Relationship between dietary inflammatory index, hs-CRP level in the second trimester and neonatal birth weight: a cohort study

Yuying Yang,1,† Hongyan Kan,1,2,† Xiaoling Yu,3,† Yuanyuan Yang,3 Li Li3 and Mei Zhao1,*

1School of Nursing, Anhui Medical University, Hefei 230032, China
2The Second Affiliated Hospital of Anhui Medical University, Hefei 230601, China
3The First Affiliated Hospital of Anhui Medical University, Hefei 230032, China

(Received 22 October, 2019; Accepted 4 December, 2019)

The aim of this study was to investigate whether diet plays a role in the effect of inflammation on birth weight. The normal pre-pregnancy body mass index and healthy single pregnant women without classical inflammatory were recruited at 16–20 weeks of pregnancy and provided blood sample to measure plasma high sensitive C-reactive protein (hs-CRP) level. The Dietary Inflammatory Index (DII) score was calculated by a three-day 24 h recall method, and a cohort of 307 eligible pregnant women was established. According to birth weight, the subjects were divided into three groups: normal birth weight (NBW) group, low birth weight (LBW) group, and high birth weight (HBW) group. The hs-CRP level and DII score were significantly different between NBW and LBW groups. The risk of higher hs-CRP in the pro-inflammatory dietary group was 1.89 times than the control group (95% CI: 1.05, 3.42). The risk of LBW with higher hs-CRP was 3.81 times than normal hs-CRP (95% CI: 1.26, 11.56). The risk of LBW in the pro-inflammatory dietary group was 10.44 times than in the anti-inflammatory dietary group (95% CI: 1.29, 84.61). The pro-inflammatory dietary in the second trimester affects the hs-CRP level, showing a positive correlation. And both of two factors increase the risk of LBW.

Key Words: cohort study, pregnancy, dietary inflammatory index, high sensitive C-reactive protein, birth weight

M
dernal nutrition during pregnancy had an important impact on the health of offspring.1 The inappropriate maternal nutritional increased the birth probability of high birth weight (HBW, birth weight greater than 4,000 g) or low birth weight (LBW, birth weight less than 2,500 g).2,3 HBW was closely related to childhood and adolescent obesity, which eventually leaded to the development of metabolic diseases in adulthood.4,5 LBW may be a risk factor of chronic diseases, such as type 2 diabetes, osteoporosis, coronary heart disease, hypertension, and kidney disease in adulthood.6 Low-grade inflammation during pregnancy was associated with premature birth, pre-eclampsia, gestational diabetes and LBW.7,8 Low-grade inflammation was characterized by a 2–4 fold increase in serum inflammatory markers such as high sensitivity C-reactive protein (hs-CRP), interleukin-6 (IL-6), tumor necrosis factor-α (TNF-α), and plasminogen activator inhibitor-1 (PAI-1), without classical symptoms of redness, swelling, heat, and pain.8,9 Animal experiments found that the injection of TNF-α in the third trimester of the rat can reduce the ability of the placenta to transport essential amino acids to the fetal circulation.10 Maternal exposure to inflammation during pregnancy inhibited placental synthetic growth factors, which played an important role in fetal development.11,12 In addition, birth weight and hs-CRP had been found to associate inversely.13 Diet plays a role in regulating inflammation. The increasing intake of β-carotene, vitamin C and vitamin E had been shown to be associated with decreasing levels of hs-CRP, IL-6 and TNF-α.14 The intake of polyunsaturated fatty acids, especially omega-3 polyunsaturated fatty acids, was negatively correlated with levels of IL-6, IL-1ra, TNF-α, and hs-CRP.15 The intake of nutrients such as iron, zinc, magnesium, monounsaturated fatty acids and linolenic acid was negatively correlated with level of hs-CRP.16,17 Moreover, it had been proven that green vegetables and fruits with rich folate, flavonoids and antioxidants can significantly reduce the concentrations of serum inflammatory markers, such as TNF-α, IL-6 and hs-CRP.18–22 Conversely, certain dietary nutrients such as saturated fatty acids and trans fatty acids can increase the levels of inflammatory marker.23–25 Different dietary components or nutrients have different inflammatory tendencies and varying degrees.

Current research has not shown whether dietary inflammatory tendency plays a role in the effect of inflammation on neonatal birth weight and the specific effect of dietary inflammatory tendency on birth weight. Therefore, the aim of this study was to investigate whether diet plays a role in the effect of inflammation on neonatal birth weight.

As a result, we hypothesized that pro-inflammatory diets are positively correlated with hs-CRP levels and may affect neonatal birth weight. The Dietary Inflammatory Index (DII) was an indicator of the overall inflammatory tendency of diet.26 In this study, we used the DII score to investigate the effects of dietary inflammatory tendencies on systemic inflammation and neonatal birth weight in normal pre-BMI and healthy pregnant women without classical inflammatory symptoms. Our research may provide a reasonable and scientific basis for clinically reducing the birth rate of LBW and HBW.

Methods

Study design and subjects. Singleton pregnant women in the Department of Obstetrics and Gynecology, Anhui Medical University were recruited, and a cohort of pregnant women was established. The subjects were healthy singleton pregnant women without classical inflammatory symptoms at 16–20 weeks of pregnancy and normal body mass index (BMI: 18.5–25 kg/m²). All subjects were followed up until the end of delivery, and 40 pregnant women with complications such as gestational hypertension, gestational diabetes, preterm birth, Connective tissue

†These authors contributed equally to this work.
*To whom correspondence should be addressed.
E-mail: zhaomei@ahmu.edu.cn

http://dx.doi.org/10.3164/jcbn.19-100
DII in the second trimester (Table 3).

To further investigate the relationship between dietary inflammatory index and serum hs-CRP levels, this study found that 96 (31.3%) of the subjects had high serum hs-CRP levels (≥3 mg/L) in the second trimester. According to the DII as a categorical variable by tertiles, we divided 307 subjects into 3 groups, and the differences in DII between the three groups were examined using the chi-square test. Using the multinomial logistic regression model, we found that the risk of excessive CRP levels was highest in the high DII group (p = 0.002). Serum hs-CRP levels and the DII levels in the second trimester were significantly different between the NBW and LBW groups (p<0.05) (Table 2). This study suggested that differences in dietary intake may affect serum hs-CRP levels.

Results

Baseline data. A total of 307 pregnant women were included in the study. Pregnant women were divided into groups according to neonatal birth weight: 277 (90.2%) in the normal birth weight (NBW) group, 15 (4.9%) in the low birth weight (LBW) group, and 15 (4.9%) in the high birth weight (HBW) group (Table 1).

Dietary intakes in subjects. This study suggests that the total dietary energy intake of the subjects basically meets the individual needs. The results showed that, except for the intake of fat, vitamin A, vitamin B2 and vitamin C, the remaining energy and nutrient intake did not differ between the three groups.

Associations with DII and serum hs-CRP levels in the second trimester. The levels of serum hs-CRP of NBW, LBW and HBW were 1.60 (0.72, 3.30), 4.37 (1.50, 6.68), 2.90 (0.89, 10.22) mg/L (p = 0.005), and the DII levels in the second trimester were −3.47 ± 2.24, −1.44 ± 2.39, and −2.53 ± 2.90, respectively (p = 0.002). Serum hs-CRP levels and the DII in the second trimester were significantly different between the NBW and LBW groups (p<0.05) (Table 2). This study suggested that differences in dietary intake may affect serum hs-CRP levels.

To further investigate the relationship between dietary inflammatory index and serum hs-CRP levels, this study found that 96 (31.3%) of the subjects had high serum hs-CRP levels (≥3 mg/L) in the second trimester. According to the DII as a categorical variable by tertiles, we divided 307 subjects into 3 groups, and the 1st tertile (anti-inflammatory dietary group) was used as the control group. The results showed that the risk of excessive CRP levels was highest in the high DII group (p = 0.002). Serum hs-CRP levels and the DII levels in the second trimester were significantly different between the NBW and LBW groups (p<0.05) (Table 2). This study suggested that differences in dietary intake may affect serum hs-CRP levels.

Table 1. General characteristics and three groups according to birth weight

| Variable                      | NBW | LBW | HBW | F(2,1) | p    |
|-------------------------------|-----|-----|-----|--------|------|
| n                             | 277 | 15  | 15  |        |      |
| Age (y, means ± SD)           | 28.34 ± 3.12 | 28.33 ± 3.87 | 28.73 ± 3.22 | 0.111 | 0.895 |
| Pre-BMI (means ± SD)          | 20.61 ± 2.62 | 19.80 ± 3.26 | 21.34 ± 2.22 | 1.279 | 0.280 |
| Monthly income (CNY)          |     |     |     |        |      |
| <4,000 [n (%)]                | 99  | 35.74 | 8  | 53.33   | 4  | 26.67 | 0.281 | 0.756 |
| 4,000–8,000 [n (%)]           | 130 | 46.93 | 4  | 26.67   | 9  | 60.00 | 0.005 |
| >8,000 [n (%)]                | 48  | 17.33 | 3  | 20.00   | 2  | 13.33 |      |      |
| Passive smoking [n (%)]       | Yes | 117 | 7   | 46.67   | 2  | 13.33 | 2.587 | 0.778 |
| No                            | 160 | 57.76 | 8  | 53.33   | 13 | 86.67 |      |      |
| Parity [n(%)]                 | Primi | 145 | 7   | 46.67   | 10 | 66.67 | 1.406 | 0.495 |
| Multipara                     | 132 | 47.65 | 8  | 53.33   | 5  | 33.33 |      |      |

NBW, normal birth weight group; LBW, low birth weight group; HBW, high birth weight group.

RXL MAX, Westlake, OH.

Data analysis. Data analysis was conducted using the Statistical Package for the Social Sciences software ver. 21.0. The mid-pregnancy DII levels were divided into tertiles for analysis. For continuous variables, ANOVA and Least-significant Difference were used to determine the differences among different groups. For categorical variables, differences were examined by using the chi-square test. Using the multinomial logistic regression model, we took the birth weight of NBW (control group), LBW and HBW as the dependent variable, hinger serum hs-CRP level (≥3 mg/L) at the second trimester, and the tertiles of DII level as the factor, and the age of pregnant women and pre-pregnancy BMI as the co-variable, and analyzed the relationship between DII, hs-CRP level in the second trimester and neonatal birth weight.
There was no statistically significant difference between the two groups of DII socers in the second trimester (pro-inflammatory tendency dietary), similar to previous studies and inconsistent with the results of Moore BF. However, the relationship between DII, hs-CRP and birth weight in the second trimester was associated with higher maternal hs-CRP and an increased risk of low birth weight, similar to previous studies.

### Table 2. Comparison of hs-CRP levels and dietary intake in the second trimester of pregnant women

| Variable          | NBW            | LBW            | HBW            | (PH)       | p     |
|-------------------|----------------|----------------|----------------|------------|-------|
| n (%)             | 277            | 15             | 15             |            |       |
| -90.20%           | 15             | 15             |                |            |       |
| hs-CRP (mg/L)     | 1.6 (0.72, 3.30)| 4.37 (1.30, 6.68)| 2.9 (0.89, 10.22)| 10.744 | 0.005 |
| DII score         | -3.47 ± 2.24   | -1.44 ± 2.39   | -2.53 ± 2.90   | 6.596     | 0.002 |
| Energy (kcal)     | 2,467.19 ± 302.14| 2,531.19 ± 268.06| 2,559.11 ± 323.56| 0.936 | 0.393 |
| Protein (g)       | 110.76 ± 19.95 | 113.57 ± 22.96 | 111.63 ± 16.20 | 0.150     | 0.860 |
| Carbohydrate (g)  | 392.32 ± 67.78 | 403.09 ± 58.24 | 388.56 ± 70.29 | 0.192     | 0.825 |
| Fat (g)           | 55.07 ± 23.11  | 75.68 ± 29.88  | 64.65 ± 25.64  | 6.366     | 0.002 |
| Saturated fatty acid (g) | 6.02 ± 5.13  | 9.32 ± 9.86   | 5.39 ± 5.60   | 2.747     | 0.066 |
| Monounsaturated fatty acid (g) | 7.82 ± 7.40 | 10.26 ± 13.62 | 9.04 ± 12.70 | 0.779     | 0.460 |
| Polyunsaturated (g) | 5.14 ± 5.16   | 4.54 ± 3.66   | 5.28 ± 4.29   | 0.109     | 0.897 |
| Cholesterol (mg)  | 694.77 ± 353.84| 891.73 ± 621.93| 743.75 ± 258.20| 2.131     | 0.120 |
| Dietary fiber (g) | 17.61 ± 6.16   | 15.93 ± 6.79   | 18.08 ± 6.02   | 1.311     | 0.271 |
| Folic acid (μg)   | 385.34 ± 162.15| 353.74 ± 190.79| 335.00 ± 175.22| 0.891     | 0.411 |
| Vit A (μg)        | 1,135.51 ± 569.02| 769.71 ± 273.98| 1,053.27 ± 731.19| 3.191     | 0.043 |
| Vit B1 (mg)       | 1.47 ± 0.31    | 1.45 ± 0.36    | 1.51 ± 0.34    | 0.126     | 0.882 |
| Vit B2 (mg)       | 1.40 ± 0.33    | 1.65 ± 0.26    | 1.30 ± 0.32    | 4.602     | 0.011 |
| Vit C (mg)        | 167.10 ± 55.57 | 136.26 ± 52.69 | 140.78 ± 48.12 | 3.663     | 0.027 |
| Vit E (mg)        | 17.19 ± 4.75   | 17.19 ± 3.66   | 17.08 ± 5.24   | 0.004     | 0.996 |
| Niacin (mg)       | 24.69 ± 5.75   | 23.11 ± 4.66   | 22.00 ± 6.79   | 1.992     | 0.138 |
| Iron (mg)         | 30.97 ± 6.34   | 29.31 ± 4.60   | 29.03 ± 5.70   | 1.130     | 0.324 |
| Zinc (mg)         | 16.66 ± 2.85   | 16.46 ± 2.84   | 15.03 ± 3.02   | 2.331     | 0.099 |
| Selenium (μg)     | 84.38 ± 29.54  | 95.45 ± 40.55  | 90.11 ± 25.48  | 1.181     | 0.308 |
| Magnesium (mg)    | 443.12 ± 74.54 | 423.80 ± 82.40 | 426.75 ± 60.69 | 0.786     | 0.457 |

### Table 3. Logistic regression analysis of the DII and serum hs-CRP in the second trimester

| DII               | Normal hs-CRP (n = 211) | High hs-CRP (n = 96) | OR (95% CI) | p     |
|-------------------|-------------------------|----------------------|-------------|-------|
| T1: −4.55         | 80 (74.47%)             | 26 (24.53%)          | 1.00 (control group) |      |
| T2: −4.54 to −2.41| 68 (68.00%)             | 32 (32.00%)          | 1.49 (0.81, 2.74) | 0.234 |
| T3: ≥−2.40        | 63 (62.38%)             | 38 (37.62%)          | 1.89 (1.05, 3.42) | 0.043 |

T1: anti-inflammatory dietary group and as a control group, T2: The middle group, T3: pro-inflammatory dietary group.

### Table 4. The relationship between DII, hs-CRP and birth weight in the second trimester

| Birth outcomes | Grouping variable | OR     | 95% CI   | p   |
|----------------|-------------------|--------|----------|-----|
| LBW            | The 2nd tertiles of DII | 4.44   | 0.48-40.99 | 0.189 |
|                | The 3rd tertiles of DII | 10.44  | 1.29-84.61 | 0.028 |
|                | High hs-CRP | 3.81   | 1.26-11.56 | 0.018 |
| HBW            | The 2nd tertiles of DII | 2.10   | 0.51-8.72 | 0.307 |
|                | The 3rd tertiles of DII | 2.20   | 0.53-9.14 | 0.279 |
|                | High hs-CRP | 1.84   | 0.61-5.55 | 0.278 |

The control group of birth outcome is NBW, The control group of mid pregnancy DII is the 1st tertiles (anti-inflammatory tendency dietary). The control group of hs-CRP is normal (<3 mg/L).

**Relationship between DII, serum hs-CRP levels and neonatal birth weight in the second trimester.** Using the multinomial logistic regression model, the result showed that the risk of LBW in pregnant women with high serum hs-CRP levels in the second trimester is 3.81 times higher than that of normal hs-CRP (95% CI: 1.26, 11.56). The risk of LBW in the 3rd tertiles of DII socers in the second trimester (pro-inflammatory tendency dietary group) was 10.44 times higher than in the first tertiles (anti-inflammatory tendency dietary group) (95% CI: 1.29, 84.61). There was no statistically significant difference between the two factors in the risk of HBW (p>0.05). The pro-inflammatory tendency dietary of the second trimester and the higher hs-CRP increase the risk of low birth weight (Table 4).

**Discussion**

This study found that a pro-inflammatory diet in the second trimester was associated with higher maternal hs-CRP and an increased risk of low birth weight, similar to previous studies and inconsistent with the results of Moore BF. However, the
difference is that we chose healthy pregnant women with a normal pre-pregnancy BMI and no classical inflammatory symptoms during pregnancy as subjects. Compared with obese pregnant women, this association was more reliable. The birth rate of LBW can be reduced by adjusting the diet during the second trimester, depending on the dietary composition or nutrients that have pro-inflammatory or anti-inflammatory effects.

The intake of nutrients such as total fat and saturated fatty acids in the diet increased with the increase of the DII score, while the intake of vitamin C and vitamin A decreased significantly. The DII score of the NBW diet was used as a control group. The diets of the LBW group and the HBW group had pro-inflammatory effects, and the pro-inflammatory trend of the LBW group was more obvious. Therefore, in the case of ensuring that various nutrients in pregnancy meet the needs of the body, the nutrition quality of pregnant women can be evaluated with the DII score to improve the dietary anti-inflammatory level of pregnant women.

This study found that a diet with a pro-inflammatory tendency in the second trimester was positively correlated with serum hs-CRP levels, which is consistent with other studies. A dietary intervention study of 14 menopausal women found that low-sugar and high-fiber, fish diets can reduce serum hs-CRP levels. A cross-sectional survey of 8,607 men in the United States found a positive correlation between dietary DII total score and serum hs-CRP level. Farhangi et al. evaluated the dietary intake of 454 patients with cardiovascular disease and calculated DII score. After adjusting for confounding factors, the DII score was positively correlated with serum hs-CRP and other inflammatory factors. Intake of SFA (saturated fatty acids) in patients over 45 years of age can significantly increase hs-CRP levels, while supplementation with EPA (eicosapentaenoic acid) and DHA (twenty-two carbon six) can significantly reduce hs-CRP levels. Therefore, pregnant women should take more anti-inflammatory foods, such as vegetables, soy products, fish, etc., and reduce the intake of pro-inflammatory foods such as sugar and red meat, thereby reducing serum hs-CRP levels.

Previous studies have found that pregnant women with pre-eclampsia and gestational diabetes had higher serum hs-CRP levels, but these diseases may increase the risk of LBW or HBW. The innovation of this study is that we used healthy pregnant women with normal pre-BMI to exclude the effects of obesity and other complications such as gestational diabetes and eclampsia on birth weight. And we did not find a relationship between pro-inflammatory diet and HBW. As a result, we found that higher hs-CRP levels in the second trimester were independent risk factors for increased risk of LBW. The underlying mechanism might be disordered placental angiogenesis via Wnt5a-Fli1 activation triggered by inflammation.

In the future clinical work, serum hs-CRP level can be included in routine prenatal examination to screen out pregnant women with low-grade inflammation, and targeted dietary intervention to avoid the occurrence of LBW.

This study found that the pro-inflammatory dietary and the higher hs-CRP level in the second trimester increased the risk of LBW. Compared with the NBW group, the DII score was higher in the HBW group, but there was no statistical difference. This may be due to the small sample size. Moreover, 15 HBW cases eventually occurred in this study and the incidence may actually be higher. This is because pregnant women in the late pregnancy will undergo ultrasound examination to check the development of the fetus. Once the ultrasound results suggest that the fetus is growing too fast, they will strictly follow the doctor’s instructions to control and change the diet, and even hospitalization to avoid the occurrence of dystocia. Other study found that supplementation with DHA, folic acid, zinc and other nutrients during pregnancy can reduce the incidence of LBW. Previous studies found the effects of maternal age, maternal history, and environmental factors on birth weight but they do not fully explain the causes of low birth weight. In recent years, studies have explained the occurrence of LBW from the perspective of low-grade inflammation. Pregnant women consume more types of dietary ingredients or nutrients during pregnancy. These ingredients or nutrients have pro-inflammatory or anti-inflammatory effects. Anti-inflammatory dietary contain more vitamins and antioxidants to improve the clinical inflammation of the body. Therefore, the more pro-inflammatory tendency in the diet of pregnant women, the higher the incidence of low birth weight in newborns.

However, due to the complexity of dietary survey and the limitation of blood sample collection, we failed to dynamically observe the changes of DII, serum hs-CRP levels and fetal development during pregnancy. Subsequently, we will further improve the research methods and provide new ideas and methods for clinical pregnant women nutrition guidance.

In summary, this study explored the relationship between DII, hs-CRP level and neonatal birth weight in the second trimester. The pro-inflammatory dietary in the second trimester affects the serum hs-CRP level, showing a positive correlation. The pro-inflammatory dietary and the higher hs-CRP in the second trimester increase the risk of low birth weight. Due to the complexity of dietary survey and the limitation of blood sample collection, this study only investigated the pregnant women in the second trimester, and did not investigate the dietary DII before and during the third trimester, which will be further improved in future studies. Therefore, the results of our study showed that while ensuring the nutritional needs of pregnant women, the dietary structure of pregnant women can be improved to reduce the incidence of low birth weight infants. To provide control for the formulation of health intervention strategies and measures in the second trimester, promote balanced diet, reasonable maintenance, maintain pregnancy and improve the quality of life.

Acknowledgments

The authors would like to thank all volunteers for their cooperation and the authors would like to thank all volunteers for their cooperation.

Funding Statement

This study was supported by the National Natural Science Foundation of China (81671471) and National College Students Innovation and Entrepreneurship Training Program of China (20181036034X).

Conflict of Interest

No potential conflicts of interest were disclosed.

References

1 Barker DJ, Gluckman PD, Godfrey KM, Harding JE, Owens JA, Robinson JS. Fetal nutrition and cardiovascular disease in adult life. Lancet 1993; 341: 1421–1422.
2 Fall CH, Yajnik CS, Rao S, Davies AA, Brown N, Farrant HJ. Micronutrients and fetal growth. J Nutr 2003; 133 (S Suppl 2): 1747S–1756S.
3 van Deventer C, Robert G, Wright A. Improving childhood nutrition and wellness in South Africa: involving mothers/caregivers of malnourished or HIV positive children and health care workers as co-designers to enhance a local quality improvement intervention. BMC Health Serv Res 2016; 16: 358.
4 Hermann GM, Dallas LM, Haskell SE, Roghair RD. Neonatal macrosomia is an independent risk factor for adult metabolic syndrome. Neonatology 2010; 98: 238–244.
Endocrinology 1995; 136: 3579–3584.
14 Araújo JR, Correia-Branco A, Moreira L, Ramalho C, Martel F, Keating E. Folic acid uptake by the human syncytiotrophoblast is affected by gestational diabetes, hyperleptinemia, and TNF-α. Pediatr Res 2013; 73 (4 Pt 1): 388–394.
15 Hashimoto R, Sakai K, Matsumoto H, Iwashita M. Tumor necrosis factor-alpha (TNF-alpha) inhibits insulin-like growth factor-I (IGF-I) activities in human trophoblast cell cultures through IGF-1/insulin hybrid receptors. *Endoc J* 2010; 57: 193–200.
16 Tzoulaki I, Jarvelin MR, Hartikainen AL, et al. Size at birth, weight gain over the life course, and low-grade inflammation in young adulthood: northern Finland 1966 Birth Cohort study. *Eur Heart J* 2008; 29: 1049–1056.
17 Aebertl I, Molinari L, Spinas G, Lehmann R, l’Allemante D, Zimmermann MB. Dietary intake of fat and antioxidant vitamins are predictors of subclinical inflammation in overweight Swiss children. *Am J Clin Nutr* 2006; 84: 748–755.
18 Graham IM, O’Callaghan P. The role of folic acid in the prevention of cardiometabolic risk in US adults. *Atherosclerosis* 2018; 276: 23–27.
19 Nanri A, Moore BF, Sauder KA, Starling AP, et al. Proinflammatory diets during pregnancy and neonatal adiposity in the Healthy Start study. *J Pediatr* 2018; 195: 121–127.e2.
20 Arnold K, Weinhold KR, Andridge R, Johnson K, Orchard TS. Improving diet quality is associated with decreased inflammation: findings from a pilot intervention in postmenopausal women with obesity. *J Acad Nutr Diet* 2018; 118: 2135–2143.
21 Mizdai M, Shivappa N, Wirth MD, et al. Dietary inflammatory index and cardiometabolic risk in US adults. *Atherosclerosis* 2018; 276: 23–27.
22 Farhangi MA, Najafi M. Dietary inflammatory index: a potent association with cardiovascular risk factors among patients candidate for coronary artery bypass grafting (CABG) surgery. *Nutr J* 2018; 17: 20.
23 Niknam M, Paknahad Z, Maracy MR, Hashemi M. Dietary fatty acids and inflammatory markers in patients with coronary artery disease. *Adv Biomed Res* 2014; 3: 148.
24 Chen H, Zhang J, Qin F, Chen X, Jiang X. Evaluation of the predictive value of high sensitivity C-reactive protein in pregnancy-induced hypertension syndrome. *Exp Ther Med* 2018; 16: 619–622.
25 Gandeovani SB, Banaem LM, Mohamadi B, Moghadam NA, Asghari M. Association of high-sensitivity C-reactive protein serum levels in early pregnancy with the severity of preeclampsia and fetal birth weight. *J Perinat Med* 2012; 40: 601–605.
26 Ertas IE, Kahyaoglu S, Yilmaz B, et al. Association of maternal serum high sensitive C-reactive protein level with body mass index and severity of preeclampsia at third trimester. *J Obstet Gynaecol Res* 2010; 36: 970–977.
27 Kumari R, Singh H. The prevalence of elevated high-sensitivity C-reactive protein in normal pregnancy and gestational diabetes mellitus. *J Family Med Prim Care* 2017; 6: 259–264.
28 Jafarnejad S, Sarem S, Jafarnejad F, Arab A. Effects of a multispecies probiotic mixture on glycemic control and inflammatory status in women with gestational diabetes: a randomized controlled clinical trial. *J Nutr Metab* 2016; 2016: 5190846.
29 Kong L, Nilsson I, Gissler M, Lavebratt C. Associations of maternal diabetes and body mass index with offspring birth weight and prematurity. *JAMA Pediatr* 2019; 173: 371–378.
30 Xu F, Ren ZX, Zhong XM, Zhang Q, Zhang YJ, Yang J. Intrauterine inflammation damages placental angiogenesis via Wnt5a-Fli1 activation. *Inflammation* 2019; 42: 818–825.
31 Carlson SE, Gajewski BJ, Alhayek S, Colombo J, Kerling EH, Gustafson KM. Dose-response relationship between docosahexaenoic acid (DHA) intake and lower rates of early preterm birth, low birth weight and very low birth weight. *Prostaglandins Leukot Essent Fatty Acids* 2018; 138: 1–5.
32 Sengpiel V, Bacelis J, Myhré R, et al. Folic acid supplementation, dietary folate intake during pregnancy and risk for spontaneous preterm delivery: a prospective observational cohort study. *BMJ Pregnancy Childbirth* 2014; 14: 375.
33 Keshidis A, Arima H, Fujii T, Ito Y, Murakami T, Takahashi K. Impact of advanced maternal age on adverse infant outcomes: a Japanese population-based study. *Ear J Obstet Gynecol Reprod Biol* 2019; 242: 178–181.
34 Heffner LJ, Elikin E, Fretts RC. Impact of labor induction, gestational age, and maternal age on cesarean delivery rates. *Obstet Gynecol* 2003; 102: 287–293.