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Prevention of Maternal Low-Grade Chronic Inflammation: The Diet's Inflammatory Potential in Pregnant Women in Southern Benin

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Abstract

Background: Pathogenic mechanisms link maternal systemic low-grade chronic inflammation to intrauterine development. A pro-inflammatory diet during pregnancy is associated with chronic maternal systemic inflammation. The objective of the study was to determine the diet inflammatory index and identify associated foods and nutrients in pregnant women of Ouidah city, Benin. **Methods:** The cross-sectional study conducted among pregnant women randomly selected by cluster sampling. Nutrient intakes and food consumed were estimated based on data of two 24-hour non-consecutive recalls. The inflammatory weightings of each nutrient were used to calculate the diet inflammatory index for each pregnant woman. **Results:** The average age of the 310 pregnant women surveyed was 27.20 ± 5.99 years. The median diet inflammatory index was −3.026 (−16.59; 1.86). The pregnant women with inflammatory diet accounted for 11.30%. Vitamin A and zinc were negatively correlated with the diet inflammatory index. Fruits, roots, tubers and sweetened drinks consumed were positively correlated with the diet inflammatory index. On the contrary, the quantities of cereals, vegetables, legums and fish consumed were negatively correlated with the diet inflammatory index. **Conclusion:** More than one pregnant woman out of ten in the Ouidah city had a pro-inflammatory diet. Reducing maternal systemic low-grade chronic inflammation may include increasing the consumption of identified anti-inflammatory foods.

Keywords

Diet, Inflammatory Index, Pregnancy, Benin

1. Introduction

An adequate maternal nutritional intake is a fundamental factor for a healthy pregnancy and the child's optimal development. The hypothesis of "developmental origins of diseases" assumes that the nutritional status of the mother during the preconception and pregnancy period can influence the development of offspring and the onset of diseases, from childhood to old age [1].

Epidemiological studies have shown a strong correlation between inflammatory markers and hyperinsulinemia, hypertriglyceridemia, body mass index and hypertension [2] [3]. Through pro-and anti-inflammatory bioactive compounds contained in food, diet has been shown to play a role in the occurrence of chronic inflammation [4] [5], which paves way for the development of metabolic syndrome and diabetes [6] [7].

Chronic inflammation in pregnant women leads to elevated blood pressure [8] and pre-eclampsia [9], which can endanger the course of pregnancy for both mother and fetus and expose the unborn child to chronic diseases [10] [11]. Sen *et al.* [12] reported that inflammation was associated with a high risk of low birthweight in infants and a high risk of low breast milk production at birth. According to Hemaltha [11], chronic inflammation in pregnant women is associated with vasculo-renal syndrome with a negative impact on the fetal growth and its development.

A pro-inflammatory diet during pregnancy is associated with chronic maternal systemic inflammation [8]. A study in America showed that the level of inflammation was higher in the second trimester of pregnancy and was associated with increased risk of gestational diabetes mellitus in African-American women [13]. In 2012, the cross-sectional study by Golzarand *et al.* [14], observed that protein C-Reactive (CRP) was strongly associated with a high carbohydrate intake with saturated fatty acid and there were significant associations between food carbohydrate intakes, saturated fatty carbohydrates and the CRP.

In Benin, the rate of eclampsia and low weight at birth were respectively 12% and 9.1% [15] [16] in 2014. Maternal nutrition needs to be improved in Benin. From 2006 to 2017-2018, according to Demographic and health surveys, the percentage of women aged 15 - 49 presenting a state of thinness (body mass index less than 18.5) increased slightly, from 9% to 11%. During the same period, the percentage of overweight or obese women (BMI greater than or equal to 25) also increased, but more significant, going from 19% to 26%. The food inflammatory in pregnant women is not much documented. The objective was to determine the diet inflammatory index (DII) in pregnant women.

2. Methods

2.1. Settings

The study was conducted in the city of Ouidah, 40 kilometers from Cotonou. The total population of the city was estimated at 187,064 inhabitants with 5833 pregnancies expected [17]. Ouidah is a coastal city, traditional fishing is practiced.

2.2. Study Design and Population

The study was cross-sectional. The study population was pregnant women municipality. Any pregnant woman residing in the Ouidah municipality for at least six months was included in the study. Pregnant woman who was absent, sick, who has been prescribed a special diet for treatment were not included. Any woman who has declared herself pregnant and whose pregnancy has not been certified by a health worker was not selected.

2.3. Sampling

Sampling method and technique

The probabilistic sampling method with the cluster sampling technique adapted from World Health Organization were used to select pregnant women.

Sample size

The sample size was determined from the Schwartz formula.

$$n = Z_{\alpha}^{2} p(1-p) / i^{2}$$

where the risk of error α that we assume is 5% for a 95% confidence interval. Since we don't have a prevalence of low-intensity inflammation in the general population in Benin, the prevalence of low-grade inflammation measured by ultra-sensitive CRP in a study carried out in Ouagadougou (39.4%) was considered [18]. By setting the aimed precision "*i*" at 7% and the cluster effect 1.5, the minimum size was 256 pregnant women. A minimum sample of 300 pregnant women was retained.

2.4. Variables

The dependent variable was "the Diet Inflammatory Index (DII) in pregnant women". It was calculated for each participant from these dietary intakes of 22 nutrients according to the method described below.

1st step: Estimation of average nutrient intake from 24 h reminders

From two 24-hour non-consecutive food recalls carried out among pregnant women, the West African food composition table and the "Alimenthèque R" software were used to determine nutrient intakes. Dietary intakes have been adjusted and normalized with Multiple Source Methods [19].

2nd step: Calculation of the inflammatory weight of nutrients

The average intake of each nutrient was multiplied by its inflammatory weight predetermined by Shivappa *et al.* [2] to obtain the inflammatory weight of each nutrient (**Table 1**).

3rd step: Calculation of the diet inflammatory index

To determine this index, the sum of the inflammatory weights of each nutrient was performed. When DII was positive, the diet was considered pro-inflammatory and when negative, the diet was as considered anti-inflammatory [2].

Table 1. Inflammatory coefficients of nutrients and energy.

Nutrients and energy	Inflammatory coefficient
Energy (kcal)	0.180
Protein (g)	0.021
Total Fatty acid (g)	0.298
Mono unsaturated fatty acid (g)	−0.009
Poly unsaturated fatty acid (g)	−0.337
Cholesterol (mg)	0.110
Carbohydrate (g/dl)	0.097
Fiber (g/dl)	−0.663
Vitamin A (μg/dl)	−0.401
ß caroten	−0.584
Thiamin (mg/dl)	−0.098
Riboflavin (mg/dl)	−0.068
Niacin (mg/dl)	−0.246
Vitamin B-6 (mg/dl)	−0.365
Folate (μg/dl)	−0.190
Vitamin B-12 (μg/dl)	0.106
Vitamin C (mg/dl)	−0.424
Vitamin D (μg/dl)	−0.446
Vitamin E (mg/dl)	−0.419
Iron (mg/dl)	0.032
Magnesium (mg/dl)	−0.484
Alcohol (g)	−0.278
Zinc (mg/dl)	−0.313
Caffeine (g)	−0.110
Eugenol (g)	−0.140
Garlic (g)	−0.412
Ginger (g)	−0.588
Omega-3 fatty acid (g)	−0.436
Omega-6 fatty acid (g)	−0.159
Saffron (g)	−1
Saturated fat (g)	0.429
Selenium μg	−0.191
Trans fatty acid (g)	0.432

Source: Designing and developing a literature-derived, population-based dietary inflammatory index [2].

The independent variables were:

- Dietary factors: energy, carbohydrates, fat, protein, micronutrients (fibers, thiamine, niacin, riboflavin, vitamin A, D, E, C, B6, B9, B12, iron, zinc, magnesium,)
- Food groups;
- Socio-demographic and economic factors: age, ethnicity, religion, education, occupation and socio-economic status.

2.5. Data Collection

Nine teams including a dietician and a community member fluent in French and local languages were formed and trained on the 24-hour multiple-pass recall technique described by Conway *et al.* [20].

2.6. Data Analysis

Dietary intakes were adjusted and normalized with Multiple Sources Meth software. Data were analyzed using the SPSS software version 18.0 (SPSS Inc., Chicago, IL). A weighting variable was created and used in the analyses to take into consideration the sample design. The averages and standard deviation were estimated for the normally distributed quantitative variables and the medians with the percentiles 25 and 75 were calculated for the asymmetric ones. Proportions were calculated for the qualitative variables. On one hand, a correlation analysis was performed to investigate the relationship between DII and nutrients and between DII and food group intakes on the other hand. The significance threshold was set at $p < 0.05$.

3. Results

3.1. Participants' Characteristics

The average age of participants was 27.20 ± 5.99 years. The most represented age group was 30 to 42 years with 34.84% (95% CI [28.98; 40.71]). Illiterate pregnant women and those with a high socio-economic level were also frequent and represented respectively 39.18% and 36.80%. **Table 2** summarizes the sociodemographic characteristics of pregnant women.

3.2. Diet Inflammatory Index of Pregnant Women

The median diet inflammatory index was −3.026 with for Q1 (−16.59) and Q3 (1.86). Among the 310 pregnant women, 35 (11.30%) had a pro-inflammatory diet and 275 (88.70%) had an anti-inflammatory diet.

3.3. Association of Food Groups with Diet Inflammatory Index

Table 3 shows that only cereals, fruits, vegetables, legumes, fish, roots and tubers and sweets and sweet products were significantly correlated with the diet inflammatory index of pregnant women's diet.

Table 2. Socio-demographic and economic characteristics of pregnant women in Ouidah, Benin, (n = 310).

Characteristics	n	Weighted frequency %
Age (years)		
[16 - 23[	73	22.50
[23 - 26[	66	20.25
[26 - 30[	70	22.08
[30 - 43[	101	34.84
Religion		
Monotheism	257	83.82
Polytheism	53	16.17
Ethnicity		
Fon	184	61.99
Mina	46	13.28
Yoruba	12	3.89
Haoussa	27	8.20
Adja	25	8.71
Others	16	3.89
Education		
Primary school	95	30.01
Secondary school	96	30.79
Non schooling	119	39.18
Occupation		
Public worker	17	4.52
Housewife	54	18.25
Craftswoman	52	19.14
Retailer	147	47.66
Farmer	40	10.40
Socio-economic level		
Weak	84	31.51
Fair	98	31.67
High	128	36.80

Maize was the main cereal in staple foods in the city. Vegetables consumed were namely tomatoes, onion, okra, pepper, leafy vegetables. Legums consumed were cowpea and beans. Mutton, goat, pork and poultry were protein source. Fruit consumption is limited as shown table III. Fish was part of the population's daily diet.

Table 3. Correlation coefficients between the overall diet inflammatory index and food group consumed in pregnant women, Ouidah, Benin (n = 310).

Foods/food groups (g)	Average intake	Standard deviation	Correlation coefficients	p
Cereals	919.90	200.14	−0.195	**0.001**
Fruits and fruit juice	10.11	22.61	0.125	**0.028**
Fats	23.08	9.49	0.103	0.071
Milk and dairy products	5.36	11.91	−0.039	0.494
Vegetables	163.95	59.01	−0.267	**<0.001**
Legums	63.59	59.59	−0.114	**0.046**
Eggs	5.78	10.92	−0.058	0.308
Fish and seafood	50.40	25.98	−0.287	**<0.001**
Roots and tubers	21.96	8.85	0.085	0.137
Sugar and sweetened beverages	21.22	9.74	0.170	**0.003**
Meat	14.55	22.86	0.009	0.880

3.4. Association of Nutrient Intakes with Diet Inflammatory Index

Table 4 shows that only carbohydrate intake was positively correlated with the diet inflammatory index at the 5% threshold. That is, there is a link between carbohydrates and the index. But, lipids, proteins, fibers, monounsaturated fatty acids, polyunsaturated fatty acids, iron, vitamin B9, niacin, riboflavin, thiamine, vitamin B6, B12, C, E, D and zinc were negatively correlated with the diet inflammatory index. Only magnesium and vitamin A resulted in an inflammatory index negatively correlated with the diet inflammatory index.

4. Discussion

The study showed that the diet was pro-inflammatory in 11.30% of pregnant women. Vitamin A and zinc were negatively correlated with the diet inflammatory index. Intakes of tubers and sugary drinks were positively correlated with the diet inflammatory index while intakes of cereals, vegetables, legumes and fish were negatively correlated with DII.

4.1. Diet Inflammatory Index of Pregnant Women

Previous studies on the prevalence of pro-inflammatory diet in pregnant women are scarce. Instead, studies have focused on measuring chronic inflammation using CRP. Therefore, Zéba *et al.* in Burkina Faso [18] reported that 39.4% of the apparently healthy pregnant women of both sexes in their sample had low-intensity chronic inflammation, while Golzarand [14] in Iran reported that 24.6% of patients hospitalized at the endocrinology clinic had chronic inflammation. Chronic inflammation during pregnancy is particularly critical because during its development, the human embryo and fetus undergo a complex series

Table 4. Correlation coefficients between the overall diet inflammatory index and nutrient intake in pregnant women, Ouidah, Benin (n = 310).

Energy and nutrient intake	Average intake	Standard deviation	Correlation coefficients	p
Energy (kcal)	2586.20	718.40	0.007	0.906
Carbohydrates (g)	359.93	162.63	**0.332**	0.000
Fats (g)	42.39	26.56	−0.102	0.072
Proteins (g)	71.53	24.87	**−0.124**	0.029
Fibers (g)	31.36	14.37	**−0.401**	0.000
Mono unsaturated fatty acid (g)	14.12	8.742	0.000	0.995
Poly unsaturated fatty acid (g)	9.416	5.37	**0.115**	0.042
Vitamin A (μg)	1260.04	857.20	**−0.920**	0.001
Thiamin (vitamin B1) (mg)	1.45	1.317	**−0.345**	0.001
Riboflavin (vitamin B2) (mg)	1.208	1.012	**−0.479**	0.001
Niacin (vitamin B3) (mg)	17.26	7.19	**−0.348**	0.001
Vitamin B6 (mg)	2.70	1.67	**−0.548**	0.001
Folate (vitamin B9) (μg)	253.64	87.33	**−0.200**	0.001
Cobalamin (vitamin B12) (μg)	1.41	1.70	**−0.263**	0.001
Vitamin D (μg)	5.63	3.35	**−0.322**	0.001
Vitamin E (mg)	4.317	3.17	**−0.157**	0.006
Vitamin C (mg)	100.09	37.10	**−0.389**	0.000
Zinc (mg)	9.77	5.22	**−0.084**	0.142
Magnesium (mg)	532.13	160.57	**−0.501**	0.001
Iron (mg)	13.31	6.42	**−0.384**	0.001

of changes in cell type and cell number. Each of these changes takes place in a strictly well chronological sequence and the disruption of the process by chronic inflammation can lead to dramatic and lasting consequences for the fetus and sustainable and dramatic consequences for the mother [13].

4.2. Nutrients Associated with the Diet Inflammatory Index

Carbohydrates and fibers

The correlation weighting between carbohydrate intake and the dietary inflammatory index was higher than that obtained by Golzarand (r = 0.19) [14]. Other studies have reported the relationship between carbohydrate intake and CRP values [8] [21] [22], between glycemic index and/or glycemic load and hs-CRP concentrations [23] [24]. In this regard, a recent meta-analysis covering randomized controlled intervention studies suggests that diets with a low glycemic index/load should be favored over diets with a high glycemic index/load in order to reduce pro-therapeutic biomarker concentrations inflammatory as hs-CRP [25]. Indeed, it is recognized that variations in blood sugar, including dysglycemia, contribute by at least two mechanisms to chronic inflammation, namely excessive glycation of proteins and activation of oxidative stress [26].

Fiber intakes are inversely correlated with the diet inflammatory index. Several cross-sectional studies reported this inverse association between fiber consumption and hs-CRP concentrations [27]. A recent literature review including seven intervention studies concluded, based on six of the seven studies, that hs-CRP concentrations could be reduced by 25% - 54% after increasing dietary fiber intakes (3.3 - 7.8 g/MJ) [28]. One should note that these decreases in hs-CRP were reported as part of weight loss in most studies considered.

Fatty acids

Lipids such as monounsaturated and polyunsaturated fatty acids were negatively correlated with the diet inflammatory index as Golzarand et al reported in a study [14] of the lifestyles of smokers and non-smokers and Shivappa *et al.* [29] in another one about CRP among diabetic and cancer patients. In fact, fatty acids have the capacity to inhibit or activate certain stages of the inflammatory process [30] [31]. Consequently, saturated fatty acids can be linked to immune system receptors and activate the signaling pathway that regulates the expression of pro-inflammatory genes [32] [33].

Proteins

Protein consumption increases the inflammatory index. Hung *et al.* [34] and Keogh *et al.* [35] reported opposite results in studies concerning followed hemodialysis patients and obese. Cavicchia *et al.* [22] found no link between protein intake and inflammatory index. However, other studies reported results similar to the present study [23]. According to Lavoie, protein-rich diets do not appear to be suitable for relieving inflammation, due to their likely deleterious effects on liver and kidney functions [36] [37].

We should note that energy was not correlated with the diet inflammatory index. Contrary results were reported between energy and the inflammatory index of diet [23]. This may be due to the fact that energy results from macronutrients whose sources influence the inflammatory index differently.

Magnesium and Vitamin A

Micronutrients such as magnesium and vitamin A were inversely associated with the inflammatory index. The results are like those of Golzarand *et al.* [14] and Shivappa *et al.* [8]. Bo *et al.* reported that dietary magnesium intakes were strongly and inversely associated with pro-inflammatory marker concentrations [27]. Evidence indicates that flavonoids are able to act to interfere with inflammation by modulating intracellular signaling cascades that control neuronal survival, death and differentiation and can have impact on gene expression and interaction with mitochondria [26].

4.3. Food Groups Associated with the Diet Inflammatory Index

Intakes of cereals, vegetables, legumes, and fish were negatively correlated with the diet inflammatory index. These results are like those of Ruiz *et al.* [38]. A recent literature review suggests, based on epidemiological studies, that each serving of whole grain cereal products consumed is associated with a 7% decrease in hs-CRP levels after adjustment for other nutritional factors [39].

The anti-inflammatory effects of vitamins C and E of provitamins A and fiber may explain that fruits and vegetables have beneficial impacts on the inflammatory profile. In a study dealing with non-smoking men, Watzl *et al.* [40] reported that consuming 8 portions per day of carotenoid-rich fruits and vegetables for 4 weeks resulted in the reduction of hs-CRP as compared to eating 2 portions per day.

Fish intakes were inversely associated with the diet inflammatory index. This result is identical to those of Labonte *et al.* which showed that erythrocyte concentrations of docosapentaenoic acid (DPAn-3) were inversely associated with hs-CRP and inflammatory score. This result implies that high concentrations of DPAn-3 are associated with a lower risk of systemic inflammation in the population [41].

Intake of sweetened beverages was positively associated with the diet inflammatory index. In fact, it has been shown that the consumption of sugary drinks (with added sugar, including among others soft drinks with or without caffeine, fruit drinks and lemonade) was positively associated with the concentrations of hs-CRP, interleukin-6 and tumor necrosis factors type 1 and 2 receptors in participants of the Health Professionals Follow-Up Study [42]. Studies carried out on patients suffering from coronary artery disease, and randomized nutritional intervention, crossover, carried out on 29 healthy men, established that consumption of 600 ml per day of sugary drinks containing different amounts (40 or 80 g) of fruits, glucose or sugar during 3 weeks increased by 60% to 109% the concentrations of CRP as compared to initial values at the beginning of this study [43] [44].

The 24-hour recall data is memory-based; therefore, it is likely to be influenced through a memory lapse. However, the use of the five-step transition techniques minimizes the magnitude of this bias.

5. Conclusion

The study shows that more than one pregnant woman out of ten had a pro- inflammatory diet. Intakes of certain foods and nutrients were associated with the diet inflammatory index. The reduction of the inflammatory potential of the diet of pregnant women could be beneficial. This implies promoting the con- sumption of potentially anti-inflammatory foods and reduction of consumption of identified pro-inflammatory foods.

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Conflicts of Interest

No conflicts of interest have been declared by the authors.

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