Original article

Association between quality and quantity of dietary carbohydrate and pregnancy-induced hypertension: A case–control study

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ARTICLE INFO

SUMMARY

Background & aims: Pregnancy-induced hypertension (PIH) is a pregnancy-specific disorder that increases maternal and infant mortality and morbidity. The quantity and quality of consumed carbohydrates are probably the main dietary factors affecting blood pressure. The present study aimed to evaluate the association of carbohydrate quality and quantity with PIH.

Methods: This case–control study was performed on 202 pregnant women with or without PIH. The dietary data were collected using 168-item semi-quantitative food frequency questionnaires. Daily glycemic index (GI) and glycemic load (GL), ratio of whole grains to total grains, ratio of solid carbohydrates to total carbohydrates, dietary fiber and carbohydrate intake, and carbohydrate quality index (CQI) were calculated and their associations with PIH were evaluated using logistic regression. We eliminated collinearity within independent variables using factor analysis and then with evaluating the relationship between extracted factors and PIH.

Results: In pregnant women in whom the daily carbohydrate intake and GL were higher than median increased frequency of PIH compared to whom had lower than median ones (OR = 3.23, 95% CI 1.46–7.17, and $P = 0.004$; OR = 2.60, 95% CI 1.21–5.56; and $P = 0.035$, respectively). Furthermore, we showed a significant inverse association between extracted factor that was mostly related to total fiber intake frequency of PIH (OR = 0.45; 95% CI 0.20–0.97, and $P = 0.049$ when higher than median values compared to lower than ones). The GI, ratio of whole grains to total grains, ratio of solid carbohydrates to total carbohydrates, and CQI did not associate with PIH.

Conclusions: These findings suggest that carbohydrate intake and GL are related to higher and daily fiber intake to lower frequency of PIH.

1. Introduction

Pregnancy-induced hypertension (PIH) is one of the most common causes of maternal, foetal and neonatal mortality and morbidity in developed and developing countries [1]. In women, pregnancy-related hypertension unmasks predispositions for future hypertension and associates with risks of cardiovascular disease (CVD) [2]. The global prevalence of PIH is between 0.4% and 3.6% and it contributed up to 8% of all maternal deaths [3]. PIH is defined as a systolic blood pressure of equivalent or more than 140 mm Hg; or a diastolic blood pressure of equivalent or more than 90 mm Hg beginning at 20 weeks of gestation without proteinuria [4]. The etiology of PIH is related to inflammatory responses, oxidative stress, endothelial dysfunction, genetic, and dietary factor [1].

Dietary habits and specific nutrient intakes are major determinants in the progression and development of hypertension [5]. Results from studies show an association between quantity and quality of consumed carbohydrates with CVD risk factors including

blood pressure, insulin and lipids [6,7]. According to Dietary Approaches to Stop Hypertension, higher carbohydrate quality is associated with solid carbohydrates, dietary fiber, and whole grains and low glycemic foods, refined grains and liquid carbohydrates such as sugar-sweetened beverages [8]. Although dietary carbohydrates have been involved in metabolic features of nutrition-related diseases, this relation is poorly understood [9]. Previous dietary studies have focused on effects of the quantity of carbohydrates on hypertension [7]. It has also been suggested that the quality of carbohydrates [10], glycaemic index (GI) [11], glycaemic load (GL) [11], whole grains [12], and dietary fiber [10] are associated with the risk of cardio-metabolic disease including hypertension, obesity, insulin resistance, and raised serum cholesterol concentrations [10–12]. To the best of our knowledge, no studies have been reported the relationship between dietary carbohydrate quality and PIH in a comprehensive manner such as carbohydrate quality index (CQI), fiber content, and solid versus liquid forms [7]. Thus, as a first study we assessed the association between quantity and quality of carbohydrates and the risk of PIH in an Iranian population. We hypothesized that a higher CQI and lower quantity would be associated with a lower risk of PIH.

2. Materials and methods

2.1. Subjects

This observational case–control study was done at the Shahid Motahari Medical Teaching Center, (one of the main teaching hospitals of Urmia University of Medical Sciences) from early October 2015 to late February 2016. One hundred one patients with PIH as cases and one hundred one normal pregnant women as controls, seeking treatment at the Department of Obstetrics and Gynecology of Shahid Motahari Hospital in Urmia, Iran, were consecutively selected. Controls were pregnant women without PIH after 20 wk of gestation and were like cases regarding exclusion criteria. 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 Ethics Committee at Urmia University of Medical Sciences. Written informed consent was obtained from all subjects.

2.2. Baseline definitions and measurements

The diagnostic criteria for PIH according to guidelines issued by the National High Blood Pressure Education Program Working Group, are blood pressure >140/90 after 20 wk of gestation, without proteinuria [4]. Exclusion criteria for cases and controls were having multiple gestations; chronic hypertension or history of hypertension; pre-existing diabetes; history of renal disease and cardiovascular disease; and abnormal thyroid hormone and lipid profile concentrations. Following an initial screening for inclusion and exclusion criteria eligible volunteers were scheduled for a baseline visit.

2.3. General characteristics, anthropometrics and blood pressure measurements

Age, occupation, number of deliveries, history of disease, physical activity, and diet were collected by an interview-administered questionnaire. Standing height was measured without shoes, using standard height scale to the nearest 0.1 cm and weight was measured with a weight scale to the nearest 0.1 kg. Body mass index (BMI) was calculated by taking the weight (kg) and dividing it by the height squared (m^2). Systolic blood pressure and diastolic blood pressure were measured in the non-dominant arm after

5 min of rest. The same person took two readings in sitting position with the forearm at the level of the heart using a validated mercury sphygmomanometers device (MicrolifeBP AG1-10, China). The mean of the two measurements used in the evaluations.

2.4. Assessment of food intake and physical activity measurement

Well-trained dietitian collected dietary data of past year after the 20th week of pregnancy using 168-item semi-quantitative, self-administered food frequency questionnaire (FFQ), through a face-to-face education of participants with standard serving-sizes, which had previously validated in the Tehran lipid and glucose study [13]. Dietary data were analyzed by Nutritionist 4 software (First Databank, Inc.; Hearst Corporation) modified for Iranian foods. Physical activity was assessed by using the international physical activity questionnaire short form.

2.5. Glycaemic index and glycaemic load

The GL was calculated by multiplying the carbohydrate content of each food item by its value of GI. Each GL value is multiplied by its replication of consumption and then the sum total of the GL values is added to calculation daily GL of each participants. Each unit of dietary GL indicates the equivalent of 1 g carbohydrate from glucose. The dietary GI was calculated by dividing the average of daily GL by the average of daily carbohydrate intake. The dietary GI indicates the GL per unit of carbohydrate and represents the quality of carbohydrate intake. The GI value for each food item was obtained from the international table of GI [14], and from the publication that lists the GI of Iranian foods [15]. The daily GI value was used for the analysis. If GI for foods had not been determined, a value was assigned with the most similar food item.

2.6. Whole grains, refined grains, fiber, and solid carbohydrates

We estimated whole grain consumption according to the consumption of corn, barely, bulgur, lentil, bean, chickpea, viciafaba, split pea, and mung bean and other items defined as whole grains and refined grain consumption defined as consumption of white rice, pasta, white bread and snacks [16]. To obtain dietary fiber intake of participants we used Nutritionist IV software (First Databank) modified for Iranian foods. We classified carbohydrate intake according to its physical form in room temperature so that solid carbohydrate intake included all carbohydrate containing solid foods. Liquid consumption defined as consumption of soft drink, sugar-sweetened beverages, and artificial and natural juices [10].

2.7. Carbohydrate quality index

According to data from the KNHANES survey, CQI included four criteria: GI; total fiber intake (g day^{-1}); ratio of solid carbohydrates to total carbohydrates; and ratio of whole grains to total grains (whole grains, refined grains and their products) [17]. For each of these 4 components, participants were divided into quintiles and received a value (ranging from 1 to 5) according to each quintile (1 to the lowest quartile and 5 to the highest quartile). In the case of GI inverse to other components of CQI, the highest score appropriated to the lowest quartile and vice versa. Finally, all values were added to determine CQI, ranging from 4 to 20 [18].

2.8. Statistical analysis

All analyses were performed using the statistical software package SAS, version 9.3 (SAS Institute, Cary, NC, USA) and SPSS

version 21 (SPSS, Inc.). Differences in general characteristics between case and control groups were compared by using independent-samples Student's *t* test (for continuous variables) and chi-square (for categorical variables). Continuous and categorical data were presented as means ± SD and frequency, respectively. Dependent variables consist of daily GI and GL, ratio of whole grains to total grains, ratio of solid carbohydrates to total carbohydrates, dietary fiber and carbohydrate intake, and CQI were stratified based on median. Values higher and lower than median considered high and low level of these independent variables, respectively. Three models of multivariable logistic regression analyses were used in determining an association of quality and quantity of dietary carbohydrate with PIH. Model 1 was crude model and no confounder entered into the model. In model 2 pre-pregnancy BMI and in model 3 age and education entered into the model, too. These confounders entered into the model because they were significantly different between cases and controls (P value < 0.05, Table 1). Although pre-pregnancy weight was significantly different between cases and controls, it was not considered as confounding factor due to high correlation with pre-pregnancy BMI. Components of quality and quantity of carbohydrate as dependent variables were highly correlated with each other. To overcome the collinearity among dependent variables, highly correlated components of quality and quantity of dietary

carbohydrate were extracted as factors, adopting an exploratory factor analysis. In this analysis, in order to create a simple and discriminating matrix, varimax rotation was applied. The number of factors was determined based on a screen plot test, eigenvalue of more than one (as Kaiser's Criterion) and the interpretability of factors. Results are expressed as the odds ratios (OR) with 95% confidence interval (CI) and a *P* value < 0.05 was considered significant.

3. Results

The general characteristics of the study participants are presented in Table 1. The mean age, weight of starting pregnancy, and pre-pregnancy BMI of healthy pregnant women were significantly lower than women with PIH (*P* value < 0.05). We found that 45.5% of women with PIH and 9.9% of healthy pregnant women were had primary education (*P* value < 0.05). Therefore, we adjusted the analyses for these confounders.

As shown in Table 2, after adjusting for pre-pregnancy BMI, age, and education, in pregnant women in whom the daily carbohydrate intake and GL were higher than median increased frequency of PIH compared to whom had lower than median ones (OR = 3.23, 95% CI 1.46–7.17, and *P* = 0.004; OR = 2.60, 95% CI 1.21–5.56; and *P* = 0.035, respectively). The GI, ratio of whole grains to total grains,

Table 1
Comparing the general characteristics of the subjects.[a]

	Case (n = 101)	Control (n = 101)	*P*-value[b]
Age	30.6 ± 5.8	27.7 ± 5.0	<0.001
Education [*n* (%)]			<0.001
Uneducated or primary school	46 (45.5)	10 (9.9)	
Junior high school	43 (42.6)	60 (59.4)	
Graduate	12 (11.9)	31 (30.7)	
Occupation [*n* (%)]			0.063
Yes	6 (28.6)	15 (71.4)	
No	95 (52.9)	86 (47.5)	
Intake of herbal medicine [*n* (%)]			0.099
Yes	3 (42.9)	4 (57.1)	
No	98 (50.3)	97 (49.7)	
Intake of supplement [*n* (%)]			0.37
Yes	97 (49.2)	100 (50.8)	
No	4 (80.0)	1 (20.0)	
Weight of starting pregnancy	73.6 ± 15.2	66.6 ± 10.3	<0.001
Pre-pregnancy BMI	28.8 ± 6.7	25.2 ± 3.9	<0.001
Number of deliveries [*n* (%)]			0.93
1	33 (55)	27 (45)	
2	30 (41.1)	43 (58.9)	
>3	38 (55.1)	31 (44.9)	
Physical activity [*n* (%)]			0.18
Light	3 (100)	0 (0)	
Moderate	97 (49.2)	100 (50.8)	
Heavy	1 (50)	1 (50)	
Specific diet plan [*n* (%)]			0.99
Yes	4 (57.1)	3 (42.9)	
No	97 (49.7)	98 (50.3)	
Energy intake (kcal/d)	2709 ± 35	2681 ± 35	0.57
Protein (g/d)	80.8 ± 1.5	82.8 ± 1.8	0.44
Fat (g/d)	81.9 ± 1.3	79.1 ± 1.7	0.11
SFA (g/d)	24.7 ± 4.6	24.5 ± 5.6	0.91
PUFA (g/d)	25.6 ± 0.9	35.0 ± 1.8	0.28
MUFA (g/d)	60.8 ± 29.0	73.6 ± 39.4	0.79
Cholesterol (mg/d)	227.2 ± 11.9	227.4 ± 16.2	0.85
Carbohydrates (g/d)	396.1 ± 5.3	380.5 ± 7.1	0.08
CQI	10.2 ± 0.2	10.6 ± 0.2	0.23
Dietary fiber intake (g day-1)	23.4 ± 0.7	25.2 ± 0.5	0.06
Ratio of solid carbohydrates to total carbohydrates	0.97 ± 0.003	0.97 ± 0.002	0.16
GI	62.5 ± 0.6	61.7 ± 0.6	0.34
Ratio of whole grains to total grains	2.0 ± 0.07	2.0 ± 0.08	0.93
GL	215.2 ± 4.5	204.6 ± 4.9	0.11

[a] Values are means ± SDs unless otherwise indicated. [a]CQI, carbohydrate quality index; GI, glycemic index; GL, glycemic load; and PIH, pregnancy induced hypertension.
[b] *P* values were computed by the independent-samples *t* test for continuous variables and by chi-square for categorical variables.

Table 2
The raw and modified odds ratios and its 95% confidence interval for PIH.[a]

	Model 1[b]			Model 2[c]			Model 3[d]		
	OR	95% CI	P-value[e]	OR	95% CI	P-value[e]	OR	95% CI	P-value[e]
CQI	0.96	0.53–1.72	0.88	1.16	0.62–2.18	0.63	1.43	0.65–2.14	0.37
Carbohydrate intake (g day^{-1})	1.81	1.04–3.18	**0.035**	1.89	1.05–3.41	**0.034**	3.23	1.46–7.14	**0.004**
Dietary fiber intake (g day^{-1})	0.60	0.34–1.04	0.07	0.62	0.35–1.12	0.11	0.63	0.30–1.31	0.22
Ratio of solid carbohydrates to total carbohydrates	0.81	0.45–1.43	0.46	0.80	0.43–1.46	0.47	0.91	0.42–1.96	0.81
GI	1.17	0.67–2.03	0.57	1.62	0.65–2.08	0.61	1.06	0.51–2.21	0.88
Ratio of whole grains to total grains	1.14	0.65–2.04	0.57	1.3	0.72–1.33	0.38	1.42	0.67–3.02	0.35
GL	1.68	0.96–2.92	0.07	1.70	0.95–3.06	0.08	2.60	1.21–5.56	**0.015**

[a] CQI, carbohydrate quality index; GI, glycemic index; GL, glycemic load; and PIH, pregnancy induced hypertension.
[b] Crude model.
[c] Adjusted for pre-pregnancy BMI.
[d] Adjusted for pre-pregnancy BMI, age, and education.
[e] Variables stratified into medians and logistic regression was employed to estimate the risk of pregnancy induced hypertension in higher than median values compared to lower than median values.

ratio of solid carbohydrates to total carbohydrates, and CQI did not associate with PIH.

To eliminate collinearity between independent variables, we used factor analysis model and the association between extracted factors and PIH was evaluated. The extracted factors and factor loads of variables were outlined in Table 3. After adjusting for pre-pregnancy BMI, age, and education, we found a significant positive association between factor 2 that is mostly related to carbohydrate intake and frequency of PIH (OR = 3.45; 95% CI 1.47–8.0; and P = 0.004) and a significant inverse association between factor 3 that is mostly related to total fiber intake and frequency of PIH (OR = 0.45; 95% CI 0.20–0.97; and P = 0.049 when higher than median values compared to lower than ones) (Table 4).

4. Discussion

To our knowledge, the present study was the first attempt to examine the association between carbohydrate quantity and quality and PIH in an Iranian population. In this study, we showed positive associations between total carbohydrate intake, factor 2 which highly loaded with carbohydrate intake, and dietary GL and frequency of PIH and inverse association between factor 3 which highly loaded with daily intake of fiber and PIH.

Carbohydrates represent the major macronutrient portion of the diets, and both their quantity and quality has been independently associated with pregnancy outcomes [19]. In this study we used GI, fiber intake, solid carbohydrates, and whole grains as measures of carbohydrate quality. Inconsistent with the study by Kim et al. [7], which suggested that higher carbohydrate quality is related to a lower prevalence of hypertension, we found no significant association between CQI and risk of PIH. This discrepancy might be explained by the difference in the type of disease and sample size.

There is ongoing scientific interest relating to whether the quality of carbohydrates, as measured by GI or GL and intake of sugar-sweetened drinks, whole grains and dietary fiber, might be more important than the quantity of carbohydrates for reducing the risks for hypertension [8,11,20]. In this study, we found positive associations between total carbohydrate intake and risk of PIH, findings is consistent with the result of Kim et al. [7] that demonstrated high carbohydrate intake has been associated with higher risk of obesity and hypertension; however, there are weaknesses in the causal relationship.

The adverse metabolic responses to diets with a high GL or GI are intensified by insulin resistance because increasing demand of insulin is needed to compensate for the increased GI [21]. It has been suggested that the effects of a high glycemic diet could considerably differ in subjects depending on their levels of adiposity as a major determinant of insulin resistance. A meta-analysis of 8 prospective studies indicated harmful effect of high dietary GI and GL on CVD [22]. Ferrannini et al. [23] found that a high dietary GL apparently induces hyperglycemia and hyper-insulinemia can lead, in turn, to hypertension which can increase the risk of CVD.

In the current study, although dietary fiber intake and whole grain were not associated with PIH, but Factor 3 which was highly loaded with dietary fiber was inversely associated with PIH. Regarding high load of fiber in this factor compared to other components we could assume that when high intake of fiber accompanied with high CQI, ratio of whole grains to total grains, and GL, could reduce frequency of PIH. It has been suggested a potential role for increasing dietary fiber intake in prevention of hypertension and its cardiovascular complications [24]. According to the American Society for Nutrition, consumption of foods rich in cereal fiber is associated with a reduced risk of CVD [25]. Previous

Table 3
Rotated factor loadings of the major factors from highly correlated components of quality and quantity of dietary carbohydrate were extracted adopting an exploratory factor analysis.[a]

	Loadings[b]						
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
CQI	**0.97**		0.11		−0.13	0.19	
Carbohydrate intake (g day^{-1})		**0.99**					0.12
Crude fiber intake (g day^{-1})	0.11		**0.97**				0.13
Ratio of solid carbohydrates to total carbohydrates				**0.99**			
GI	−0.14				**0.95**	−0.14	0.20
Ratio of whole grains to total grains	0.20		0.10		−0.14	**0.95**	
GL		0.13	0.14		0.20		**0.95**

[a] Factor loadings <0.1 are excluded for simplicity. CQI, carbohydrate quality index; GI, glycemic index; and GL, glycemic load.
[b] Factor 1 is mostly related to CQI, Factor 2 to carbohydrate intake, Factor 3 to crude fiber intake, Factor 4 to ratio of solid carbohydrates to total carbohydrates, Factor 5 to dietary glycaemic index, Factor 6 to ratio of whole grains to total grains, and Factor 7 to dietary glycaemic load.

Table 4
The raw and modified odds ratios and its 95% confidence interval for PIH in seven factors of highly correlated components of quality and quantity of consumed carbohydrate extracted using factor analysis.[a]

	Model 1[b]			Model 2[c]			Model 3[d]		
	OR	95% CI	P-value[e]	OR	95% CI	P-value[e]	OR	95% CI	P-value[e]
Factor 1	0.76	0.42–1.35	0.34	0.82	0.45–1.52	0.54	0.63	0.28–0.43	0.27
Factor 2	2.14	1.17–3.19	0.013	2.21	1.18–4.16	0.014	3.45	1.47–8.0	0.004
Factor 3	0.45	0.25–0.80	0.007	0.46	0.25–0.85	0.014	0.45	0.20–0.97	0.049
Factor 4	0.77	0.44–1.38	0.38	0.56	0.30–1.06	0.08	0.70	0.31–1.57	0.40
Factor 5	0.82	0.46–1.46	0.50	0.81	0.44–1.50	0.51	0.64	0.29–1.41	0.27
Factor 6	1.51	0.66–3.44	0.33	1.39	0.45–4.29	0.56	1.19	0.55–2.58	0.66
Factor 7	1.27	0.70–1.31	0.43	1.23	0.65–2.30	0.52	1.48	0.66–3.31	0.34

[a] Factor 1 is mostly related to carbohydrate quality index, Factor 2 to carbohydrate intake, Factor 3 to crude fiber intake, Factor 4 to ratio of solid carbohydrates to total carbohydrates, Factor 5 to dietary glycaemic index, Factor 6 to ratio of whole grains to total grains, and Factor 7 to dietary glycaemic load.
[b] Crude model.
[c] Adjusted for pre-pregnancy BMI.
[d] Adjusted for pre-pregnancy BMI, age, and education.
[e] Variables stratified into medians and logistic regression was employed to estimate the frequency of pregnancy induced hypertension in higher than median values compared to lower than median values.

studies found an inverse association of dietary fiber with CVD mortality risk [26], which is in line with two prospective studies have examined the relationship between dietary fiber intake and the risk of hypertension [27,28]. Two meta-analysis studies showed that increasing fiber consumption in the general population may contribute to the prevention of hypertension [29,30]. Several mechanisms have been suggested that dietary fiber can reduce the risk of hypertension. The potential mechanisms that could explain the relation to the dietary fiber consumption and prevention to high blood pressure are their effect on satiety which may lead to lower insulin responses. Besides, dietary fiber is accompanied by more micronutrients and phytochemicals and which could be associated with improving endothelial function and insulin sensitivity [31,32].

One of the limitations of the present study is its case–control design, in which cause and effect relationship is not determined. We tried to match cases and controls regarding to inclusion and exclusion criteria. So these two groups were comparable in the most of baseline characteristics. In some characteristics which cases and controls were significantly different, we used three statistical models to control their effects. To obtain dietary fiber intake of participants we used Nutritionist IV software (First Databank) modified for Iranian foods. Our software program is probably as in precise as all other similar instruments. In addition, the multivariate analysis favors errors of type 1. The most important advantage of the present study is that we estimated the levels of dietary intake (e.g. solid or liquid carbohydrates, whole or refined grains, and total fiber intake) based on a semi-quantitative FFQ modified for Iranian foods, which might have been representative of a subject's typical intake. In addition, the calculation of GL is probably of sufficient validity in the light of the numerous other confounders in this kind of investigations of intake of food.

5. Conclusion

In conclusion, these findings suggest that carbohydrate intake and dietary GL is related to higher and daily fiber intake to lower prevalence of PIH. Further investigations into the mechanisms underlying the role of carbohydrate quantity and quality in the development of hypertension are warranted.

Transparency Declaration

The lead author affirms that this manuscript is an honest, accurate, and transparent account of the study being reported. The lead author affirms that no important aspects of the study have

been omitted and that any discrepancies from the study as planned have been explained.

Conflict of interests, source of funding and authorship

Acknowledgements

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnesp.2019.06.001.

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