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Article

# Characterization of Nutritional Consumption in Vegan Pregnant Women and Its Effects on Birth Weight

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## Abstract

**Objective:** The implications of strictly vegan diets during pregnancy remains insufficiently understood, we aimed to determine the impact of specific components of vegan diet on pregnancy outcomes, with particular emphasis on neonatal birthweight. **Methods:** This secondary analysis of a prospective observational study included women with singleton pregnancies who delivered at a single medical center and adhered to a consistent diet. Participants were classified as vegan or non-vegan and reported demographic data and supplement use. During the third trimester, women completed a validated Food Frequency Questionnaire. Pregnancy outcomes were retrieved from a computerized database. SGA was defined as birthweight <10th percentile. **Results:** Among 230 participants, 54 followed a vegan diet. Vegan diet had lower protein intake (60 vs. 82 g/day,  $p < 0.001$ ). Higher protein percentage was associated with lower risk of SGA (RR=0.8, 95% CI: 0.673-0.956,  $p < 0.014$ ). Amino acids profile differed significantly, with Leucine showing the strongest association with birthweight ( $p=0.003$ ). Vegan diets included higher carbohydrate (256 vs. 217 g), fiber (48 vs. 30 g), folate (627 vs. 416  $\mu\text{g}$ ), and iron (17 vs. 12 mg) intake, and lower fat (72 vs. 79 g), calcium (764 vs. 1053 mg), vitamin D (0.24 vs. 5.5  $\mu\text{g}$ ), vitamin B12 (1.5 vs. 4.6  $\mu\text{g}$ ), DHA (0 vs. 0.07 g), and choline (270 vs. 394 mg) (all  $p < 0.05$ ). **Conclusions:** Vegan diet during pregnancy may increase the risk of SGA, possibly due to inadequate protein intake and composition, particularly leucine. Vitamin D, calcium, B12, and choline deficiencies are more common in vegan pregnant women.

**Keywords:** pregnancy; vegan diet; intrauterine growth; birth weight; protein; leucine

## 1. Introduction

In most Western countries, the prevalence of individuals adhering to a vegan diet typically ranges from 1% to 5% of the adult population [1,2]. The characteristics of the vegan diet are different from those of the lacto-ovo-vegetarian diet and a Pesco-vegetarian diet, due to avoiding all types of food from the animal source.

Pregnancy is a nutritionally sensitive period which requires maintaining a proper nutritional status and an adequate supply of vitamins and minerals. Excess or insufficient weight gain and nutritional deficiencies during this period may directly affect short and long-term maternal and fetal health [3]. According to the American Academy of Nutrition and Diet, a properly planned and balanced vegan diet is safe and can provide the full range of nutritional needs throughout the life cycle and pregnancy [4]. However, concern exists regarding the ability of a vegan diet to optimally provide several micronutrients. The main consideration and concern is the adequate intake of Iron,

B12, Vitamin D, Iodine, Zinc, Choline and Docosahexaenoic acid (DHA) [5], all of them are particularly significant for normal fetal development and maternal health [6].

Evidence on the effects of plant-based diets during pregnancy remains limited, as most available data focused on general plant-based patterns rather than strictly vegan diets and was based on a small sample size [7]. Findings were inconsistent, particularly regarding neonatal birth, with similar pregnancy length between the groups. As for microelements and vitamins, there was inconclusive data suggesting increased risk for vitamin B12 and iron deficiencies among vegans.

In our previous publication examining the association between vegan diet and pregnancy outcomes, we found that vegan women have a fivefold increased risk for small for gestational age (SGA) birthweight compared to women following an omnivorous diet [8]. These results are supported by recent study which examined pregnancy outcome in vegan women compared to vegetarian and omnivorous women that found an increased risk of SGA and low birth weight percentile among vegan women compared to non-vegan women [9]. Nevertheless, little is known about which specific nutritional factors within vegan diets may underline these associations. Therefore, the present study aimed to identify which dietary characteristics of vegan diets are related to the increased risk of SGA.

## 2. Materials and Methods

This is a secondary data analysis of a prospective observational study which included women who gave birth at a single, tertiary university-affiliated medical center between May 2018 and June 2019 [8]. Eligibility was limited to women aged 18 years or older with singleton pregnancies. Only women who maintained the same diet for at least 3 months prior to and throughout the current pregnancy were enrolled. Exclusion criteria were a prior medical indication for a specific restrictive diet, such as pre-gestational diabetes mellitus, celiac disease, lactose intolerance, and inflammatory bowel disease, and having undergone bariatric procedures or other bowel resections. The comparison was made by comparing vegan to non-vegan women.

Each woman completed a Food Frequency Questionnaire (FFQ), a validated tool used to assess habitual dietary intake by recording the frequency and portion size of foods consumed [10], and demographic questionnaire during the third trimester of pregnancy. Pregnancy outcome data were obtained from a real-time computerized database. Collected variables included duration of adherence to the specific diet, maternal age, gravidity, parity, medical history, use of vitamins and supplements, pre-pregnancy body mass index (BMI), gestational weight gain, mode of conception (spontaneous or via assisted reproductive technologies), mode of delivery, and gestational age at birth. Birthweight percentiles were adjusted for sex and gestational age based on national reference curves [11]. SGA was defined as below the 10% percentile on the local birthweight curves [11]. The local institutional review board approved the study (0715-17-TLV), and all women provided written informed consent.

### 2.1. Nutritional Analysis

The nutritional analysis was performed based on the FFQ. Analysis of average daily intake of energy, macro-nutrients (carbohydrate, protein, fat and dietary fibers) and micro-nutrients (iron, calcium, vitamin D, vitamin B12, choline, omega 3, zinc, and amino acids) were collected using the FFQ and personal reporting on taking supplements based on the collected data, the percentage of carbohydrates, proteins, and fats in the total caloric intake was calculated. An analysis of the amino acid composition from the total protein consumed was performed. Women with incomplete or inconsistent data and women with consumption higher than 5000 kcal/day and/or low than 500 kcal/day were excluded. The calculation of the total nutritional consumption, plus the nutritional supplements, performed according to self-report. Our reference to the vitamins and minerals recommended for consumption in pregnancy according to the recommendations of the Ministry of Health [12]. Women were asked regarding their use of specific supplements, including Folic acid (400 mcg), Iron (25 mg), Vitamin B12 (1000 mcg), Omega-3, and a combined pregnancy multivitamin. To

calculate the contribution of Omega-3 and multivitamins, when no specific composition was recorded, an average calculation was performed for nutritional consumption among the prevalent product formulations available in the market. To incorporate Omega-3 contributions into dietary assessments, daily consumption was calculated by adding 200 mg DHA and 100 mg EPA daily. The multivitamin's nutritional input was appraised by factoring in 40 mg of iron, 250 mg of Calcium, 8.75 mcg of Vitamin D, and 12 mcg of Vitamin B12.

## 2.2. Data Analysis

Data analysis was performed using IBM statistical software, SPSS Statistics version 25. Continuous variables underwent assessment for normal distribution. Normally distributed variables were reported as mean and standard deviation, while non-normally distributed variables with extreme values were reported as median and interquartile range. Statistical significance was set at  $p < 0.05$  for all tests. For normally distributed continuous variables, independent T-tests were utilized for group comparisons. Non-normally distributed variables were compared using the Mann-Whitney test. Categorical variables were compared using chi-squared and Fisher's exact test. The relationship between neonatal weight and categorical variables such as gender, pregnancy weight gain, and vegan diet was explored using one-way ANOVA. Multivariable linear regression was applied to examine the correlation between a vegan diet and neonate's weight. Logistic regression was employed for SGA as a dichotomous outcome. To uncover potential interactions between nutritional components and neonate weight, the Chi-square Automatic Interaction Detection (CHAID)[13]. The level of significance for the splitting nodes was 0.05. All tests were adjusted for confounding factors in accordance with study assumptions and regression conditions.

## 3. Results

Overall, 230 women were eligible for analysis, of them, 54 vegan and 176 non-vegan women. Demographic characteristics are presented in Table 1. Vegan women were older than the non-vegan women (35.0 vs 32.7 years, respectively,  $p < 0.001$ ).

**Table 1.** Participants' characteristics for the study and control groups.

	All(n=230)	Not Vegan (n=176)	Vegan (n=54)	P
	Mean $\pm$ SD Or N (%)	Mean $\pm$ SD Or N (%)	Mean $\pm$ SD Or N (%)	
Age (years)	33.2 $\pm$ 4.0	32.6 $\pm$ 3.8	35.0 $\pm$ 4	<0.001
Pre-pregnancy weight (kg)	59.8 $\pm$ 9.4	60.4 $\pm$ 9.7	58.1 $\pm$ 8.1	0.121
Pre-pregnancy BMI (kg/m <sup>2</sup> )	22.3 $\pm$ 3.2	22.6 $\pm$ 3.3	21.4 $\pm$ 2.6	0.008
GWG (kg)		13.2 $\pm$ 4.4	11.8 $\pm$ 4	0.037
Gravidity	2.07 $\pm$ 1.4	2.02 $\pm$ 1.5	2.2 $\pm$ 1.3	0.125

Abbreviations: Pre\_weight: Pre-pregnancy weight, Pre\_BMI: Pre-pregnancy BMI, calculated by weight divided by squared height, GWG: Gestational weight gain.

No significant differences were found in the percentage of women taking Iron, Folic acid, Omega-3 and multivitamin supplements, and 70% of the study participants took a multivitamin and iron supplement, 63% of the women took Folic acid supplement and 34% took Omega-3 supplement without significant differences between vegan and non-vegan women. The only dietary supplement that was statistically different between the groups was B12 with approximately 56% of vegan women taking B12 compared to only 26% of other women ( $p < 0.001$ ) (Supplemental table).

Pregnancy outcomes are presented in Table 2. Birthweight and birthweight percentile were lower among vegan women (3254 gr vs. 3031 gr and 54.5% vs. 37.5%  $p < 0.004$  and  $p < 0.008$  respectively). The rate of SGA was higher among vegans (14.8 % vs 5.7%  $p < 0.041$ ) and vegan women gained less weight than non-vegan (13.2 $\pm$ 4.4 vs. 11.8 $\pm$ 4  $p = 0.037$ ).

**Table 2.** Pregnancy outcome according to diet.

Parameter	Not Vegan (n=176)	Vegan (n= 54)	P
	Mean or Median ±SD/ IQR	Mean or Median ±SD/ IQR	
Birthweight (gr)	3254 ±513.5	3031 ±437	0.004
Percentile (%)	54.5 (27.2,73)	37.5 (20.5,59.2)	0.008
SGA (%)	5.7	14.8	0.041
Male gender (%)	44.9	57.4	0.107

Abbreviations: SGA: Small for Gestational Age.

Nutritional data are presented in Table 3. The macronutrient intake showed significantly lower protein and fat intake in the vegan women compared to non-vegan women both in absolute terms ( $p < 0.001$ ,  $p < 0.028$ , respectively) and after calculating the percentage of calories in total daily intake ( $p < 0.001$ ). In contrast, vegan women showed a significantly higher intake of carbohydrates compared to non-vegans, in total consumption ( $p < 0.038$ ) and in the percentage of calories from carbohydrates out of the total daily caloric intake ( $p < 0.001$ ). Vegan women consumed more dietary fibers, Iron, and Folate compared to non-vegan women ( $p < 0.001$ ). Non-vegan women consumed more Calcium (with and without supplement), Vitamin B12, Vitamin D (with and without supplement) Choline and DHA compared to vegan women ( $p < 0.001$ ). The composition of protein consumed was significantly different in the type of amino acids, both in absolute terms and as a percentage of the total protein consumed. These differences were found in the consumption of Threonine, Isoleucine, Leucine, Lysine, Methionine, Cysteine, Phenylalanine, Tyrosine, Valine, Histidine, and Serine ( $p < 0.001$ ).

**Table 3.** Nutritional intake according to diet.

Parameter	Not Vegan (n=176)	Vegan (n=54)	P
	Mean or Median* ±SD/ IQR*	Mean or Median* ±SD/ IQR*	
Energy (kcal)	2034 (1602,2810)	1967 (1560,2570)	0.692
Fat(gr)	79 (61,115)	72 (54,99)	0.028
Fat (% From Calories)	35 ±5.9	31 ±6.9	<0.001
Protein (gr)	82 (65,112.5)	60 (46,82)	<0.001
Protein (% From Calories)	16 ±3.4	12 ±1.8	<0.001
Carbohydrates (gr)	217 (179,296)	256 (203,311)	0.038
Carbohydrates (% From Calories)	45 ±7.2	52 ±7.9	<0.001
Fibers (gr)	30 (22,43)	48 (38,61)	<0.001
Calcium (mg)	1053 (839,1412)	764 (610,944)	<0.001
Calcium Total (mg)	1212 (1032,1597)	970 (762,1107)	<0.001
Iron (mg)	12.7 (9.8,17.5)	17 (14,21)	<0.001
Iron Total (mg)	72.2 (41,79)	76.6 (41,83)	0.03
Vit B12 (mcg)	4.6 (2.8,6.5)	1.5 (0.7,2.6)	<0.001
Vit D (mcg)	5.5 (3.3,9.8)	0.24 (0.15,0.47)	<0.001
Vit D Total (mcg)	12.6 (9.5,12.5)	8.8 (0.47,9)	<0.001
Zinc (mg)	9.7 (7.6,13.7)	9.5 (7.7,12)	0.397
ALA (gr)	2.18 (1.5,3)	2.5 (1.8,3.5)	0.052
Folate (mcg)	416 (330,604)	627 (512,812)	<0.001
Choline (mg)	394 (287,538)	270 (225,351)	<0.001
DHA (gr)	0.07(0.027,0.149)	0 (0,0)	<0.001
Tryptophan (gr)	7.16 (3.9,12.7)	4.2 (3.9,12.6)	0.546

Threonine (gr)	2.5 (1.8,3.4)	1.3 (1.1,1.8)	<0.001
Isoleucine (gr)	2.8 (2,3.9)	1.4 (1,1.9)	<0.001
Leucine (gr)	5 (3.6,6.8)	2.4 (1.7,3.1)	<0.001
Lysine (gr)	4.28 (2.9,5.9)	1.6 (1.2,2.3)	<0.001
Methionine (gr)	1.37 (0.9,1.9)	0.6 (0.4,0.8)	0.001
Cysteine (gr)	0.7 (0.5,1)	0.6 (0.4,0.7)	<0.001
Phenylalanine (gr)	2.9 (2.1,4)	1.7 (1.3,2.2)	<0.001
Tyrosine (gr)	2.3 (1.7,3.2)	1.02 (0.7,1.3)	<0.001
Valine (gr)	3.49 (2.4,4.7)	1.7 (1.3,2.2)	<0.001
Arginine (gr)	3.3 (2.5,4.6)	2.7 (1.9,3.8)	<0.001
Histidine (gr)	1.6 (1.1,2.3)	0.8 (0.6,1.1)	<0.001
Serine (gr)	3.2 (2.3,4.3)	1.8 (1.3,2.3)	<0.001
Tryptophan %	9.18 (3.6,16.7)	10.9 (4.1,23.4)	0.286
Threonine %	2.9 ±0.34	2.2 ±0.32	<0.001
Isoleucine %	3.3 ±0.42	2.3 ±0.34	<0.001
Leucine %	5.9 ±0.81	4 ±0.6	<0.001
Lysine %	5 ±0.84	2.7 ±0.53	<0.001
Methionine %	1.6 ±0.27	0.95 ±0.2	<0.001
Cysteine %	0.88 ±0.12	0.93 ±0.15	0.026
Phenylalanine %	3.5 ±0.41	2.8 ±0.4	<0.001
Tyrosine %	2.7 ±0.45	1.7 ±0.28	<0.001
Valine %	4 ±0.57	2.8 ±0.4	<0.001
Arginine %	4 (3.6,4.3)	4.1 (3.5,4.9)	0.148
Histidine %	1.9 ±0.24	1.4 ±0.2	<0.001
Serine %	3.8 ±0.47	2.9 ±0.38	<0.001

Abbreviations: % From Calories: Percentage of total daily calories, Total: Nutritional intake plus consumption of dietary supplements, % Amino acid: Percentage of total protein consumed.

Table 4 presents the results of the logistic regression analysis with SGA as the dichotomous outcome variable. In the fully adjusted model, a higher percentage of protein in the maternal diet was found to be independently associated with a significantly lower risk of SGA (OR = 0.80, 95% CI: 0.67–0.96,  $p = 0.014$ ). No significant associations were observed for maternal pre-pregnancy weight, dietary fat, carbohydrate percentage, or adherence to a vegan diet.

**Table 4.** Logistic regression analysis for factors associated with small-for-gestational-age (SGA) neonates.

	Parameter	OR	95% Confidence Interval		Sig.
			Lower Bound	Upper Bound	
Step 1	Pre_weight	0.994	0.937	1.055	0.838
	Vegan	1.452	0.420	5.017	0.556
	Gender (female)	2.348	0.749	7.361	0.143
	Protein %	0.866	0.707	1.061	0.165
	Carbohydrate %	0.996	0.918	1.080	0.918
	Fat %	0.954	0.86	1.058	0.37
	Constant	3.037			0.782
Step 2	Pre_weight	0.994	0.937	1.054	0.834
	Vegan	1.433	0.425	4.828	0.561
	Gender (female)	2.359	0.755	7.369	0.14
	Protein %	0.867	0.708	1.062	0.167
	Fat %	0.957	0.876	1.045	0.324
Constant	2.225			0.764	
Step 3	Vegan	1.454	0.435	4.865	0.543
	Gender (female)	2.416	0.789	7.393	0.122

	Protein %	0.866	0.707	1.06	0.162
	Fat %	0.957	0.877	1.045	0.330
	Constant	1.489			0.829
Step 4	Gender (female)	2.27	0.757	6.802	0.143
	Protein %	0.846	0.7	1.023	0.084
	Fat %	0.953	0.873	1.041	0.286
	Constant	2.779			0.505
Step 5	Gender (female)	2.29	0.767	6.835	0.137
	Protein %	0.807	0.677	0.962	0.016
	Constant	1.112			0.936
<b>Step 6</b>	<b>Protein %</b>	<b>0.802</b>	<b>0.673</b>	<b>0.956</b>	<b>0.014</b>
	Constant	1.997			0.577

According to the CHAID algorithm, the proportion of the amino acid leucine relative to total dietary protein had the strongest association with neonatal birthweight. The mean birthweight of neonates born to women whose leucine intake exceeded 5.636% of total protein was 267 g higher than that of neonates whose maternal leucine proportion was equal to or below this threshold ( $p=0.003$ ).

#### 4. Discussion

In this prospective study we have shown that there is an association between a vegan diet and an increased risk of SGA which may be mediated by insufficient protein levels and lower Leucine intake.

Our finding that lower birthweight among vegan might be explained due to insufficient protein levels is supported by other studies[14,15]. A recent study based on the Danish National Birth Cohort which included 18 vegan women, demonstrated lower protein intake among vegan pregnant women and lower birthweight by an average of ~240 g[16]. The researchers attributed the differences in neonatal birthweights to the lower protein intake observed among vegan women compared to omnivorous women.

We demonstrated a significant association between higher protein intake and a 0.8-fold lower risk of delivering SGA neonate. Protein intake among women who adhere to vegan diet was only 12% of total daily calories, compared to 16% among non-vegan women which is lower than the recommendations of 14%-17% protein intake during pregnancy [17] without any differences in caloric intake between the groups.

Additionally, our findings highlight the significant importance of protein composition. Neonates of women who consumed more than 5.636% Leucine had a higher birthweight of an average 267 g more than those with lower intake. This finding is supported by previous studies which described the changes in amino acid metabolism from early pregnancy. Herring et al. described a significant increase in protein synthesis in the second and third trimesters along with a decrease in protein catabolism indicating high utilization for protein during pregnancy[17,18]. These studies indicated that during pregnancy there is an increased demand for all amino acids with variations between different amino acids and throughout the stages of pregnancy[17,18].

Leucine nutritional requirement during pregnancy is higher than other amino acids [18]. In vivo studies have found that Leucine significantly contributes to fetal growth. The fetal/maternal Leucine ratio is lower among fetuses with intrauterine growth restriction (IUGR) compared to appropriate growth fetuses [19]. Leucine has been reported to be linked to early fetal development through the Mammalian Target of Rapamycin (mTOR) pathway and its action [20]. The mTOR regulates cell growth and protein synthesis by controlling the gene transcription and mRNA translation rate. It is particularly sensitive to the supply of BCAAs and especially Leucine [20]. In addition, Leucine is a Hydroxy Beta-Methyl butyric acid (HMB) substrate that activates anabolic processes. Its consumption during late gestation has been demonstrated to positively affect fetal development in an animal model[21].

Our findings are supported by other studies which demonstrate that a vegan diet is associated with significantly higher intake levels of dietary fibers and carbohydrates [5]. Additionally, vegan pregnant women consumed less fat both in absolute terms and as a percentage of total daily caloric intake.

The micronutrients intake pattern of vegan women exhibited significantly lower levels of Calcium, vitamin D, Choline, and vitamin B12 compared to their non-vegan counterparts. These results are aligned with previous studies highlighting the increased risk of inadequate intake of these nutrients in vegan diet [5,16]. Although prenatal multivitamin supplementation in vegan women reduced the gap between actual calcium intake and the Dietary Reference Intake (DRI) of 1000 mg/day, their intake remained below the recommended levels for vegans, which range from 1200 to 1500 mg/day[5].

Like Calcium, vitamin D levels among vegans remained below the RDA of 15 µg/day for pregnant women, even after supplementation. This low intake of vitamin D, including among non-vegan women, is consistent with national guidelines in Israel recommending routine vitamin D supplementation for all pregnant women[12]. Vitamin D deficiency during pregnancy has been associated with neonatal rickets, gestational diabetes, preeclampsia, preterm birth, and small for gestational age (SGA) infants[6].

The low Choline consumption in both groups is also consistent with recent data on the widespread lower levels in both general population and pregnant women[22]. The two groups did not reach the recommended dietary intake, but among the vegan group, the differences between the actual consumption and the recommendations were higher and stood at 270 mg/day compared to the recommendation for 450 mg/day in the United States or 480 mg/day in Europe[23]. Choline plays vital roles in lipid transport, membrane structure, neurotransmission, and methyl group donation. During pregnancy, maternal choline demand increases significantly, as large amounts are transferred to the fetus. Deficiency during pregnancy is linked to adverse outcomes, including neural tube defects, impaired cognitive development, and maternal complications such as acute fatty liver(24). Interestingly, despite the available data, there are no recommendations regarding the supplementation of Choline for pregnant and/or vegan women, and most multivitamin supplements for pregnant women do not contain choline [22].

Neither group met the recommended Iron intake of 27 mg/day during pregnancy, and vegan women who require approximately 80% more due to lower iron bioavailability, remained particularly below target[4]. These findings support current evidence of inadequate iron intake among pregnant women[6] and reinforce the recommendation for routine iron supplementation as a preventive measure against anemia[6].

The strengths of our study lie in its examination of a strictly vegan diet, with all its inherent limitations, and in the relatively large number of vegan women included in the cohort. Nevertheless, our study has several limitations. First, the nutritional data was collected from self-report questionnaires. Women were asked to complete the questionnaires from the third trimester of pregnancy and towards birth. It is likely that the women maintained the same lifestyle throughout the pregnancy, but responses may not fully reflect dietary intake during the earlier stages. In addition, standard FFQs may not fully capture vegan-specific foods, such as fortified products and plant-based alternatives, potentially leading to underestimation of intake in this group. Finally, being a single-center study, the results might not represent all population sectors.

## 5. Conclusions

This prospective study demonstrates that an increased risk of SGA among vegans is potentially due to insufficient protein and specific amino acid deficiencies, notably Leucine. Pregnant women, irrespective of diet, exhibit lower-than-required intake of Iron, Vitamin D, and Choline. These deficiencies, including vitamin B12 and Calcium, are more pronounced among vegans. Women at risk of nutritional deficiencies, particularly those adhering to vegan diet, should seek professional nutritional guidance.

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**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Conflicts of Interest:** The authors declare no conflicts of interest.

## Appendix A

**Table A1.** Prenatal supplement adherence in vegan versus non-vegan women.

Parameter	All (n=225-230)	Not Vegan (n=171-176)	Vegan (n=54)	P
Multivitamin	158 (70%)	122 (70.2%)	36 (66.7%)	0.609
Iron supplement	167 (72.6%)	129 (73.3%)	38 (70.4%)	0.728
B12 supplement	76 (33%)	46 (26.1%)	30 (55.6%)	0.000
Folic acid supplement	145 (63%)	110 (62.5%)	35 (64.8%)	0.872
Omega 3	78 (33.9%)	55 (31.3%)	23 (42.6%)	0.140

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