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The influence of maternal dietary patterns on gestational weight gain: A large prospective cohort study in China

Xueling Wei M.Sc. [a,b], Jian-Rong He M.Sc. [a,b], Yan Lin M.Sc. [c], Minshan Lu M.Sc. [a,b], Qianling Zhou Ph.D. [a], Shenghui Li B.Sc. [a], Jinhua Lu M.Sc. [a,b], Mingyang Yuan M.Sc. [a,b], Niannian Chen M.Sc. [a,b], Lifang Zhang M.Sc. [a,b], Lan Qiu M.Sc. [a,b], Weibi Mai B.Sc. [d], Yonghong Pan B.Sc. [d], Caixin Yin M.Sc. [c], Cuiyue Hu B.Sc. [a], Huimin Xia M.D. [a], Xiu Qiu Ph.D. [a,b,*]

[a] *Division of Birth Cohort Study, Guangzhou Women and Children's Medical Center, Guangzhou Medical University, Guangdong, China*
[b] *Department of Woman and Child Health Care, Guangzhou Women and Children's Medical Center, Guangzhou Medical University, Guangdong, China*
[c] *Nursing department, Guangzhou Women and Children's Medical Center, Guangzhou Medical University, Guangdong, China*
[d] *Department of Obstetrics and Gynecology, Guangzhou Women and Children's Medical Center, Guangzhou Medical University, Guangdong, China*

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A B S T R A C T

Objective: The relationship between dietary patterns and gestational weight gain (GWG) in different pregnancy stages has rarely been reported among the Asian population. The aim of this study was to examine the relationship between dietary patterns and GWG in Chinese pregnant women.
Methods: Participants were women from the Born in Guangzhou Cohort Study who completed a validated food frequency questionnaire at 24 to 27 wk gestation (N = 5733). Dietary patterns were generated by cluster analysis. Maternal prepregnancy weight was self-reported; weights during pregnancy were extracted from medical records. Regression analyses were performed to test the associations between dietary patterns and total GWG and GWG rates (linear regression), and the adequacy of GWG (logistic regression).
Results: According to food consumption frequency, six dietary patterns were generated: "richer in cereals," "richer in vegetables," "richer in meats," "richer in fruits," "richer in fish, beans, nuts, and yogurt," and "richer in milk and milk powder." Compared with women following the richer in cereals pattern, those who followed the richer in fruits pattern had a significantly higher GWG (β = 0.592; 95% confidence interval [CI], 0.166–1.018) and total rate of GWG; those who followed the richer in fish, beans, nuts, and yogurt" pattern had a greater GWG rate in the second trimester, and also had a decreased risk for inadequate GWG (odds ratio, 0.797; 95% CI, 0.638–0.997).
Conclusion: Consuming a variety of foods and frequent consumption of fruits during pregnancy contributes to a more rapid increase in GWG among pregnant women in China. Findings may be useful in pregnancy weight monitoring.

Introduction

Gestational weight gain (GWG) is an important indicator of pregnancy outcomes [1,2]. Inappropriate GWG, either inadequate or excessive, leads to adverse health consequences for both mothers and infants [3]. Inadequate GWG is related to fetal growth restriction, preterm birth, and failure to initiate breastfeeding [3]. Excessive GWG is accountable for pregnancy complications (e.g., gestational diabetes, gestational-induced hypertension, and thromboembolism), cesarean delivery, macrosomia, postpartum maternal obesity, and long-term adverse cardiovascular and metabolic outcomes for the infants [4–7]. Excessive adiposity or body weight gained during pregnancy is not easy to reduce after delivery, leading to postpartum weight retention [5], which is an important risk factor for the development of metabolic diseases, such as obesity and diabetes [7]. Excessive GWG contributes to the increasing obesity epidemic globally, which may place serious economic burden on developed and developing countries [8]. In 2011, the proportion of excessive GWG was 38.2% among Chinese pregnant women [2].

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* Corresponding author: Tel.: +86 20 3836 7162.; Fax: +86 20 38076639
E-mail addresses: Xiu.qiu@bigcs.org, qxiu0161@163.com (X. Qiu).

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Maternal diet in pregnancy is an important modifiable factor for inappropriate GWG [9,10]. A recent systematic review demonstrated a clear association between energy intake and GWG [11]. However, evidence for the associations between individual macronutrients and GWG remains inconsistent [11]. Dietary pattern analysis is a comprehensive dietary assessment [12–14]. Representing the intakes of certain food categories but not nutrients, dietary pattern would be more practical in informing and guiding healthy eating and weight management during pregnancy compared with information obtained from single-nutrient analyses. Studies have reported associations between dietary patterns and GWG in the Western population [15–17]. For example, a significant association between the “fast food” pattern and the rate of GWG was found among Finnish women [15]. In Netherlands, Tielemans et al. reported that the “margarine, sugar and snacks” pattern was positively associated with excessive GWG [16]. Shin et al. found that inadequate consumption of vegetables was positively associated with excessive GWG among the American population [17]. Moreover, there is evidence that certain dietary patterns were associated with maternal weight gain in early but not through the entire pregnancy [16]. Weight gain during the first two trimesters was found to be a risk factor for the development of gestational diabetes mellitus (GDM) [18], excessive GWG [19], and postpartum weight retention [20]. It is thus important to investigate the effects of diet on weight gain at different pregnancy stages individually.

The Asian population has distinct dietary habits compared with the Western population. Information about GWG and dietary pattern is rarely reported in Asia. To date, only one study in Singapore has investigated the relationship between dietary pattern and GWG, which reported that intake of plant- and animal-based proteins was associated with lower risk for inadequate GWG and greater risk for excessive GWG, respectively [21]. Grains, particularly rice, feature heavily in the Asian diet. The Cantonese, who live in the southern part of China, have a culture of drinking soup characterized by a thin texture and salty taste before and after meals [22], and of frequent consumption of sweet soups as desserts [23].

This study was to explore the associations between maternal dietary patterns and GWG, total GWG rate, and GWG rates in different stages of pregnancy, and to identify patterns in relation to inadequate and excessive GWG among the Chinese population, using data of the Chinese pregnant women from the Born in Guangzhou Cohort Study (BIGCS).

Methods

Study design and population

The BIGCS is a large prospective cohort study in Guangzhou. It aims to explore the influences of early life factors on a range of maternal, child, and adolescent health outcomes in China. The cohort profile and methodology have been reported elsewhere [24]. In brief, women invited to participate in the BIGCS study population were recruited at <20 wk gestation, were Chinese, were able to understand Mandarin or Cantonese, intended to deliver at Guangzhou Women and Children's Medical Center (GWCMC) and remain in Guangzhou for ≥3 y after delivery. The BIGCS was approved by the Institutional Ethics Committee of the GWCMC. Written consent was obtained from all participants before any assessments. Data for the present study was obtained from a self-administered questionnaire at recruitment (Q1), a self-administered food frequency questionnaire (FFQ) at 24 to 27 wk of gestation (Q2), and medical records from the GWCMC.

In all, 11 859 participants were recruited between February 2012 and April 2015. We excluded those who dropped out of the study (n = 791), had pregnancy terminations or stillbirths (n = 130), experienced neonatal death (n = 20), had multiple pregnancies (n = 239), were missing delivery data (e.g., gestational weeks at delivery) or were still pregnant when the data was accessed (n = 281), had no dietary assessment at Q2 (n = 2834), reported implausible data on food items (a weekly intake frequency <32) at Q2 (n = 13), or did not have information on prepregnancy weight (n = 916) or weight at delivery admission (n = 902). There were 5733 women included in the study.

Maternal characteristics variables

Information on maternal sociodemographic characteristics (including maternal age [y], education level [high school or below, vocational or technical college, undergraduate, postgraduate], monthly income [≤1500, 1501–4500, 4501–9000, or ≥9001 renminbi], and parity [defined as the number of live births women have ever had before the current pregnancy and categorized into 0, i.e., primiparous; and ≥1, i.e., multiparous]), lifestyle (including exposure to passive tobacco smoke, and folic acid intake during early pregnancy), and anthropometric (maternal height and prepregnancy weight) were obtained from Q1. Prepregnancy body mass index (BMI; prepregnancy BMI, kg/m^2) was computed and categorized into four types: <18.5, 18.5 to 24.9, 25 to 29.9, and ≥30 kg/m^2.

Dietary assessment and dietary pattern

Dietary assessment was based on the frequency of food consumption “in the past week,” using the FFQ that has initially been validated in BIGCS [25]. The FFQ includes 64 general food items and some traditional Cantonese foods items, including tong sui (Cantonese sweet soup), lap mei (cured meat and sausages), and siumei (roasted red meat and poultry).

Dietary patterns were generated using the same methods reported by Lu et al. in the same cohort study [26]. First, individual food items were combined into 30 groups by similar nutrient profile or culinary use (e.g., grouping pork, beef, and mutton into red meat). The consumption frequency of each food group was calculated by summing the frequency of each item within the food group. Second, for each participant, the contribution (%) of every food group was calculated by dividing the consumption frequency of each food group by the total consumption frequency across all food groups. Third, cluster analysis with K-means method was conducted to generate dietary patterns [14]. Cluster analysis creates mutually exclusive groups of people with relatively homogeneous food consumption, and individuals belong to only one identified cluster [12,14]. Cluster analysis provides a clear description of the food items the subgroups are consuming [27]. The women were ranked into different clusters by the K-means method, in which participants were classified into a predetermined number of mutually exclusive groups by comparing Euclidean distances between each participant and each cluster center in an interactive process until no further changes occur. Owing to the large sample size, we believed that a cluster number of 2 to 6 would be sufficient to reflect the diversity of participants' dietary characteristics. We thus varied the number of clusters from 2 to 6 to identify the optimal classification (i.e., foods in each cluster represented and adhered to the Asian dietary culture and habit to the best extent). A cluster number of 6 was finally selected. Each cluster (i.e., pattern) was labeled based on foods that were highly consumed and on the distribution of foods within clusters.

Outcomes

During each antenatal visit, maternal weight (kg) was measured in the antenatal outpatient clinic, and maternal weight (kg) before delivery was measured at delivery admission. Weight data was extracted from medical records. Total GWG (kg) was represented by the difference in maternal weight between prepregnancy and delivery stage.

The total GWG rate (kg/wk) was calculated by dividing the total GWG (kg) by gestational weeks at the predelivery measurement. Furthermore, GWG rate in different trimesters were calculated. GWG rate in the second trimester was calculated as weight before 28th week of gestation minus weight after 13th week of gestation, divided by the time interval between the two measures (kg/kw). GWG rate in the third trimester was calculated as weight at admission for delivery minus weight after 28th week of gestation, divided by the interval between the two measures (kg/wk). In terms of the “adequacy of gestational weight gain,” GWG was categorized into inadequate, appropriate, and excessive GWG, which were based on the recommended cutoff values set by the Institute of Medicine [7].

Statistical analysis

Differences in six dietary patterns across maternal characteristics were explored, using one-way analysis of variance (ANOVA) for continuous variables, Kruskal–Wallis test for ordinal variables and χ^2 test for categorical variables. A traditional Cantonese dietary pattern (richer in cereals) was chosen as the reference pattern for regression analyses. Regression coefficients (β) and 95% confidence intervals (CIs) were generated using multivariate linear regression to determine the effect of dietary patterns on total GWG (adjusted for maternal age, educational level, prepregnancy BMI, parity, and gestational age at delivery), rate of total GWG (adjusted for maternal age, educational level, prepregnancy BMI, and parity), and rate of GWG in different trimesters (adjusted for maternal age, educational level, prepregnancy BMI, and parity). Dietary patterns were expressed as dummy variables and taken into account in linear regression models. Multivariate logistic regression models with odds ratios (ORs) and 95% CIs, were performed to assess the effect of dietary patterns on the risk for inadequate GWG or excessive

GWG (adjusted for maternal age, educational level, parity, and gestational age at delivery). Maternal characteristics that showed a significant association with outcomes in the univariate analyses were adjusted as potential confounders (indicated previously) in the linear and logistic regression analyses.

Cluster analysis was performed by R statistical software (The R project, http://www.r-project.org), and the rest analyses were performed by SPSS statistical software version 20 (SPSS, Inc., Chicago, IL, USA). A two-tailed $P < 0.05$ was considered to be statistically significant.

Results

Dietary patterns

Six dietary patterns were generated; namely "richer in cereals," "richer in vegetables," "richer in meats," "richer in fruits," "richer in fish, beans, nuts, and yogurt," and "richer in milk and milk powder", according to the food groups predominant in each cluster. Foods distribution in each pattern was described in Supplementary Table 1. The richer in fish, beans, nuts, and yogurt (23.2%) and richer in fruits pattern (11.2%) had the largest and smallest proportion of participants, respectively (Supplementary Table 1).

Participant characteristics

Among the 5733 study participants, the majority were 29 y of age, held an undergraduate degree (55.5%), were primiparous (88.2%), and did not have a history of passive smoking during pregnancy (71.3%; Supplementary Table 2). On average, participants gained 14.6 kg (SD 4.3) during pregnancy at a rate of 0.38 kg/wk (SD 0.11). There were 21.5% and 31.3% of women with inadequate and excessive GWG, respectively (Supplementary Table 2). Participants included in the analysis were slightly older and in a higher socioeconomic status than those who were excluded from the current analyses (Supplementary Table 3).

There were significant associations between dietary patterns in maternal age, education level, monthly income, passive smoking exposure during pregnancy, prepregnancy BMI (kg/m^2), parity, GWG, GWG rate, and adequacy of GWG (Supplementary Table 2). Women followed the richer in fish, beans, nuts and yogurt pattern tended to be older, have higher education level and monthly income, and larger proportion of adequate GWG ($P < 0.05$). Women who followed the richer in fruits pattern (11.2%) appeared to gain more weight and at a more rapid total GWG rate, compared with those who followed other dietary patterns. Women who adhered to the richer in meats pattern were more likely to be exposed to secondhand smoke during pregnancy (Supplementary Table 2).

Dietary patterns and outcomes

Compared with the reference pattern (richer in cereals), the richer in fruits pattern was positively correlated to GWG (β, 0.634; 95% CI, 0.195–1.072; $P = 0.005$) and the total rate of GWG (β, 0.015; 95% CI, 0.004–0.026; $P = 0.008$) in crude models. After adjustment for potential confounders, the richer in fruits pattern remained significant in relation to GWG (β, 0.592; 95% CI, 0.166–1.018; $P = 0.007$) and the rate of GWG (β, 0.015; 95% CI, 0.004–0.026; $P = 0.007$). Women who followed the richer in fish, beans, nuts and yogurt pattern had marginally higher GWG (adjusted β, 0.341; 95% CI, −0.017 to 0.699; $P = 0.062$) and higher rate of GWG (adjusted β, 0.009; 95% CI, 0.000–0.018; $P = 0.060$; Table 1). We did not find a significant correlation between the remaining three patterns (richer in vegetables, richer in meats, and richer in milk and milk powder) and GWG or the rate of GWG (Table 1). The richer in fish, beans, nuts and yogurt pattern was positively correlated to rate of GWG in the second (adjusted β, 0.024; 95% CI, 0.001–0.048) but not the third trimester (Table 2).

Women who followed the richer in fish, beans, nuts and yogurt pattern pattern had a significantly lower risk for inadequate GWG (adjusted OR, 0.797; 95% CI, 0.638–0.997). The richer in fruits pattern was associated with excessive GWG after adjusting for potential confounders (Table 3).

Discussion

The present study generated six dietary patterns of Chinese pregnant women based on the frequency of foods consumption and added to the limited literature of on maternal dietary pattern in Asia. The present study demonstrated that a diet high in fruit and Cantonese desserts was related to a higher GWG rate. A diet containing a variety of foods was associated with a higher GWG rate and a lower risk for inadequate GWG among Chinese participants.

The patterns used in the present study were similar to those reported by Lu et al. in the same cohort [26]. Patterns found to be significantly correlated to GWG in the present study were also positively correlated with infant birthweight score in Lu et al. [26]. Because GWG is related to fetal growth [7], we might explain Lu et al.'s finding that dietary pattern has an effect on infant growth by influencing GWG. The potential mediating effect of GWG between maternal dietary pattern and infant growth is warranted in future analyses.

Table 1
Associations between six dietary patterns and gestational weight gain (N = 5733)

Dietary patterns	N	GWG (kg)*		GWG rate (kg/wk)†	
		Crude β (95% CI)	Adjusted β (95% CI)	Crude β (95% CI)	Adjusted β (95% CI)
Richer in cereals	872	Reference	Reference	Reference	Reference
Richer in vegetables	1147	−0.009 (−0.387 to 0.370)	0.084 (−0.284 to 0.452)	0.001 (−0.010 to 0.010)	0.002 (−0.007 to 0.012)
Richer in meats	927	−0.138 (−0.536 to 0.259)	−0.089 (−0.475 to 0.298)	−0.004 (−0.014 to 0.006)	−0.002 (−0.012 to 0.008)
Richer in fruits	640	**0.634 (0.195 to 1.072)**	**0.592 (0.166 to 1.018)**	**0.015 (0.004 to 0.026)**	**0.015 (0.004 to 0.026)**
Richer in fish, beans, nuts, and yogurt	1330	0.252 (−0.116 to, 0.619)	0.341 (−0.017 to 0.699)‡	0.007 (−0.003 to 0.016)	0.009 (0.000 to 0.018)§
Richer in milk and milk powder	817	0.154 (−0.257 to 0.564)	0.237 (−0.161 to 0.636)	0.004 (−0.006 to 0.015)	0.006 (−0.004 to 0.016)

BMI, body mass index; GWG, gestational weight gain.
The statistically significant results are highlighted in bold.
*GWG represented by the difference in maternal weight between prepregnancy and delivery stage. Adjusted for maternal age, educational level, prepregnancy BMI, parity (0/≥1), and gestational age at delivery.
†GWG rate calculated by dividing the total GWG (kg) by gestational weeks at which the maternal weight at delivery was measured. Adjusted for maternal age, educational level, prepregnancy BMI, and parity (0/≥1).
‡$P = 0.062$.
§$P = 0.060$.

Table 2
Association between dietary patterns and rate of gestational weight gain in different trimesters

Dietary patterns	GWG rate (kg/wk)			
	Second trimester* N = 4267 (74.4%)		Third trimester* N = 4396 (76.7%)	
Richer in cereals	821 (19.2)	Reference	830 (18.9)	Reference
Richer in vegetables	682 (16)	0.000 (−0.024 to 0.024)	708 (16.1)	−0.010 (−0.031 to 0.012)
Richer in meats	493 (11.6)	−0.005 (−0.031 to 0.020)	517 (11.8)	−0.016 (−0.039 to 0.006)
Richer in fruits	968 (22.7)	0.014 (−0.013 to 0.042)	993 (22.6)	0.010 (−0.014 to 0.035)
Richer in fish, beans, nuts, and yogurt	658 (15.4)	**0.024 (0.001 to 0.048)**	679 (15.4)	−0.014 (−0.035 to 0.007)
Richer in milk and milk powder	645 (15.1)	0.003 (−0.023 to 0.028)	669 (15.2)	−0.016 (−0.039 to 0.007)

BMI, body mass index; GWG, gestational weight gain
GWG rate calculated by dividing the total GWG (kg) by gestational weeks at which the maternal weight at delivery was measured
Statistically significant results are highlighted in bold
*Adjusted for maternal age, educational level, prepregnancy BMI, and parity (0/≥1).

A pattern of high fruit intake (the richer in fruits pattern) in the present study was found to be positively related to GWG and total GWG rates. This might be because fruits being generally rich in vitamins, minerals, dietary fiber, antioxidants, and phytochemicals, which can help to stimulate the immune system and detoxification enzymes, improve cholesterol synthesis, and modulate hormone metabolism and antioxidants [28]. The underlying mechanisms demonstrate the beneficial effects of fruit on women's health and fetal growth. However, the present study revealed a small effect of the richer in fruits pattern on excessive GWG. This finding is not in line with the literature that the increase of whole fruit intake has no adverse effect of excessive weight gain in general adult and pregnant women population [29,30]. Although fruits are generally low in energy density, some fruits (e.g., dried dates, watermelon) contain large amounts of simple sugars (e.g., glucose, fructose, sucrose), which are related to overweight or obesity [31]. Further analyses detecting the effects of high and low sugar fruits on GWG might be warranted. Dietary advice on fruit consumption to pregnant women should be given with caution. Low sugar fruits might be more suitable for pregnant women.

The positive effect of the richer in fish, beans, nuts and yogurt pattern on GWG rates and its protective effect on inadequate GWG are observed in the present study. First, women who consume a varied diet are likely to have a healthy lifestyle, contributing to a healthy GWG. Second, the richer in fish, beans, nuts and yogurt pattern, with frequent consumption of a variety of foods, would contribute to intake of various essential nutrients and minerals, and further contribute to adequate weight gain in pregnancy. This pattern is a healthy dietary pattern, and eating a variety of foods has been encouraged in many dietary guidelines [32,33]. However, pregnancy dietary guidelines for weight management are still lacking in China. The present results, therefore, provide an appropriate evidence base to recommend a balanced and varied diet for pregnant women in China. In addition, the richer in fish, beans, nuts and yogurt pattern in the present study was found to have greater effect on GWG rate in second the trimester rather than throughout pregnancy. This result is inconsistent with the literature that dietary patterns influence GWG at earlier stage of pregnancy [16], which is a critical period for weight management [19].

The richer in cereals pattern is characterized by frequent consumption of Chinese cereal (e.g., rice) and soup in the present study. This is a typical and traditional pattern because rice and Chinese soup are usually consumed at every meal among the Cantonese. In comparison to the reference pattern, richer in meats, richer in vegetables, or richer in milk and milk powder patterns had no effect on GWG, total GWG rate, or GWG rates in different trimesters. The results are inconsistent with our unreported analyses that there is no independent effect of “consuming a diet dominant in meats” or “consuming a diet dominant in vegetables” (in comparison to the reference group “consuming a balanced diet”) on GWG or GWG rate, measured by a question at Q2, regarding to self-perceived general type of diet. Our results, together with the

Table 3
Associations between six dietary patterns and risk for inadequate and excessive gestational weight gain, defined by the United States Institute of Medicine

Dietary patterns	Inadequate GWG (n = 1233)			Excessive GWG (n = 1795)		
	N (%)	Crude OR (95% CI)	Adjusted OR (95% CI)*	N (%)	Crude OR (95% CI)	Adjusted OR (95% CI)*
Richer in cereals	205 (16.6)	1.00 (Reference)	1.00 (Reference)	252 (14)	1.00 (Reference)	1.00 (Reference)
Richer in vegetables	271 (22)	1.065 (0.853–1.331)	1.045 (0.835–1.309)	361 (20.1)	1.154 (0.939–1.419)	1.175 (0.954–1.447)
Richer in meats	208 (16.9)	0.909 (0.720–1.149)	0.903 (0.713–1.144)	256 (14.3)	0.911 (0.732–1.133)	0.914 (0.733–1.139)
Richer in fruits	123 (10.0)	0.892 (0.681–1.169)	0.904 (0.689–1.187)	238 (13.3)	**1.405 (1.113–1.774)**	**1.393 (1.101–1.763)**
Richer in fish, beans, nuts, and yogurt	261 (21.2)	0.813 (0.652–1.013)	**0.797 (0.638–0.997)**	419 (23.3)	1.062 (0.870–1.295)	1.094 (0.894–1.338)
Richer in milk and milk powder	165 (13.4)	0.872 (0.681–1.117)	0.852 (0.664–1.094)	269 (15)	1.157 (0.927–1.443)	1.164 (0.932–1.454)

GWG, gestational weight gain.
GWG represented by the difference in maternal weight between prepregnancy and delivery stage.
GWG was categorized into inadequate, appropriate, and excessive GWG, which were based on the recommended cutoff values set by the Institute of Medicine.
Statistically significant results are highlighted in bold.
*Adjusted for maternal age, educational level, parity (0/≥1), and gestational age at delivery.

unreported data, imply that frequent consumption of meats or vegetables has no independent effect on maternal weight gain during pregnancy in the study population. The richer in milk and milk powder pattern having no effect on weight gain contradicts the literature, which states that dairy products are associated with GWG in the United States [17]. Cultural difference in diet might explain the inconsistency in research findings: Milk is not consumed on a regular basis in China; further, there is a less diverse range of dairy products in China compared with the West [34].

The present study had several strengths, including its prospective design and large sample size. In addition, we used cluster analyses with K-means to generate dietary patterns. There are two widely used methods for empirically deriving dietary patterns [17,35]: One is a cluster analysis, and the other is a factor analysis. The cluster analysis we used could better identify groups of people with a good or poor nutritional status in comparison with factor analysis, which reduces dietary data into patterns according to intercorrelations between food intakes and does not provide a clear description of exactly what has been consumed [14,27]. The present results, together with findings reported by Lu et al. in the same cohort, imply that cluster analysis is an appropriate way to account for the Asian dietary pattern, in addition to factor analysis [36].

The present study had some limitations. First, food quantity and portion size were not documented in the FFQ. The lack of a daily analysis of the calorie content of meals and the energy expenditure of pregnant women is a limitation of this study. However, it was believed that the quantities recorded in the FFQ are prone to bias [37] because individuals are generally incapable of describing food portions accurately [37], and there are sustainable within-subject variations in the indication of food quantities [38]. Instead, a simple FFQ is suggested to be sufficient to indicate actual intakes [39,40]. Heady reported a positive association between the frequency of consumption and actual intake of most foods [41]. Second, the self-reported data on prepregnancy weight would potentially bias the outcomes. Third, we measured dietary intake over 1 wk, only once between 24 and 27 wk gestation. It is a short period and the patterns derived may not reflect diet in every stage of pregnancy. Nevertheless, studies have suggested that overall dietary habits tend to remain stable throughout pregnancy [42,43].

Conclusions

To our knowledge, this was the first large-scale prospective study to explore the relationship between dietary patterns and GWG in a Chinese population. The richer in fruits and richer in fish, beans, nuts and yogurt dietary patterns were found to be independently associated with a higher GWG rate, and the richer in fish, beans, nuts and yogurt pattern was related to a reduced risk for inadequate GWG but not excessive GWG, among Chinese pregnant women. Consuming a variety of diets during pregnancy should be promoted and recommended in the dietary guideline for pregnancy weight management in China.

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Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.nut.2018.07.113.

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