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Original Article (Pages: 4489-4501)

Association of Dietary Patterns during Pregnancy and Cord Blood Nitric Oxide Level with Birth Weight of Newborns

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Abstract

Background: Maternal nutrition during pregnancy affects the birth weight of neonates. Some of the undesirable pregnancy outcomes are linked to lower birth weights. This study aimed to assess the relationship between maternal dietary patterns, weight gain during pregnancy and nitric oxide (NO), as an endothelial relaxing factor, and the possible effects on birth weight.

Materials and Methods: At first, a pilot study was done, and finally a number of 233 mothers who referred to 4 public and private hospitals in Isfahan, the Central of Iran, during March 2014 to March 2015 via a convenience sampling method, were elected and participant in this study. Dietary patterns were assessed using a Persian version of Food Frequency Questionnaire (FFQ). Gestational weight gain was measured, too. Cord blood nitric oxide (NO) level, and neonate's anthropometric characteristics were measured after delivery.

Results: The study participants consisted of 233 mother-neonate pairs. Overall, 4.3% of boys and 11.8% of girls, had low birth weight (< 2.500 gr). Mean gestational weight gain was 12.85 ± 4.37 kg, and there was a statistically significant between three birth-weight categories (Low birth weight, normal birth weight and high birth weight) ($P<0.05$). Gestational weight gain during pregnancy was associated with consumption of chicken, cereals, sugar, and birth weight of neonates, too ($P<0.05$). Nitric oxide had an inverse correlation with birth weight; however, this association was not statistically significant ($r = -0.10$, $P >0.05$).

Conclusion: Dietary patterns during pregnancy play as a main role in being low birth-weight neonates, in part by having impacts on gestational weight gain. In our samples among some Iranian mother-neonate pairs, endothelial function does not show a direct association with birth weight through releasing NO.

Key Words: Birth weight, Infants, Nitric oxide, Pregnancy, Weight gain.

*Please cite this article as: Naghavi S, Baradaran Mahdavi S, Moradi B, Tajadini MH, Kelishadi R. Association of Dietary Patterns during Pregnancy and Cord Blood Nitric Oxide Level with Birth Weight of Newborns. Int J Pediatr 2017; 5(3): 4489-4501. DOI: **10.22038/ijp.2017.21112.1772**

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Received date Dec.23, 2016; Accepted date: Jan. 22, 2017

1- INTRODUCTION

The effects of fetal growth and length of pregnancy on birth weight have long been demonstrated (1). The period of fetal development has been contributed to many adulthood diseases (2). The association between low birth weight and increased risks for coronary artery diseases, hypertension and diabetes have been shown (3). Small for gestational age (SGA), is contributed with higher risk of morbidity and mortality during pregnancy (4). Up to 10% of all neonates are SGA (5). Inadequate fetal-placental oxygen supply is a main cause of decreasing pregnancy associated rise in uterine artery blood flow and diameter at high altitude, results in higher risk for an SGA infant being born (1, 6). In addition, decreased venous blood level of nitric oxide metabolites (NOx), and increased endothelin/NOx ratio is associated with lower birth weight during pregnancy and in post-partum condition (7). Previous researches highlighted that preeclampsia as a condition in which placental blood flow is decreased, have an impressive effect on gestational growth (8). On the contrary, other researchers showed that serum nitrate concentration is significantly higher in pregnancies complicated with preeclampsia than in normal pregnancies or non-pregnant women (9).

The role of some prenatal factors in decreasing fetal growth has been investigated. Mothers who smoke cigarette, deliver low birth-weight infants more than non-smokers (10). Impaired vasodilation because of reduced NO production, is mentioned to result in decreasing fetal blood flow in smokers compared to non-smokers (11). Moreover, pre-pregnancy body weight and height and pregnancy weight gain showed effects on birth weight babies (12), so that higher prenatal care in combination with a higher educational level among mothers, led to reduction in low birth-weight risk (13). Additionally, pre-pregnancy nutritional status of mothers as well as usage of alcohol or drugs, influences on SGA children (5). The effect of maternal nutrition during pregnancy on fetal growth and development is well documented (14). Maternal under nutrition due to food supply restrictions or, etc. affects placental growth and its adaptation to surrounded environment (15). Maternal nutrition during pregnancy not only affects fetal and vascular bed development, but also affects colostrum quantity and post-natal productivity as well as, the role of angiogenic factors such as NO, in embryonic development are discussed (16). While a growing body of evidence has focused upon the impact of deprivation of special nutrients on fetal growth (17), or the effect of maternal diet on developing adverse pregnancy outcomes (18); the research about the relationship of maternal dietary patterns according to food guide pyramid with birth weight is limited worldwide. This study aimed to assess such a relationship between maternal dietary patterns, weight gain during pregnancy and NO, as an endothelial relaxing factor, with the birth weight of neonates in a sample of Iranian population.

2- MATERIALS AND METHODS

2-1. Study design and study population

The current cohort was conducted from March 2014 to March 2015 in 4 public and private hospitals (Al-Zahra, Shahid Beheshti, Amin, and Sina) of Isfahan city, Central of Iran, along with our recently published cohort on air pollution and placental dysfunction bio markers (19). Participants were selected by convenience sampling technique, a non-probability sampling method considering the accessibility of researchers to the patients. The inclusion criteria for mothers consisted of followings: Iranian ethnicity, term delivery and singleton pregnancy. Exclusion criteria were stillbirths or neonates that needed resuscitation at birth and any known abnormality immediately at birth. In order to achieve the main sample size, at first, we conducted a pilot study with a number of 20 patients. We obtained 0.14 as the variance (s^2) of this small study with 95% of the confidence interval (CI). Then we utilized the following formula considering α = 0.05 as type one error, d = 0.05 as effect size and z = 1.96 as the constant. The number of sample population was measured about 215 according to this statistical approach. We focused on 250 as final sample size due to possible losses of patients.

$$n = \frac{z^2_{\frac{\alpha}{2}} \times s^2}{d^2} = 215$$

Demographic and medical information as well as self-reported weight before pregnancy was recorded, and total weight gain during pregnancy was calculated like our previous article (19). Working status of mothers (housewife or employed), history of smoking, alcohol usage, pre pregnancy chronic diseases such as diabetes and hypertension or any past medication history was considered as well. The anthropometric indices of newborns were measured after delivery by trained nurses, including weight, length, thigh length as well as circumferences of head, abdomen, chest and thigh. Newborn's weight was categorized into three groups. Those with birth weight of less than 2.500 grams (gr) were considered as small for gestational age (SGA), those between 2.500 to 4.000 gr as appropriate for gestational age (AGA), and those with birth weight of more than 4.000 gr as large for gestational age (LGA) (20).

2-2. Dietary assessment

A modified Persian version of Food Frequency Questionnaire (FFQ), containing 160 items, was used to assess the dietary patterns of pregnant women. The Persian version was previously validated (21), and used in Iran (22). We recorded the participants' responses as how many times per week, they used a specific nutrient in last three months. Then the whole items within the food questionnaire were assigned in to 18 main categories for doing analyses.

2-3. Laboratory measurements

Immediately after cutting the umbilical cord by double clumping method, 5 mL of maternal cord blood was depleted via 5 mL sterile syringes for the study purposes by the same nurses. Serum was isolated from the obtained cord blood by centrifuge at 2,800 rpm for 15 minutes. NO, as a marker of endothelial activation, was assessed via enzyme-linked immune-sorbent assay method (Abcam, Cambridge, MA. USA), according to the manufacturer protocols.

2-4. Statistical analysis

Ceramer's V and Gamma tests were run to determine the association between categorical variables; t-test was performed to compare the difference between mean values in boy and girl neonates. Information on birth weight was recorded using categorizing into low birth weight (LBW) (< 2.500 gr), normal birth weight (NBW) (2.500 - 4.000 gr), and high birth weight (HBW) (> 4.000 gr). Ponderal index (PI), was defined as 100 × (birth-weight [gr]/height [cm] ^{3}). A lower ponderal index indicates a longer, thinner infant, while a higher ponderal index indicates a shorter and/or fatter infant.

Birth weight as the outcome variable, weight gain during pregnancy as a prenatal (independent) factor, and nitric oxide levels as a response (explanatory) variables, were analyzed in linear regression models. Two types of regression tests were done. First, simple linear regression tests correlated NO and weight gain during pregnancy with birth weight using ENTER method. In this method, we actually determined the possible correlation of mentioned variables with birth weight as well as strength of the association. Then the same variables were retained to second models using STEPWISE method of multiple linear regression tests adjusted for gender, maternal age, maternal occupation, paternal occupation, maternal weight before pregnancy and birth rank. Indeed confounding variables were retained to the analyses, and significant independent variables were identified. The parameters in each linear regression model were estimated, and 95% confidence intervals (CIs), were computed. All the statistical tests were two-sided, and the significant level was set as 0.05. Analyses were performed in the IBM SPSS version 18.0 (SPSS, Inc., Chicago, IL) for windows.

2-5. Ethics statement

Current study was conducted according to the Research and Ethics Committee of Isfahan University of Medical Sciences approval (ID number: 188059). Sufficient information on the study goals and methodology was given to volunteers, and then a written consent was obtained from all the participants before involvement throughout the project. Mothers could leave the study whenever they wanted.

3- RESULTS

Two hundred and thirty-three newborns were recruited to this study (51.3% boys). **Table.1** shows the distribution of some characteristics of newborns according to birth-weight categories and gender. Most of the mothers were housekeeper (91.7%). Results showed that 60.4% of ponderal index values were less than 2.60, which indicated a longer, thinner infant. Almost half of the mothers, experienced their first delivery (50.7%), and 35.5% of them had their second delivery. Mean value of maternal age was 27.68 ± 5.37 years. Mean values of maternal age among three birth-weight categories, were statistically different ($P = 0.03$). The mean value of maternal weight before pregnancy was 62.43 ± 12.60 kg and there was no significant differences among three birth-weight categories of this variable ($P = 0.191$). Total mean maternal weight gain during pregnancy was 12.85 ± 4.37 kg, and mean maternal weight gains during pregnancy were statistically significant between three birth-weight categories (10.51 ± 2.51 kg, 12.98 ± 4.41 kg and 15.88 ± 5.05 kg among LBW, NBW and HBW infants, respectively) ($P = 0.018$); while there was no differences between maternal weight gain during pregnancy by newborn's gender ($P > 0.05$).

The cord blood NO ranged from 136.82 to 236.02 mg/mL with a mean of 181.83 ± 24.08 mg/mL in boys; while the same factor ranged from 115.05 to 239.66 mg/mL with a mean of 117.62 ± 24.31 mg/mL in girls and these two means were not statistically different ($P = 0.192$). Results showed that 32.2% of mothers reported using seafood rarely or never; 85% reported not to use processed foods frequently. **Table.2** shows the details of maternal food intake (consumption frequencies per week). The first decile of birth weight was measured as 2.56 kg. The links between neonate's gender, birth rank, maternal age, maternal and paternal occupation and birth weight, were assessed considering low birth-weight values as less than 2.56. Only the neonate's gender was distributed significantly different between LBW neonates (73.9% LBW in girls versus 26.1% in boys, $P = 0.015$, Fisher's exact test). The prevalence of drinking Doogh (diluted yoghurt), for two times and less per week, was 78.3% among the mothers whose newborns were LBW, while the same value was 56.3% in mothers with normal-weight newborns (Fisher's exact test, $P = 0.029$ and odds ratio [OR] = 2.79). In addition, the prevalence of using sugar in the mothers of

LBW and normal-weight newborns for two times and less, was 91.3% and 75.2%, respectively (Fisher's exact test, P=0.025 and OR=3.46). No other significances were found in terms of major food groups and birth weight (**Table.3**).

Furthermore, the results showed that the mean weight gain during pregnancy was 10.47 ± 3.91 kg among mothers who used chicken for one time and less per week, while the same value was 13.12 ± 4.34 kg in mothers who used chicken more than twice a week (P = 0.013, Mann-Whitney test). About the cereals and sugar, the mean weight gains were statistically more in mothers who consumed each one more than three times a week compared than those with two times and less a week (13.37 ± 4.36 and 11.62 ± 4.06 with P = 0.002 for cereals, 14.29 ± 4.44 and 12.47 ± 4.26 with P = 0.011 for sugar, Mann-Whitney test). Regarding the relationship of food groups and NO, the only significant finding was the lower mean value of cord blood NO in mothers who used chicken for one time and less per week compared than those with more than twice a week (164.32 ± 21.82 and 180.86 ± 24.39 mg/dl with P = 0.005, Mann-Whitney test). The regression models showed that cord blood NO was not correlated with birth weight as a dependent variable (P > 0.05 and r = -0.10); while the maternal weight gain during pregnancy showed a significant relationship to the same variable (P < 0.05 and r = 0.24) (**Table-4**).

Table-1: Distribution of the study population according to birth weight categories

Variables		Birth weight category			Total	P-value*
		LBW	NBW	HBW		
Gender	Boy	5 (27.8)[a]	107 (53.0)	3 (60.0)	116 (51.3)	0.113
	Girl	13 (72.2)	95 (47.0)	2 (40.0)	110 (48.7)	
Maternal occupation	Housekeeper	16 (88.9)	191 (92.7)	3 (60.0)	221 (91.7)	**0.029**
	Others	2 (11.1)	15 (7.3)	2 (40.0)	19 (8.3)	
Paternal occupation	Laborer	3 (16.7)	45 (22.1)	0 (0.0)	49 (21.5)	**0.003**
	Employee	1 (5.8)	25 (12.3)	2 (40.0)	28 (12.3)	
	Doctor	0 (0.0)	2 (1.0)	0 (0.0)	2 (0.9)	
	Engineer	1 (0.0)	5 (2.5)	1 (20.0)	6 (2.6)	
	Self-employed	9 (50.0)	115 (56.8)	2 (40.0)	126 (55.3)	
	Unemployed	3 (16.7)	7 (3.4)	0 (0.0)	10 (4.4)	
	Retired	2 (11.1)	1 (0.5)	0 (0.0)	3 (1.3)	
	Others	0 (0.0)	4 (2.0)	0 (0.0)	4 (1.7)	
Ponderal Index $100\times(g/cm^3)$$	< 2.60	13 (81.2)	124 (60.2)	0 (0.0)	137 (60.4)	**0.008**
	(2.60, 2.80)	1 (6.3)	52 (25.2)	2 (40.0)	55 (24.2)	
	> 2.80	2 (12.5)	30 (14.6)	3 (60.0)	35 (15.4)	
Birth rank	1st	8 (44.4)	101 (52.1)	1 (20.0)	110 (50.7)	0.783
	2nd	8 (44.4)	66 (34.0)	3 (60.0)	77 (35.5)	

	> 3rd	2 (11.1)	27 (13.9)	5 (20.0)	30 (13.8)	
Maternal age (year)	Total	29.61±6.22[b]	27.39±5.24	32.20(4.44)	27.68±5.37	**0.035**
	Boy	28.80±7.98	27.13±7.97	33.67(5.51)	27.38±5.19	0.452
	Girl	29.92±5.77	27.68±5.55	30.00(1.41)	27.99±5.55	
Maternal weight before pregnancy (kg)	Total	57.84±12.41	62.71±12.66	67.49±7.63	62.43±12.60	0.191
	Boy	57.62±8.63	62.56±11.99	65.14±3.85	62.41±11.73	0.968
	Girl	57.93±13.91	62.88±13.42	71.00±12.73	62.44±13.49	
Maternal weight gain during pregnancy (kg)	Total	10.51±2.51	12.98±4.41	15.88±5.05	12.85±4.37	**0.018**
	Boy	9.81±2.94	13.37±4.08	12.46±2.50	13.19±4.06	0.246
	Girl	10.77±2.40	12.55±4.73	21.00±1.41	12.49±4.65	
Newborn's height (cm)	Total	47.05±2.35	50.19±2.18	52.47±1.69	50.02±2.35	**<0.001**
	Boy	47.28±2.55	50.33±2.21	52.28±2.22	50.24±2.32	0.130
	Girl	46.38±1.70	50.04±2.14	52.75±1.06	49.78±2.36	
Newborn's head circumference (cm)	Total	32.47±1.47	34.86±1.39	36.77±2.22	34.71±1.58	**<0.001**
	Boy	32.24±1.77	35.15±1.36	37.79±2.44	35.09±1.58	**<0.001**
	Girl	32.56±1.41	34.54±1.35	35.25±0.35	35.25±0.35	
Newborn's chest circumference (cm)	Total	30.79±2.33	32.88±1.98	35.32±1.05	32.76±2.10	**<0.001**
	Boy	30.39±1.97	32.92±1.98	35.20±1.39	32.87±2.05	0.508
	Girl	30.94±2.51	32.83±1.99	35.50±0.71	32.66±2.16	
Newborn's belly circumference (cm)	Total	28.99±3.12	31.24±2.32	33.33±4.68	31.12±2.49	**0.001**
	Boy	29.59±2.34	31.34±2.43	36.75±1.13	31.36±2.53	0.178
	Girl	28.66±3.57	31.12±2.18	29.25±2.84	30.86±2.43	
Newborn's thigh circumference (cm)	Total	12.07±1.29	14.02±1.79	15.49±1.49	13.90±1.83	**<0.001**
	Boy	12.32±1.43	13.82±1.65	14.91	13.76±1.66	0.242
	Girl	11.96±1.28	14.26±1.91	15.78±1.98	14.05±1.98	
Newborn's thigh length (cm)	Total	10.63±1.37	10.93±1.59	09.52±1.59	10.87±1.59	0.112
	Boy	09.84±0.79	10.76±1.50	09.38±2.24	10.69±1.51	0.070
	Girl	10.92±1.45	11.12±1.68	09.73±0.86	11.07±1.63	

a Numbers in parentheses, percentage.
b mean value± standard deviation.
$ 100 × [birth-weight (g)/height (cm) ^{3}].
* Significant p-values are presented as bolded numbers (significant at level of 0.05).
LBW: low birth weight, NBW: normal birth weight, HBW: high birth weight.

Table-2. Maternal dietary intake during pregnancy (frequency per week).

Variables	Rarely or never		1 to 2 times per week		3 to 4 times per week		More than 4 times per week	
	number	%	number	%	number	%	number	%
Milk	27	11.6	160	68.7	39	16.7	7	3
Cheese	15	6.4	178	76.4	36	15.5	4	1.7
Doogh*	47	20.2	91	39.1	81	34.8	14	6
Yogurt	13	5.6	161	69.1	49	21	10	4.3
Whey	152	65.2	58	24.9	14	6	9	3.9
Egg	37	15.9	104	44.6	78	33.5	14	6
Meat	17	7.3	177	76	39	16.7	0	0
Chicken	21	9	201	86.3	11	4.7	0	0
Seafood	75	32.2	155	66.5	2	0.9	1	0.4
Cereals	1	0.4	57	24.5	173	74.2	2	0.9
Beans	15	6.4	138	59.2	72	30.9	8	3.4
Vegetables	3	1.3	128	54.9	99	42.5	3	1.3
Oil	3	1.3	213	91.4	17	7.3	0	0
Sugar	7	3	173	74.2	53	22.7	0	0
Ice cream	119	51.1	97	41.6	13	5.6	4	1.7
Nuts	33	14.2	172	73.8	27	11.6	1	0.4
Processed food	198	85	33	14.2	2	0.9	0	0
Fruit	13	5.6	29	12.4	132	56.7	59	25.3

*Doogh: A drink which is made by yogurt, water and other additives.

Table-3: The relationship of maternal dietary intake and neonatal low birth weight

Variable	Total consumption (time per week)	Low birth weight				P-value **	Odds ratio	95% confidence interval	
		Yes		No					
		n	%	N	%			Lower limit	Upper limit
Milk	≤ 2	21	91.3	164	76.6	0.193	2.69	0.61	11.93
	≥ 3	2	8.7	42	20.4				
Cheese	≤ 2	17	73.9	172	83.5	0.256	1.79	0.66	4.86
	≥ 3	6	26.1	34	16.5				
Doogh*	≤ 2	18	78.3	116	56.3	**0.029**	2.79	1.00	7.81
	≥ 3	5	21.7	90	43.7				
Yogurt	≤ 2	16	69.6	154	74.3	0.59	1.30	0.51	3.32
	≥ 3	7	30.4	52	25.2				
Whey	≤ 1	15	65.2	133	64.6	0.95	1.03	0.42	2.54

	≥ 2	8	34.8	73	35.4				
Egg	≤ 2	11	47.8	126	61.2	0.22	1.72	0.72	4.08
	≥ 3	12	52.2	80	38.8				
Meat	≤ 2	19	82.6	171	83	0.96	1.03	0.33	3.21
	≥ 3	4	17.4	35	17				
Chicken	≤ 1	2	8.7	18	8.7	0.99	1.01	0.22	4.64
	≥ 2	21	91.3	188	91.3				
Seafood	≤ 1	8	34.8	64	31.1	0.71	1.18	0.48	2.93
	≥ 2	15	65.2	142	68.9				
Cereals	≤ 2	9	39.1	47	22.8	0.09	2.18	0.89	5.34
	≥ 3	14	60.9	159	77.2				
Beans	≤ 2	13	56.5	136	66	0.36	1.50	0.62	3.58
	≥ 3	10	43.5	70	34				
Vegetables	≤ 2	11	47.8	117	56.8	0.41	1.43	0.61	3.40
	≥ 3	12	52.2	89	43.2				
Oil	≤ 2	21	91.3	191	92.7	0.80	1.21	0.30	5.67
	≥ 3	2	8.7	15	7.3				
Sugar	≤ 2	21	91.3	155	75.2	**0.02**	3.46	0.78	15.25
	≥ 3	2	8.7	51	24.8				
Ice cream	≤ 1	11	47.8	104	50.5	0.80	1.11	0.47	2.64
	≥ 2	12	52.2	102	49.5				
Nuts	≤ 1	2	8.7	30	14.6	0.44	1.79	0.40	8.03
	≥ 2	21	91.3	176	85.4				
Processed food	≤ 1	20	87	174	84.5	0.75	1.23	0.34	4.37
	≥ 2	3	13	32	15.5				
Fruit	≤ 3	17	73.9	153	74.3	0.97	1.02	0.38	2.72
	≥ 4	6	26.1	53	25.7				

*Doogh: A drink which is made by yogurt, water and other additives.
** Significant p-values are bolded for emphasis.

Table-4: The relationship of NO and weight gain during pregnancy with birth weight

Variables	Linear regression		Adjusted Linear regression [a]	
	B [b]	P-value [c]	B [b]	P-value [c]
Cord blood NO	-0.06	0.386	-0.10	0.147
Weight gain during pregnancy	0.17	0.016	0.24	0.001

[a] Adjusted for maternal age, maternal weight before pregnancy, maternal and paternal occupation, newborn's gender and birth rank.
[b] Regression coefficient.
[c] Significant p-values are bolded for emphasis.

4- DISCUSSION

In the current survey, we investigate the contribution of maternal dietary patterns in neonatal birth weight in terms of the effect of maternal weight gain during pregnancy as well as the endothelial response of placenta by releasing nitric oxide as a vasodilator factor, was considered.

Regards to routine dietary recommendations given to pregnant women according to standard food guide pyramid at outpatient visits or antenatal care sessions, we categorized foods as 18 main groups and investigated the relationships by measuring the consumption frequency of food items in one week, unlike previous similar researches done in this field (23, 24). Some prenatal factors such as birth rank, maternal age, maternal and paternal occupation did not associate with child birth weight in our study, while most of the LBW notates were among girls. It is shown that socio-demographic and lifestyle factors were associated with pregnancy diet, for instance, consumption of salad, fruit, cereals, fish, eggs, white meat and non-white bread were related to higher education and age and non-white women (25). Hence it seems that these factors have an impact on pregnancy outcomes in part by modifying maternal dietary patterns during pregnancy.

Nowadays, the link between eating a nutritious diet during pregnancy and the children's general health, even until adulthood is well-known (3). Whereas a growing body of evidence has assessed maternal nutrition during pregnancy, and its relationship to the pregnancy outcomes worldwide (26, 27). In Iran, there are limited researches (22, 23, 28) investigating dietary related fetal growth and specially birth weight as the main goal. In our study calculation of odds ratio in the two groups regarding consumption frequency of Doogh (a kind of drink which is made by water and yogurt), showed that the mothers who drank Doogh twice (or less) a week, had LBW neonates 2.79 times higher than those who drank it for more than three times per week. The similar result was found considering consumption of sugar with an odds ratio as 3.46 showing the association of low-carbohydrate diet with LBW children being born. It is shown that eating high glycemic carbohydrate results in feto-placental overgrowth and excessive maternal weight gain as well (29). So, there is evidence in which high-carbohydrate intake has been proposed to suppress placental growth in early pregnancy (30). Since the high consumption of fat and sugar is connected with the higher risk of developing gestational diabetes mellitus (31), timely advices should be given to pregnant women, in order to prevent future health problems in children. More in the literature, higher risk for having SGA neonates has been related to consumption of red and processed meat and high-fat diary compared with a diet based on vegetables, fruits and fish (28). Pregnant women require more energy and protein intake to ensure the fetal growth and development sufficiently. Nevertheless, according to the guidelines which are provided by the Institute of Medicine's (IOM), and emphasized by American College of Obstetricians and Gynecologists, to avoid adverse pregnancy outcomes, including LBW, gestational weight gain should be maintained within the recommended ranges (32). Moreover, higher gestational weight gain has been linked with increased risk for having LGA neonates (33).

In our study consumption of white meat (chicken), cereals and sugars were associated with higher gestational weight gain. For mothers who consumed chicken more than twice a week, gestational weight gain was 25.31% more than those who consumed chicken one or less. For mothers who consumed cereals and sugar more than three times per week, gestational weight gains were 13.09% and 12.74% more than mothers with two times or less respectively. These are rich foods regard to carbohydrate and protein and are served as energy supplies for fetal growth. Similar to our work, the association of low protein intake during pregnancy with thinner infants has been mentioned (34); whilst some research has reported opposite results (35). Besides, gestational weight gain has been strongly linked to birth weight (36). Our findings obtained from adjusted regression models are consistent with previous researches. It should be noticed that excessive weight gain during pregnancy increases the risk of macrosomia and hyperglycemia (37). We considered the association of cord blood NO with birth weight as well. NO is an endothelial derived vasodilator and thus, has an important role in regulating the transfer of nutrients and oxygen for the fetus (38). However, endothelium in pregnancy is not well understood (39). A reduction in arterial blood pressure maybe due to decrease in vascular resistance is seen concurrent with other physiological changes in normal pregnancy (40). It seems that pathological conditions during pregnancy such as preeclampsia and diabetes, may be attributed to alternations in endothelial activation. A recent study investigated these changes in healthy pregnancy and in endothelial damage conditions via a complete assessment of endothelial bio markers. Among these biomarkers, matrix metalloproteinases (MMPs), endothelin, Von Willebrand factor and soluble thrombomodulin (sTM), have been introduced responsible for endothelial dysfunction, which occurs in thrombotic states (41). Intrauterine growth retardation is also linked to impairing NO synthesis (42). We found inverse association between NO and birth weight; however, this was not statistically significant, although our sample size was larger than mentioned study. Moreover, we found that maternal weight gain during pregnancy had a significant relationship with NO; this finding underscores the adverse effects of maternal malnutrition, which might have effects on endothelial function from early life.

4-1. Strengths and limitations

It has been shown that pre-pregnancy Body mass index (BMI), besides to gestational weight gain can be related independently to the higher risks for gestational diabetes and gestational hypertension (43). We did not retain this variable to our analyses. In addition, we did not adjust the results regarding the history of pre-pregnancy diabetes and hypertension, although the participants were not known cases of gestational diabetes or gestational hypertension. However, this study is the first of its kind in which cord blood NO was measured and maternal dietary intake was categorized into 18 main groups and analyzed qualitatively.

5- CONCLUSION

In brief, we conclude that maternal consumption of carbohydrates (sugar), and dairy (Doogh), are linked to higher birth weight in neonates. Consumption of white meat (chicken), cereals and sugar are associated with higher gestational weight gain, and consumption of white meat (chicken), is correlated to higher level of cord blood NO. Weight gain during pregnancy is significantly correlated to higher neonatal birth weight, while there was no significant relationship between cord blood NO and birth weight.

Moreover, we found that although different food groups are consumed by Iranian pregnant women, correction of food habits considering higher intake of seafood, white meat and dairy and less intake of processed foods, should be suggested to this population to reach appropriate recommended gestational weight gain, and thus prevent the birth of babies with low birth weight. Further, investigations are warranted in this field.

6- ABBREVIATIONS

LBW: Low birth weight; NBW: Normal birth weight; HBW: High birth weight;

LGA: Large for gestational age; AGA: Appropriate for gestational age; SGA: Small for gestational age; PI: Ponderal index; BMI: Body mass index; NO: Nitric oxide; FFQ: Food frequency questionnaire.

7- CONTRIBUTIONS

Dr. Saba Naghavi – Study concept and data collection.

Dr. Sadegh Baradaran Mahdavi –literature review and preparing the manuscript (corresponding author).

Mrs. Bita Moradi – Acquisition of data and data analysis.

Mr. Mohammad Hasan Tajadini– Study design and data collection.

Dr. Roya Kelishadi – Study concept and revision of the manuscript (corresponding author).

8- CONFLICT OF INTEREST

None to declare.

9- ACKNOWLEDGMENTS

This study was funded by Isfahan University of Medical Sciences, Isfahan, Iran (ID number: 188059). We want to thank all the participants of this research.

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