. According to previous studies in China, the prevalence of LBW was 2·0–3·5 %, and the prevalence of SGA was 5·1–11·9 %[20–23]. The WHO has set up a target

Abbreviations: DBI-P, diet balance index for pregnancy; DQD, diet quality distance; HBS, higher bound score; LBS, lower bound score; LBW, low birth weight; SGA, small for gestational age.

* **Corresponding author:** Qianling Zhou, email qianling.zhou@bjmu.edu.cn

(i.e. reducing 30 % of the number of LBW infants in 2012) to reduce the prevalence of LBW by 2025. In other words, there would be a 3 % reduction in LBW per year between 2012 and 2025[24]. However, the annual LBW reduction rate between 2000 and 2015 in eastern Asia (where China is located) was only 0·83 %[25]. Reducing the population of LBW infants in China would contribute to a more rapid reduction in the prevalence of LBW in eastern Asia. Several studies have explored the association between maternal nutrients/food intake during pregnancy and neonatal birth weight[26,27]. For example, Heppe *et al.*[26] conducted a prospective cohort study to examine maternal dietary intake in the first trimester and its association with birth weight. However, there has been no exploration on the influence of maternal diet quality represented by DBI-P on birth weight in the literature. In addition, mid-pregnancy is the period of more rapid intrauterine growth of the fetus compared with early pregnancy, it is thus important to take maternal diet in mid-pregnancy into account.

The present study was a prospective birth cohort in Beijing, China, to evaluate maternal diet quality using the DBI-P and to explore the association between maternal diet quality and birth weight.

Methods

Study design and setting

The Peking University Birth Cohort in Tongzhou (PKUBC-T) was conducted in collaboration between the School of Public Health, Peking University, and the Tongzhou Maternal and Child Health Hospital, to investigate the short-term and long-term effects of maternal pre-pregnancy and antenatal exposures on the health outcomes of children from birth to six years old[28].

The PKUBC-T was registered at ClinicalTrials.gov (NCT 03814395). This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by the Institutional Review Board (IRB00001052-18003) of the Peking University Health Science Centre. Written informed consent was obtained from all participants at enrollment.

The present study applied data from the PKUBC-T regarding maternal diet during pregnancy and its impact on neonatal birth weight. All data used for analysis were anonymous. Tongzhou is a district located in southeastern Beijing, with a population of 1·68 million residents by the end of 2019[0].

The participants

Baseline recruitment was conducted from June 2018 to February 2019. Pregnant women who visited the outpatient clinic for the first antenatal examination in Tongzhou Maternal and Child Health Hospital and met the following inclusion criteria were recruited: aged 18 to 49 years, with gestational weeks of less than 14 weeks, lived in the Tongzhou District in the past 6 months, had no intention to move out of the district after delivery and planned to receive antenatal care and to deliver in the Tongzhou Maternal and Child Health Hospital. Women who had chronic pre-pregnancy diseases, including diabetes, hypertension and liver and kidney diseases, were not enrolled in this study.

A total of 5426 pregnant women enrolled in the PKUBC-T. After an exclusion of those who did not complete any dietary assessment (*n* 101), completed only a 1-d assessment in both trimesters (*n* 1330), provided unreasonable responses (i.e., energy intake of < 500 kcal/day or > 3500 kcal/day, *n* 70) and failed to complete dietary assessments within the suggested gestational weeks (see below, *n* 69), 3856 participants were included in the analysis. There were 3145 and 1950 participants who completed the inconsecutive 2-d 24-h dietary recalls in the first and second trimesters, respectively. A total of 1239 out of 3856 participants (32·13 %) completed dietary assessments in both trimesters (Fig. 1).

Dietary assessment

Maternal dietary intake was assessed by the 2-d inconsecutive 24-h recall method in early (gestational week: < 14) and mid-pregnancy (gestational week: 14–28). Participants were required to recall the type and amount of foods consumed in breakfast, lunch, dinner and extra meals within 24 h of the previous day for two inconsecutive days in each trimester. At the first hospital visit during early pregnancy, participants completed the first 24-h dietary recall *via* a tablet computer. Food portion models were provided to help participants estimate the amount of foods consumed. Nurses provided guidance and advice in filling the dietary recall. Participants were required to conduct the 24-h dietary recall again at the next antenatal visit (2 to 14 days after the first dietary assessment) *via* the tablet computer.

At the mid-pregnancy hospital visit, participants were required to complete the first 24-h dietary recall *via* their own smartphones, under the guidance of nurses in the outpatient clinic. A colour-printed food portion guide was used to assist participants in estimating the quantities of foods consumed. Upon the completion of the first recall, participants were provided with a QR code and required to complete the online 24-h dietary recall 2 to 14 d after leaving the hospital. Researchers reminded those who did not submit the second dietary survey by text messages every week. Participants who failed to fill in the second dietary recall within a 14-d interval were considered as 'lost to follow-up' and were no longer reminded. Foods consumed were coded and classified into twelve different categories according to the China food composition table[29].

Diet balance index for pregnancy

The scoring method of DBI-P was based on the recommended food intake (online Supplementary Table 1). According to the dietary guidelines for pregnancy[8] and the Chinese Dietary Reference Intakes[9], the recommended food intake in each trimester (online Supplementary Table 1) was developed by Wang *et al.*[7]. As assessed, energy and macronutrients from the recommended food amounts met at least 95 % of the recommended nutrient intakes, and micronutrient intakes met at least 90 % of the recommended nutrient intakes. Therefore, the recommended food intake was a reliable criterion for diet quality assessment[7].

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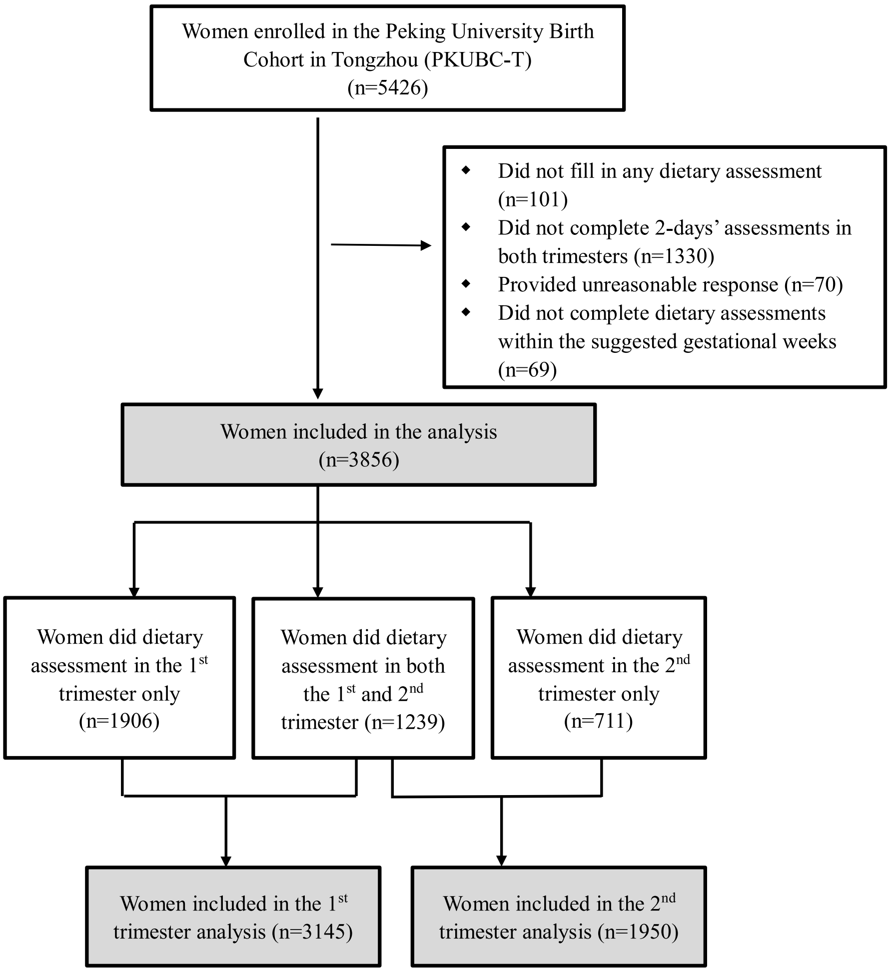

Fig. 1. Flow chart of participants' selection.

The DBI-P consists of nine different components, including cereal, vegetable, fruit, soyabean and nut, dairy, meat, aquatic food, egg and food variety. For each component, a score of 0 indicates adequate intake, while the negative and positive scores demonstrate insufficient and excessive food intake, respectively. Dietary guidelines[8] recommend that pregnant women consume a sufficient or plenty amount of vegetables and fruits, as well as soybean, nut and dairy; thus, a negative score (range: −12 to 0) was used to indicate the level of inadequate intake. The score of the food variety component also ranges from −12 to 0. The food variety was assessed by the intake of twelve identified food variety subgroups, including (1) rice; (2) wheat; (3) corn, coarse grains and starchy roots; (4) dark-coloured vegetables; (5) light-coloured vegetables; (6) fruits; (7) soybean and nut; (8) milk and dairy; (9) livestock meat; (10) poultry; (11) egg and (12) aquatic food. For each food variety subgroup, a score of 0 was assigned if the intake amount reached or exceeded the minimal recommended intake (25 g per day); otherwise, a score of −1 was assigned. In addition, both positive and negative scores were used to evaluate the intake levels of cereals (range: −12 to 12) and animal foods (range: −12 to 8), which the guidelines recommend that pregnant women consume in an appropriate amount. A negative score was given when participants consumed an insufficient amount of cereals/animal foods, and a positive score was given when they consumed an excessive amount. The scoring criteria were different in the first and second trimesters due to the differences in recommended intake in two trimesters (see Supplementary Table 2 for the scoring method in detail)[7].

Three indicators were used to reflect diet quality, including the Higher Bound Score (HBS), Lower Bound Score (LBS) and Diet Quality Distance (DQD). The scoring system of these three indicators was presented in Supplementary Table 3. The HBS was calculated as the sum of the positive scores of all subgroups. The HBS reflected the degree of excessive dietary intake (a score of 0: a sufficient intake, no excess, 1–4: a relatively appropriate intake, 5–8: mild excess, 9–12: moderate excess and >= 13: severe excess). The LBS was calculated as the absolute value of the sum of the negative points of all subgroups. The LBS reflected the degree of insufficient dietary intake (a score of 0: a sufficient intake, no insufficiency, 1–12: a relatively appropriate intake, 13–24: mild insufficiency, 25–36: moderate insufficiency and >= 37: severe insufficiency). The DQD was the sum of the absolute values of each subgroup, which comprehensively reflected the degree of imbalanced dietary intake (a score of 0:

a balanced intake, 1–12: a relatively balanced intake, 13–24: mild imbalance, 25–36: moderate imbalance and >= 37: severe imbalance)[7].

The DBI-P method was compared with the 24-h dietary recall method among ninety-nine pregnant women in Shanghai. The results from the two methods agreed, and the authors concluded that the DBI-P method was reliable and had better practicability than the 24-h dietary recall method[10].

Assessment of outcomes

Neonatal birth weight was measured by midwives within one hour of childbirth using the infant scale (ACS-20-YE, Jiangsu Wuxi Weighing Equipment Factory Co. Ltd). The birth weight was measured twice and accurate to ten digits. If two weight values were the same, the value was used and recorded. If two values were different, the measurement was repeated a third time, and two similar values were recorded. If three values were different from each other, the average of the three was used. LBW was defined as a birth weight below 2500 ***g***. SGA was calculated according to the birth weight curves for neonates of different gestational ages in China[30]. A birth weight below the 10th percentile of the same gestational age and sex was defined as SGA, and a birth weight between the 10th and 90th percentiles was defined as normal birth weight.

Assessment of covariates

Maternal socio-demographic information (including age at delivery, educational level, annual family income and parity), folic acid use before and during pregnancy, multivitamin use during pregnancy, passive smoking during pregnancy, daily energy intake in the first and second trimesters, pre-pregnancy BMI and gestational weight gain were considered as covariates. Information on maternal age, education level and parity was obtained from the hospital's medical records. Information on family income, pre-pregnancy weight, folic acid use before and during pregnancy, multivitamin use and passive smoking during pregnancy was collected by a self-administered questionnaire at the first antenatal visit (7–13 gestational weeks). Information on daily energy intake in each trimester was collected by 2-d inconsecutive 24-h recalls (detailed above) and calculated according to the *China Food* Composition Table 2009. Maternal height and weight were measured by trained nurses. Height was measured at the first antenatal visit, and weight was measured at every antenatal visit. Pre-pregnancy BMI was calculated using pre-pregnancy weight (in kilograms) divided by the square of height (in metres). Gestational weight gain was calculated as weight measured at or before the day of delivery (no more than four weeks before delivery) minus pre-pregnancy weight.

Statistical analyses

Categorical variables were presented as frequencies (%). The normality of continuous data was assessed by the Shapiro–Wilk test. Continuous variables that were normally distributed were presented as the mean ± standard deviation (SD), and those that were non-normally distributed were presented as the median and interquartile range. A-hundred percent stacked bar charts were drawn to describe and compare the distribution of HBS, LBS and DQD scores in five classes (balanced intake, a relatively balanced intake, mild imbalance, moderate imbalance and severe imbalance)[7]. For participants who completed dietary assessments in both trimesters, paired-samples t tests were used to compare the difference of DBI-P components scores, and χ^2 test was used for compare the difference of distribution of DBI-P indicators. Mann–Whitney U tests were used to compare the between-group (LBW *v.* normal, SGA *v.* normal) differences of continuous variables, and χ^2 test was used for categorical variables. Multivariate logistic regression analysis was performed to evaluate the association between the score for each DBI-P subgroup (including cereal, vegetable, fruit, dairy, soybean and nut, meat, aquatic food, egg and food variety) and LBW or SGA. Variables that had a $P < 0{\cdot}1$ in univariate analysis were judged as potential confounders. SPSS software (version 22) was used to analyse the data, and a two-sided value of $P < 0{\cdot}05$ was considered as statistically significant.

Results

A total of 3856 (71·1 %) participants completed dietary assessments in the first or second trimester and were included in the present study. Participants' age, education level, family income, parity, pre-pregnancy BMI, gestational weight gain, folic acid use before and during pregnancy, multivitamin use and passive smoking during pregnancy and the outcome variables of LBW and SGA are presented in Table 1. The median age of the participants was 29 years (IRQ 27–31). There were 80·1 % of the participants who had a bachelor's degree or above and 57·3 % who had a family income of more than 100 000 RMB per year (the average income in China was 43 834 RMB per year)[31]. The prevalence of LBW and SGA was 3·8 % (131/3423) and 6·0 % (205/3423), respectively. There were significant differences ($P < 0{\cdot}05$) between the included subjects (n 3856) and cohort subjects (n 5426) in parity and folic acid use before pregnancy.

High levels of insufficient intake (DBI-P score < 0) of vegetables (87·3 % and 86·6 %), dairy (95·9 % and 96·7 %), soybeans and nuts (63·0 % and 68·5 %) and aquatic foods (80·5 % and 85·3 %), as well as low food variety (99·7 % and 98·9 %) in the first and second trimesters, were observed. A proportion of 85·2 % of participants consumed insufficient fruits in the second trimester. There were 52·3 % and 40·7 % of participants who consumed excessive cereals and 55·9 % and 51·8 % of participants who consumed excessive meat in the two trimesters, respectively (Table 2). According to the HBS, 16·6 % and 19·5 % of participants had moderate or severe degrees of excessive dietary intake in the two trimesters, respectively. According to the LBS, 29·6 % and 39·5 % of participants had moderate or severe degrees of insufficient dietary consumption in the two trimesters, respectively. For DQD, 45·8 % and 55·9 % of participants had moderate or severe imbalanced dietary intake in the two trimesters, respectively (Table 3).

When comparing the DBI-P scores of participants who conducted dietary assessments in both trimesters, it showed that the scores of cereal, vegetables, dairy product, meat and food variety

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Table 1. Characteristics of women included in the present study and cohort subjects
(Number and percentages or median and interquartile range)

Characteristics	Women with 2-d DR (n 3856)		Cohort subjects (n 5426)		
	n	%	n	%	P
Age, years					
Median	29		29		0·098
IQR	27–31		27–32		
Education level					
High school or below	766	19·9	1142	21·0	0·181
Bachelor's degree or above	3090	80·1	4284	79·0	
Family income, RMB/year					
≤ 100 000	1646	42·7	2314	42·6	0·980
> 100 000	2210	57·3	3112	57·4	
Parity					
Primiparous	2483	64·4	3333	61·4	0·004*
Multiparous	1373	35·6	2093	38·6	
Pre-pregnancy BMI, kg/m^2					
Median	21·6		21·6		0·587
IQR	19·8–23·9		19·8–24·0		
Gestational weight gains, kg					
Median	14·5		14·5		0·907
IQR	11·0–18·4		11·0–18·5		
Folic acid use before pregnancy					
Yes	2271	58·9	3062	56·4	0·018*
No	1585	41·1	2364	43·6	
Folic acid use during pregnancy					
Yes	3119	80·9	4381	80·7	0·899
No	737	19·1	1045	19·3	
Multivitamin use during pregnancy					
Yes	1867	48·4	2597	47·9	0·620
No	1989	51·6	2829	52·1	
Passive smoking during pregnancy					
Yes	1627	42·2	2304	42·5	0·799
No	2229	57·8	3122	57·5	
LBW					
Yes	131	3·8	163	3·6	0·663
No	3292	96·2	4406	96·4	
SGA					
Yes	205	6·0	262	5·7	0·762
No	3218	94·0	4307	94·3	

IQR, interquartile range; DR, dietary recall; LBW, low birth weight; SGA, small for gestational age.
* $P < 0{\cdot}05$.

Table 2. Distribution of scores of diet balance index for pregnancy components in the first and second trimesters (%)

Score	First trimester (n 3145)			Second trimester (n 1950)		
	< 0	0	> 0	< 0	0	> 0
Cereal	40·9	6·8	52·3	37·0	7·1	55·9
Vegetable	87·3	12·7	–	86·6	13·4	–
Fruit	22·5	77·5	–	85·2	14·8	–
Dairy product	95·9	4·1	–	96·7	3·3	–
Soybean & nuts	63·0	37·0	–	68·5	31·5	–
Meat	46·7	12·6	40·7	35·5	12·7	51·8
Aquatic food	80·5	19·5	–	85·3	14·7	–
Egg	57·0	6·6	36·3	57·7	21·6	20·7
Food variety	99·7	0·3	–	98·9	1·1	–

The score range was different for each component: cereal (–12~12), vegetable (–6~0), fruit (–6~0), dairy product (–6~0), soybean and nut (–6~0), aquatic food (–4~0), meat (–4~4), egg (–4~4) and diet variety (–12~0).
-: not available.

were significantly higher in the second trimester than in the first trimester. Inversely, the scores of fruits, soybean and nuts and eggs were significantly higher in the first trimester than those in the second trimester. A relatively large difference was observed in fruits (Table 4). The proportions of participants who had moderate or severe degrees of excessive, insufficient and imbalanced dietary intake were all higher in the second trimester than in the first trimester (Fig. 2(a)–(c)) ($P < 0{\cdot}05$).

Univariate analyses showed the differences in maternal DBI-P component scores between the LBW/SGA and normal birth weight groups in the two trimesters (online Supplementary Table 4). The multivariate analyses showed that fruit intake in the second trimester was negatively associated with the risk of LBW (OR = 0·850, 95 % CI = 0·723, 0·999), and dairy intake in the second trimester was negatively associated with the risk of SGA (OR = 0·885, 95 % CI = 0·787, 0·996) (Table 5).

Discussion

This birth cohort study evaluated diet quality in early- and mid-pregnancy and explored the association between DBI-P and birth weight among pregnant women living in Beijing, China. The prevalence of LBW and SGA was 3·8 % and 6·0 %, respectively. We found imbalanced total dietary intake, especially high levels of insufficient intake of vegetables, dairy product and aquatic foods and low food variety in both trimesters. Insufficient intake of fruits was more severe in the second trimester than in the first trimester. Fruit and dairy intake in the second trimester was negatively associated with the risk of LBW and SGA, respectively.

The insufficient intake of vegetables in both trimesters was serious in our study (87·3 % and 86·6 %) as well as in a cohort study (n 610) in Chengdu, China (77·7 % and 64·4 %, dietary intake measured by 24-h dietary recalls)[7]. Similarly, a cross-sectional study (n 7630) by Li et al.[32] used FFQ to recall maternal diet during pregnancy and found that 72·3 % of women had insufficient consumption of vegetables in northwest China. Actually, there was a decrease in vegetable intake in China from 1982 to 2015[33]. In terms of dairy product, the intake insufficiency found in our study was similar to Li et al.[32], who found that 89·6 % of pregnant women had insufficient consumption of dairy in northwest China. The proportions of insufficient intake of aquatic foods were 80·5 % and 85·3 % in the first and second trimesters, respectively, in our study, slightly lower than that reported by Li et al.[32] (92·2 %). The subtle difference between Li et al.[32] and our study can be illustrated by sample size (7630 v. 3856) and geographical variation (Shaanxi v. Beijing). The intakes of dairy product, aquatic foods and eggs have remained at a low level, with only a small increase over decades in China[33]. For food variety, our study was consistent with Li et al.[32]. Although there has been a significant decrease in cereal intake over decades in China[33], coarse grains, rice and wheat are still major staple foods in the Chinese diet[34].

In consistent with the studies in Chengdu (n 610)[7], Shanghai (n 99)[10] and Lanzhou (n 690)[11] that used 24-h dietary recalls, our study revealed that relatively few women had an excessive

Table 3. Distribution of diet balance index for pregnancy categories among participants in the first and second trimesters (%)

DBI-P categories	A balanced intake	A relatively balanced intake	Mild imbalance	Moderate imbalance	Severe imbalance
First trimester (*n* 3145)					
HBS	39·6	28·0	15·8	14·5	2·1
LBS	0	14·8	55·7	27·4	2·2
DQD	0	5·6	48·6	39·5	6·3
Second trimester (*n* 1950)					
HBS	36·8	27·8	15·9	16·7	2·8
LBS	0	13·5	47·0	33·6	5·9
DQD	0	5·1	38·9	43·4	12·5

DBI-P, diet balance index for pregnancy; HBS, higher bound score; LBS, lower bound score; DQD, dietary quality distance.
Score range of HBS (0–20). No dietary excess: 0; a relatively appropriate intake: 1–4; mild dietary excess: 5–8; moderate dietary excess: 9–12; severe dietary excess: 13–20.
Score range of LBS (0–60). No dietary insufficiency: 0; a relatively appropriate intake: 1–12; mild dietary insufficiency: 13–24; moderate dietary insufficiency: 25–36; severe dietary insufficiency: 37–60.
Score range of DQD (0–60). A balanced dietary intake: 0; a relatively balanced intake: 1–12; mild dietary imbalance: 13–24; moderate dietary imbalance: 25–36; severe dietary imbalance: 37–60.

Table 4. Comparison of mean scores (SD) of DBI-P components in the first and second trimesters among participants who had completed dietary assessments in both trimesters
(Mean values and standard deviations, *n* 1239)

	1st trimester		2nd trimester		
DBI-P components	Mean	SD	Mean	SD	*P*
Cereal	1·4	5·7	2·0	6·2	0·001*
Vegetable	–2·9	1·6	–2·8	1·6	0·01*
Fruit	–0·6	1·3	–2·9	1·9	< 0·001*
Dairy product	–4·3	1·8	–3·9	1·7	< 0·001*
Soybean & nut	–3·0	2·6	–3·2	2·6	0·003*
Meat	0	2·7	0·7	2·7	< 0·001*
Aquatic food	–2·9	1·6	–2·9	1·5	0·45
Egg	–0·5	2·5	–1·0	2·4	< 0·001*
Food variety	–4·1	1·6	–3·9	1·8	< 0·001*

DBI-P, diet balance index for pregnancy.
SD, standard deviation.
* $P < 0·05$.

total dietary intake; however, a relatively large proportion of women had an insufficient total dietary intake in both the first and second trimesters. It appears that overconsumption during pregnancy is not an issue in our study population and in China, whereas insufficient consumption exists. Therefore, women who had moderate and severe degrees of insufficient intake during pregnancy should be targeted for dietary intervention.

Our study demonstrated that a higher proportion of pregnant women in the second trimester had moderate or severe total insufficient intake than those in the first trimester. Our result was in line with the study in Lanzhou[11], but in contrast to the study in Chengdu[7]. Our results might be attributed to significantly lower fruit consumption in the second trimester (fruit was the main contributor to the LBS score). Our results were consistent with two prospective cohort studies (maternal diet assessed by FFQ) in Japan (*n* 23 406)[35] and Norway (*n* 51 675)[36] in which total fruit consumption was higher in early pregnancy than in mid-pregnancy. As explained by the Norwegian study, nausea and vomiting are more common in early pregnancy, in which case women tend to have more frequent consumption of fruits to avoid symptoms[36]. In addition, different criteria of DBI-P in the two trimesters could contribute to the differences in the results.

Our study is novel in exploring the association between maternal DBI-P components and LBW and SGA. Dairy intake in the second trimester was found to be negatively associated with the risk of SGA in our study. In a systematic review and meta-analysis, the consumption of a higher amount of milk and related products during pregnancy was associated with a reduced risk of SGA (OR = 0·69, 95 % CI: 0·56, 0·84)[37]. A review found that maternal dietary patterns associated with a lower risk of SGA had similar characteristics across studies, most importantly was the high consumption of dairy foods[38]. Dairy and dairy products provide valuable proteins, Ca and other minerals, which are beneficial for pregnant women to meet the essential energy and nutrient requirements. Additionally, milk functions as an endocrine signalling system promoting anabolism and glucose transferring to the fetus by activating the nutrient-sensitive kinase mTORC1[39]. Our findings support the recommendation released by the Chinese Nutrition Society of increasing dairy intake in mid-pregnancy[8]. Large proportions of insufficient dairy intake were found in both trimesters in the present study; pregnant women should thus consume enough dairy products.

Fruit intake in the second trimester was negatively associated with the risk of LBW. A study in Korea found that higher fruit consumption was positively associated with fetal growth[40]. Mechanisms have been proposed by researchers to explain the association between fruit intake and birth weight. Fruits are the main source of vitamin C, vitamin A, folate, potassium and Mg. A maternal diet high in fruits during pregnancy is associated with a lower risk of hypertension, which is a major factor for fetal growth restriction[41]. Moreover, micronutrients from fruits are beneficial for immunologic and placental functions, which are critical for fetal growth[42]. Admittedly, high-fruit consumption may be an indicator of a healthy lifestyle and affluence. Those who maintain a healthy lifestyle are less likely to have adverse pregnancy outcomes.

Although the above significant associations in the second trimester were observed in our study, there was no significant association between any DBI-P component (cereal, vegetables, fruits, dairy products, soybeans and nut, animal food or food variety) and outcomes (LBW and SGA) in the first trimester. Nutrition in early pregnancy mainly plays a role in maintaining the growth of organs and cell division or avoiding fetal abnormalities. Fetal weight increases in the first trimester are not as

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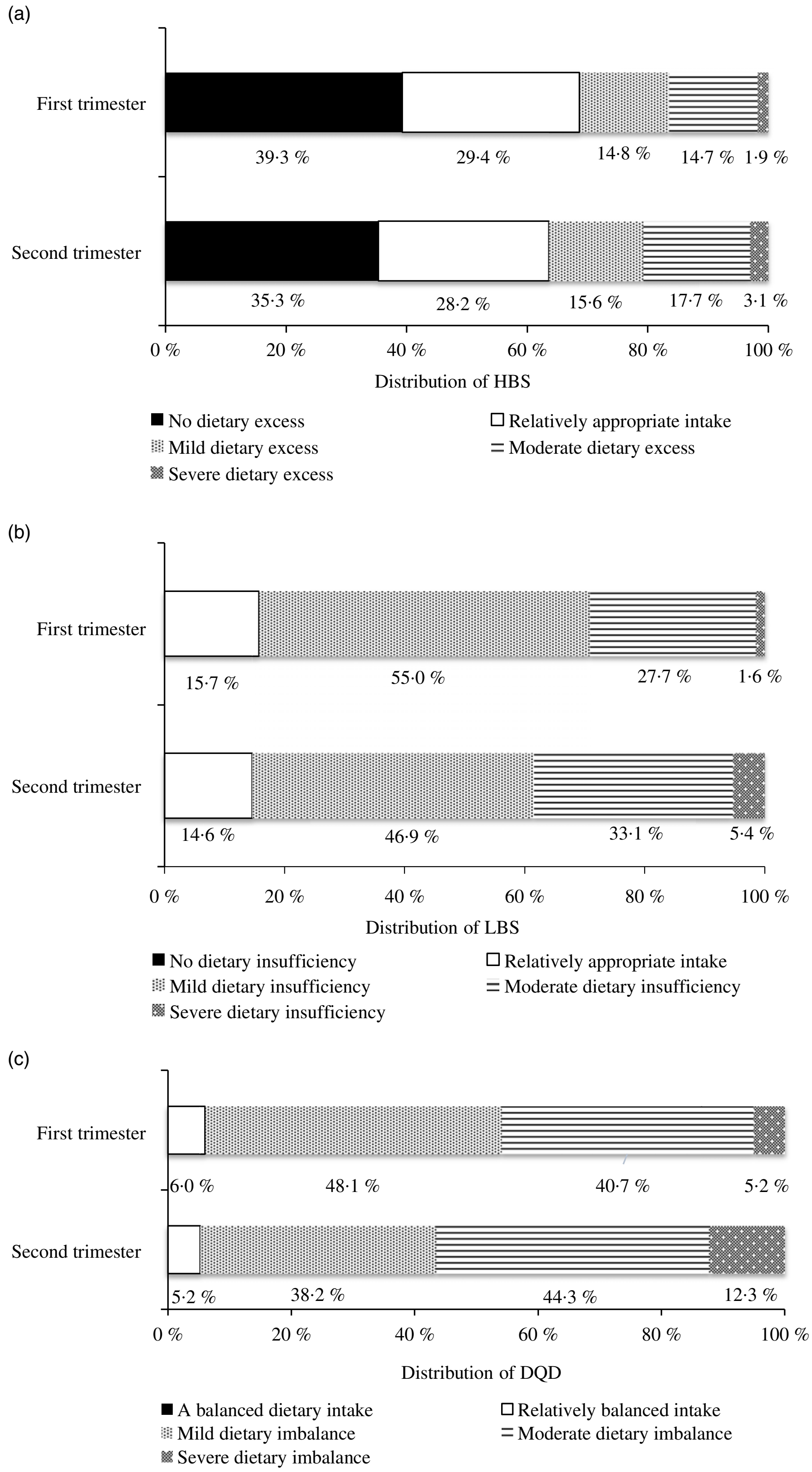

Fig. 2. (a) Distribution of HBS among participants who had completed dietary assessments in both the first and second trimesters (*n* 1239). HBS, higher bound score. Score range of HBS: 0–20. No dietary excess: 0; a relatively appropriate intake: 1–4; mild dietary excess: 5–8; moderate dietary excess: 9–12; severe dietary excess: 13–20. (b) Distribution of LBS among participants who had completed dietary assessments in both the first and second trimesters (*n* 1239). LBS, lower bound score. Score range of LBS: 0–60. No dietary insufficiency: 0; a relatively appropriate intake: 1–12; mild dietary insufficiency: 13–24; moderate dietary insufficiency: 25–36; severe dietary insufficiency: 37–60. (c) Distribution of DQD among participants who had completed dietary assessments in both the first and second trimesters (*n* 1239). DQD, dietary quality distance. Score range of DQD: 0–60. A balanced dietary intake: 0; a relatively balanced intake: 1–12; mild dietary imbalance: 13–24; moderate dietary imbalance: 25–36; severe dietary imbalance: 37–60.

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Table 5. The associations between DBI-P and LBW and SGA by logistic regression analysis†
(Odd ratio and 95 % confidence intervals)

	LBW				SGA			
	1st trimester (*n* 2540)		2nd trimester (*n* 1662)		1st trimester (*n* 2446)		2nd trimester (*n* 1609)	
Components	OR	95 % CI	OR	95 % CI	OR	95 % CI	OR	95 % CI
Cereal	0·998	0·950, 1·048	0·954	0·906, 1·005	0·983	0·954, 1·013	1·008	0·976, 1·040
Vegetable	0·956	0·809, 1·129	1·107	0·912, 1·345	1·006	0·911, 1·111	0·902	0·799, 1·019
Fruit	0·982	0·805, 1·198	0·850	0·723, 0·999*	0·966	0·856, 1·091	0·919	0·828, 1·019
Dairy	0·887	0·765, 1·028	1·046	0·867, 1·263	1·078	0·989, 1·175	0·885	0·787, 0·996*
Soybean & nut	0·981	0·885, 1·087	1·004	0·892, 1·130	1·022	0·960, 1·089	0·941	0·870, 1·016
Meat	0·975	0·885, 1·075	0·959	0·855, 1·077	0·995	0·938, 1·055	0·947	0·882, 1·017
Aquatic food	0·940	0·795, 1·111	0·935	0·764, 1·145	1·038	0·941, 1·146	0·931	0·816, 1·062
Egg	1·022	0·920, 1·135	0·995	0·877, 1·130	1·032	0·968, 1·099	1·054	0·971, 1·144
Variety	0·853	0·724, 1·006	1·009	0·844, 1·205	0·983	0·888, 1·089	0·909	0·818, 1·011

DBI-P, diet balance index for pregnancy. LBW, low birth weight. SGA, small for gestational age.
* $P < 0·05$.
† Adjusted for pre-pregnancy BMI, gestational weight gains, multivitamin use during pregnancy, and preterm birth for LBW. Adjusted for parity, pre-pregnancy BMI, gestational weight gains, folate use before pregnancy, and preterm birth for SGA.

much as those in mid- and late-pregnancy. As a result, the effect of food consumption on fetal weight change in early pregnancy might not be easily found. Our results support the knowledge that nutrition in mid-pregnancy is a key determinant of neonatal birth weight.

Our study found no association between other DBI-P components (including cereal, vegetables, soybeans and nut, animal food and food variety) and LBW or SGA in either the first or second trimesters. Previous studies failed to reach a conclusion in terms of the relationships between birth weight and vegetables[43] and aquatic food[44,45], according to systematic reviews and other cohort studies. Generally, sample size and definition method of diet quality may lead to different results. A matched case–control study found no association between meat consumption and SGA[46], which was similar to our study. Regarding diet diversity, the majority of research has been conducted in African countries and India[47–49]. The cultural differences between China and the above countries might contribute to the variations in results.

The present study had some strengths. First, the sample size of this study was relatively large, and the bias of the results was thus reduced. Second, inconsecutive 2-d 24-h dietary recalls were innovatively used in this study to gather diet information in pregnancy. This method is difficult to conduct in large-scale human studies, and great efforts and strategies were made throughout the study to ensure its implementation, such as conducting dietary assessments at the time of antenatal clinical visits, using online questionnaires, hiring nurses to give guidance and sending text messages to those who did not fill in questionnaires on time. Third, the DBI-P, which was specially designed to evaluate the diet quality of pregnant women in China, was used in this study. This was also the first study to explore the association between DBI-P components and birth weight. Finally, this study was a prospective study that had strong power in illustrating causal relationships.

Limitations of this study should be acknowledged. It would be a good supplement for this study if maternal diet was collected in late pregnancy, a period being important for fetal growth. The reasons why we did not conduct a dietary survey in late pregnancy were as follows. First, the respondent burden would be too high for the pregnant women to complete dietary assessment in every trimester, and our manpower to support the assessment in late pregnancy was insufficient. Second, previous studies have shown that diet changed little during pregnancy[50]. In addition, DBI-P should be applied carefully for cross-country comparison, as its generalisability has not yet been confirmed. Moreover, underestimation of dietary intake might exist in our study because the 24-h dietary recall method is prone to recall bias. Finally, diet consumed on weekdays and weekends might be different. Our dietary results were not differentiated between weekdays and weekends; therefore, the generalisability of our findings to all days or weekdays/weekends only could not be confirmed.

Conclusion

In conclusion, our results revealed an imbalanced diet among pregnant women, including severe insufficiency in vegetables, dairy and aquatic foods and low dietary diversity in early and mid-pregnancy. Higher consumption of fruits and dairy products in pregnancy may be suggested, in an attempt to prevent the occurrence of LBW and SGA. This study adds knowledge to recommendations or public health initiatives in China that can help achieve the goal set by the WHO to reduce the number of LBW and SGA children.

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W. Y., Q. Z. and H. W. conceptualised the study. N. H., M. J., X. C. and J. L. collected the data. W. Y. analysed the data and drafted the manuscript. Q. Z. supervised the drafting of the manuscript and provided critical comments on this paper. W. H. provided critical comments on this paper. All authors have read and approved the final manuscript.

All authors declare that they have no competing interests.

Supplementary material

For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S0007114522000708

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