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Continuing Education for Nutrition Professionals

Nutrition in Pregnancy and Lactation

Nutrition in pregnancy and lactation: how a healthy infant is born

Abstract

Maternal nutrition during pregnancy and lactation influences the growth and potential development of the fetus and contributes to the maturity of a healthy baby.

The lack of sufficient calories, of macro- and micronutrients, can lead to deficiencies in building materials for the development and growth of the fetus: moreover there is growing evidence that the maternal nutritional status can alter the epigenetic state of the fetal genome, therefore alterations in nutrition during crucial periods of fetal development may result in developmental adaptations that permanently change the physiology, the metabolism of the offspring, and, as a consequence, predispose these individuals to diseases as adults.

In this review we collected indications for the recommended intake of calories and nutrients for a healthy diet during pregnancy and lactation, also analyzing some nutritional choices that may increase the risk of nutritional deficiencies and the way to prevent them.

Pregnancy-related dietary changes should begin prior to conception, with appropriate modifications throughout pregnancy and lactation, and appropriate supplementation of vitamins and minerals.

Keywords

Nutrition, pregnancy, lactation, celiac disease, vegetarian diet, bariatric surgery.

Introduction

Pregnancy is a critical period, during which maternal nutrition and lifestyle greatly influence the health of mother and child. Maternal nutrition at conception and during pregnancy influences the growth and potential development of the fetus and contributes to the maturity of a healthy baby.

There is growing evidence that maternal nutrition can alter the epigenetic state of the fetal genome (structural changes – DNA methylation and histone modifications – that occur to the DNA without changing the DNA sequence, and can result in altered gene expression) [1], therefore alterations in nutrition during crucial periods of fetal development may result in developmental adaptations that permanently change the structure, physiology, and metabolism of the offspring, thereby predisposing individuals to metabolic, endocrine, and cardiovascular diseases in adult life. This phenomenon, known as "fetal programming," has led to the recent theory of "fetal origins of adult disease" [2, 3].

Pregnancy provides a unique opportunity to influence the long term health of the infant and mother.

Metabolism in a normal pregnancy

Pregnancy is characterized by complex endocrine-metabolic adaptations including major changes in intermediate metabolism, changes that are a necessary and indispensable adaptation to ensure a continuous supply of nutrients to the fetus in order to sustain its exponential growth. The mother's ability in regulating this metabolic balance is therefore essential for the health of both the mother and fetus.

From a metabolic point of view, there are two different periods during gestation. In the first half of pregnancy, there are maternal changes that lead to the storage of energy and nutrients. In contrast, late pregnancy is better characterized as a catabolic state with decreased insulin sensitivity and increased maternal glucose and free fatty acid concentrations, allowing greater substrate availability for fetal growth.

Normal pregnancy has been characterized as a "diabetogenic state" because of the progressive increase in postprandial glucose and insulin response in late gestation [4]; the basis of these physiological changes is the development of a state of insulin resistance, that begins near mid-pregnancy and reaches its maximum value in the third trimester and returns to normal levels after delivery [4].

During the first trimester of pregnancy, insulin sensitivity is higher than normal, resulting in an increase of peripheral glucose utilization and lower blood glucose levels, increased glycogen synthesis and a reduction in hepatic gluconeogenesis. These changes facilitate glucose and lipid uptake by the adipose tissue, increasing the lipid stores [5].

The second half of pregnancy is characterized by a state of insulin resistance, decreasing the uptake of glucose by the maternal tissue sensitive to insulin, mainly the white adipose tissue and muscle [5, 6]; this reduction in insulin sensitivity is accompanied by a compensatory increase in β-cell mass and function [7].

During this period of gestation, because of the high fetal glucose requirement and despite increased glucose production and insulin resistance, after a moderate period of fasting, there is a trend toward lower maternal plasma glucose values [7]. During the post prandial period, such a metabolic state allows a greater and more prolonged rise in blood glucose and therefore a higher glucose supply to the fetus, as the fetus' glucose supply arrives via passive glucose diffusion and is therefore concentration dependent [7, 8].

Though the specific mechanisms of the alteration of insulin secretion and action remain uncertain, they are classically related to the metabolic effects of several hormones in the maternal circulation; these are of feto-placental origin such as human placental lactogen (HPL), progesterone and estrogen, and are of maternal origin such as prolactin (PRL) and cortisol [9]. More recently, new molecules were considered as potential mediators of insulin resistance in pregnancy such as leptin, adiponectin, resistin and TNF-α [10, 11].

During pregnancy, the metabolic changes occurring in the liver and adipose tissue have an impact on lipid metabolism.

In early pregnancy, the increase in estrogen secretion and insulin levels inhibits lipolysis and promotes the creation of fat stores. Following an initial reduction during the first eight weeks of pregnancy, plasma levels of triglycerides and cholesterol tend to increase. The high plasma levels of triglycerides seem to be secondary to both an increased hepatic synthesis of VLDL (secondary to the elevation of estrogen levels), as well as a decreased lipoprotein lipase activity (LPL) in the adipose tissue determined by insulin resistance [12, 13].

In the second half of pregnancy, the transition from an anabolic to a catabolic state determines an increase in circulating lipids and promotes its use as an energy source in the mother's tissues, preserving glucose and amino acids which are transferred toward the fetus [9, 14].

In pregnant women during fasting there is an increase in circulating levels of free fatty acids and ketone compared with a non-pregnant state. Metzger et al. have found that lipid oxidation in pregnant women is highly accelerated with a prompt production of ketone bodies even after a short fast (18 hours) [15]. The typical metabolic changes in response to fasting, that is, plasma glucose and insulin reduction, and plasma free fatty acid and ketone increase, tend to develop much faster in pregnant as opposed to non-pregnant women. Precisely for this reason Freinkel defined the metabolic fasting profile of pregnant women as "accelerated starvation" [8].

Preconceptional nutritional status and recommended weight gain in pregnancy

The nutritional status of women should be evaluated during preconception to optimize maternal health and reduce the risk of pregnancy complications, birth defects, and chronic disease in their children in later adulthood.

Preconception evaluation should include, in addition to the assessment of nutritional status, a more general investigation on the health of the couple; it is therefore necessary to investigate any use or abuse of social drugs, eating disorders, food avoidance or special diets (vegetarian, vegan), signs and symptoms of malabsorbitive disease (celiac disease). Proper nutrition should begin before pregnancy together with the use of some vitamin supplements such as folic acid.

Ideally women who are underweight, overweight or obese should be seen for pre-pregnancy dietary counseling to optimize weight prior to conception and therefore reduce associated risks during pregnancy.

Pre-pregnancy body weight and gestational weight gain have independent, but cumulative effects on pregnancy outcome.

A pre-gestational body mass index (BMI) > 25 kg/m^2 and excessive weight gain are risk factors for fetal macrosomia, birth trauma, prolonged labor, cesarean section, obesity and metabolic disorders in childhood [16]. Instead, a BMI < 18.5 kg/m^2 and poor weight gain are linked with low birth weight (< 2,500 g), increased risk of preterm birth and increased perinatal mortality and morbidity [17].

There is no international consensus on appropriate weight gain per weight category in pregnancy [18, 19]; however, the Institute of Medicine (IOM) guidelines, which are based on observational data in the USA, are widely used as a guide, and evidence suggests that women who gain weight within these ranges have better outcomes [20].

The optimal weight gain for obese women is controversial; there is recent evidence that weight gain ≤ 5 kg, is associated with better maternal and fetal outcomes [21].

Recommended daily energy intake and the need for macro- and micronutrients

Adequate nutrition is important to ensure good pregnancy outcomes, because diet is an indispensable tool to meet maternal energy demands, maintain the increased maternal tissues and placenta, and provide the foetus with essential nutrients for its development.

It is often said that a pregnant woman is "eating for two": although this is technically correct, mothers-to-be often overestimate their need for additional calories, which can be easily met by adding a small snack or two during the day [22].

The most accurate way to monitor whether the mother is getting the appropriate energy intake is to monitor her weight gain.

First of all we should assess the total daily energy intake for every pregnant woman, which will be split into different macronutrients (carbohydrates, fats and proteins).

The recommended calories intake estimate for appropriate weight gain, considering also the reduction of physical activity during pregnancy, is correlated to the pre-pregnancy BMI, and calculated according to the pre-pregnancy maternal body weight (**Tab. 1**).

Table 1. Recommended daily allowance of calories, in relation to pre-pregnancy BMI and maternal body weight.

Pre-pregnancy BMI (kg/m^2)	kcal/kg/day
< 19.8	36-40
19.8-26	30
26-33	24
> 33	12-18

In the first trimester, as long as the woman does not begin pregnancy with insufficient energy stores, she doesn't require more than the total recommended daily energy intake for non-pregnant women, while during the second and third trimester the additional intake is 365 kcal/day for underweight women, 300 kcal/day for normal weight women and 200 kcal/day for overweight/obese women [23].

The recent recommendations from the Italian Society of Nutrition suggest adding, to the basal daily energy requirements, 350 kcal/day in the second and 460 kcal/day in the third trimester of the pregnancy [24].

Moreover we should encourage the consumption of foods rich in macro- and micronutrients, and not only calories, because of heightened demand during gestation: healthy eating in pregnancy should also exclude food sources which might contain teratogens, or be the source of food-borne illness such as toxoplasmosis (undercooked meat or vegetables contaminated with soil) or listeriosis and brucellosis (mould-ripened soft cheeses, unpasteurised milk or pates).

Carbohydrates, fat and proteins

Carbohydrates (CHO) represent the primary energy source in pregnancy.

Starch and sugar are the major types of carbohydrates: grains and vegetables (corn, pasta, rice, potatoes, breads) are sources of starch; natural sugars are found in fruits and juices; sources of added sugars are soft drinks, candy, fruit drinks, and desserts.

CHO should represent 45-60% of the total daily amount (TDA) of calories per day: as part of an overall healthy diet, the intake of starch and fibers should be chosen over simple and added sugars, which must be limited to no more than 15-25% of energy [24, 25]. Starch and fiber tend to limit the peak of the maternal post-prandial hyperglycemia, which is strictly correlated to fetal growth and maternal weight gain: moreover they improve the intestinal transit.

Some authors suggest restricting CHO, in cases of overweight or diabetes, to 45% of the TDA of calories, but not less than 40%, split into three meals and two snacks, because of the increased risk of triglyceridemia and ketonemia, due to the "accelerated starvation" typical of pregnant women [26].

Lipids, including sterols, phospholipids and triglycerides, which are primarily made up of fatty acids, are an energy source but also basic building material of body tissue and integral to body functioning: they are essential for the formation of cell membranes, hormones, cytochines and for proper eye and brain development [22].

Dietary fat intake (through butter, vegetable oils, whole milk, visible fat on meat, oily fish, seeds and nuts) during pregnancy should be 20-35% of the TDA of calories; less than 10% should be saturated fatty acids; polyunsaturated fatty acids should represent 5-10% of the total dietary fat intake, of which 4-8% PUFA w-6, 0,5-2% PUFA w-3, 100-200 mg of DHA (a type of PUFA w-3) [24, 25].

The DHA must be deposited in adequate amounts in brain and retinal tissue for visual and cognitive development during fetal and early postnatal life.

The pathways to form DHA from the precursor essential fatty acid, α-linolenic acid, exist in man, but most evidence indicates that the overall contribution of α-linolenic acid to DHA is limited; therefore, adequate intakes of preformed PUFA w-3, and in particular DHA, appear important for maintaining optimal tissue function [27].

Pregnant and lactating women should achieve a DHA dietary intake of at least 100-200 mg per day, which can be easily met by consuming one to two portions of oily fish (like herring, mackerel, salmon) per week, which is a good source of PUFA w-3 and also safer with regard to environmental contamination by methylmercury [27].

Proteins are the major structural component of all cells in the body, and function as enzymes, in membranes, as transport carriers, and as some hormones.

Sources, such as meat, poultry, fish, eggs, milk, cheese, and yogurt, provide all nine indispensable amino acids in adequate amounts, and for this reason are considered "complete proteins". Proteins from plants, legumes, grains, nuts, seeds, and vegetables tend to be deficient in one or more of the indispensable amino acids [25].

The Italian Society of Human Nutrition recommends an adult woman consume 0.71-0.9 g/kg/day, corresponding to about 43-54 g/day: during pregnancy the daily protein intake for a normal weight woman should increase to 0.5-1 g in the first, 7-9 g in the second, and 23-29 g in the third trimester [24].

Patients at risk for low protein intake are vegetarians, in particular vegans, women experiencing severe nausea and vomiting, and low-income women experiencing food insecurity: so they should be carefully monitored (**Tab. 2**).

Table 2. Dietary reference intake (DRI) for adult women in pregnancy and not (modified from: Italian Society of Human Nutrition, 2012 [24]).

Nutrients	DRI for adult women	DRI in pregnancy
Energy		350 kcal in the 2nd trimester; 460 kcal in the 3rd trimester
CHO	45-60% TDA of calories	45-60% TDA of calories
Fiber	25 g	30 g
Lipids	20-35% TDA of calories	20-35% TDA of calories
Proteins	0.71-0.90 g/kg	0.5-1 g in the 1st trimester; + 7-9 g in the 2nd trimester; + 23-29 g in the 3rd trimester

CHO: carbohydrates; TDA: total daily amount.

Iron

Iron is necessary for both fetal/placental development and to expand maternal red cell mass. Iron requirements in pregnancy is 27 mg/day compared to 18 mg/day in a non-pregnant state [24].

If the woman, prior to conception, has taken adequate levels of iron, the physiological changes of pregnancy, such as the cessation of menstruation, increased intestinal absorption and mobilization of reserves, would be sufficient to cover the increased demand in pregnancy. However, epidemiological data indicate that about 41.8% of pregnant women worldwide are anemic before pregnancy and at least half of this anemia burden is thought to be due to iron deficiency [28].

In 2012 a Cochrane systematic review that included 43 randomized controlled trials from 30 different countries, stated that/determined that women taking daily iron supplements were less likely to have low birth weight babies compared to controls (RR 0.81); daily iron supplementation reduced the risk of maternal anemia at term by 70% and iron deficiency at term by 57% [29].

The recent WHO guidelines recommend daily oral iron supplementation with 30-60 mg of elemental iron as part of antenatal care to reduce the risk of low birth weight, maternal anaemia and iron deficiency [30].

Calcium

Pregnancy requires about 300 mg of calcium for fetal skeletal development, primarily in the second and third trimester. This amount is a relatively small percentage of total maternal body calcium and is easily mobilized from maternal stores if necessary; moreover calcium absorption increases and renal excretion decreases during pregnancy [31].

The RDA for calcium is 1,000 mg/day in pregnant women which does not differ from that of women of childbearing age after 18 years, 1,300 mg/day for girls 14 to 18 years old [24, 32].

Women who have a normal dietary calcium intake do not require supplementation in pregnancy. Supplementation is recommended only in adolescents and in women who do not consume milk and dairy products.

Calcium supplementation is also used to prevent hypertensive disorders in pregnancy. A recent review has shown that it does not appear to be effective in nulliparous women in whom dietary calcium intake is adequate; it may reduce preeclampsia in high risk populations and in those with low dietary intake [33].

Folic acid

A systematic review of randomized clinical trials showed that folic acid supplementation, started before conception until 6-12 weeks of pregnancy, reduces the risk of the first occurrence, as well as the recurrence, of neural tube defects (NTD) (RR 0.28, 95% CI 0.13-0.58) [34]. Some studies have suggested that supplementation with folic acid may also reduce the risk of structural cardiac and craniofacial abnormalities [35, 36].

The effect of periconceptional folic acid supplementation on NTD is explained by the fact that folate is required for nucleotide synthesis and cellular methylation potential and therefore modifies DNA synthesis, cell proliferation, and gene regulation; a low availability of folate in this

period might interfere with the orderly closure of the neural tube.

All guidelines recommend supplementation of 0.4 mg/day for women who have had a previous child with neural tube defects. In women "at risk" (familiarity or previous pregnancies with NTD, epilepsy treated with valproate or carbamazepine, pregestational diabetes, obesity) an intake of 4 mg/day is recommended [37-39].

Emerging evidence has suggested that folic acid supplementation can reduce the risk of gestational hypertension or preeclampsia, but while earlier studies showed the protective effect of folic acid on reduced risk of preeclampsia [40-42], some recent studies failed to find such an effect [43, 44].

A number of mechanisms have been proposed to explain the observed beneficial effect of folic acid supplementation on preeclampsia. The first is related to placental implantation and development. Placental growth is a period of increased cell proliferation and differentiation; therefore, higher folate intakes may be required to support appropriate placental implantation and development in early pregnancy. The second is related to the effect of folic acid on lowering blood homocysteine levels [45], as hyperhomocysteinemia is a risk factor for a number of pregnancy complications including preeclampsia [46]. The third is related to the fact that folate improves systemic endothelial function [47].

Iodine

Adequate iodine is crucial for thyroid hormone production, which is required for normal neurodevelopment during pregnancy and early childhood.

The iodine maternal requirement is increased during pregnancy as a result of an increased requirement for thyroxine (T4) in order to maintain normal metabolism in the mother [48], a transfer of T4 and iodine from the mother to the fetus and a supposed greater than normal loss of iodine through the kidneys due to an increase in renal clearance [49].

Because of these three factors, the recommended dietary intake of iodine during pregnancy is higher than the value of 150 mg day recommended for non-pregnant women; the recommended iodine intake is 200 mcg/day for the WHO [50], 220 mcg/day for the IOM [51] and 220-250 mcg/day for the American Thyroid Society [52].

Severe maternal iodine depletion (and consequently an important deficit in maternal thyroid function) causes severe fetal hypothyroidism, which impairs myelination of the central nervous system, determining developmental delays and, at in extreme cases, cretinism. Maternal sequelae include infertility, spontaneous abortion, stillbirth, preterm birth, and preeclampsia. There is no controversy concerning the importance of identifying and managing severe iodine deficiency to prevent these complications [52].

Even if the evidence is less clear regarding whether or not mild-to-moderate iodine deficiency in pregnancy is harmful, there is some evidence for developmental concerns with milder forms of iodine deficiency; moreover, uncontrolled trials have noted modest benefits of maternal supplementation on childhood neurologic development [53-55].

The American Thyroid Association and the Endocrine Society therefore recommend supplementation with 100 to 200 micrograms of iodine throughout pregnancy [52].

Vitamin D

Vitamin D deficiency in pregnancy has been associated with an increased risk of pre-eclampsia [56-58], gestational diabetes mellitus [59], small-for-gestational age infants [60, 61], impaired fetal skeletal formation causing infant rickets (softening of bones commonly leading to deformities and/or fractures) and reduced bone mass [59, 60, 62], as well as other tissue-specific conditions.

Vitamin D status is most commonly assessed through measurement of serum 25-hydroxyvitamin D (25(OH)D or calcidiol) levels, which reflect the vitamin D produced cutaneously and that obtained from foods or supplements. There is still controversy regarding adequate or optimal levels of serum 25(OH)D for overall health. The IOM has recently defined levels of serum 25(OH)D greater than 50 nmol/L (or 20 ng/ml) as adequate for pregnant women [63]; however, other investigators argue that optimal levels should be set higher (> 75 nmol/L or 30 ng/ml) [64].

American studies on pregnant women show that 25% of black women and 5% of Caucasian women have a vitamin D deficiency (< 37.5 nmol/L), and respectively 54% and 47% have an insufficiency (35-75 nmol/L) [65].

Several scientific societies recommend supplementation with 400 U (10 micrograms daily) of vitamin D for all pregnant women [66, 67]. The WHO and the Italian guidelines, since there is no evidence from RCTs that supplementation with

vitamin D during pregnancy has effects on relevant maternal or neonatal outcomes, do not recommend routine supplementation, but they do recommend it for women at high risk of deficiency (women of South Asian, African, Caribbean and Middle East origins; women who rarely expose themselves to the sun; women who follow a diet low in vitamin D) [37, 67].

Maternal nutrition during lactation

For an infant, no food is better than breast milk.

The WHO and other scientific societies promote exclusive breastfeeding as the best source of nutrition for the baby for the first six months of life, and as the main food until the first year of life [68, 69]. Breastmilk, in fact, provides all the nutrients essential for optimal growth of the baby and important protective factors against infection. However, after the first 6 months, lactation, even if sufficient in terms of quantity, is no longer able to meet the increased nutritional requirements of the baby, so the progressive introduction of foods (weaning) is necessary.

The energy, protein, and other nutrients in breastmilk come from the mother's diet and her own body stores. Milk production is determined mostly by infant demand rather than maternal lactation capacity [70]. This is illustrated by the ability of mothers to successfully breastfeed twins or triplets [71]. Factors that influence the volume of milk consumed are the infant's current weight, weight gain, birth weight, and gender [72].

Virtually all mothers can produce adequate amounts of breastmilk but a chronically deficient diet depletes maternal energy, vitamins and minerals stores.

These deficiencies can be avoided if the mother improves her diet before, during, and between cycles of pregnancy and lactation, or takes supplements.

Moderate weight loss of the mother, typical of the post-partum period, with or without exercise does not adversely affect lactation [73].

The energy cost of exclusive breastfeeding from birth to 6 months postpartum is 500 kcal/day. This estimate is based upon the average volume of milk produced (780 ml/day) and the average energy content of milk (67 kcal/100 ml). In well-nourished women, the energy cost of lactation is subsidized by mobilization of tissue stores (approximately 170 kcal per day). Therefore, the recommended dietary allowance (RDA) for energy is 330 kcal per day more than non-pregnant, non-lactating women: from 7 to 12 months of age, based on an average milk production of 600 ml/day and the same energy content, the additional energy required for lactation is 400 kcal per day [24].

Breastfeeding increases the mother's need for water, so it is important that she drinks enough to compensate her loss of fluids: if the adequate intake for a woman of childbearing age is about 2,000 ml/day, during lactation an increase of about 700 ml/day is recommended [24].

Requirements for vitamins A, C, E, B6, B12, folate, niacin, riboflavin, and thiamine, and the minerals iodine, selenium, and zinc are increased in lactating women. In contrast, allowances for vitamins D and K, and the minerals calcium, fluoride, magnesium, and phosphorus do not differ between lactating and non-lactating states [74]. The maternal requirement for iron is not increased during lactation, because of post-partum amenorrhea, which prevents its loss [24].

The current recommendation is to provide vitamin D supplementation to all breastfed infants rather than increase supplementation in the mother.

The vitamin K content of human milk is not affected by maternal vitamin K intake, therefore no additional vitamin K is required during lactation [75].

Approximately 210 mg per day of calcium is secreted in milk. Increased bone mobilization and decreased urinary excretion provide the calcium needed for milk production [76]; intestinal calcium absorption does not appear to increase [77]. Changes in calcium homeostasis are independent of maternal calcium intake [78, 79]. As an example, in one report, loss of bone mass during lactation was similar with calcium supplementation (1 g per day) and placebo [78, 79]. Because lactation-induced bone loss is not prevented by increased calcium intake, and bone loss is recovered after weaning, the dietary recommendation for calcium is the same for lactating and non-lactating women of the same age [24].

Fish and shellfish contribute high-quality protein and other essential nutrients including omega-3 fatty acids to the diet. Large amounts of essential fatty acids are beneficial to the infant for brain development. However, currently available data are insufficient to demonstrate an association between subsequent cognition in children and increased omega-3 fatty acid intake in their mothers during breastfeeding.

Consumption of certain fish and shellfish by breastfeeding women may increase the newborn's

risk to develop nervous system alterations, since both inorganic and organic mercury are transferred from maternal serum to human milk [80].

To prevent this, breastfeeding mothers should not eat shark, swordfish, king mackerel, or tilefish because they contain high concentrations of mercury.

Breastfeeding mothers can eat up to two average servings of fish and shellfish that have lower concentrations of mercury (shrimp, canned light tuna, salmon, pollock, and catfish) (**Tab. 3**).

Table 3. Comparison of the dietary reference intake (DRI) for adult women of childbearing age, for women during pregnancy and during lactation (modified from: Italian Society of Human Nutrition, 2012 [24]).

	Acceptable micronutrients distribution range (AMDR)		
Nutrients (unit of measure/day)	**Adult women**	**Pregnancy**	**Lactation**
Vitamin A (mcg)	400-600	500-700	800-1,000
Vitamin B6 (mg)	1.1-1.3	1.6-1.9	1.7-2
Vitamin B12 (mcg)	2-2.4	2.2-2.6	2.4-2.8
Vitamin C (mg)	60-85	70-100	90-130
Thiamin (mg)	0.9-1.1	1.2-1.4	1.2-1.4
Riboflavin (mg)	1.1-1.3	1.4-1.7	1.5-1.8
Niacin (mg)	14-18	17-22	17-22
Folic acid (mcg)	320-400	520-600	450-500
Vitamin D (mcg)	10-15	10-15	10-15
Vitamin E (mg)	12	12	15
Vitamin K (mcg)	140	140	140
Calcium (mg)	800-1,000	800-1,000	800-1,000
Phosphorus (mg)	580-700	580-700	580-700
Magnesium (mg)	170-240	170-240	170-240
Iron (mg)	10-18	22-27	8-11
Zinc (mg)	7-8	9-11	10-13
Copper (mg)	0.7-0.9	0.9-1.2	1.2-1.6
Selenium (mcg)	45-55	45-55	59-70
Iodine (mcg)	150	220	290

Special diet

Vegetarian diet

Vegetarianism is the practice of abstaining from the consumption of meat (red meat, poultry, seafood and the flesh of any other animal), and may also include abstention from by-products of animal.

There are a number of vegetarian diets, which exclude or include various foods.

The more common vegetarian diets are: ovo-lacto vegetarianism (or lacto-ovo vegetarianism) which includes animal/dairy products such as eggs, milk, and honey; lacto-vegetarianism includes dairy products but not eggs; veganism excludes all animal flesh and products, such as milk, honey, and eggs, as well as items refined or manufactured through any such product.

Many international scientific societies state that "vegetarian diets properly planned, including totally vegetarian or vegan diets, are healthful, adequate from the nutritional point of view, and may confer health benefits in the prevention and in the treatment of certain diseases. Well-planned vegetarian diets are appropriate for individuals in all stages of the life cycle, including pregnancy, lactation, infancy, childhood and adolescence, and for athletes" [81-84].

Both vegetarian and vegan diets can satisfy the nutritional requirement of pregnancy and lactation and lead to positive outcomes in terms of fetal and newborn development, growth and health, as long as the woman and a nutrition specialist correctly plan them.

Some studies show a lower incidence of preeclampsia among vegan patients [85], and of preterm delivery among patients with low-cholesterol diet [86], but without good information and programming, vegetarian pregnant women may be at risk for nutritional deficiencies.

Vegetarian diets, particularly those excluding all animal products, may not provide adequate amounts of essential amino acids, iron, vitamin B12, vitamin D and calcium, iron or complex lipids for normal embryonic and fetal development. In addition, the high bulk of food required in vegetarian diets (especially for vegans) can make meeting energy requirements during pregnancy difficult [87].

In general, the lacto-ovo-vegetarian diet appears more balanced: it presents a reduced risk of vitamin (such as vitamin B12 or D), and mineral (such as calcium and iron) deficiencies that are present only, or more available, from food of animal origin.

The most important difference between proteins of plant and animal origin is in the concentration of indispensable or essential amino acids. Animal foods are considered complete or high-quality proteins because they contain all nine essential amino acids that the body needs for growth and repair of body tissues [25]. Plant-based foods are usually incomplete, meaning that they are deficient in one or more of the essential amino acids. Use of fortified soy products, consumption of foods with

complementary amino acids, and increased intake of dairy products and/or eggs (if acceptable to the women) can correct these deficiencies.

Natural sources of vitamin B12 in human diets are restricted to foods of animal origin. During pregnancy, low serum vitamin B12 concentration is an independent risk factor for neural tube defects, preeclampsia, and other pregnancy-related complications: low serum vitamin B12 concentrations also lead to consequences for the mother such as macrocytic anemia, neurological complications, and cognitive disabilities [88]. The breastfed infant of a vitamin B12-deficient mother is at risk for severe developmental abnormalities, growth failure, and anemia.

Usually, the intake of vitamin B12 during pregnancy is not the focus of nutritional research because in mixed balanced diets with high intake of foods of animal origin the intake of vitamin B12 is well above the current recommended dietary intakes: on the other hand, some studies have demonstrated a vitamin B12 deficiency in infants born to mothers adhering to a strict vegetarian (vegan) diet. In this case, supplementing with 2.6 mcg in pregnancy and 2.8 mcg during lactation of vitamin B12 is fundamental [24].

While an ovo-lacto-vegetarian diet is associated with an increased risk of vitamin B12 deficiency, there is a significant reduction in risk of folate deficiency.

A deficiency of calcium and vitamin D during pregnancy is associated with many disorders of calcium metabolism, including hypocalcemia and neonatal tetany, tooth enamel hypoplasia of the newborn and maternal osteomalacia.

The intake of calcium and vitamin D is usually ensured by the consumption of milk and dairy products. The bioavailability of calcium from sources of vegetable origin is influenced by the presence of oxalates and phytates, that are inhibitors of its absorption [89]. This explains why spinach and rhubarb have poor bioavailability, while broccoli, cabbage, sesame seeds, almonds and soy products are a rich source of bioavailable calcium.

Moreover, phytoestrogens consumption tends to be higher among herbivores than among omnivores. One prospective longitudinal study suggested this exposure during pregnancy may increase the prevalence of hypospadias in male offspring [90].

The vegetable sources of iron are legumes, spinach, molasses, soy products, tofu, whole grains, dried fruit, but, also in this case the mineral is present in a form not easily available by the organism [91]. To minimize the risk of nutritional deficiencies, taking vitamin and DHA supplements is recommended for every pregnant woman, especially vegetarians, to ensure the daily intake of nutrients.

Celiac disease

The gluten-free diet is the only effective therapy in the treatment of celiac disease, and should be life-long so as to avoid acute complications (diarrhea, malabsorption, folate and iron deficiency, weight loss or failure to thrive) and chronic (intestinal lymphoma, osteoporosis, infertility) [92]. Gluten is a protein found in wheat and cereals such as barley and rye, that in a gluten-free diet must be eliminated.

Cereals such as rice, corn, buckwheat, millet, teff, and pulses such as quinoa, amaranth and soy beans are a good gluten-free substitute of high nutritional value and rich in fiber.

Naturally gluten-free foods are meat, fish, eggs, milk and dairy products, fruits and vegetables. Thanks to new technologies, many products suitable for the celiac are available on the market, or rather products with gluten content below 20 ppm, adhering to international standards for the definition of a "gluten-free" product.

According to some authors, in recent years there has been a progressive increase in overweight and obesity among celiac patients [93]. This phenomenon could be due to the composition of gluten-free foods in the diet, because gluten-free foods tend to have a high rate of saturated fat, carbohydrates with high glycemic index and a low content of protein and fiber; moreover the healing of the damage to the intestinal mucosa led to better nutrient absorption.

Celiac disease is associated with diabetes mellitus type I (DM1) with a prevalence that varies, depending on the studies, between 0.6% and 16.4% [94]. This high prevalence is due to the fact that both are autoimmune diseases and have a common genetic susceptibility conferred by HLA DR3/DQ2: this haplotype is present in more than 90% of celiac patients and in 55% of patients with DM1; also HLA-DQ8, usually positive in patients with celiac disease, confers susceptibility to the development of DM1.

Unfortunately a gluten-free diet, rich in carbohydrates with high glycemic index, contrasts with the dietary recommendations of a diabetic patient, who should consume carbohydrates with a low glycemic index: the management and the glyco-

metabolic control of patients with this comorbidity are very difficult, especially in pregnant women where glycometabolic control is crucial for fetal growth [93].

While celiac disease is a risk factor for nutritional deficiency due to malabsorption, a gluten-free diet can still present a deficiency of calcium, vitamin D, iron, folate, vitamin B12 and magnesium. The use of vitamins and minerals supplements is recommended, making sure that the supplement in question is gluten-free, to avoid deficits that may result from this kind of diet, which can be exacerbated by increased gravidic demands.

The maternal concern that celiac disease and a gluten-free diet can negatively influence pregnancy and fetal growth is unjustified: indeed a gluten-free diet eliminates the risk of adverse pregnancy outcomes due to celiac disease.

Post bariatric surgery

Maternal obesity has adverse effects on fertility and pregnancy, with higher risk of miscarriage, gestational diabetes and hypertension, fetal macrosomia, caesarean section, and also on fetal development, in particular the epigenetic imprinting for metabolic syndrome in adulthood.

Bariatric surgery alone does not guarantee an easy and safe correction of morbid obesity, but today it is an effective intervention to support the necessity and determination of obese patients to lose excess weight and to be able to keep it off in the long run, when following a dietary approach proves too difficult. [95].

Bariatric procedures can be classified as restrictive, malabsorptive or both.

Restrictive procedures consist of reducing the stomach's capacity so as to induce early satiety and reduce energy intake. The most common restrictive procedure is the laparoscopic adjustable gastric banding (LAGB): in the LAGB procedure, an inflatable silicon gastric band is placed horizontally around the proximal part of the stomach. Restrictive procedures determine a smaller weight decrement over time than the malabsorptive approach, but are easier to perform and less invasive. Nutritional deficiencies are less common with the restrictive approach.

Malabsorptive procedures are used less frequently and include biliopancreatic diversion (BPD) and biliopancreatic diversion with duodenal switching. BPD consists of a partial gastrectomy, creating a small gastric pouch that is linked to the distal small bowel through a portion of the ileum in order to bypass a large part of the small bowel. These procedures appear to modify the physiology of digestion and of other enterohormonal mediators, and these changes would affect satiety and energy balance, with additional effects on weight loss.

There are also procedures that combine both restrictive and malabsorpitive mechanisms, so the amount of food introduced is less, the initial part of the digestive tract is skipped and an early sense of satiety is induced.

Bariatric surgery can lead to considerable weight loss and better control of some possible comorbidities, like hypertension and diabetes, in addition to a lower risk of complications during pregnancy [96, 97].

Women are generally advised to delay pregnancy for 12 to 18 months following bariatric surgery. This is done in an effort to optimize weight loss, to get used to the new alimentary habits and to reduce the potentially adverse effect of post-bariatric surgical nutritional deficiencies [98].

Metabolic and nutritional derangements can occur after bariatric surgery, particularly after malabsorptive procedures: women who undergo restrictive procedures may also develop minor deficiencies [99]. Reduced oral intake and alterations in digestive anatomy result in malabsorption of various micronutrients and minerals, particularly iron, folate, vitamin B12, calcium, and vitamin D.

Absorption of iron and folate are reduced due to lower acid content in the gastric pouch and bypass of the duodenum, the main site of absorption.

Calcium deficiency can also result from bypass of the duodenum, where there is the higher concentration of receptors for calcium; vitamin D deficiency, typical of obese patients, and its lower intake, increases the risk of osteopenia and osteoporosis [100].

A reduction in the availability of both gastric acid and intrinsic factor may lead to B12 deficiency.

These nutrient deficiencies without adequate supplementation can led to a number of adverse pregnancy outcomes: iron and vitamin B12 deficiencies represent a risk for maternal anemia; folate deficiency for neural tube defects [101]; vitamin A deficiency for fetal microphthalmia [102]; vitamin K deficiency for fetal cerebral hemorrhage [103]; Wernicke's encephalopathy due to thiamine deficiency is a particular concern for women with hyperemesis gravidarum and gastric bypass.

To reduce the risk of complications from micronutrient deficiency, specific supplementation

regimens need to be tailored to the individual patient and the type of bariatric procedure performed [104] (**Tab. 4**).

Some precautions may be useful to optimize absorption of certain substances: for example, calcium citrate, compared to calcium carbonate, is preferable because its absorption is not dependent on gastric acid; in patients with partial gastrectomy, given the lack of intrinsic factor, vitamin B12 should not be taken orally; if iron is taken with vitamin C, absorption is improved.

Another important suggestion concerns women who have undergone percutaneous adjustable gastric banding: the volume of fluid within the bandage which embraces the stomach may be adjusted in pregnancy, reducing it in case of nausea, vomiting and malnutrition, but not routinely: this adjustment allows adequate increase of maternal weight, reduces the risk or the extent of nutritional deficit and leads to a normal fetal/newborn weight.

Table 4. Specific recommendations of nutrients intake for pregnant women after bariatric surgery.

Nutrients	RDA (Recommended Daily Allowance)
Vitamin B1 (thiamine)	1.4 mg
Vitamin D	400 UI
Vitamin K	120 mg
Zinc	11 mg
Biotin	30 mg
Iron	65 mg
Folic acid	800 mg
Calcium citrate	1,200 mg
Vitamin B12	Oral or sublingual 350-500 mg, once a week; intramuscolar 1,000 mg, once a week

Conclusion

Although it is clear that prenatal nutrition impacts the short- and long-term health of the infant and mother, many scientific questions remain unanswered due to the many challenges of performing high quality scientific research during pregnancy.

However, what is certain is that a woman's nutritional status and her nutritional habits should be assessed preconceptionally, with the goal of optimizing maternal, fetal, and infant health.

Pregnancy-related dietary changes should begin prior to conception, with appropriate modifications throughout pregnancy and lactation, and appropriate supplementation of vitamins and minerals, especially with such diet choices that increase the risk of lacking certain nutrients.

Declaration of interest

The Authors declare that there is no conflict of interest.

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