

# We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

5,200

Open access books available

129,000

International authors and editors

150M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index  
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?  
Contact [book.department@intechopen.com](mailto:book.department@intechopen.com)

Numbers displayed above are based on latest data collected.  
For more information visit [www.intechopen.com](http://www.intechopen.com)



# Undernutrition during Pregnancy

*Hoang Anh Nguyen*

## Abstract

Experience in being pregnant is exciting but is very challenging. The term “undernutrition,” as used in this chapter, focuses more on inadequate intake of energy and nutrients to meet the desired outcome of a healthy mother and her baby. Evidence shows that women with undernutrition before and during pregnancy have increased risk of metabolic disorders (i.e., gestational diabetes mellitus) and are at increased risk of complications during labor and birth. To date, nutritional therapies promoting healthier pregnancies fall into the following two major categories: (1) management of gestational weight gain and (2) the prevention or treatment of nutrient deficiencies related to pregnancy. A literature search on PubMed, the Cochrane library, Google scholar, and Cumulative Index of Nursing and Allied Health Literature was conducted to identify the relevant nutritional therapies. As a result, this chapter will analyze and discuss gestational weight gain and its effect on the health of women and her baby. The chapter briefly proposes evidence-based nutritional therapy for gestational diabetes as well as gestational common nutrient imbalance, such as vitamin D, folic acid, and omega-3 docosahexaenoic acid deficiency. The recommendations, in this chapter, would be a partial answer for these problems in Asia.

**Keywords:** gestational diabetes mellitus, gestational weight gain, folate deficiency, vitamin D deficiency, omega-3 docosahexaenoic acid, pregnancy outcomes

## 1. Introduction

The association between inadequate intake of energy and nutrients before and during pregnancy and severe maternal outcomes has been well documented in the observational studies. It is crucial for women to be fully aware of nutrition requirements without waiting until getting a positive pregnancy test result. The reason for this is that there are major changes associated with metabolism and physiology to support embryo development in the mother. The mother’s diet is the only source of nutrition for her baby. Maternal undernutrition may affect the developing baby. Weight gain is a part of healthy pregnancy, but the recommendation for an optimal gestational weight gain is still controversial, especially in Asian countries. Moreover, some observational studies have shown that gestational diabetes and nutrient deficiencies during pregnancy may need to be considered differently for an individual’s prenatal body mass index (BMI). Thus, in this chapter, an attempt was made to address these issues. Moreover, the role of personalized nutritional counseling, as discussed in each issue, needs to be understood carefully.

## 2. Gestational weight gain

Getting pregnant leads to significant changes of weight in the body of women. It is normal for women to put on more weight in the last two trimesters than the first trimester as it supports the growth of fetus, the placental development, and amniotic fluid as time goes. However, putting on weight very quick per week (i.e., 0.5–1 kg in a week) is strongly associated with a life-threatening condition, such as preeclampsia [1, 2], so it is worth to notice healthcare professionals about abnormal weight gain. A woman with prepregnancy overweight and obesity should take a plan of gestational weight gain GWG into account during prenatal visits. A cohort study of 3539 women with a follow-up period of 17 years demonstrated that overweight women (BMI > 25) at the beginning of pregnancy had an increased risk of diabetes, cardiac disease, or endocrine diseases later in their life [1]. Moreover, excessive or inadequate weight-gain levels during pregnancy can affect small or large gestational age, an increased risk of cesarean delivery, and other adverse pregnancy outcomes, including gestational diabetes mellitus and preeclampsia [1–4].

The World Health Organization definition of body mass index (BMI) is “a person’s weight in kilograms divided by the square of the person’s height in meters ( $\text{kg}/\text{m}^2$ ).” For instance, a pregnant woman who weighs 50 kg and her height is 1.6 m will have a BMI of 19.5. BMI has been well recognized as an effective measurement to identify overweight and subsequent health risks in an individual. The increasing level of BMI from overweight to extreme obese is thought to accompany the increasing risk of health problems (Canadian Health Guideline 2004). The American Institute of Medicine (IOM) recommended the ideal amount of weight gained during pregnancy based on WHO-BMI ranges from underweight to obesity, but not all obesity classes were addressed (**Table 1**). The origin of the IOM recommendations about gestational weight gain (GWG) came primarily from the American population-based studies despite its popular applicability to European and Asian countries. In the Asian population-based studies reviewed, the recommendations of the IOM concerning gestational weight gain (GWG) have limited applicability for Asian women to get their desired GWG. The accumulated evidence on noncommunicable diseases demonstrated that Asian adults get more body fat and have greater risks of diabetes and cardiovascular diseases at their lower BMI in comparison with non-Asian population. Thus, Asian regional BMI cutoff points [6] developed by the panel of WHO consultation minimize these risks (**Table 2**). A large meta-analysis study with more than 300,000 Asian women confirmed that the IOM recommendations about GWG can be applicable in Asian countries when using regional BMI cutoff points for overweight or obese [7]. The evidence was not attempted to define a GWS guideline for all Asian women as the data of this study were based primarily on East Asian countries, such as China, Taiwan, Korea, and Japan. Moreover, Korean and Taiwanese women tend to gain more weight during pregnancy than other Asian women [8]. This requires more comparative studies in Asia. However, its strength confirmed that the guideline for GWG may need to be considered differently for Asian women. To date, a global consensus regarding a desired GWG is still understudied.

| Recommendations                         | Underweight | Normal weight | Overweight | Obese     |
|---|-------------|---------------|------------|-----------|
| Prenatal BMI ( $\text{kg}/\text{m}^2$ ) | <18.5       | 18.5–24.9     | 25.0–29.9  | $\geq 30$ |
| Total weight gain range (kg)            | 12.5–18     | 11.5–16       | 7–11.5     | 5–9       |

**Table 1.**

*Recommended weight gain during pregnancy based on the 2009 Institute of Medicine (IOM) guideline [5].*

|               | Asian BMI cutoff points (kg/m <sup>2</sup> ) | Total weight gain range (kg)* |
|---------------|--|-------------------------------|
| Underweight   | <18.5  | 12.5–18                       |
| Normal weight | 18.5–22.9                                    | 11.5–16                       |
| Overweight    | 23–27.5                                      | 7–11.5                        |
| Obese         | 27.6–29.9                                    | 7–11.5                        |
|               | ≥30  | 5–9                           |

*\*These recommendations suggested by the author should only be used as a reference for public health strategists, nutritional practitioners, or healthcare professionals in Asia. These recommendations were based on ideas in a large meta-analysis study [7]; thus, they are not considered as a completed guideline.*

**Table 2.**  
 The proposed gestational weight gain recommendation based on Asian regional BMI cutoff points [6].

An excessive amount of weight gained during pregnancy could be predictive of weight retention at 6 months postpartum [2] and of an increased risk of weight management challenges later in life [3, 4]. A meta-analytic study of over 65,000 women by Nehring et al. demonstrated that women with GWG above the IOM recommendations were likely to have an additional gain of 3 kg at 3 years and of 4.7 kg at 15 years after pregnancy, compared to those with GWG within the recommendations [3].

## 2.1 Brief nutrition recommendations for gestational weight gain

Transitions to a new weight gain during a pregnancy may need to meet additional calories every day. According to the IOM expert panel's recommendation on macronutrients for pregnant women with normal BMI, an estimation of additional 0, 340, and 452 kcal for the first, second, and third trimester, respectively [9, 10] was recommended. Moreover, additional calories should also be personalized to an individual's prenatal BMI [10].

- If prenatal BMI is less than 18.5 kg/m<sup>2</sup>, the mother needs to begin an additional 150 kcal per day for her first 3 months, and continuously add 50 and 150 kcal for her second and third trimester, respectively. They can benefit from protein supplements [10].
- If women are overweight or obese, they do not need to add calories in their first trimester. In two last trimesters, they need to add between 450 and 500 kcal per day to meet their gestational weight gain. Prenatal overweight or obesity is strongly associated with an increased risk of pregnancy complications as well as postpartum weight retention. They may need supports to lose weight effectively during prenatal visits. Evidence has shown that overweight or obese women who reduced at least 3 BMI units before conception can lower the chance of developing gestational diabetes by two-fold [10, 11].
- For multiple pregnancy, woman with normal BMI should consume about 40–45 kcal/kg/day while an estimated 30–35 and 42–50 kcal/kg/day have been advised for overweight and underweight BMI, respectively [12–14].

Adding small meals or one or two extra snacks during the day may facilitate these targets. There is no need to stick on high-energy density diets, but, a balanced diet with nutrient-dense foods has the benefit of providing a range of vitamins and minerals.

### 3. Management of gestational diabetes mellitus during pregnancy

Gestational diabetes mellitus (GDM) is one of the common pregnancy complications related to diet. Pregnancy is related with a biological reduction of insulin sensitivity by about 60% [15], which supports fetus development by an increase of glucose into the placenta. Some women were present with elevated blood glucose levels during their pregnancy although no diabetes was diagnosed before their pregnancy. The excessive blood glucose level can cause hyperglycemia which will develop gestational diabetes mellitus. Fortunately, the well-managed blood glucose levels typically turn normal after delivery. GDM globally happens in about 3–28% of pregnant women. The prevalence of GDM in European countries is about 5.4%, while 10.1% GDM occurs in Eastern and Southeastern Asian countries, except in Indonesia, the Philippines, Myanmar, Cambodia, and Laos [16]. Among the latter, Vietnam and Singapore have the greatest prevalence of GDM (about 20%). The prevalence of diabetes during a pregnancy has been increasing markedly in Africa and Asia [16]. It is closely associated with the increase of obesity and sedentary lifestyle. It is the most common medical complication during a pregnancy. Women with a healthy weight can be affected. This is likely due to participation of pregnancy-related hormones, such as human placental lactogen (HPL). A 30-fold increase of HPL by the 20th week of gestation causes improperly elevated blood sugar levels, which contributes to the developing GDM between the second and the third trimester [17, 18]. However, women who enter into pregnancy overweight or obese are at a markedly increased risk of developing GDM. The increased release of pro-inflammatory cytokines and adiponectin was associated with an accumulation of adipose tissues, particularly with central obesity [19–21]. These releases contribute to a severe GDM, including increased glucose blood levels [22], endoplasmic reticulum stress [23], and increased insulin resistance [21, 24]. Women, diagnosed with a lower adiponectin concentration at their early trimester, are likely to develop an increased insulin resistance and GDM later in their semesters [25].

Several adverse outcomes are associated with diabetes during a pregnancy: mothers with the untreated GDM have a higher risk of hypertension, preeclampsia, cesarean delivery, and labor complications; their babies are at increased risk of macrosomia, large for gestational age, fetal organomegaly, shoulder dystocia, hypoglycemia, and perinatal morbidity and mortality due to the excessive glucose flux into the placenta [26, 27].

#### 3.1 Nutritional therapy for gestational diabetes mellitus

The role of nutrition in the management of gestational diabetes mellitus is now drawing considerable attention in public because of the natural process without side effects for women and their unborn baby. Diet-based interventions in the pregnancy aim to control maternal hyperglycemia as well as to lower risks of macrosomia. The concept of these interventions is a three-step nutritional therapy (NT), including a personalized dietary counseling, appropriate energy restriction, and promotion of a balanced diet.

Some observational studies reviewed that it is beneficial for women to take three-step NT into consideration in prenatal or early pregnancy visits if they have one or more of the following contributory factors for GDM [28–30]:

1. Being overweight or obese (BMI cut offs  $\geq 23$  kg/m<sup>2</sup> for Asian population; BMI  $\geq 25$  kg/m<sup>2</sup> for non-Asian population)

2. Having GDM or abnormal glucose tolerance in previous pregnancy
3. Having diagnosed polycystic ovary syndrome (PCOS)
4. Having macrosomia in previous pregnancy (birth weight > 4 kg)
5. Having a family member with diabetes
6. Hypertension (140/90 mm Hg) [12] or recurrent hypertension
7. Secondary lifestyle
8. HDL < 35 mg/dL, triglyceride > 250 mg/dL
9. High risk race: Asian, Indian subcontinent, Aboriginal and Torres Strait Islander, Pacific Islander, Maori, Middle Eastern, non-white African.

### **3.2 A personalized counseling for GDM**

Women with diagnosed gestational diabetes need to be put on a proper diet. Thus, they should seek a tailored nutritional counseling by a registered nutritional therapist. Personalized dietary counseling was associated with a well-controlled maternal hyperglycemia and a proper weight gain due to the mothers' better awareness about GDM and meal plans [31, 32]. The dietary counseling needs to be tailored for an individual; this consists of things like not only her diet and lifestyle but her expectation and barrier. For instance, the nutritional advice on a restricted diet of fast foods should also discuss about where a patient can get healthy foods and her related barriers. Moreover, understanding the effects of the dietary advice on not only an individual but also her family members has shown the significant improvement of clinical outcomes [33, 34]. This is likely due to family member's additional support.

Some meta-analysis and systematic review studies demonstrated that women with GDM had encountered the weight management, in particular overweight or obese people [32]. A majority of these cases are largely associated with their unhealthy lifestyle choices, including low physical activities, problematic portion control, and poor diet. In the context, the counseling needs to take these issues into consideration. Moreover, it is important to promote healthy food choices in the consultation. Importantly, the nutritional advice for GDM is tailored, relevant, and applicable to the patient.

### **3.3 Energy restriction and appropriate weight gain for GDM**

Energy restriction aims to ensure that women and their babies get enough energy to develop and grow, but minimizes the reductant amount of weight gained. The influence of energy balance on dietary macronutrient intake and physical activity could be considered as a primary factor in the reduced fat composition. There is some established evidence that moderate caloric restriction can improve maternal hyperglycemia as well as reduce insulin requirement, but, there is no association between restricted caloric intake and birth weight. However, severe caloric restriction to either less than 1200 kcal per day or 50% of daily energy

requirement is related to the production of ketonuria and ketonemia, which is called ketosis [35, 36]. According to the recommendations of American Diabetes Association about energy restriction, obese women with GDM can benefit from a 30–33% energy restriction or a limit of 25 kcal per kg per day, but there was no report related to GDM women with normal weight [35, 37, 38]. Some studies suggested a caloric restriction of 30–34 kcal/kg (actual weight of pregnant women) for those with normal BMI [36]. However, further interventional studies are needed to take this recommendation into action.

### 3.4 Promotion of a balanced diet with high fiber and low carbohydrate

The transport of glucose into the placenta depends on how accelerated the mother's postprandial blood glucose concentrations are. The excessive amount of glucose crosses the placenta, which can affect birth weight. A postprandial high blood glucose levels in GDM women is typically higher. Insulin is a metabolic hormone released from beta-cells in the pancreas, which play an essential role in the blood glucose regulation. Dietary carbohydrate is absorbed into the intestine and converted into simple glucose, which leads to a significant increase of maternal blood glucose concentrations. After a meal, GDM women found normoglycemia very challenging. They sometimes need medications to turn their blood glucose normal. One of the major purposes in the GDM nutritional management is thus to achieve normoglycemia after meal. The postprandial blood glucose level depends on the amount of glucose absorbed in the intestine and released into the bloodstream. There is some established evidence that a diet rich in fibrous carbohydrate, such as vegetables and fruits, and low in starchy and high glycemic index carbohydrate, may be helpful to reduce postprandial blood glucose as well as to change body fat composition [39, 40]. The American Diabetes Association guideline focuses on how much energy from dietary carbohydrate a GDM woman consumes [41]. The guideline demonstrated that the consumption of dietary carbohydrate among women with GDM should be limited to 40–45% of total daily energy, with a smaller percentage at breakfast than at lunch or dinner.

Glycemic index (GI) is a measurement related to the amount of carbohydrate in certain foods and its effect on a blood glucose increase after eating, a rank of values from 0 to 100. A high GI in foods ( $\geq 70$ ) causes a sharp increase in blood glucose compared with a food with a medium (56–69) or low GI ( $\leq 55$ ). Some established evidence recommended that the GDM women can consume low GI or complex carbohydrates, even greater than 45% of the total energy, without a quick response of increased blood glucose [42, 43]. Glycemic control can be achieved by increasing the consumption of foods with low GI, such as whole grains, green vegetables, and legumes, instead of high-GI foods like potatoes or sweet foods. Rice, a starchy food, is routinely eaten by 60% of world population, primarily in Asian countries. Approximately three-fourths of the total carbohydrate calorie requirement in Southeast Asia comes from rice [44]. Like potatoes or white breads in western countries, white rice can be a staple part of Asian meals. Unfortunately, the refined white rice may increase risk of hyperglycemia. It is a challenge for Asian women with GDM to avoid white rice due to its preferred taste or flavor, but following a low-GI diet guideline along with white rice will facilitate their glycemic control (**Table 3**). Several conventional studies demonstrated that the different types of rice have variations in GI value. For instance, among 12 types of rice commercially available in the United Kingdom, a nonblind, randomized trial indicated that rice noodles, long-grain rice, white basmati rice, and easy-cook long-grain rice were classified as low-GI foods, compared with others [45]. This is likely due to the difference in amylose composition and its effect on gelatinization [46, 47] rather

| Groups                 | Foods   |
|------------------------|---|
| Starchy foods          | Limit a cup of white rice a day. Avoid white rice or glutinous rice in breakfast or late dinner.<br>Swap white rice for the low-GI starchy foods, such as rice noodles, brown rice, udon noodles, whole spaghetti, and sweet corn.<br>Should be chosen preferentially   |
| Raw Fruits             | <b>Swap fruit juices or soft-drinks for low-GI raw fruits</b> , such as apple, orange, grapefruit, green grape, and banana; 1–2 servings (80–160 g) a day.<br><b>Accepted fruit juices:</b> Apple and orange  |
| Vegetables and legumes | Boiled/steamed/raw vegetables or vegetable soups from carrots, sweet potato, pumpkin, green banana and green leafy vegetables (i.e., spinach, green broccoli, or Moringa leaves); 3–4 servings (240–320 g) per day.<br><b>Low-GI legumes:</b> red kidneys, soy beans, and black beans; 1–2 servings per week.   |
| Dairy products         | Natural/white yogurts; 1–2 servings a day.  |
| Meats                  | About 20% of total energy with smaller proportions in red meats than oily fish and chicken.   |
| Things to avoid        | <ul style="list-style-type: none"> <li>• Fast foods and animal fat or skin.</li> <li>• Skipping meals.</li> <li>• Alcohol or alcoholic drinks.</li> <li>• Drinking soft drinks or sugary foods between meals.</li> <li>• Very big meal; keeping meals medium sized and regular will prevent hyperglycemia throughout the day. Additional healthy snacks would be beneficial.</li> </ul> |

**Table 3.**  
*Recommended low-GI diet for Asian pregnancy with GDM.*

than the dietary fiber content solely [46]. Rice with higher amylose composition has greater GI. The gelatinization represents the thickening of starch granules when heated in the presence of water. Thus, rice with greater gelatinization, such as glutinous rice, will have higher GI [48].

The evidence stated that the consumption of a high amount of fat, particularly with saturated fatty acids, can affect both the insulin-induced signaling pathway on cell membranes and lipid metabolism after a meal [49, 50]. Saturated fatty acids in strong relation to insulin resistance are well documented in not only epidemiological but also intervention studies [51]. Moon demonstrated that diets rich in saturates appear to impair the insulin-induced normal signaling by reducing IRS-1 expression and phosphorylated PI3K levels [52]. This results in significantly decreased transfer of glucose across the muscle cell membrane via GLUT-4, glucose transporter proteins, and the increased serum glucose. In addition, in a current study on mice with impaired Toll-like receptor-4, Zhou also demonstrated that saturated fatty acids are associated with glucose intolerance through reducing functions of nucleotide-binding oligomerization domain 1 (NOD1) in insulin-stimulated glucose uptake in adipocytes [53]. Thus, women with GDM may need to avoid saturated fats, but increase consumption of polyunsaturated fatty acids, especially fish oil [54]. A randomized double-blinded, placebo-controlled trial on fish oil supplementation and its effects on GDM demonstrated that omega-3 supplementation was associated with upgraded expression of genes related to insulin activities and inflammation among GDM women [55]. To date, taking omega-3 supplements routinely has not been recommended for the treatment of GDM due to lack of evidence. However, omega-3 supplements may need to be considered additionally for pregnant women if they find fish consumption challenging.



#### 4. Management of vitamin D deficiency during pregnancy

Vitamin D is essential for absorption of dietary calcium and phosphate in the small intestine and for the deposition of calcium and phosphate in the mother's bones, and for her baby's as well. Moreover, maternal vitamin D was known as the only source for the unborn baby. Gestational vitamin D deficiency during pregnancy is related to infantile rickets. Moreover, the lack of vitamin D in the first trimester of pregnancy is predictable to preeclampsia and gestational diabetes mellitus [56, 57]. Maternal vitamin D is primarily synthesized under her skin while exposed to sunlight. First, due to sunlight, the 7-dehydrocholesterol under skin will be converted into cholecalciferol (vitamin D<sub>3</sub>). Then, the hydroxylation of vitamin D<sub>3</sub> in the liver occurs to form 25(OH)D. Finally, 25(OH)D is continuously hydroxylated in the kidney to become a biologically more active form, 1,25(OH)<sub>2</sub>D. Serum 25(OH)D concentrations are clinically measured to indicate an individual's vitamin D status due to its stable half-life of 2–3 weeks. There is some established evidence that inadequate serum vitamin D concentrations at early childhood puts individuals into a higher risk of metabolic disorders later in their life, such as heart disease and diabetes as vitamin D receptors are present in almost tissues.

Those women who smoke, use sunscreen, or cover their skin with clothing increase significantly risk of vitamin D deficiency. Unfortunately, some individuals have encountered getting an adequate amount of vitamin D due to their darker skin tone. A global sunshine calendar developed by the Vitamin D Day (<https://www.vitamindday.net/>) suggested a practical tip for an individual to get enough vitamin D while exposed to sunlight, no matter where he or she lives.

One of the biggest concerns about getting vitamin D from sun is skin cancer due to ultraviolet (UV) radiation exposure. There was an association between less education and misconception of vitamin D from sunlight. A cross-sectional survey of 3922 participants in the United States demonstrated that individuals with a high school diploma or less had misconception of a longer sunlight exposure related to achievement of a sufficient vitamin D, which may need more studies about vitamin D-related sun exposure behaviors and risk of skin cancer [58]. In natal visits, it is important for registered nutritional practitioners to take women's vitamin D knowledge as well as their sun safety behaviors into consideration [59].

Mushroom, oily fish, egg yolks, and vitamin D fortified milk is a dietary source of vitamin D. Oral vitamin D supplementation is as available as drops or tables, which can be taken over the counter or on registered nutritional practitioner's prescription. Oral vitamin D supplementations among pregnant population have shown to improve maternal vitamin D status and lower risk of premature birth delivery. According to the guideline of the Royal College of Obstetrics and Gynecology (RCOG), a daily vitamin D supplementation of 400 units is recommended for women with singleton gestation [60]. To date, there is still no vitamin D guideline for twin or multiple pregnancies although it shares an increased risk of gestational outcomes. Some experts from the Society of Maternal Fetal Medicine suggested that women with twin gestations should consume daily vitamin D supplementations of 1000 units [61]. Oral vitamin D supplementations within the guideline, plus sunlight exposure, will not lead to symptoms of excessive vitamin D.

There is a hypothetical concern that which is better: taking vitamin D supplementation alone or in combination with calcium? The evidence from a Cochrane systematic review confirmed that the consumption of vitamin D combined with calcium is related to an increased risk of premature birth [62]. The effect and cause behind the evidence were not well documented. Thus, it is important for the registered nutritional practitioners or nutritional therapist to take measures to

manage this risk when making a description of vitamin D combined with calcium for preeclampsia. It is beneficial for public to take vitamin D supplement alone over the counter within the guideline.

Women who enter into pregnancy obese are also at increased risk of nutrient deficiencies, in particular, deficiencies of vitamin D. Also in pregnant women, BMI is inversely associated with the serum concentrations of vitamin D. Obese women are at a markedly increased risk of vitamin D deficiency compared to women with BMI in the normal range, and the offsprings of obese women also have lower levels of vitamin D in their cord blood. The prevalence of vitamin D deficiency in pregnant women can be quite high in some populations, reaching, for example, one third in the USA, 35% in the UK, and 77% in Germany [63]. Vitamin D is believed to be sequestered in the adipose tissue, making it less available in obese people.

Hence, obese women have an even higher prevalence of vitamin D deficiency during pregnancy. Recently, the RCOG guidelines recommended that obese pregnant women should be taking at least 1000 units a day of vitamin D supplementation, compared with a daily vitamin D supplementation of 400 units for those women with healthy BMI [60, 64].

Women at higher risk of vitamin D deficiency, such as obesity, need to follow a maternal vitamin D assessment in prenatal, first trimester, and last trimester visits to ensure a proper vitamin D supplementation.

## **5. Management of folic acid deficiency during pregnancy**

Folate or vitamin B9, a family member of water-soluble vitamins, plays an important role in the production of neurotransmitters and synthesis of DNA in cells, especially in early pregnancy. Folate is naturally found in dark green leafy vegetables and legumes while folic acid, a synthetic form of vitamin B9, is generally added in supplements or fortified milk or foods. Folate deficiency in pregnancy generally occurs when maternal dietary supply does not meet a suddenly increased folate requirement for the embryogenesis [65]. This requires an adequate amount of folate prior to conception and continuing throughout within next 28 days, an essential period of neural tube formation. The failure will lead to abnormal fetus development, even death. New parents are often unaware of their pregnancy as well as unprepared of an increased folate demand of this important event [65, 66].

All pregnant women need to consume a daily folate supplementation of 400 µg or 0.4 mg. Folate deficiency is strongly associated with abnormal neural tube development. Evidence has shown that the risk of neural tube defects among obese pregnant women is double that of women with normal BMI. As a result, a higher dosage of folate supplementation is recommended for pregnant women with high BMI. It is important for these women to take this raised amount of folic acid at least a month prior to conception to their first trimester. The Center for Maternal and Child Enquiry jointly with the Royal College of Obstetrics and Gynecology recommends that women with a body mass index higher than 29.9 should take a supplement on top of their diet, with 5 mg of folic acid daily [67]. In contrast, the recommended folic acid dosage for women with a healthy BMI, of course, is only 0.4 mg daily.

## **6. DHA in a pregnancy**

Omega-3 docosahexaenoic acid (DHA; 22:6n-3) is an important component in the cell membrane, specially brain cells. It has been postulated that low maternal

DHA concentrations could be related with increased risk of postpartum depression and preterm birth. During the embryogenesis, maternal DHA levels significantly increased, which may contribute to reduce oxidative stress-induced impairment of the neurotrophic factors [68]. Omega-3 DHA is pronouncedly found in a fetus brain from the last trimester to 12 months after delivery [69, 70]. Oily fish, river eels, and wide carps are often a rich source of omega-3 essential fatty acids (FA). DHA in the diet can be obtained from river eels, wide carps, and marine-derived fatty fish, such as salmon, mackerel, anchovies, sardines, and sea trout. One of the biggest concerns about seafood consumption is risk of mercury exposure. According to the United States Environmental Protection Agency (EPA)'s fish advice, it is safe for pregnant women to consume 2 servings (6.2 ounces or 175 g) of certain cooked fish with a low average mercury concentration ( $\leq 0.15 \mu\text{g/g}$ ) [71, 72]. Some oily fish species labeled as "the best choice to consume" are Atlantic mackerels, anchovies, herrings, haddocks, lobsters, salmon, sardine, and light tuna. However, women, who might become pregnant, should avoid or consume less than 100 g per week predatory fish species, such as bigeye tuna, swordfish, marline, shark, and orange roughy [73–75]. Alternatively, oral DHA supplementation alone of 200–300 mg was recommended for all pregnant women [72].

## **7. Conclusion**

Based on the present work, there are three main conclusions which may help women have a healthy baby during their pregnancy. First, an increase in body weight is necessary during the last two trimesters. However, the gestational weight gain should be interpreted with some cautions related to prenatal BMI, especially overweight or underweight. Second, gestational diabetes is strongly associated with a greater risk of poor pregnancy outcomes. Once diagnosed, diet-based interventions aim to control maternal hyperglycemia. As a result, seeking a tailored nutritional counseling by a registered nutritional therapist will put on a proper diet, including the appropriate management of energy restriction and the promotion of a balanced diet with high fiber and low GI carbohydrate. Moreover, the management of blood glucose during pregnancy may benefit from avoiding saturated fats, but increasing consumption of polyunsaturated fatty acids. Last, it has clearly been shown that pregnant women may find it harder to consume enough specific nutrients, such as vitamin D, folate, and omega-3 DHA. Consuming fortified or enriched foods or oral nutrient supplementations may optimize a diet.

IntechOpen

## Author details

Hoang Anh Nguyen<sup>1,2,3\*</sup>

1 British Association for Nutrition and Lifestyle Medicine, UK

2 Nutrition Informatics and Genomics Unit, Child Nutrition Foundation (CNF), UK

3 Nutrition Therapy, University of Worcester, Worcester, UK

\*Address all correspondence to: [stevenguyen.uk.hcm@gmail.com](mailto:stevenguyen.uk.hcm@gmail.com)

## IntechOpen

---

© 2019 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

## References

- [1] Moll U, Olsson H, Landin-Olsson M. Impact of pregestational weight and weight gain during pregnancy on long-term risk for diseases. *PLoS One*. 2017; **12**(1):e0168543. DOI: 10.1371/journal.pone.0168543
- [2] Haugen M, Brantsaeter AL, Winkvist A, et al. Associations of pre-pregnancy body mass index and gestational weight gain with pregnancy outcome and postpartum weight retention. A prospective observational cohort study. *BMC Pregnancy and Childbirth*. 2014; **14**:201. DOI: 10.1186/1471-2393-14-201
- [3] Nehring I, Schmoll S, Beyerlein A, Hauner H, von Kries R. Gestational weight gain and long-term postpartum weight retention. A meta-analysis. *The American Journal of Clinical Nutrition*. 2011; **94**(5):1225-1231
- [4] Kirkegaard H, Stovring H, Rasmussen KM, Abrams B, Sorensen TI, Nohr EA. How do pregnancy-related weight changes and breastfeeding relate to maternal weight and BMI adjusted waist circumference 7 year after delivery? Results from a path analysis. *The American Journal of Clinical Nutrition*. 2014; **99**(2):312-319
- [5] Institute of Medicine. *Weight Gain During Pregnancy: Reexamining the Guidelines*. Washington, D.C: The National Academies Press; 2009
- [6] WHO Expert Consultation. *Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies*. *Lancet*. 2004; **363**:157-163
- [7] Goldstein RF, Abell SK, Ranasinha S, Misso ML, Boyle JA, Harrison CL, et al. Gestational weight gain across continents and ethnicity: Systematic review and meta-analysis of maternal and infant outcomes in more than one million women. *BMC Medicine*. 2018; **16**(1):153. DOI: 10.1186/s12916-018-1128-1
- [8] Cheng HR, Walker LO, Tseng YF, Lin PC. Post-partum weight retention in women in Asia. A systematic review. *Obesity Reviews*. 2011; **12**(10):770-780
- [9] Institute of Medicine. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*. Washington, DC: The National Academies Press; 2005
- [10] Kominiarek MA, Rajan P. Nutrition recommendations in pregnancy and lactation. *The Medical Clinics of North America*. 2016; **100**(6):1199-1215
- [11] Brown LS. Nutrition requirements during pregnancy. In: Sharlin J, Edelstein J, editors. *Essentials of Life Cycle Nutrition*. USA: Jones & Bartlett Learning Publish; 2011. pp. 1-24. ISBN: 9780763777920
- [12] Oteng-Ntim E, Varma R, Croker H, Poston L, Doyle P. Lifestyle interventions for overweight and obese pregnant women to improve pregnancy outcome: Systematic review and meta-analysis. *BMC Medicine*. 2012; **10**:47
- [13] Goodnight W, Newman R. Society of Maternal-Fetal Medicine. Optimal nutrition for improved twin pregnancy outcome. *Obstetrics and Gynecology*. 2009; **114**(5):1121-1134
- [14] Institute of Medicine. *Dietary Reference Intakes: The Essential Guide to Nutrient Requirements*. Washington DC: The National Academies Press; 2006
- [15] Lacroix M et al. Lower adiponectin levels at first trimester of pregnancy are associated with increased insulin

- resistance and higher risk of developing gestational diabetes mellitus. *Diabetes Care*. 2013;**36**(6):1577-1583
- [16] Nguyen CL, Pham NM, Binns CW, Duong DV, Lee AL. Prevalence of gestational diabetes mellitus in eastern and southeastern Asia. A systematic review and meta-analysis. *Journal Diabetes Research*. 2018;**2018**:6536974. DOI: 10.1155/2018/6536974
- [17] Dias S, Pheiffer C, Abrahams Y, Rheeder P, Adam S. Molecular biomarkers for gestational diabetes mellitus. *International Journal of Molecular Sciences*. 2018;**19**(10):2926
- [18] Kang YE, Kim JM, Joung KH, et al. The roles of adipokines, proinflammatory cytokines, and adipose tissue macrophages in obesity-associated insulin resistance in modest obesity and early metabolic dysfunction. *PLoS One*. 2016;**11**(4):e0154003
- [19] Makki K, Froguel P, Wolowczuk I. Adipose tissue in obesity-related inflammation and insulin resistance: Cells, cytokines, and chemokines. *ISRN Inflammation*. 2013;**2013**:139239
- [20] Romeo GR, Lee J, Shoelson SE. Metabolic syndrome, insulin resistance, and roles of inflammation-mechanisms and therapeutic targets. *Arteriosclerosis, Thrombosis, and Vascular Biology*. 2012;**32**(8):1771-1776
- [21] Tamori Y, Sakaue H, Kasuga M. RBP4, an unexpected adipokine. *Nature Medicine*. 2006;**12**:30-31
- [22] Sudharshana Murthy KA, Bhandiwada A, Chandan SL, Gowda SL, Sindhusree G. Evaluation of oxidative stress and proinflammatory cytokines in gestational diabetes mellitus and their correlation with pregnancy outcome. *Indian Journal of Endocrinology and Metabolism*. 2018;**22**(1):79-84
- [23] Liong S, Lappas M. Endoplasmic reticulum stress is increased in adipose tissue of women with gestational diabetes. *PLoS One*. 2015;**10**(4):e0122633
- [24] American Diabetes Association. Standards of Medical Care in Diabetes. *Diabetes Care*. 2018;**41**(Supplement 1):S13-S27
- [25] Eades CE, Cameron DM, Evans JMM. Prevalence of gestational diabetes mellitus in Europe. A meta-analysis. *Diabetes Research and Clinical Practice*. 2017;**129**:173-181. DOI: 10.1016/j.diabres.2017.03.030
- [26] Sweeting AN, Ross GP, Hyett J, et al. Gestational diabetes mellitus in early pregnancy: Evidence for poor pregnancy outcomes despite treatment. *Diabetes Care*. 2016;**39**(1):75-81. DOI: 10.2337/dc15-0433
- [27] Kim C, Ferrara A, editors. *Gestational Diabetes During and After Pregnancy*. New York: Springer; 2010
- [28] American Diabetes Association. Classification and diagnosis of diabetes. *Diabetes Care*. 2017;**40**(Suppl.1):S11-S24
- [29] The American College of Obstetricians and Gynecologists (ACOG). *Gestational Diabetes Mellitus*. ACOG Practice Bulletin No. 180. USA: The American College of Obstetricians and Gynecologists; 2017
- [30] Farrar D. Hyperglycemia in pregnancy: Prevalence, impact, and management challenges. *International Journal of Women's Health*. 2016;**8**:519-527. DOI: 10.2147/IJWH.S102117
- [31] Shepherd E, Gomersall JC, Tieu J, Han S, Crowther CA, Middleton P. Combined diet and exercise interventions for preventing gestational diabetes mellitus. *The Cochrane*

Database of Systematic Reviews. 2017;  
**11**:CD010443. DOI: 10.1002/14651858.  
CD010443.pub

[32] Han S, Middleton P, Shepherd E,  
Van Ryswyk E, Crowther CA. Different  
types of dietary advice for women with  
gestational diabetes mellitus. The  
Cochrane Database of Systematic  
Reviews. 2017;**2**:CD009275. DOI:  
10.1002/14651858.CD009275.pub3

[33] Khooshehchin TE, Keshavarz Z,  
Afrakhteh M, Shakibazadeh E,  
Faghihzadeh S. Perceived needs in  
women with gestational diabetes: A  
qualitative study. *Electronic Physician  
Journal*. 2016;**8**(12):3412-3420. DOI:  
10.19082/3412

[34] Letherby G, Stephen N, Stenhouse  
E. Pregnant women with pre-existing  
diabetes: Family support in managing  
the pregnancy process. *Human Fertility*.  
2012;**15**(4):200-204

[35] Magon N, Seshiah V. Gestational  
diabetes mellitus: Non-insulin  
management. *Indian Journal of  
Endocrinology and Metabolism*. 2011;  
**15**(4):284-293

[36] Reader DM. Medical nutrition  
therapy and lifestyle interventions.  
*Diabetes Care*. 2007;**20**(3):S188-S193

[37] American Diabetes Association.  
Nutrition principles and  
recommendations in diabetes. *Diabetes  
Care*. 2004;**27**(Supp. 1):S36-S46

[38] Agarwal MM, Dhatt GS, Shah SM.  
Gestational diabetes mellitus:  
Simplifying the international association  
of diabetes and pregnancy diagnostic  
algorithm using fasting plasma glucose.  
*Diabetes Care*. 2010;**33**(9):2018-2020

[39] Wylie-Rosett J, Aebbersold K, Conlon  
B, Isasi CR, Ostrovsky NW. Health  
effects of low-carbohydrate diets:  
Where should new research go? *Current  
Diabetes Reports*. 2013;**13**(2):271-278

[40] Hernandez TL, Van Pelt RE,  
Anderson MA, et al. A higher-complex  
carbohydrate diet in gestational diabetes  
mellitus achieves glucose targets and  
lowers postprandial lipids: A  
randomized crossover study. *Diabetes  
Care*. 2014;**37**(5):1254-1262

[41] Thomas AM, Gutierrez YM.  
Gestational Diabetes Mellitus. Chicago,  
IL: American Dietetic Association; 2005

[42] Dornhorst A, Frost G. The  
principles of dietary management of  
gestational diabetes: Reflection on  
current evidence. *Journal of Human  
Nutrition and Dietetics*. 2002;**15**:  
145-156. Quiz 157-149

[43] Shin D, Lee KW, Song WO. Dietary  
patterns during pregnancy are  
associated with risk of gestational  
diabetes mellitus. *Nutrients*. 2015;**7**(11):  
9369-9382

[44] Fitzgerald MA, McCouch SR, Hall  
RD. Not just a grain of rice: The quest  
for quality. *Trends in Plant Science*.  
2009;**14**:133-139

[45] Ranawana DV, Henry CJK,  
Lightowler HJ, Wang D. Glycaemic  
index of some commercially available  
rice and rice products in Great Britain.  
*International Journal of Food Sciences  
and Nutrition*. 2009;**60**:99-110

[46] Yusof BNM, Talib RA, Karim NA.  
Glycaemic index of eight types of  
commercial rice in Malaysia. *Malaysian  
Journal of Nutrition*. 2005;**11**(2):151-163

[47] Ishak WRW, Muda WAMW, Bakar  
NA, Malik VS, Willett WC, Frank BH,  
et al. Glycaemic index of commercially  
available brown rice in East Coast of  
Peninsular Malaysia. *Middle-East  
Journal of Scientific Research*. 2016;  
**24**(4):1430-1435

[48] Eleazu CO. The concept of low  
glycemic index and glycemic load foods  
as panacea for typ. 2 diabetes mellitus;

prospects, challenges and solutions. *African Health Sciences*. 2016;**16**(2): 468-479

[49] Arner P, Andersson DP, Bäckdahl J, Dahlman I, Rydén M. Weight gain and impaired glucose metabolism in women are predicted by inefficient subcutaneous fat cell lipolysis. *Cell Metabolism*. 2018;**28**(1):45-54.e3

[50] Bray GA, Lovejoy JC, Smith SR. The influence of different fats and fatty acids on obesity, insulin resistance and inflammation. *Journal of Nutrition*. 2002;**132**:2488-2491

[51] Riccardia G, Giacob R, Rivellesea AA. Dietary fat, insulin sensitivity and the metabolic syndrome. *Clinical Nutrition*. 2004;**23**(4):447-456

[52] Moon HS, Dalamaga M, Kim SY, et al. Leptin's role in lipodystrophic and nonlipodystrophic insulin-resistant and diabetic individuals. *Endocrine Reviews*. 2013;**34**(3):377-412

[53] Zhou YJ, Tang YS, Song YL, Li A, Zhou H, Li Y. Saturated fatty acid induces insulin resistance partially through nucleotide-binding oligomerization domain 1 signaling pathway in adipocytes. *Chinese Medical Sciences Journal*. 2013;**28**(4):211-217

[54] Hernandez TL, Anderson MA, Chartier-Logan C, Friedman JE, Barbour LA. Strategies in the nutritional management of gestational diabetes. *Clinical Obstetrics and Gynecology*. 2013;**56**(4):803-815

[55] Jamilian M, Samimi M, Mirhosseini N, et al. A randomized double-blinded, placebo-controlled trial investigating the effect of fish oil supplementation on gene expression related to insulin action, blood lipids, and inflammation in gestational diabetes mellitus-fish oil supplementation and gestational diabetes. *Nutrients*. 2018;**10**(2):163. DOI: 10.3390/nu10020163

[56] Bodnar LM, Simhan HN, Catov JM, et al. Maternal vitamin D status and the risk of mild and severe preeclampsia. *Epidemiology*. 2014;**25**(2):207-214

[57] Niyazoglu M, Hatipoglu E, Aydogan B, Dellal F, Yavuz A, Hacıoglu Y, et al. Relation of maternal vitamin D status with gestational diabetes mellitus and perinatal outcome. *African Health Sciences*. 2015;**15**:523-531

[58] Kim BH, Glanz K, Nehl EJ. Vitamin D beliefs and associations with sunburns, sun exposure, and sun protection. *International Journal of Environmental Research and Public Health*. 2012;**9**(7):2386-2395

[59] De-Regil LM, Palacios C, Lombardo LK, Pena-Rosas JP. Vitamin D supplementation for women during pregnancy (Review). *Cochrane Database of Systematic Reviews*. 2016;**1**: 1-124

[60] The Royal College of Obstetricians and Gynaecologists. Vitamin D in Pregnancy. Scientific Impact Paper No. 43. London: The Royal College of Obstetricians and Gynaecologists; 2014. [https://www.rcog.org.uk/globalassets/documents/guidelines/scientific-impact-papers/vitamin\\_d\\_sip43\\_june14.pdf](https://www.rcog.org.uk/globalassets/documents/guidelines/scientific-impact-papers/vitamin_d_sip43_june14.pdf)

[61] Goodnight W, Newman R. Optimal nutrition for improved twin pregnancy outcome. *Obstetrics and Gynecology*. 2009;**114**:1121-1134

[62] De-Regil LM, Palacios C, Ansary A, Kulier R, Peña-Rosas JP. Vitamin D supplementation for women during pregnancy. *The Cochrane Database of Systematic Reviews*. 2012;**2**(2): CD008873. DOI: 10.1002/14651858.CD008873.pub2

[63] Palacios C, Gonzalez L. Is vitamin D deficiency a major global public health problem? *The Journal of Steroid*



Biochemistry and Molecular Biology. 2014;**144**(Pt A):138-145

[64] Dovnik A, Mujezinovic F. The association of vitamin D levels with common pregnancy complications. *Nutrients*. 2018;**10**:867

[65] Tamura T, Picciano M. Folate and human reproduction. *The American Journal of Clinical Nutrition*. 2006;**83**: 993-1016

[66] Deave T, Johnson D, Ingram J. Transition to parenthood: The needs of parents in pregnancy and early parenthood. *BMC Pregnancy and Childbirth*. 2008;**8**:30. DOI: 10.1186/1471-2393-8-30

[67] Centre for Maternal and Child Enquires and Royal College of Obstetricians and Gynaecologists Joint Guideline: Management of women with obesity in pregnancy. London: Centre for Maternal and Child Enquiries; 2010

[68] Weiser MJ, Butt CM, Mohajeri MH. Docosahexaenoic acid and cognition throughout the lifespan. *Nutrients*. 2016;**8**(2):99

[69] Emmett R, Akkersdyk S, Yeatman H, Meyer BJ. Expanding awareness of docosahexaenoic acid during pregnancy. *Nutrients*. 2013;**5**:1098-1109

[70] U.S. EPA. Exposure Factors Handbook 2011 Edition (Final Report). Washington, DC: U.S. Environmental Protection Agency; 2011. EPA/600/R-09/052F

[71] European Commission. Information Note, Subject: Methyl Mercury in Fish and Fishery Products. <https://www.efsa.europa.eu/sites/default/files/assets/af040608-ax9.pdf> [Accessed October, 12, 2018]

[72] The United States Environmental Protection Agency (EPA). EPA-FDA Fish Advice: Technical Information.

<https://www.epa.gov/fish-tech/epa-fda-fish-advice-technical-information> [Accessed October 12, 2018]

[73] Knowles TG, Farrington D, Kestin SC. Mercury in UK imported fish and shellfish and UK-farmed fish and their products. *Food Additives & Contaminants*. 2003;**20**(9):813-818

[74] Farah N, Kennedy C, Turner C, O'Dwyer V, Kennelly MM, Turner MJ. Maternal obesity and pre-pregnancy folic acid supplementation. *Obesity Facts*. 2013;**6**:211-215. DOI: 10.1159/000350393

[75] Zhang Z, Fulgoni VL, Kris-Etherton PM, Mitmesser SH. Dietary Intakes of EPA and DHA Omega-3 Fatty Acids among US Childbearing-Age and Pregnant Women: An Analysis of NHANES 2001-2014. *Nutrients*. 2018; **10**(4):416. DOI:10.3390/nu10040416