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The Impact of Nutrient Intake on Pregnancy Outcomes: Narrative Review

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Abstract

This review examines the latest evidence on dietary habits, nutrient intake, and lifestyle factors influencing pregnancy outcomes. It emphasizes the critical role of adhering to recommended nutrient intake, maintaining regular physical activity, adopting healthy dietary habits, and achieving appropriate gestational weight gain in promoting favorable maternal and neonatal health outcomes. The analysis reveals that deficiencies in essential nutrients, such as folate, iron, vitamin D, and omega-3 fatty acids, significantly impact pregnancy, increasing the risk of adverse outcomes like gestational diabetes, preeclampsia, low birth weight, and preterm delivery. Additionally, lifestyle factors, including smoking, alcohol consumption, and physical activity levels, are explored for their contributions to maternal and fetal health. Despite advancements in research, gaps persist in understanding the specific effects of certain nutrient deficiencies and dietary patterns. This review underscores the importance of routine nutritional assessments, personalized dietary counseling, and targeted public health interventions to improve pregnancy outcomes on a global scale.

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Introduction

Pregnancy is a time of rapid and complex physiological changes from conception time until birth.[1] The physiological changes at the gastrointestinal tract during pregnancy involve a decrease in gastric and intestinal peristalsis together

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with an increase in the intestinal absorption capacity of water and nutrients.[2] Pregnancy is a metabolic challenge to be met by the mother and her baby and it is a state of oxidative stress compared with non-pregnancy.[3] According to its high metabolic rate and level of mitochondrial activity, the placenta is the main source of this oxidative stress.[3] In the third trimester, insulin sensitivity may gradually decline to 50% of the normal value. This decline is caused by several factors such as an increase in the levels of estrogen, progesterone, and human placental lactogen.[4] Maternal insulin resistance leads to the mother's using more fats than carbohydrates for energy and spares carbohydrates for her fetus.[4]

Pregnancy is one of the more important periods in women's life when increased micronutrients and macronutrients are most required in the body; both for the health and well-being of the mother and for the growing fetus and newborn child.[5] During pregnancy, the fetus grows within sequential patterns of tissue and organ growth, differentiation, and maturation. In early gestation, the major determinant of fetal growth is the fetal genome. But in late pregnancy; environmental, nutritional, and hormonal influences become significantly important.[3]

The objective of this review is to summarize the latest research on nutrients intake, body weight, dietary patterns, and lifestyle during pregnancy, with a particular focus on the impact of lifestyle factors such as physical activity levels and smoking on pregnancy outcomes.

Materials and Methods

This review used a comprehensive approach to gather up-to-date evidence covering approximately the past 12 years. The search encompassed reputable databases including PubMed, Google Scholar, ScienceDirect, and official websites such as the World Health Organization (WHO). The search strategy involved the utilization of keywords such as pregnancy, requirements, supplementation, nutrients, dietary habits, lifestyle factors, dietary patterns, and maternal and neonatal outcomes. To ensure consistency and relevance, articles in languages other than English were excluded from consideration. The search was diligently conducted to identify relevant English-language articles published within the timeframe of 2013 to 2025.

Nutrients and Pregnancy Outcomes

During pregnancy, the demand for nutrients increases to support the growth and development of the fetus, as well as to accommodate changes in maternal metabolism and tissue development6. While micronutrient requirements rise during preconception and pregnancy, energy and protein needs show a notable increase, particularly in the second and third trimesters.[6]

Global deficiencies in essential micronutrients, known as Micronutrient Deficiencies (MNDs), remain a pervasive health challenge. Pregnant women and children under the age of five are especially susceptible, as their increased nutritional demands make them more vulnerable to the adverse effects of these deficiencies.[7] On a global scale, 50% of all preschool-aged children and 67% of all women of reproductive age would exhibit deficits in some form of MNDs, particularly folate, iron, vitamin A, and zinc.[8] Importantly, maternal MNDs are often attributed to factors such as poor dietary quality, high fertility rates, closely spaced pregnancies, and heightened physiological demands.[5] These challenges are exacerbated by inadequate healthcare systems with limited capacity, socio-economic disparities, and cultural factors such as early marriage, adolescent pregnancies, and certain traditional dietary practices.[5]

On the other hand, the proportion of protein to carbohydrates or fat in the maternal diet plays a role in shaping the body composition and adiposity of the developing fetus.[9] A systematic review and meta-analysis, encompassing 7135 dietary studies of pregnant women, revealed several trends. Notably, the average total energy intake was lower, while carbohydrates were higher, compared to the recommended level.[10]

Carbohydrate, Fiber and Added Sugar Intake

Maternal dietary carbohydrate intake is a necessary fetal exposure. Particularly, glucose is the main source of energy for fetal growth.[11] Both the dietary glycemic index (GI) and glycemic load (GL) serve as indicators of dietary carbohydrate quality and significantly impact the levels of circulating glucose throughout the day during pregnancy. Elevated blood glucose (BG) levels are closely linked to an augmented risk of unfavorable outcomes in the offspring.[11]

In the context of pregnancy, diets characterized by low carbohydrate content and high total fat, as well as saturated fatty acids (SFAs), are associated with an increased susceptibility to gestational diabetes mellitus (GDM). Conversely, a diet with a low glycemic index is correlated with a reduced risk of GDM.[12] A prospective cohort study involving expectant mothers and their offspring in Singapore found noteworthy associations. In diets with identical caloric content, greater carbohydrate intake combined with lower fat intake was associated with a 0.07 standard deviation (SD) increase in gestational weight gain (GWG) and a 14% higher probability of excessive GWG. Similarly, the highest tertile consumption of carbohydrate-rich foods was linked to a 0.20 SD elevation in GWG.[13]

Dietary fiber (DF) includes polysaccharides, oligosaccharides, lignin, and associated plant substances that are resistant to digestion by gastrointestinal enzymes with complete or partial fermentation in the human large intestine. Plants are the primary source of DF. Recently, artificially synthesized DF has also been developed.[14] The consumption of fiber-rich foods during pregnancy offers numerous health benefits for expectant mothers, including a reduction in the risks of diabetes, preeclampsia (PE), and constipation.[15] A recent study carried out in low-income rural environments revealed that the mean±SD daily dietary fiber intake during pregnancy was 25.89±5.09 mg/g, which falls below the recommended levels.[15] A study by Gomez-Arango *et al*. (2018) shed light on the potential consequences of low dietary fiber intake. This study demonstrated that inadequate dietary fiber intake might contribute to the overgrowth of *Collinsella* bacteria and alter the overall fermentation pattern in the gut microbiota of pregnant women.[16] The research found a positive association between *Collinsella* abundance and circulating insulin (rho=0.30, P=0.0006), independent of maternal body mass index (BMI), while also noting a negative correlation with dietary fiber intake (rho=-0.20, P=0.025).[16]

Added sugar comprises all sugars introduced into foods during preparation, processing, or at the table, excluding naturally occurring sugars. Numerous sources of added sugar include sugar-sweetened beverages, cakes, cookies, pastries, candies, juice drinks, smoothies, and milk-based desserts.[17] While the 2015–2020 Dietary Guidelines for Americans recommend that all individuals limit added sugar intake to less than 10% of total calories, specific limits have not been established for pregnant women.[17] A position paper from the Academy of Nutrition and Dietetics advises pregnant women to curtail added sugar consumption to lower caloric intake without compromising nutrient sufficiency.[18]

The National Health and Nutrition Examination Survey 2003–2012 revealed that pregnant women consumed 14.8% of their total energy from added sugar, in contrast to nonpregnant women who consumed 15.9%.[17] Cioffi *et al*. (2018) suggested that pregnant women had higher energy intakes, but this was not linked to increased added sugar consumption. Although education and income influenced dietary choices during pregnancy, added sugar intake surpassed recommendations for all women, regardless of pregnancy status.[17]

Protein Intake

Protein serves as a vital cornerstone of a wholesome human diet, serving to facilitate both growth and maintenance functions. Its significance extends to structural roles (such as keratin and collagen) as well as functional roles (including enzymes, transport proteins, and hormones) within the body.[19] Consequently, the intake of dietary protein stands as a pivotal factor influencing the prospects of embryonic survival, growth, and development.[9] According to a report of a joint WHO/FAO/UNU expert consultation, the definition of protein requirement is as follows: "the lowest level of dietary protein intake that will balance the losses of nitrogen from the body, and thus maintain the body protein mass, in persons at energy balance with modest levels of physical activity (PA), plus, in children or pregnant or lactating women, the needs associated with the deposition of tissues or secretion of milk at rates consistent with good health".[19] The recommended dietary allowance for protein during the initial trimester of pregnancy is estimated at 46 g/day (0.8 g/kg bw/day), subsequently rising to 71 g/day (1.1 g/kg bw/day) during the second and third trimesters.[6] A deficiency in maternal protein intake can lead to outcomes such as embryonic losses, intrauterine growth restriction, and diminished postnatal growth due to the scarcity of specific amino acids crucial for cell metabolism and function.[9] Conversely, excessive maternal protein intake may yield consequences including intrauterine growth restriction and embryonic demise, attributable to the surplus of amino acids leading to phenomena like ammonia toxicity, homocysteine elevation, and hydrogen sulfide generation via amino acid catabolism.[9] An interesting prospective study enrolled 98 Portuguese pregnant women revealed notable positive associations between total dairy and yogurt intake during the first trimester with head circumference (HC) ($\beta = 0.002$, $P = 0.014$) and placental weight ($\beta = 0.333$, $P = 0.012$). Furthermore, alterations in total dairy intake in the first and second trimesters exhibited a negative association with maternal weight gain during pregnancy ($\beta = -0.007$, $P = 0.020$).[20]

Fat and Fatty Acids Intake

Fatty acids (FAs) act as substrates and mediators of prostaglandin synthesis and steroidogenesis and, therefore, are critical in the early stages of the productive processes; for promoting ovulation and improving embryo quality.[21] FAs are classified by molecular structure into SFAs, monounsaturated fatty acids (MUFAs), and also PUFAs.[21] Without a doubt, the developing fetus completely depends on the maternal essential fatty acid level, and deficiency of the essential fatty acids could result in an adverse pregnancy outcome.[22] Wherever an imbalance in omega-3 and omega-6 fatty acids supply results in abnormal vascularization, increased oxidative stress and altered placental inflammation may contribute to endothelial dysfunction. Thus, intrauterine growth restriction, PE, and GDM may occur.[23]

Omega-3 docosahexaenoic acid (DHA) and omega-6 arachidonic acid (ARA) are essential fatty acids during pregnancy, as they serve as structural components of membrane lipids in the developing fetal brain and central nervous system.[22] Beneficial effects of maternal adequate intake of n-3 PUFA have also been observed in pregnancy outcomes: low birth weight (LBW), preterm delivery (PTD), gestational length, and postnatal depression.[24]

According to the European guidelines, the recommended intake of DHA during pregnancy is at least 200 mg per day. This threshold can be achieved by eating 2 servings of fish per week, consuming plant-based ω-3 PUFAs, and supplementing with fish oil capsules.[24] A study concucted by Jiang *et al*. (2025) suggested that DHA supplementation during pregnancy may alleviate the adverse effects of GDM on placental fatty acid transport protein (FATP4) expression and support better neurodevelopmental outcomes in offspring by enhancing essential fatty acid transport through the peroxisome proliferator-activated receptor gamma (PPAR-γ)/FATP4 pathway. This study underscores the therapeutic potential of DHA in improving fetal outcomes in GDM-affected pregnancies.[25] A randomized controlled trial indicated that a supplement of 600 mg DHA per day in the last half of gestation resulted in longer gestation duration (2.9 days; $P = 0.041$), and greater birth weight (172 gm; $P = 0.004$), length (0.7 cm; $P = 0.022$), as well as HC (0.5 cm; $P = 0.012$). Moreover, the DHA group had fewer infants born at less than 34 weeks of gestation ($P = 0.025$) and shorter hospital stays for preterm infants (40.8 compared with 8.9 days; $P = 0.026$) than did the placebo group.[26] Kim *et al*. (2019) documented that preconception-specific SFAs (myristic acid and arachidic acid) were associated with a higher probability of live birth.[21] Furthermore, there exists a positive correlation between total MUFAs and both pregnancy and live birth, while also exhibiting a reduced risk of pregnancy loss. Conversely, total PUFAs were associated with a reduced likelihood of pregnancy loss (RR = 0.97, 95% CI: 0.95–1.00) and an increased likelihood of live birth (RR = 0.96, 95% CI: 0.94–0.99). However, a 1% increase in total PUFAs was linked to a higher risk of pregnancy loss (RR = 1.10, 95% CI: 1.00–1.20).[21]

Vitamin A Intake

Vitamin A, a fat-soluble nutrient, is derived from two primary sources: preformed retinoids and provitamin carotenoids. Retinoids, including retinal and retinoic acid, are obtained from animal sources such as eggs, liver, dairy products, and fish liver oil. Carotenoids like beta-carotene are found in plant sources like dark or yellow vegetables, including kale, sweet potatoes, and carrots. Carotenoids can be converted to vitamin A in the liver and stored.[1] The physiological roles of vitamin A encompass vision, growth, bone metabolism, immune function, gene transcription, and antioxidant activities. Moreover, increased vitamin A is required during pregnancy to support fetal growth and tissue maintenance, provide fetal reserves, and assist in maternal metabolism.[1]

In a recent WHO guideline, vitamin A supplementation during pregnancy is generally not recommended.[27]

However, for women affected by vitamin A deficiency, a recommended dose of up to 10,000 IU per day or up to 25,000 IU per week (for a minimum of 12 weeks during pregnancy until delivery) is suggested to prevent night blindness.[27] It's important to note that excessive retinoic acid (a form of vitamin A) in maternal blood during the early months of pregnancy has been linked to miscarriage and congenital malformations, particularly involving the central nervous and cardiac systems.[28] Additionally, a higher intake of retinol (above 10,000 IU/day) during pregnancy is considered a risk factor for fetal cardiopathy.[28]

Vitamin A deficiency affects one out of every six pregnant women worldwide and is responsible for nearly 6% of child deaths under the age of 5 in Africa.[29] An investigation involving 189 maternal-infant pairs revealed that low maternal serum retinol concentrations were associated with maternal anemia ($P = 0.04$) and a trend towards lower birth weight ($P = 0.06$).[30] Another study by Mezzano *et al.* (2022) discovered a significant positive correlation between retinol-binding hormone and length-for-age at birth ($\beta = 0.12$, $P < 0.030$).[29] On the other hand, a Cochrane meta-analysis of 19 trials indicated that vitamin A supplementation during pregnancy had no significant effects on maternal or newborn mortality, stillbirth (SB), LBW, preterm birth (PTB), or newborn anemia. However, it did reduce the risk of maternal anemia, infections, and night blindness, particularly among vitamin A-deficient women.[1]

Vitamins B1, B2, B3, B6 and B12 Intake

B-complex vitamins, contain vitamins B1 (thiamin), B2 (riboflavin), B3 (niacin), B6 (pyridoxine), and B12 (cyanocobalamin), constitute a group of water-soluble vitamins crucial for energy production, cellular metabolism of protein, fat, and carbohydrates, and blood cell formation.[1] These vitamins serve as coenzymes in numerous intermediary metabolic pathways that contribute to energy generation and blood cell synthesis.[1]

Evidence from trials suggests that vitamin B6 supplementation among infertile women can enhance reproductive performance, leading to a 40% increase in the likelihood of conception and a 30% reduction in early pregnancy loss.[31] An investigative case-control study in Spain unveiled an association between the intake of various B vitamins and the risk of small for gestational age (SGA) births. Notably, vitamins B1, B3, and B12 exhibited a protective effect at higher intakes, while moderate B6 intake correlated with a reduced risk of SGA. Conversely, no significant connections were found between dietary vitamin B2 intake and SGA.[32] Additionally, Yakob *et al*. (2021) demonstrated that the divergence in mean 1-methyl-5-carboxylamide-2-pyridone/N-1-methylnicotinamide (2-pyr/MNA) ratios between women who experienced miscarriages and controls implies the existence of a potentially protective threshold of niacin levels in preventing first-trimester miscarriages.[33] Similarly, a retrospective study conducted between May 2018 and April 2020 highlighted significant differences. A higher proportion of women in group A (supplemented with 5-methyltetrahydrofolate (5-MTHF), vitamin B12, and vitamin B6) achieved clinical pregnancies and live births compared to group B (supplemented with folic acid only) ($P = 0.01$; $P = 0.02$, respectively). This suggests that women supplemented with 5-MTHF and vitamin B12 have an increased likelihood of achieving clinical pregnancies and live births compared to those supplemented with folic acid alone.[31]

Folic Acid Intake

Folic acid, also known as vitamin B9, constitutes one of the eight essential vitamins in the B complex. This water-soluble vitamin was initially extracted from spinach in the 1940s. Its name, "folic acid," is derived from the Latin word "folium," signifying leaf, due to its abundant presence in green leafy vegetables. Natural sources of folate encompass liver, yeast, mushrooms, and various green leafy vegetables.[34] Folic acid serves as the synthetic form incorporated into foods and prenatal supplements, initially lacking biological activity until it undergoes reduction to become the active folate derivative, 5-methyltetrahydrofolate (5-MTHF).[31] The term "folate" (folacin) is a general designation encompassing folic acid.[34]

Throughout pregnancy, the heightened demand for folate predominantly arises from the necessity for blood cell production, expansion of uterus tissue and the placenta, fetal growth, and the augmentation of blood volume.[34] Beyond this, folate plays a pivotal role in DNA synthesis, epigenetic modifications, and cell proliferation.[31] However, the amplified requirement for folate, ranging from 5 to 10 times higher, in pregnant women renders them susceptible to folate deficiency.[34]

Folate deficiency during pregnancy escalates the risk of neural tube defects (NTDs) and other intricate congenital malformations.[31] Hence, a recommended daily intake of 400 µg/day of folic acid, derived from fortified foods, supplements, or a combination of both, is suggested for all women of reproductive age, starting at least one month before conception and continuing until at least the 12th week of gestation.[1] Conversely, women receiving folic acid supplementation demonstrated improved oocyte quality and a higher proportion of mature oocytes compared to those without such supplementation.[31] Salcedo-Bellido *et al*. (2017) indicated that moderate intake of vitamin B9 was correlated with a reduced risk of small gestational weight, with significant effects observed in quintiles 3 and 4 (OR 0.64; 95% CI, 0.41–1.00; OR 0.58; 95% CI, 0.37–0.91).[32]

Vitamin C and E Intake

Vitamin C (ascorbic acid) is a hydro-soluble lactone (synthesized from glucose) that is essential to the human body for several functions. Humans lack the terminal enzyme in the biosynthetic pathway for ascorbic acid synthesis, so diet is critical for its availability.[3] Vitamin C counteracts hydroxyl radicals, contributes to protecting the fetus from oxygen-free radical damage, is involved in the regeneration of oxidized vitamin E, promotes endothelial cell proliferation, inhibits endothelial cell apoptosis and lipid peroxide formation, as well as improves endothelial function.[3]

As for vitamin E, plants make 8 different types of vitamin E, 4 (α-, β-, γ-, and δ-) tocopherols and 4 (α-, β-, γ-, and δ-) tocotrienols. However, according to the Institute of Medicine (IOM), only α-tocopherol meets vitamin E requirements in the human body because it is the only form that reverses vitamin E deficiency symptoms, as well as being the only vitamin E form maintained in tissues and plasma.[35] In the diet, α-tocopherol is found in nuts, seeds, and vegetable oils such as wheat germ, sunflower seed, safflower, and olive. Generally, plasma α-tocopherol concentrations <12 µmol/L are associated with increased infection, anemia, stunting of growth, and poor outcomes during pregnancy in both infant and mother.[35]

Among the various strategies proposed to alleviate maternal and fetal complications, the consumption of antioxidants such as vitamins E and C has gained attention.[36] In a study conducted by Cardoso and Surve (2016), pregnant women in the intervention group, who were supplemented with daily oral doses of vitamin C (500 mg) and vitamin E (400 IU), experienced a noteworthy 46% decrease in the incidence of PE compared to the control group, which did not receive vitamin E and C supplementation.[37] Furthermore, the intervention group exhibited a 46% reduction in the risk of PTD. Although the intervention group also showed a 50% reduction in the risk of SBs and neonatal deaths, these findings did not achieve statistical significance.[37]

An insightful cross-sectional study revealed a significant positive correlation between maternal plasma levels of vitamin C and various neonatal parameters, including weight ($r = 0.448$, $P < 0.001$), length ($r = 0.67$, $P < 0.001$), and BMI ($r = 0.52$, $P = 0.003$), as well as placental weight ($r = 0.373$, $P < 0.001$). Conversely, a significant negative correlation with the placental apoptotic index was observed ($r = -0.817$, $P < 0.001$).[3] In a more recent study, the relationship between dietary intake of vitamins E or C and small for gestational age (SGA) births was investigated, and no significant associations were found.[32]

Vitamin D Intake

Approximately 80% to 90% of vitamin D is synthesized in the skin through exposure to ultraviolet radiation (sunlight), while the remaining 10% to 20% is acquired from dietary sources.[38] Ultraviolet radiation penetrates the skin's epidermal layer, converting 7-dehydrocholesterol (provitamin D3) into vitamin D3 (cholecalciferol). This synthesized vitamin D3 is released into the bloodstream and subsequently binds to the vitamin D binding protein (VDBP). The vitamin D3-VDBP complex is then converted to 25-hydroxyvitamin D (25(OH)D) in the liver, re-entering circulation.[38] In the kidney, a secondary hydroxylation process transforms 25(OH) D into 1, 25-dihydroxy vitamin D (1,25(OH)2D), the biologically active form. This active form attaches to intracellular vitamin D receptors present in numerous organs and cells throughout the body, regulating cellular activity.[38]

Vitamin D holds a crucial role in maintaining bone equilibrium, fostering brain development, and modulating the immune system.[5] It significantly impacts maternal and infant health, as the fetus's vitamin D levels are entirely contingent on the mother's circulating 25-hydroxy vitamin D (25(OH)D) levels. Vitamin D is pivotal in regulating fetal growth by modulating parathyroid hormone and enhancing calcium absorption.[39] The World Health Organization (WHO) currently advises against routine oral vitamin D supplementation for all pregnant women to improve pregnancy outcomes, except in cases of suspected vitamin D deficiency, where an intake of 200 IU per day may be warranted.[40] Global estimates indicate that vitamin D deficiency affects approximately one billion individuals and is prevalent among pregnant women.[5] A longitudinal study involving 82 mothers revealed that 7.33% were deficient in vitamin D, 76.6% exhibited insufficient levels, and 15.9% had normal levels.[39] Notably, mothers in the third tertile of vitamin D serum levels had significantly higher mean newborn birth weights, lengths, and head circumferences compared to those in the first tertile ($P < 0.001$, $P = 0.004$, and $P < 0.001$, respectively). Additionally, maternal 25(OH)D serum levels displayed an inverse correlation with fasting blood sugar levels, revealing a potential link between vitamin D deficiency and the risk of elevated blood glucose or GDM.[39]

A systematic review and meta-analysis from 16 studies demonstrated that women with deficient vitamin D levels had an increased risk of LBW (OR = 2.39; 95%CI 1.25–4.57; P= 0.008) compared to women with adequate vitamin D levels.[41] Hubeish *et al*. (2018) explored the association between maternal serum vitamin D level and the rate of primary cesarean section (CS) in Lebanon's study.[42] Approxamitly, the rate of primary CS was three times higher in the deficient group with ≤ 30 ng/mL serum vitamin D level than in the control group with > 30 ng/mL serum vitamin D level (40.9% vs. 12.8%, respectively with a P value of < 0.0001). In the deficient group, the primary CS was a result of failure to progress, failure of induction, and failure to descend (58.8%, 23.7%, and 17.5% respectively).[42] In a randomized clinical trial by Mojibian *et al*. (2015), no significant differences were observed in the incidence of PE, gestational hypertension (GH), preterm labor, or LBW between two groups of pregnant women (Group A received 400 IU of vitamin D daily, and Group B received 50,000 IU of vitamin D every two weeks orally until delivery).[43]

Iron Intake

Iron, an essential micronutrient, plays a vital role in the biological functioning of all cells by facilitating processes like oxygen delivery, electron transport, and enzymatic activity.[44] The demand for iron surges during pregnancy to accommodate the expansion of maternal blood volume, fetal growth and development, and the establishment of iron stores for the initial six months of infancy.[44] Supplementation with (30 mg to 60 mg) per day of iron for pregnant mothers was recommended to avoid many adverse pregnancy conditions such as anemia, puerperal sepsis, LBW, and PTB.[45] Additionally, adequate intake of nutrients such as iron and folic acid is essential for preventing NTDs and promoting healthy brain development, underscoring their importance for optimal neurodevelopment.[46]

Iron deficiency arises due to inadequate dietary intake of absorbable iron (insufficient to meet heightened demands during pregnancy) or iron loss through factors such as parasitic infections (e.g., hookworm) or blood loss during childbirth1. Globally, the estimated prevalence of anemia in pregnancy stands at around 41.8%.[47] Consequently, the World Health Organization (WHO) has advocated for the use of iron supplementation during pregnancy in low- and middle-income countries, as well as in several high-income countries.[48]

In a prospective cohort study conducted by Fite *et al*. (2022), The prevalence of LBW was 5.04 (95% CI = 2.78–9.14) times more among mothers with iron deficiency compared to mothers with normal iron status.[49] Similarly, the risk of LBW was found to decrease by 3% for every 10 mg increase in daily iron dose (RR=0.97, 95% CI 0.95 to 0.98; P for linear trend <0.001; 13 trials)48. In a large multicenter retrospective study involving 44,002 pregnant women, anemia was associated with a substantial rise ($P < 0.001$) in adverse maternal and neonatal outcomes. These included conditions like GDM, polyhydramnios, PTB, LBW, neonatal complications, and neonatal intensive care unit (NICU) admissions.

These adverse outcomes were more pronounced in pregnant women with anemia compared to those without.[50] Another cohort study reported that total iron intake was significantly linked to a decreased risk of SGA births (P=0.010), and animal-derived iron intake was associated with a reduced risk of PTB and extreme PTB.[51]

Calcium Intake

Calcium, a vital component of teeth and bones, also plays crucial roles in muscle activation, nervous signalling, and enzyme functioning.[52] During pregnancy, calcium is actively transported across the placenta, and maternal calcium needs to surge, particularly in the third trimester.[1] Calcium deficiency can occur during pregnancy due to physiological changes, increased fetal requirements, and higher maternal urinary calcium excretion, which is roughly twice as much during this period.[51] Alarmingly, in Africa, deficiency risks are notably high, with calcium deficiency being 54% more prevalent among pregnant women and children.[51]

Covering the increased calcium demands can be achieved through diet (with a recommended intake of 1.2 g/day), and some recommend supplementation of 0.3–2.0 g/day to maintain maternal calcium balance, bone density, and support fetal development, especially in women with low dietary calcium intake.[1] A randomized double-blind placebo-controlled clinical trial revealed that calcium-vitamin D co-supplementation in healthy pregnant women for 9 weeks significantly elevated plasma total antioxidant capacity, 25(OH)D levels, and serum calcium. Additionally, diastolic blood pressure decreased significantly in the co-supplementation group compared to placebo. However, no significant impact on pregnancy outcomes was observed36. Research by Mosha *et al*. (2017) indicated that higher calcium intake was linked to a reduced risk of PTB, extreme PTB, and neonatal mortality.[51]

Iodine Intake

Iodine, an essential micronutrient, is crucial for the synthesis of thyroid hormones and normal fetal neurodevelopment.[46] In healthy adults, iodide absorption from the diet is over 90%.[53] The human body contains 15–20 mg of iodine, mainly concentrated in the thyroid gland. However, chronic iodine deficiency can lead to thyroid iodine levels falling below 20 μg.[53] During pregnancy, the iodine requirement increases by at least 50% due to heightened maternal thyroxine production, iodine transfer to the fetus, and increased renal iodine excretion.[53] WHO recommends a daily iodine intake of 250 μg for pregnant and lactating women.[53]

Severe maternal iodine deficiency can lead to maternal and fetal hypothyroidism, spontaneous abortion (SA), congenital anomalies, growth retardation, SB, and perinatal mortality. Low urinary iodine concentration (UIC) and elevated thyroid-stimulating hormone (TSH) levels are associated with an increased risk of PTD and adverse pregnancy outcomes.[54] Adequate UIC levels (150-249 μg/L) have been linked to lower incidences of PE, placenta previa, and fetal distress55. Clinical and subclinical hypothyroidism during pregnancy is also associated with increased risks of PTD and other adverse outcomes.[55]

Zinc Intake

Zinc is an essential micronutrient that serves as a critical component of numerous enzymes and nucleic acids. Its involvement in DNA and RNA synthesis, as well as transcription and replication, plays essential roles in the human immune system and the development of the fetal nervous system. Zinc also contributes to antioxidant defense, wound healing, and vision maintenance.[1,52] In many developing countries, zinc deficiency ranks among the most common micronutrient deficiencies (MNDs). Alarmingly, around 82% of pregnant women globally experience zinc deficiency, stemming from either insufficient intake or chronic infections that lower plasma zinc concentrations. Among pregnant women, low zinc concentration can result in reduced placental zinc transport and inadequate fetal zinc supply.[56] A study from China highlighted the consequences of insufficient zinc intake in late pregnancy, revealing associations with fetal growth retardation, congenital malformations, and even fetal death.[52] Another study by Jyotsna *et al*. (2015) found that the mean serum zinc levels were significantly lower in LBW neonates compared to term appropriate-for-gestational-age (AGA) newborns. Similarly, the zinc levels in mothers of LBW babies were significantly lower than those in mothers of term AGA newborns.[56] These findings underscore the importance of adequate zinc intake during pregnancy for both maternal and fetal health.

Caffeine Intake

Caffeine is a stimulant substance from the xanthine group, consumed globally from coffee intake, and also from many sources including tea, soda, chocolate, energy drinks as well as some medication. Indeed, it is estimated that 89% of women aged 18-24 years consume caffeinated beverages with an average intake of 166 mg/day of caffeine.[57] The half-life of caffeine increases significantly in pregnancy from 3 hours in the first trimester to 80-100 hours in late pregnancy due to decreasing activity of the maternal liver enzyme that is substantial for caffeine metabolism (by one-third in the first trimester and by half in the second trimester of pregnancy).[18,58] In addition to this, caffeine and its metabolites pass the placental barrier easily, and caffeine excretion is delayed due to the immaturity of the fetal liver.[58] According to WHO recommendations caffeine intake should be below 300 mg/day during pregnancy, while in the Nordic countries and USA, a maximum caffeine intake of 200 mg/day was recommended59. A Norwegian mother and child cohort study revealed that coffee caffeine was associated with gestation length (8 h/100 mg/day, P <10-7) but not with spontaneous PTD risk.[59]

Energy, Body Weight Parameters, and Pregnancy Outcomes

During pregnancy, the body undergoes significant changes to support fetal growth and development. These changes include the formation of maternal tissue, increased uterine size, mammary gland hypertrophy, and accumulation of fat reserves.[2] Adequate energy and nutrient intake are crucial to ensure a healthy pregnancy and proper development of the fetus. The Institute of Medicine (IOM) recommends an increase in energy intake by 340-450 kcal/day during the second and third trimesters of pregnancy to meet the growing demands.[60] Sun and Chien (2021) demonstrated that a significant reduction in physical activity (PA) from pre-pregnancy to pregnancy is a risk factor for excessive GWG.[61] While most women reduced their PA during pregnancy, only those who were physically active before pregnancy experienced the substantial decrease linked to excessive GWG. The authors recommended that health professionals prioritize developing strategies to address the concerning trend of declining PA during pregnancy, particularly among low-risk pregnant women. Their recommendations align with existing evidence that pregnant women with a normal pre-pregnancy BMI should aim for a weight gain of 11.5 to 16 kg and engage in moderate-intensity PA for at least 150 minutes per week.[61]

However, excessive gestational weight gain (GWG) among obese women can lead to metabolic impairments in both the mother and the baby.[60] Studies have shown that many pregnant women gain weight outside the recommended guidelines, with a significant percentage gaining excessive weight.[62] Maternal pre-pregnancy BMI has been found to have a stronger impact on pregnancy outcomes than GWG itself. Higher pre-pregnancy BMI is associated with increased risks of adverse outcomes such as PE, gestational hypertension (GH), GDM, CS, PTB, and small- or large-for-gestational-age (SGA/LGA) infants.[63] A large cohort study of 536 098 Chinese pregnant women showed that pre-pregnancy underweight was associated with PTB, LBW, and SA (spontaneous miscarriage (SM)); overweight women had an increased risk of LBW; obese women had a higher risk of LBW, SM, ectopic pregnancy (EP) and SB.[64] Excessive GWG is also associated with adverse outcomes, including increased risk of large-for-gestational-age (LGA) infants, macrosomia, and cesarean deliveries65. Conversely, inadequate GWG is associated with a higher risk of small-for-gestational-age (SGA) infants and PTB.[65]

Pregnant women need to strive for a balanced and healthy weight gain within the recommended guidelines to minimize the risk of complications and ensure the well-being of both the mother and the developing baby.

Dietary Patterns and Pregnancy Outcomes

A healthy lifestyle was linked to a reduced risk of adverse pregnancy outcomes (APOs), suggesting that adopting a healthy lifestyle before pregnancy may help lower the risk of APOs, which can increase the likelihood of future chronic diseases in both the mother and child.[66]

Dietary patterns (DPs), a measure of the overall diet, have become widespread in nutrition research as an alternative method to studying individual components of the diet.[67] Namely, DP identifies the influence of foods eaten in combination and allows for interactions between nutrients. These patterns can vary based on cultural, geographical, and regional influences, leading to diverse dietary habits around the world.[67] There are three main methods for deriving DPs: a priori, posteriori, and hybrid methods.[68] Priori Approaches (Investigator-driven methods): These approaches are based on existing nutritional knowledge and recommendations to assess the relationship between the quality of overall diet and a specific disease by using dietary scores and dietary indexes69. Examples of a priori DPs include the Healthy Eating Index (HEI), Dietary Approaches to Stop Hypertension (DASH), and the Alternative Mediterranean Diet.[69] The posteriori approaches: These approaches utilize statistical methods, such as principal component analysis and cluster analysis, to identify common patterns of food consumption from actual dietary data.[70] Factor analysis, specifically principal component analysis, is a mathematical procedures that regroup and isolate food variables into a set of clusters based on their correlations and estimates patterns in the observed data.[71]. Researchers then use summary factor scores for these patterns to analyze their relationships with outcomes.[71] By using DPs, researchers aim to capture the broader dietary context and potential synergies or interactions between nutrients. This approach provides a more comprehensive understanding of how overall dietary habits contribute to health outcomes, rather than focusing solely on individual nutrients or foods.

The Traditional Mediterranean and The Dietary Approaches to Stop Hypertension Diets

The traditional Mediterranean diet (MD) is considered one of the healthiest DPs worldwide.[72] According to the new MD pyramid (Figure 1).[73] The MD is characterized by its emphasis on a substantial intake of olive oil, fruits, vegetables, legumes, nuts, and whole grains. It also encourages moderate consumption of fish and limits the intake of red and processed meats. This dietary pattern promotes low SFA intake and emphasizes the consumption of monounsaturated fats from olive oil. Additionally, the MD is notable for its richness in dietary fiber, a well-balanced ratio of n-6/n-3 essential fatty acids, and abundant antioxidants, particularly polyphenols from olive oil, as well as vitamins E and C.[74]

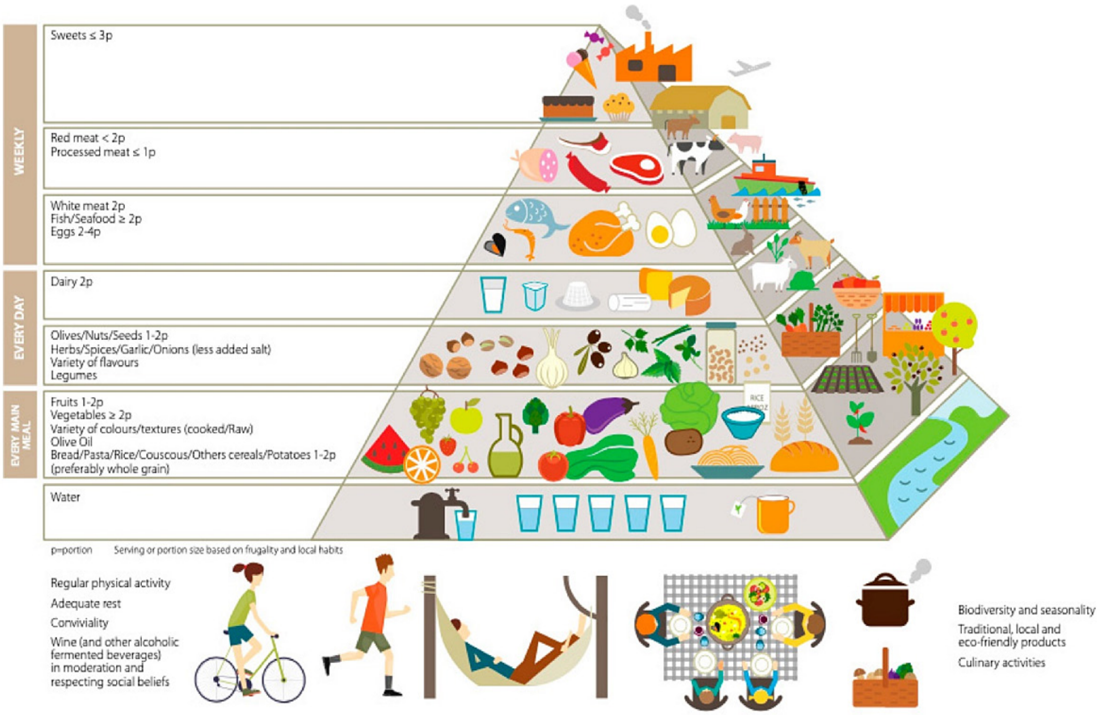

Fig.1: New Pyramid for a Sustainable Mediterranean Diet. This graphic representation was conceived to be adapted to the dietary pattern related to the various geographical, socio-economic and cultural contexts, dietary needs, and meal patterns of the Mediterranean region with a focus on "environmental sustainability".[73]

Another similar diet is, the Dietary Approaches to Stop Hypertension (DASH) diet is a well-known dietary pattern that promotes a high intake of nutrient-rich foods, such as fruits, vegetables, whole grains, lean proteins, and nuts while limiting the consumption of red meats, saturated fats, trans fats, sugar, and sodium.[75] This dietary approach is designed to help lower blood pressure and improve overall cardiovascular health.

In 1995, the Mediterranean Dietary Score (MDS) a scoring system was introduced by Trichopoulou *et al* to assess adherence to the MD, enabling the assessment of its role in analytical epidemiologic studies.[72] The total score for adherence to the Mediterranean diet ranges from 0 (indicating minimal adherence) to 9 (representing maximal adherence) to the traditional MD.[72] Scoring within the range of 0-3 indicates low adherence, while a score of 4-6 reflects moderate adherence and a score of 7-9 indicates high adherence to the MD.[74] Findings from a French Caribbean Mother-Child Cohort Study revealed that following the MD during pregnancy was linked to a reduced risk of PTD, particularly among overweight and obese women (adjusted odds ratio (AOR 0.7, 95%, CI 0.6, 0.9).[76] Another study demonstrated that adhering to the Mediterranean and DASH diets and following a high-fiber diet during pregnancy were linked to a lower risk of adverse metabolic outcomes in both pregnant women and their children.[77] This study found that the MD and DASH diet were associated with a lower risk of GDM (OR: 0.60; OR: 0.36, respectively) and reduced excessive gestational weight gain (OR: 0.41; OR: 0.3, respectively). Additionally, the MD was linked to reduced risks of small for gestational age, fetal growth restriction, and childhood overweight in offspring (OR: 0.83; OR: 0.50; OR: 0.85). A high-fiber diet was also shown to lower risks of GDM (OR: 0.22) and pregnancy hypertension (OR: 0.45), as well as reduce birth weight (−109.54 g).[76] Further research highlights that excessive weight gain during pregnancy increases risks of instrumented and Cesarean deliveries, GDM, postpartum maternal obesity, macrosomia, NTDs, childhood obesity, and later-life diseases in newborns.[2]

Regarding the DASH diet, in the context of pregnancy, recent research has explored the potential benefits of the DASH diet for maternal and fetal health, particularly for pregnant women with chronic hypertension and gestational hypertension (GH).[75] A randomized controlled clinical trial investigated the effects of the DASH diet on pregnant women with chronic hypertension and GH. The study found that participants following the DASH diet experienced improved clinical outcomes. The DASH diet group had a lower incidence of preeclampsia (PE), prematurity, and low birth weight (LBW) compared to the control group. Additionally, significant differences were observed in SGA at delivery and neonatal length between the two groups.[78] Another cohort study focused on healthy, normotensive pregnant women and their adherence to DASH dietary recommendations throughout pregnancy. The study revealed that higher adherence to the DASH diet was associated with lower diastolic blood pressure and mean arterial pressure in trimesters 1 and 3. This suggests that following the DASH diet during pregnancy may have a positive impact on blood pressure regulation.[79] It is important to note that while some studies have shown the benefits of the DASH diet in pregnancy, not all outcomes have consistently demonstrated significant differences. For example, another study did not find significant differences in delivery type, postpartum hemorrhage, postpartum gestational hypertension, mean birth weight, or Apgar score between the DASH diet and control diet groups.[78] Another study conducted by Tayyem *et al*. identified four distinct DPs, which were labelled as "fruit and vegetables," "healthy," "traditional," and "fat and sugar." However, no significant association was found between these identified dietary patterns and the occurrence of CS across all tertiles.[80]

Overall, MD and DASH diet appear to have potential benefits for improving maternal and fetal health outcomes during pregnancy, particularly in the context of hypertension. However, more research is needed to fully understand its effects and to determine its suitability for different populations of pregnant women.

Lifestyle Factors and Pregnancy Outcomes

Smoking

Globally, cigarette smoking is the most common product of tobacco use. However, all types of tobacco are harmful, and there is no safe level of tobacco exposure.[81] In 2020, 22.3% of the world population used tobacco, 36.7% and 7.8% of all men and women, respectively.[81] Smoking during pregnancy is associated with many adverse complications or birth outcomes.[82] Besides, Maternal smoking may increase the rate of CS and the rate of newborn morbidity and mortality.[82] Dahly *et al*. (2018) suggested that pregnant women who never smoked tended to have longer offspring with more fat-free mass and fat mass.[83] A population-based birth-cohort study conducted in a northern province of the Netherlands revealed that smoking during pregnancy was significantly associated with SGA (OR 3.00, 95% CI 1.80–4.99) in multivariable logistic regression analyses.[84]

Physical Activity and Pregnancy Outcomes

All pregnant and postpartum women without contraindications should exercise for at least 150 minutes per week of moderate-intensity aerobic PA.[85] The benefits of PA for maternal and fetal health include a decreased risk of PE, GH, GD, excessive GWG, delivery complications, PPD, and newborn complications. Additionally, PA has no adverse effects on birth weight or an increased risk of SB.[85]

A cohort study of 2029 pregnant women indicated that 1334 (65.8%) underwent CS and 692 (34.2%) underwent normal vaginal delivery, whereas the OR of CS was 0.68 (95% CI: 0.47–0.97) for a pregnant woman who increased her activity level during pregnancy compared to pre-pregnancy.[86] Screening for pregnancy endpoints (Cork) study suggested that fat mass at the highest centiles was lower among infants of women who exercise frequent moderate-intensity PA early in the pregnancy (-92 g at the 95th centile, 95% CI: -168 to -16).[83]

Alcohol

Prenatal alcohol exposure presents a significant and widespread public health concern, as it has been associated with a range of adverse health outcomes for both expectant mothers and developing fetuses. These include serious conditions such as SB, SA, PTB, LBW, intrauterine growth retardation, congenital malformations, and fetal alcohol spectrum disorder.[87,88] In the United Kingdom, official guidelines from the Department of Health advise pregnant women to completely abstain from alcohol consumption. However, for those who choose to drink, the recommendation is to limit intake to one to two units once or twice a week. Additionally, the National Institute of Health and Clinical Excellence recommends avoiding alcohol consumption before conception and during the first three months of pregnancy and stresses the importance of avoiding intoxication or binge drinking, defined as consuming more than five standard drinks or 7.5 units of alcohol.[89]

A comprehensive multinational European study conducted between October 2011 and February 2012, involving 7905 women (comprising 53.1% pregnant individuals and 46.9% new mothers), highlighted variations in alcohol consumption during pregnancy across different countries.[89] The highest rates of alcohol consumption during pregnancy were observed in the UK (28.5%), Russia (26.5%), and Switzerland (20.9%), while the lowest rates were seen in Norway (4.1%), Sweden (7.2%), and Poland (9.7%). Additionally, the study noted that 39% of participants reported consuming at least 1 unit of alcohol per month during pregnancy, averaging at around 15.8%.[88] Another cross-sectional survey, which focused on the South West of England, explored the prevalence and patterns of alcohol consumption both before conception and during the initial trimester. The findings indicated that although some women exceeded recommended drinking limits, only a minority consumed quantities of alcohol that could potentially harm the fetus. Furthermore, the study highlighted that alcohol consumption was more common among multiparous women and those of white ethnicity.[89]

Conclusion

To conclude, adequate maternal nutrition and healthy lifestyle practices during pregnancy are critical for optimizing maternal and fetal health outcomes. This review highlights the importance of meeting daily requirements for essential nutrients, including carbohydrates, proteins, fats (especially omega-3 fatty acids), vitamins, and minerals such as folate, iron, and calcium. Furthermore, adherence to dietary patterns like the Mediterranean or DASH diets and maintaining regular physical activity can significantly improve pregnancy outcomes and reduce complications. On the contrary, inadequate nutrient intake can negatively affect maternal and neonatal outcomes. While the impact of some nutrient deficiencies is well-documented, the relationship between vitamin D intake and

CS remains unclear, indicating a need for more experimental studies in this area.

Healthy pregnancy outcomes are achieved through the mother's adherence to recommended nutrient intake, regular physical activity (150 minutes per week at moderate intensity), healthy dietary habits, and lifestyle factors, as well as appropriate gestational weight gain based on pre-pregnancy BMI. Routine nutritional assessments and personalized dietary counselling should be integral to prenatal care. Additionally, public health initiatives aimed at raising awareness about the dangers of harmful substances, including alcohol and tobacco, are essential for safeguarding maternal and fetal well-being.

Future research should focus on identifying culturally specific dietary patterns and their impacts on pregnancy outcomes to enhance global guidelines. By adopting these evidence-based practices, we can ensure better health trajectories for mothers and their children.

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Author Contributions

- **Amal Yadak:** Contributed to the conception, execution, data acquisition and analysis and drafted the review.
- **Sabika Allehdan:** Contributed to the conception, execution, data acquisition and analysis and drafted the review.
- **Reema Tayyem:** Contributed to the conception, execution, data acquisition and analysis and drafted the review.
- **Amal Yadak:** Interpretated, and revised the review
- **Oqba Al-Kuran:** Interpretated, and revised the review
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