International Journal of Gynecology and Obstetrics 131 S4 (2015) S213–S253

Contents lists available at ScienceDirect

International Journal of Gynecology and Obstetrics

journal homepage: www.elsevier.com/locate/ijgo

The International Federation of Gynecology and Obstetrics (FIGO) recommendations on adolescent, preconception, and maternal nutrition: "Think Nutrition First"[#]

Mark A. Hanson[a], Anne Bardsley[b], Luz Maria De-Regil[c], Sophie E. Moore[d], Emily Oken[e], Lucilla Poston[f], Ronald C. Ma[g], Fionnuala M. McAuliffe[h], Ken Maleta[i], Chittaranjan N. Purandare[j], Chittaranjan S. Yajnik[k], Hamid Rushwan[l], Jessica L. Morris[l,*]

[a] *Institute of Developmental Sciences, University of Southampton; and NIHR Nutrition Biomedical Research Centre, University Hospital Southampton; Southampton, UK*
[b] *Liggins Institute, University of Auckland, Auckland, New Zealand*
[c] *Micronutrient Initiative, Ottawa, Canada*
[d] *MRC Human Nutrition Research, Cambridge, UK*
[e] *Department of Population Medicine, Harvard Medical School and Harvard Pilgrim Health Care Institute; and Department of Nutrition, Harvard TH Chan School of Public Health; Boston, MA, USA*
[f] *King's College London, London, UK*
[g] *Department of Medicine and Therapeutics, The Chinese University of Hong Kong; and the Hong Kong Institute of Diabetes and Obesity, The Chinese University of Hong Kong, Hong Kong, China*
[h] *UCD School of Medicine and Medical Science, University College Dublin, National Maternity Hospital, Dublin, Ireland*
[i] *University of Malawi College of Medicine, Blantyre, Malawi*
[j] *Grant Medical College, Mumbai, India*
[k] *Indian College of Obstetricians and Gynaecologists, Mumbai, India*
[l] *International Federation of Gynecology and Obstetrics, London, UK*

Contributors

In addition to the authors, the following people provided important contributions during the creation of the document: Carlos Blanco, Carlos Echeverry, Torvid Kiserud, Gwyneth Lewis, Francisco Mardones, Susan Morton, Sian Robinson, Michael Ross, and Gerard Visser. In addition to the FIGO Executive Board, all relevant FIGO Committees and Working Groups contributed to and supported the document.

Acknowledgments

This project was funded by an unrestricted educational grant from Abbott. The content was developed by FIGO, with no input from Abbott. Some of the material on nutrient recommendations contained within these guidelines is sourced from Gluckman P, Hanson M, Chong YS, Bardsley A. *Nutrition and Lifestyle for Pregnancy and Breastfeeding*. Oxford: Oxford University Press; 2015.

Conflict of interest

The authors have no conflicts of interest to declare.

A mother brings her child for a check-up at a clinic in Kenya. Photograph courtesy of Micronutrient Initiative.

[#] This document was endorsed by the FIGO Executive Board at its annual meeting held on May 30–31, 2015, in Melbourne, Australia

* Corresponding author at International Federation of Gynecology and Obstetrics, FIGO House, Suite 3, Waterloo Court, 10 Theed Street, London, SE1 8ST, UK.
Tel.: +44 207 928 1166
E-mail address: Jessica@figo.org (J.L. Morris).

List of abbreviations/acronyms

ALA	Alpha-linolenic acid
BMI	Body mass index
DHA	Docosahexaenoic acid
ELCAMC	Estudio Colaborativo Latino Americano de Malformaciones Congénitas (Latin American Collaborative Study of Congenital Malformations)
FAO	Food and Agriculture Organization
FIGO	International Federation of Gynecology and Obstetrics
GDM	Gestational diabetes mellitus
GI	Glycemic index
HTLV	Human T-cell lymphotropic virus
LA	Linoleic acid
LMICs	Low- and middle-income countries
MDD-W	Minimum dietary diversity index for women
MDGs	Millennium Development Goals
NCDs	Noncommunicable diseases
NTDs	Neural tube defects
PCBs	Polychlorinated biphenyls
PUFAs	Polyunsaturated fatty acids
RM	Rosso and Mardones chart
SQ-LNS	Small quantity lipid-based nutrient supplements
UNSCN	United Nations Subcommittee on Nutrition
WHO	World Health Organization

1. Executive summary

Adolescent, preconception, and maternal nutrition represent a major public health issue that affects not only the health of adolescents and women, but also that of future generations. These FIGO recommendations aim to address several issues relating to nutrition in adolescent and young women before, during, and after pregnancy. FIGO calls for:

- Increased awareness of the impact of women's nutrition on their health and the health of future generations.
- Greater attention given to the links between poor maternal nutrition and increased risk of later noncommunicable diseases (NCDs) in the offspring as a core component of meeting global health goals.
- Action to improve nutrition among adolescent girls and women of reproductive age.
- Public health measures to improve nutritional education, particularly for adolescents, girls, and young women.
- Greater access to preconception services for women of reproductive age to assist with planning and preparation for healthy pregnancies and healthy children.

FIGO recommends that maternal nutrition should be part of a life course approach that views perinatal health within the context of women's overall health. This approach emphasizes the importance of the adolescent and young adult periods for lifelong health, and the potential benefits to health and human capital in the next generation gained by achieving healthy lifestyles prior to conception.

In this regard, FIGO also emphasizes that nutrition in adolescent and young women is modifiable. Attention should be paid to nutritional status before pregnancy whenever possible, and adoption of good dietary and lifestyle habits needs to be strongly encouraged at all stages.

The recommendations view malnutrition as poor nutrition in all its forms, from both deficient (energy and protein undernutrition) or excessive (obesity) consumption of macronutrients, to micronutrient malnutrition—which results from a diet with insufficient vitamin and mineral density, poor bioavailability of nutrients, or increased body requirements due to infection or growth. It is important to stress that malnutrition can result from overconsumption of non-nutritive calories—food *quality* counts as much as food *quantity*.

FIGO recommends promotion of a varied and healthy diet as the first step to meeting the nutrient needs of adolescent girls and young women. It is critical that micronutrient deficiencies are recognized and rectified through interventions including dietary diversity, consumption of fortified foods, and supplementation as appropriate. Common nutrient deficiencies in adolescent girls and young women that may require supplementation include:

- Iron: adolescent girls and pregnant women are at risk of iron deficiency due to menstrual blood loss and increased pregnancy demands, and commonly require iron supplements.
- Iodine: required early in pregnancy and often lacking in diets if iodized salt is not used.
- Folate: required before conception and in early pregnancy as dietary intake is usually inadequate. All women of reproductive age are advised to consume 400μg of folic acid per day as supplements or fortified foods.
- Vitamin B12: dietary intake is very low in vegetarian diets and absent in vegan diets.
- Calcium: lacking in diets low in dairy products; there is a higher requirement especially in adolescents during the growth spurt.
- Vitamin D: food sources are minimal unless fortified, and inadequacy is common, especially in women with minimal sun exposure, or darkly pigmented skin.

Pregnant women need early access to prenatal care to receive nutrition counseling and treatment for conditions that may jeopardize their pregnancy outcome, such as malaria, tuberculosis, HIV, gastrointestinal infections, and NCDs. These conditions can compromise nutrition through malabsorption and altered metabolism, with a number of consequences including increased risk of vitamin and mineral deficiencies and weight loss.

FIGO recognizes body weight/body mass index (BMI; calculated as weight in kilograms divided by height in meters squared) as another modifiable risk factor with important effects on a woman's nutritional status. Underweight women may be lacking in a number of important nutrients, and their diets should be carefully assessed and supplemented as required. Obesity itself confers risks of adverse pregnancy outcomes. Furthermore, overweight or obese women may have poor quality diets that are high in energy but low in nutritional value. Both of these conditions can negatively affect pregnancy outcomes. Thus, FIGO recommends that attention be paid to preconception or early pregnancy body weight and BMI, and steps be taken to modify weight by improving diets and encouraging appropriate levels of physical activity.

Adequate gestational weight gain is important for maintaining the health of both the mother and possibly for her baby. FIGO recommends that healthcare professionals take action to ensure appropriate gestational weight gain in relation to prepregnancy BMI. However, this should not be overemphasized at the expense of important assessments such as blood pressure measurement, urine testing for protein, and abdominal examination, as can sometimes occur in low-resource settings.

FIGO strongly recommends that dangerous exposures and behaviors such as smoking, alcohol intake, or use of recreational drugs are avoided prior to conception. If such habits persist in pregnancy, women should be encouraged and assisted to give them up as soon as possible because of the risk of detrimental effects on fetal nutrition, growth, and development.

FIGO calls for action to reduce the exposure of adolescents and pregnant women to mercury, arsenic, lead, and cadmium, which can be ingested via food and water. These heavy metals can have detrimental effects on fetal growth and development.

FIGO encourages healthcare providers to be cognizant of situations affecting a woman's ability to meet the nutrient demands of pregnancy:

- Young age at conception, when the mother's own growth is not complete.
- Hard physical labor, which increases nutrient and fluid requirements.
- Multiple pregnancy, which increases nutrient demand.
- Short interpartum interval, which gives limited opportunity for repletion of nutritional reserves, especially in the setting of concurrent pregnancy and breastfeeding.

FIGO recommends that the period that follows birth be used to improve the nutritional status of both mother and child. FIGO endorses the WHO recommendation of exclusive breastfeeding for the first 6 months of the infant's life.

FIGO acknowledges that there are potential barriers to dietary change, and supports the adoption of gender-sensitive policies to improve access to adequate and nutritious food for women and girls.

Concerted action is required from healthcare providers and educators working together in the community to improve the health and well-being of girls, women, and their children. Standard care should involve a wide range of healthcare providers working together, with a focus on nutrition, health, and lifestyle during adolescence, and a woman's reproductive life and beyond. These recommendations seek to empower and to provide opportunities for all levels of healthcare provider to contribute to achieving this goal.

Key messages

- In many societies women and adolescent girls are poorly nourished, in terms of the level and balance of both macro- and micronutrients in their diet. This circumstance is detrimental to their current and future health and that of their children.
- Good health and nutrition before conception are key to a mother's ability to meet the nutrient demands of pregnancy and breastfeeding, and are vital to the healthy development of her embryo, fetus, infant, and child.
- The continuum of poor maternal health and poor infant and childhood development contributes substantially to the global burden of disease and disability, affecting the way that individuals respond to a number of environmental challenges—ranging from infections to an obesogenic lifestyle.
- Healthcare providers need to "Think Nutrition First"—focusing on optimizing adolescent and maternal nutrition and health, starting in the preconception years. This approach will have considerable positive benefits for ensuring women's health and that of their children, as well as securing the health, productivity, life expectancy, and well-being of future generations.

2. Target audience of the FIGO recommendations

This document is directed at a range of stakeholders with the intention of highlighting the central role that nutrition has on adolescent, maternal, and infant well-being. This is an area that has traditionally been of low priority but which has major implications for girls' and women's health as well as the health of their offspring. The recommendations aim to create a global framework for action to improve the nutritional care and support of adolescent girls and women through their prepregnancy, pregnancy, postpregnancy, and interpregnancy periods of life. FIGO proposes that these guidelines should be widely disseminated among:

- **Healthcare providers:** physicians (obstetricians, gynecologists, pediatricians, neonatologists, general/family, adolescent and youth health, reproductive health, family planning, and fertility practitioners), nurses, midwives, dieticians/nutritionists, pharmacists, community health workers.
- **Healthcare delivery organizations and providers:** government, federal, and state legislators; health maintenance organizations and other hospital and outpatient care providers; health insurance organizations; international development agencies and nongovernmental organizations; educational bodies and community organizations concerned with youth and adolescents; pharmacists.
- **Professional organizations:** international, regional, and national professional organizations of obstetricians and gynecologists; general/family practitioners, nurses, midwives, pediatricians; neonatologists, pharmacists etc.
- **Teachers/educators:** especially those teaching health to adolescents.
- **Women and their families.**

3. Adolescent, preconception, and maternal nutrition: Background, definition, and issues

3.1. Nutrition: Why is it important?

- FIGO calls for increased awareness of the impact of women's nutrition on themselves and future generations, and supports action to improve nutrition among adolescent girls and women of reproductive age.

Good nutrition is fundamental for good health. Maternal nutrition in particular represents a major public health challenge because it affects not only women's health, but also that of future generations. Poor nutrition in adolescent girls and young women compromises reproductive health and increases risks of adverse pregnancy outcomes for both mother and child. Improving nutrition and establishing healthy dietary habits, particularly in adolescent girls and young women, paves the way for periconceptional health and, if maintained through pregnancy, will promote normal fetal growth and development. In turn, the health of the next generation will benefit through reduced risk of stunting, obesity, and chronic noncommunicable diseases (NCDs)—predominantly diabetes mellitus, cardiovascular disease, and some forms of cancer, but also atopic conditions such as asthma, bone and joint disease, and some mental illnesses—and improved cognitive and behavioral development. This is illustrated in Figure 1.

Encouraging good nutrition—an adequate diet that provides all essential micronutrients and macronutrients in the correct amounts and proportions—will help to ensure optimal health for adolescent girls and young women, and will equip them for future motherhood. A woman's fitness and health is fundamental to her own well-being and that of her children. It is fundamental to the health and prosperity of a society.

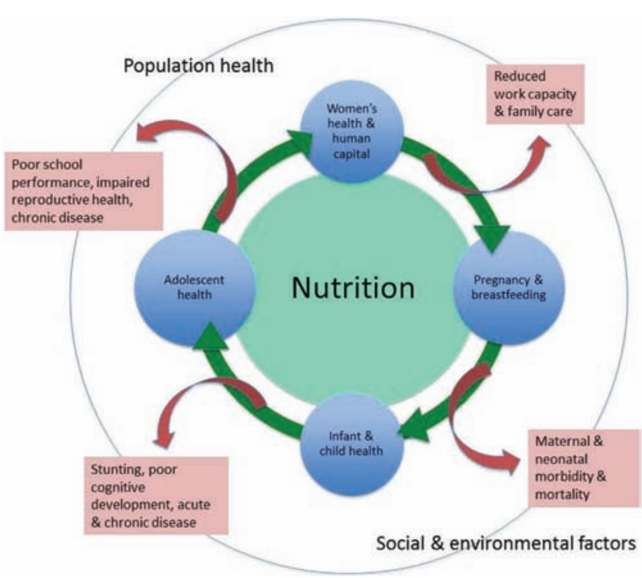

Figure 1 The central role of nutrition in determining health across the life course and across generations. All stages in a woman's life are connected by the effects of good or poor nutrition. Poor nutrition at any stage has negative consequences that disrupt the cycle and impact later life stages, including future generations.

3.1.1. Improving nutrition of adolescent girls and young women to reduce the global burden of NCDs

- FIGO calls for greater attention to the links between poor maternal nutrition and NCDs in the next generation as a core component to meeting global health goals.

Substantial evidence shows that good maternal health and nutrition before and during pregnancy can have a positive effect on the long-term risk of NCDs in the next generation. NCDs are the leading cause of death in most countries around the world. This is true of high-income countries, but also of most low- and middle-income countries, except those in Sub-Saharan Africa where women are more prone to die from infectious diseases. Over the next decade, deaths caused by NCDs are expected to increase by 15%, with the greatest increase occurring in Sub-Saharan Africa [1,2].

The burden of disability caused by NCDs exacts a huge socioeconomic toll throughout the world, undermining the achievement of the United Nations Millennium Development Goals (MDGs), which aimed to eliminate extreme poverty and hunger and improve maternal health, among other efforts, to meet the needs of the world's poorest people [3]. To address this, the WHO developed a global action plan for the prevention and control of NCDs, seeking to raise the priority accorded to NCD prevention in global, regional, and national agendas [4]. The main aims are to create health-promoting environments that encourage positive lifestyle factors (such as healthy diet and exercise) and discourage negative factors (such as tobacco and alcohol use). These behaviors have special importance in the period prior to and during pregnancy and lactation, but remain important throughout a woman's life.

In 2012, WHO member states also endorsed global targets for 2025 for improving maternal, infant, and young child nutrition and are committed to monitoring progress [5]. Three targets stand out for their relevance to women of reproductive age: a 50% reduction of anemia in women of reproductive age, a 30% reduction in low birth weight, and increasing to at least 50% the rate of exclusive breastfeeding in the first 6 months of life (Box 1). The targets are vital for identifying priority areas for action and catalyzing global change. Achieving these global targets will require an integrated approach to educating, empowering, and supporting girls and women from early adolescence through their reproductive years.

Box 1

WHO global targets 2025: Improving maternal, infant, and young child nutrition.

- Reduction by 50% of anemia in women of reproductive age
- Reduction by 30% of low birth weight
- Increase in the rate of exclusive breastfeeding in the first 6 months, up to at least 50%
- Reduction by 40% of the number of children under 5 years of age who are stunted
- No increase in childhood overweight
- Reduction in childhood wasting to less than 5%

Source: WHO [5].

3.1.2. Focus on women's preconception health and nutrition for long-term benefits

- FIGO calls for public health measures to improve nutrition education—particularly for adolescents—and access to preconception services for women of reproductive age to assist with planning and preparation for healthy pregnancies, emphasizing the importance of healthy nutrition.

A girl's or woman's nutritional health and lifestyle before and during pregnancy can influence clinically important pregnancy outcomes, including gestational hypertension and diabetes, preterm delivery, and fetal growth restriction [6,7], which can have lasting effects on her long-term health. It also influences the future health of her offspring, not only in terms of perinatal survival but for risk of later NCDs. This is because nutritional factors in utero and during early life impact not only on the physical development of the individual, but also on the risk of congenital anomalies, the development of cognitive and sociobehavioral abilities, and metabolic adaptations that affect the long-term risk of obesity and NCDs. Adults affected positively or negatively by these early-life influences pass on the effects to the next generation, through both maternal and paternal factors that influence the in utero and early-life environment. Thus there is a cycle of passing "health capital" from one generation to the next.

There are a number of possible intervention points at which this cycle of risk can be interrupted (Figure 2). In particular, evidence has highlighted the importance of the preconception period in setting the stage for optimal fitness of prospective parents and their future offspring. Messages about diet and lifestyle patterns that ensure women have adequate nutrition and good physical health, and that minimize harmful exposures and behaviors, are best conveyed by the time of early adolescence, well in advance of pregnancy. This is a time when many patterns of behavior are established, with lifelong consequences. If factors affecting body composition and risk of obesity and NCDs can be improved from childhood, these will not only positively affect the future adolescent and woman's own health, but convey significant health benefit for future generations.

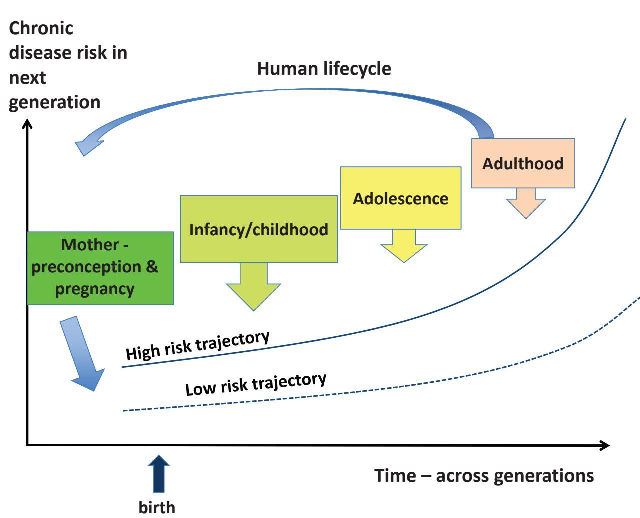

Figure 2 Life course model of chronic disease risk. Developmental trajectories established in early life, influenced by factors such as maternal diet and body composition, affect the risk of disease across the life course. Timely intervention early in life (prepregnancy or during pregnancy) can reduce later disease risk. Adapted with permission from Godfrey KM, Gluckman PD, Hanson MA. Developmental origins of metabolic disease: life course and intergenerational perspectives. Trends Endocrinol Metab. 2010;21(4):199-205; and Gluckman P, Hanson M, Seng CY, Bardsley A. Nutrition and Lifestyle for Pregnancy and Breastfeeding. Oxford: Oxford University Press; 2015.

3.1.3. New scientific insights

New research has revealed that nutritional factors can affect both male and female germ cells before conception, and can modify the development of the embryo and fetus. A woman's oocytes are formed only during her own fetal life, and it is possible for egg quality to be affected by events or exposures at any time from her own conception to her offspring's conception. Oocyte physiology can be affected by changes in levels of circulating metabolites and metabolic hormones that are responsive to nutritional status [8]. Other effects occur via epigenetic mechanisms such as DNA methylation, which modifies gene expression in a stable manner without changing the underlying DNA sequence of the organism, providing a non-genomic form of inheritance that can be passed across generations. Epigenetic processes allow one genotype to display multiple phenotypes depending on environmental cues, a phenomenon known as "developmental plasticity" [9,10]. Such cues can include both under- and overnutrition, maternal hyperglycemia, or dietary deficiency or imbalance of nutrients such as folate, vitamin B12, vitamin B6, and choline, which are involved in the methylation cycle. These cues can induce epigenetic and other responses in the oocyte and embryo that modify the growth and metabolic trajectory (Figure 3). For example, conception during a period of famine or low seasonal food availability affects epigenetic changes in the offspring that may influence disease risk [11,12]. Obesity and/or insulin resistance prior to conception also increase the risk of later metabolic disease in the offspring [13]. Additionally, the effects of these conditions on the oocyte cause reduced fertility and increased risk of congenital abnormalities in the fetus [14]. It is now essential that these new insights are translated into messages about the importance of a healthy lifestyle for healthy offspring, applicable to both adolescent girls and women.

3.1.4. Future fathers also count

The influence of the male partner's health on offspring health should also not be underestimated. As with a woman's oocytes, the testis is formed when the male is a fetus, and the germ cells from which sperm ultimately differentiate are sequestered in fetal life. Thus, it is possible that the father's sperm can be affected by environmental factors from his conception through to the production of mature sperm much later [15]. As with female germ cells, obesity, poorly controlled diabetes, and micronutrient deficiencies (e.g. selenium, zinc) in males can affect sperm quality and fertility, and future offspring health [16–18]. However, while the health of future fathers is an influencing factor in the health of their children, these FIGO guidelines focus on women.

3.2. Defining good versus poor nutrition

Nutrition is defined as the intake of food necessary for optimal growth, function, and health. Good nutrition is defined as a well-balanced diet that provides all essential nutrients in optimal amounts and proportions, whereas poor nutrition is defined as a diet that lacks nutrients (either from imbalance or overall insufficient food intake) or one in which some components are present in excess [19].

Nutrition is at the core of many current issues in women's health. This is not only because poor nutrition can lead to poor health, but because many of the socioeconomic factors that are associated with poor health and access to health care, such as

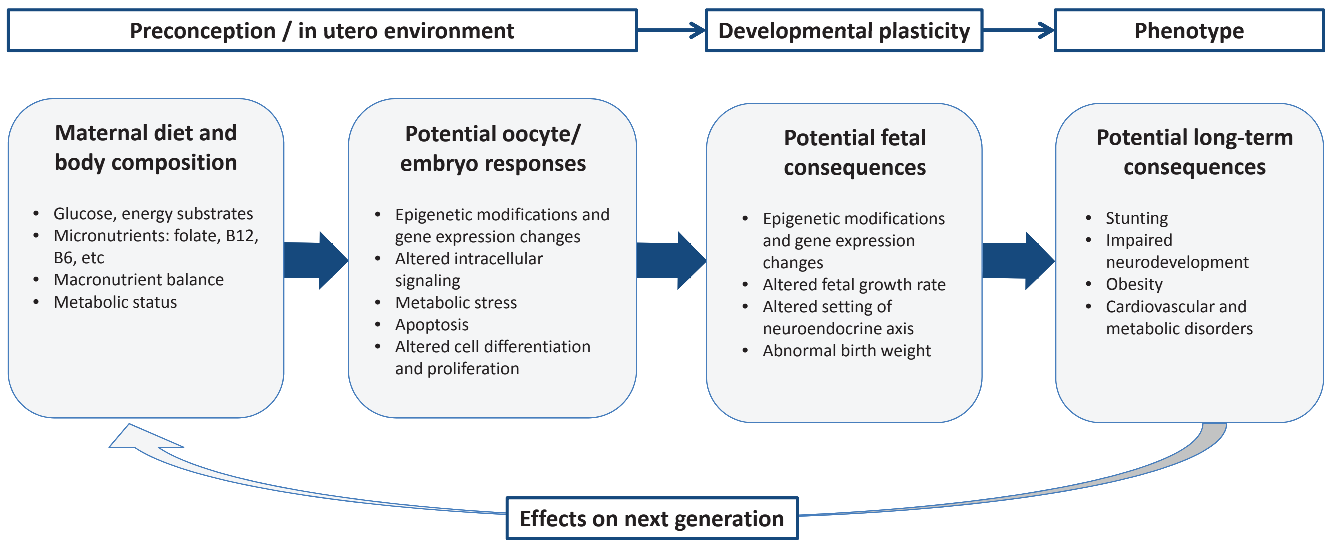

Figure 3 Effects of the preconception and in utero environment on offspring phenotype and future health. Maternal nutritional factors provide cues to the fetus during critical periods of developmental plasticity, triggering epigenetic and other responses that have lasting impacts on offspring health and that can be passed in a similar manner to the next generation.

poverty and low educational attainment, are those associated with poor nutrition. Poor nutrition can also have profound effects on reproductive outcomes. There are a number of nutritional states that are considered suboptimal or "poor." Malnutrition is sometimes thought to refer to an inadequate intake of macronutrients such as calories and protein (i.e. undernutrition), but it can also denote inadequate intake or increased losses of specific or multiple vitamins and minerals (micronutrient malnutrition) because of an unbalanced diet. This can occur even in the context of excess energy intake (overnutrition) if the diet is nutrient-poor (Box 2).

It is important to recognize that under- and overnutrition can occur at the same time in sections of a population, and over time in the same family or even in the same person as circumstances change. There are many well-known factors contributing to such change, including socioeconomic progress, urbanization, and adoption of a "Western lifestyle." This "nutrition transition" creates a double burden of obesity coexisting with undernutrition, and is common in countries undergoing rapid economic growth (see Regional Case Study 1: India). While undernutrition still causes the death of almost 1.5 million women and children every year, growing rates of overweight and obesity worldwide are producing an increase in NCDs, which are also associated with substantial mortality and morbidity. Ensuring access to a healthy diet and reducing exposure to foods high in fat, sugar, and salt helps prevent malnutrition in all its forms [20].

Box 2
Defining malnutrition.

- Malnutrition (poor nutrition) refers not only to inadequate intake of macronutrients (energy and protein undernutrition), but also to inadequate intake or increased losses of single or multiple vitamins and minerals (micronutrient malnutrition), such that the body's requirements are not met.
- Malnutrition can result from over-consumption of non-nutritive energy and underconsumption of nutrient-dense foods.
- A good diet is more than a matter of food quantity—quality is critical.

3.2.1. Undernutrition

Undernutrition is usually associated with inadequate intake because of food shortage or insecurity, but can also result from increased nutritional requirements or losses, or an impaired ability to absorb or utilize nutrients. Undernutrition can lead to stunting in early life, and to underweight and wasting throughout the lifespan, which can result in reduced resistance to infection and other debilitating conditions that reduce productivity and affect the ability of adolescent girls and women to care for their families. Globally, undernourished women are likely to be deficient in a number of micronutrients, including iron and folate, which can weaken their reproductive performance.

There is increasing evidence on the impact of maternal undernutrition on neonatal outcomes and long-term effects on intellectual, physical, and social development of the child. Exposure to undernutrition in utero is associated with congenital anomalies, lower birth weight, stunting in childhood, shorter adult height, lower educational attainment, and reduced economic productivity [24]. Women who are themselves stunted face greater risks of obstetric complications in pregnancy [25]. Low birth weight resulting from undernutrition has also been linked to an increased risk of obesity and NCDs in later life [26–28].

3.2.2. Overnutrition

Overnutrition is the regular consumption of excess energy, generally leading to overweight, and ultimately to obesity. Maternal overnutrition and obesity produce a range of health risks for the woman, including hypertensive disorders of pregnancy, gestational diabetes mellitus (GDM), and obstructed delivery. Risks for the fetus include macrosomia, high blood glucose/glucose intolerance, high blood insulin and neonatal hypoglycemia, congenital anomalies, preterm birth, stillbirth/infant death, and development of childhood obesity and later NCDs. About 75% of children with obesity become obese as adults [29], perpetuating the obesity epidemic and its associated risks of NCDs [30,31]. The prevalence of obesity is increasing around the world, including in low- and middle-income countries (LMICs) where modernization, urbanization, and economic development

Regional Case Study 1: Thinking Nutrition First in India

The double burden of undernutrition and obesity

India is facing a double burden of undernutrition and infectious diseases on one hand, and a rapidly increasing incidence of NCDs on the other. India has the largest number of low birth weight babies in the world and the highest number of undernourished children below 5 years of age, and at the same time is one of the world's major sites of diabetes and coronary heart disease. Indians manifest diabetes at a younger age and at a lower BMI relative to white populations [21].

Low birth weight resulting from fetal undernutrition is known to be associated with an increased risk of diabetes. More recently, the role of fetal overnutrition (e.g. resulting from maternal diabetes) has also been demonstrated in India. Thus there is a U-shaped association between maternal nutrition and diabetes risk, creating a double burden of disease in this region. There are also situations in which an aspect of undernutrition occurs in the context of overnutrition of the fetus, e.g. micronutrient deficiencies in a diabetic pregnancy (Figure 4) [22].

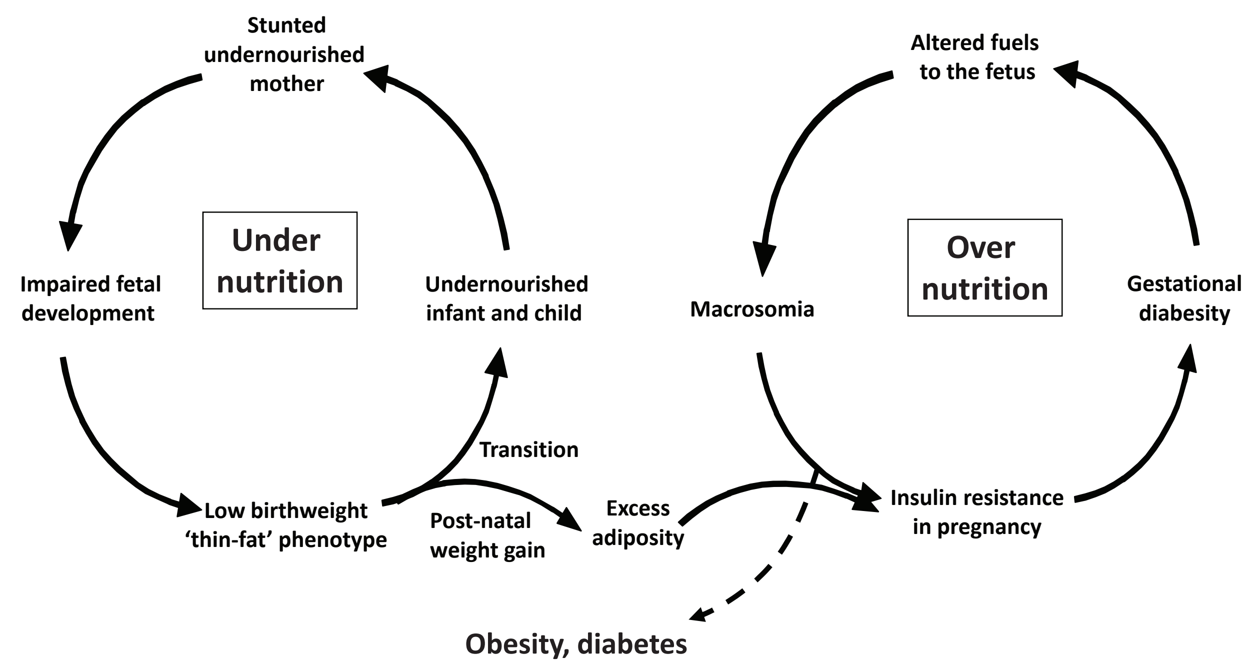

Figure 4 The double burden of under- and overnutrition in a low/middle-income country such as India. Undernutrition in one generation predisposes the next to obesity and noncommunicable diseases (NCDs) when faced with increased food availability and lifestyle changes. This promotes diabesity in pregnancy and NCD risk in the next generation, perpetuating the cycle of disease. Figure adapted with permission from FIGO, from Yajnik CS. Nutrient-mediated teratogenesis and fuel-mediated teratogenesis: Two pathways of intrauterine programming of diabetes. Int J Gynecol Obstet 2009;104(Suppl):S27–31.

Rapid transition and urbanization are driving forces of such a combination of adverse effects on offspring [23]. Increases in education and wealth have correlated with an increase in the prevalence of overweight and obesity, while poor sectors of the population remain undernourished. One-third of Indian women are vegetarian, and only approximately 7% eat meat, chicken, or fish on a daily basis. Fruit and vegetable consumption is very low in the lower socioeconomic strata; only a third of women consume milk or curds once a week. Women from wealthier families are more likely to have a healthy and well-balanced diet, but an increase in income in poor families is sometimes associated with greater consumption of unhealthy foods. Half of households use non-iodized or inadequately iodized salt. A number of national programs to improve health of children, adolescents, and pregnant women are in place in India. These concentrate on nutrition, prenatal health care, institutional delivery, immunization, and social support.

(the nutrition transition) have introduced diets that are higher in energy but low in nutrient quality [32].

3.2.3. Micronutrient malnutrition

Vitamin and mineral deficiencies can occur because of an inadequate dietary intake, low bioavailability of dietary nutrients, or increased nutrient requirements, for example because of rapid growth or menstrual bleeding, parasitic or other infections (malaria, helminths, HIV), and inflammation. Micronutrient deficiencies are not exclusive to low-resource settings as they often coexist with obesity and other NCDs. An individual's nutrient levels can be affected by lifestyle factors that affect absorption and metabolism, such as alcohol consumption and tobacco smoking. As many micronutrients pass from mother to baby, deficiency in the mother leads to deficiency in the fetus and newborn. The mechanisms of transfer across the placenta differ between micronutrients, so this risk is greater for some micronutrients than for others.

The causes of micronutrient deficiencies are interconnected. At the most basic level, the problem is related to an inadequate diet. The diets of some ethnic and cultural groups (e.g. strict vegetarian or vegan diets), or in communities with limited access to affordable animal-based food products, can lead to micronutrient deficiencies [33,34]. For specific population groups including pregnant women, iron, folate, and vitamin B12 may be lacking, especially in LMICs. Other nutrients of concern include calcium, vitamins A and D, and zinc. Adequacy for some nutrients such as iodine and selenium varies regionally depending on local conditions, and can be present in limited or excess quantity in the diet despite an otherwise adequate food supply [35–37].

Micronutrient malnutrition can exist in the presence of abundant food and even overnutrition, because of increasing intakes of energy-dense foods rich in sugars and oils, and lower intakes of micronutrient-rich foods like animal products, vegetables, and fruits. These micronutrient-poor, obesogenic diets are becoming ever more common among resource-constrained sections of society, especially in urban areas, where they are more available and affordable than diets of high nutritional content [38]. In the USA, this has led to what is known as the "hunger-obesity paradox," where the prevalence of overweight increases as food insecurity increases [39]. Hunger occurs episodically when sufficient food is not available, and overeating, typically of nutrient-poor foods that offer more dietary energy at lower cost, tends to occur when food becomes available [40]. Such unfavorable trends in food consumption patterns can lead to micronutrient deficiencies that undermine women's health and put them at risk of poor pregnancy outcomes. For example, diets commonly consumed by obese women in the USA are characterized by a higher than optimal percentage of energy from fat, while also being low in essential nutrients such as iron and folate [41,42].

3.3. Approaches to reducing micronutrient deficiencies

Globally, around two billion people are estimated to be deficient in one or more vitamins or minerals. Among them, children and women of reproductive age, including those pregnant, are particularly vulnerable to such deficiencies. Women of reproductive age account for approximately one third of all cases of anemia worldwide. In 2011, 496 million women between 15 and 49 years of age and 32 million pregnant women were anemic [43]. Iron deficiency is believed to contribute to at least half of the worldwide burden of anemia, especially in non-malaria-endemic countries, and thus is considered the most prevalent nutritional deficiency in the world. In addition to iron deficiency, pregnant women, particularly those living in LMICs, are often deficient in multiple other nutrients. Vitamin A deficiency affects approximately 19 million pregnant women worldwide [44] and hundreds of millions of women of reproductive age are exposed to insufficient iodine intake [45].

The consequences of micronutrient deficiencies in adolescent girls and women of reproductive age include impaired physical and cognitive performance, and reduced immunological response. When these women become pregnant they have increased risk of complications at delivery and having preterm babies, with low birth weight or small for gestational age. Insufficient iodine intake in pregnancy is considered the principal cause of preventable mental impairment in their neonates and leads to thyroid under-function and goitrogenesis in adults.

Clinical signs of micronutrient deficiencies, however, are frequently nonspecific and only appear when the nutritional status is severely depleted. Despite their large prevalence, micronutrient deficiencies often remain silent and invisible and are thus called "hidden hunger" [46]. Interventions to control micronutrient deficiencies in adolescent girls and women of reproductive age, including during pregnancy, can be broadly divided into dietary modification, supplementation, and fortification (at central level or at the point-of-use) of staple foods and condiments. Measures to prevent, diagnose, and treat infectious diseases and infestations such as hookworm can be used to complement these interventions.

A community health worker counsels a pregnant woman on supplements in Nepal. Photograph courtesy of Micronutrient Initiative.

3.3.1. Dietary modification

The strategy of dietary modification is often focused on improving variety in the diet and introducing practices to improve the intake, absorption, and utilization of vitamins and minerals so that daily requirements are met. These approaches often concentrate on increasing the intake of foods rich in bioavailable iron, especially meat and vegetables for improved vitamin intake. Some strategies that can also be used to increase iron and zinc bioavailability include increasing intake of foods that enhance, and reducing those that inhibit, iron absorption, as well as using food processing techniques such as fermentation to reduce the iron inhibitor content. Some vegan women may choose to eat animal products during pregnancy or may tailor their diets, e.g. by consuming yeast for added vitamin B12.

3.3.2. Supplementation

Supplementation refers to the direct provision of vitamins and minerals in the form of liquid, pill, tablet, or dispersible formulations. This is probably the most widespread intervention practiced clinically and in public health, as it has proven effective to improve micronutrient statuses and reduce their associated clinical conditions. Supplements can be given daily or intermittently (i.e. once, twice, or three times a week on nonconsecutive days). Currently supplementation efforts are focused on the provision of iron, folic acid, iodine, calcium, and multiple micronutrient formulations.

3.3.2.1. Pregnant and lactating women

Iron and folic acid

International organizations have advocated routine iron and folic acid supplementation for every adolescent and adult pregnant woman. While iron supplementation with or without folic acid has been used in a variety of doses and regimens, current recommendations for pregnant women include the provision of a standard daily dose of 30–60 mg of elemental iron and 400 μg of folic acid to reduce the risk of anemia and low birth weight, starting as soon as possible after gestation begins and continuing for the rest of the pregnancy and, if possible, during the 3 months following child birth [47]. FIGO supports this recommendation via the work of its Working Group on Best Practice in Maternal–Foetal medicine and its advice, currently in progress, on periconceptional folic acid for the prevention of neural tube defects.

Multiple micronutrient supplements

Recent evidence suggests that the benefit of multiple micronutrient supplements on birth and pregnancy outcomes outweigh those observed with iron and folic acid and thus could be the option of choice in countries with a high incidence of low birth weight or small for gestational age babies [48]. In addition to iron and folic acid, supplements may be formulated to include other vitamins and minerals according to the United Nations Multiple Micronutrient Preparation, which includes 15 vitamins and minerals at RDA level [49]. Multiple micronutrient supplements are also recommended for pregnant and lactating women affected by an emergency situation [50].

Calcium

Various studies have suggested that calcium supplementation during pregnancy has a beneficial effect on reducing the risk of pregnancy-induced hypertension. As a result, WHO recommends that in populations where calcium intake is low, women receive as part of the prenatal care between 1.5 and 2.0 mg of elemental calcium per day, from 20 weeks of pregnancy until the end of pregnancy to prevent pre-eclampsia. This intervention still faces many challenges in terms of acceptability by women and its alignment with iron and folic acid supplementation.

Iodine

Current global guidance recommends considering iodine supplementation in pregnant and lactating women, alongside efforts to scale up salt iodization, in settings where large proportions of the population do not have access to iodized salt. In these areas, women can receive iodine supplements either as a single annual dose of 400 mg or a daily dose of 250 µg [51]. In other countries such as the USA, Canada [52], and Australia it is recommended that all pregnant and lactating women take daily iodine supplements of 150 µg [53]. It is important to highlight that many commercially available multiple-micronutrient supplements including prenatal formulations contain iodine in this dose.

3.3.2.2. Adolescent girls and nonpregnant women of reproductive age

Intermittent (mainly once a week) use of oral iron supplements has been proposed as an effective and programmatically more feasible alternative to daily iron supplementation to prevent anemia among women who have initiated menstruation. WHO recommends the provision of 60 mg of elemental iron and 2800 µg (2.8 mg) of folic acid once a week in cycles of 3 months or, if possible, throughout the school or calendar year [54]. This intervention can be integrated into national programs for adolescent and reproductive health. However, to ensure that the daily needs are met and not exceeded, it is advisable that supplementation is preceded by an assessment of the nutritional status of women of reproductive age and of the existing measures to control anemia and folate insufficiency, such as programs for hookworm control, food fortification, or adequate diet promotion.

3.3.3. Food fortification

3.3.3.1. Fortification of staple foods and condiments

Food fortification is the addition of one or more essential nutrients to a food, whether or not it is normally contained in that food, for the purpose of preventing or correcting a demonstrated deficiency of one or more nutrients in the general population or in specific population groups [55]. This process usually takes place during food processing by the food industry at a central level so that it reaches the intended population on

Regional Case Study 2: Thinking Nutrition First in South America

Success of fortification of food staples with folic acid

The evidence that folic acid can prevent neural tube defects (NTDs) is unequivocal [63] but this important discovery has yet to be applied globally. The difficulties of reaching women in the preconceptional period with folic acid supplements, owing to weak health systems or cultural barriers, have hindered progress toward NTD reduction and contributed to the adoption of recommendations for fortification of food staples such as wheat and maize flour and rice with folic acid in several countries.

In 2014, 76 countries included folic acid in their wheat flour fortification standard. In South America, all but one of the countries has widely adopted flour fortification with folic acid—and with remarkable positive effects. Thanks to ELCAMC (Estudio Colaborativo Latino Americano de Malformaciones Congénitas: Latin American Collaborative Study of Congenital Malformations), which has monitored congenital anomalies in South American countries since the 1960s, data for pre- and post-fortification rates of 52 selected types of congenital anomalies could be analyzed in Chile, Argentina, and Brazil, where fortification was implemented in 2000, 2003, and 2004 respectively. A total of 3 347 559 births were reported over the period of 1982–2007. Data showed that the prevalence of eight of the 52 congenital anomaly types was significantly lower following fortification [64]. Spina bifida and anencephaly were substantially reduced in all three countries. In Chile, for example, the prevalence of spina bifida was 67% lower following fortification (0.73 to 0.24 per 1000 births) and anencephaly was 50% lower (0.56 to 0.26 per 1000 births). In terms of costs saved, the reduction of 43% in NTDs in the first year following fortification in Chile was associated with an estimated net saving of I$ 1.8 million (international dollars) [65]. In these rapidly industrializing countries, this focus on maternal nutrition has brought not only considerable health but also substantial economic benefit.

WHO recommendations [66]

Wheat and maize flour fortification should be considered when industrially-produced flour is regularly consumed by large population groups in a country. Decisions about which nutrients to add and the appropriate amounts to add should be based on a number of factors including: (1) the nutritional needs and deficiencies of the population; (2) the usual consumption profile of “fortifiable” flour (i.e. the total estimated amount of flour milled by industrial roller mills, produced domestically or imported, which could in principle be fortified); (3) sensory and physical effects of the added nutrients on flour and flour products; (4) fortification of other food vehicles; and (5) costs.

a mass level. Fortification is considered one of the most cost-effective interventions [56], and among its advantages is that it does not require the active participation of end users.

Staple foods

In 2015, globally 82 countries have legislation to mandate fortification of at least one industrially milled cereal grain, mainly with iron and folic acid. Although the majority of the countries have legislation to fortify wheat and maize flour (81 and 12, respectively), rice is becoming an interesting option where this cereal is a staple. Fortification with iron and folic acid has proved to be an effective and safe strategy to reduce anemia [57] and prevent neural tube defects [58,59]. (See Regional Case Study 2: South America).

Condiments and seasonings

WHO recommends that all food-grade salt, used in household and food processing, is fortified with iodine as a safe and effective strategy for the prevention and control of iodine deficiency disorders in populations living in both stable and emergency settings [60]. Salt iodization is implemented in more than 120 countries around the world and 71% of households worldwide are estimated to have access to adequately iodized salt. Although many countries have successfully eliminated iodine deficiency disorders, or made substantial progress in their control, largely as a result of this intervention, there are countries that do not adhere to this recommendation and are facing increasing rates of iodine deficiency. It is important to highlight that iodine fortification levels can be adjusted and this intervention is compatible with ongoing efforts to reduce salt intake for NCD prevention. Soy and fish sauces, curry powder, or bouillon powders or cubes may be also be a useful alternative for iron fortification if they are consumed consistently by most of the population, as is the case in many Asian and African countries, but their effectiveness on a large scale has not been determined.

3.3.3.2. Point of use fortification

This is a relatively novel intervention that refers to the addition of vitamins and minerals in powder form to energy-containing foods at home or in any other place where meals are consumed, such as schools, nurseries, and refugee camps. Micronutrient powders can be added to foods either during or after cooking or immediately before consumption without the explicit purpose of improving the flavor or color. In some cases point-of-use fortification is also known as home fortification [61]. This intervention can also include specialized products that also provide energy, protein, macro-minerals and essential fatty acids such as small quantity lipid-based nutrient supplements (SQ-LNS) and full-fat soy flour (and soy protein isolate) with a vitamin-mineral mix [62]. The evidence of effectiveness of these interventions in women of reproductive age and pregnant women is limited and their comparative advantage in relation to other existing interventions remains to be confirmed.

4. Recommendations for optimizing nutrition throughout the life cycle

- FIGO recommends that adolescent, preconception, and maternal nutrition should be part of a life course approach that views perinatal health within the context of women's overall health, and that of their partners, and dismisses the artificial dichotomy between reproductive and nonreproductive health.
- Standard care should involve a wide range of healthcare providers working together, with a focus on nutrition, health, and lifestyle during adolescence and through a woman's reproductive life and beyond.

4.1. "Think Nutrition First"

Nutrition in adolescent and pregnant women is modifiable. Concerted action is required from healthcare providers and educators working together across the whole community to improve the health and well-being of girls, women, and their children. These recommendations seek to empower and to provide opportunities for all levels of healthcare providers to contribute to achieving this goal.

Women who have better nutritional status at the time they conceive are better able to meet the demands imposed by pregnancy, and tend to have more successful pregnancy outcomes. Ideally, optimal nutrition will come from food sources, but food fortification and/or supplementation is advisable in some cases, particularly in low-resource settings where young girls and women are undernourished (see section 3.3: Approaches to reducing micronutrient deficiencies). There are a number of nutrients that affect pregnancy outcomes early in gestation, even before the woman knows that she is pregnant. Folate is a well-known example of a nutrient that is essential in very early pregnancy. Maternal folate insufficiency can have profound effects on the fetus, and preconceptional folic acid supplementation is widely recommended, as folate requirements for pregnancy are unlikely to be met by diet alone in most women.

Nutritional assessment should therefore be part of history-taking and examination in all routine healthcare visits, from adolescence and throughout the reproductive lifespan. Important points that should be considered during such assessments are outlined in Table 1. The importance of specific nutrients at different pregnancy stages is illustrated in Figure 5.

4.2. Providing advice about a healthy diet

- FIGO recommends promotion of a varied and healthy diet as the first step to meeting the nutrient needs of adolescent girls and women, with the provision of supplements or fortified foods when necessary.

In providing dietary advice to optimize maternal nutrition, healthcare providers need to know about nutrition beliefs and practices in their local community. If any are unhealthy or harmful, they should be discouraged respectfully, and alternatives offered. In order to give food recommendations that are appropriate to the local situation, healthcare providers should be aware of the seasonal availability and nutritional value of foods, and be able to identify good sources of all of the important nutrients. Consideration of costs and ease of procurement of the recommended foods is important for ensuring that advice can be followed without undue stress for the women and their families.

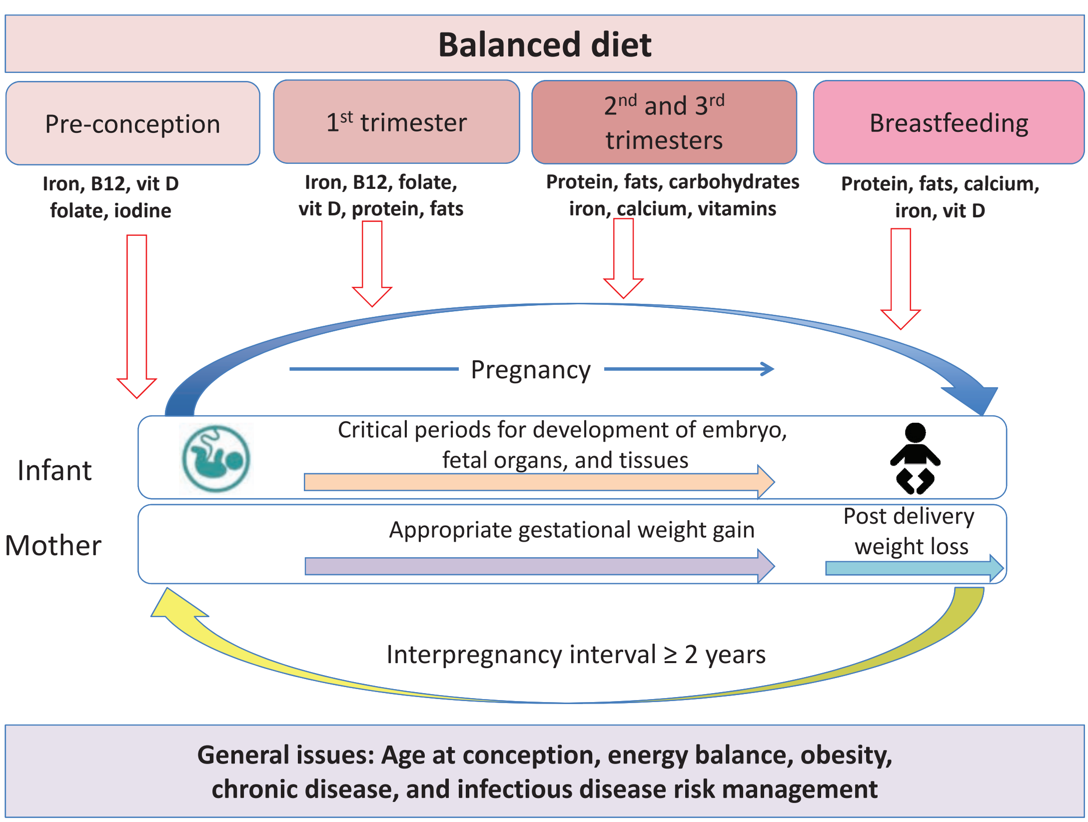

Figure 5 Examples of key nutritional issues for mother and baby through different stages of pregnancy.

Table 1
FIGO recommendations on adolescent, preconception, and maternal nutrition: Action points for healthcare providers.

Pre-pregnancy – adolescent girls		
Involved professionals	Assessment considerations	Discussion points
• School health educators • Community health workers • Nutritionists • Family doctors (GPs) • Ob-gyns	• Diet composition • Physical activity • Height, weight, BMI • Obesity risk – Waist circumference + other anthropometric measures • Anemia • Risk of specific nutritional problems (low nutrient density) – Folate – Iron – Calcium – Vitamin B12 – Vitamin D – Iodine – Zinc – PUFAs	• Importance of a healthy diet and exercise • Problems of sedentary behavior such as screen time[a] • Weight loss counselling • Risky behaviors and exposures • Pregnancy risk – Contraception (timing and spacing) – encourage reversible methods such as IUD and implants that do not require regular action – Folic acid supplementation 400 μg/day – Encourage early pregnancy care • Local environmental issues (e.g. pollution, chemicals)
Pre-pregnancy – when planning a pregnancy		
Involved professionals	Assessment considerations	Discussion points
• Community health workers • Nutritionists • Family doctors (GPs) • Ob-gyns • Midwives	• Diet composition • Physical activity history • Height, weight, BMI • Obesity risk – Waist circumference + other anthropometric measures • Anemia • Risk of specific nutritional problems (low nutrient density) – Folate – Iron – Calcium – Vitamin B12 – Vitamin D – Iodine – Zinc – PUFAs	• Importance of a healthy diet and exercise • Problems of sedentary behavior such as screen time • Weight loss counselling • Risky behaviors and exposures – Tobacco, alcohol, recreational drugs – Environmental toxins • Chronic disease screening and management • Supplementation – Folic acid supplementation 400 μg/day – Other nutrients as required (iron, iodine, vitamin B12)
During pregnancy		
Involved professionals	Assessment considerations	Discussion points
• Community health workers • Nutritionists • Family doctors (GPs) • Ob-gyns • Midwives	• Diet composition • Physical activity • Height, weight, BMI, waist circumference (other anthropometric measures?) • Gestational weight gain • Blood pressure • Gestational diabetes risk • Anemia • Risk of specific nutritional problems (low nutrient density, deficiencies from specific diets or undernutrition) *First trimester* – Folate – Vitamin B12 – Iodine – PUFAs *Second and third trimesters* – Iron, iodine, zinc, copper, calcium – Folate, B vitamins, vitamin D – Energy (+450 kcal/day)	• Dietary counselling • Safe levels of exercise • Sedentary time • Weight management and gestational weight gain • Risky behaviors and exposures – Tobacco, alcohol, recreational drugs – Sources of food-borne infection – Environmental toxins • Pregnancy complication screening and management (GDM, blood pressure) • Supplementation – Folic acid supplementation 400 μg/day – Iron supplementation 30–60 mg/day – Other nutrients as required (iodine, vitamin B12, vitamin D)
Post-pregnancy (during lactation)		
Involved professionals	Assessment considerations	Discussion points
• Community health workers • Nutritionists • GPs • Ob-gyns • Midwives • Pediatricians • Lactation consultants	• Diet composition • Risk of specific nutritional problems (low nutrient density) – Protein – PUFAs – Vitamins/minerals – Energy (additional intake as recommended by each country; approximately +330 kcal/day) • Weight status and postpartum weight loss • Screening for diabetes as appropriate • Breastfeeding success	• Healthy diet and physical activity, sedentary time • Achieving a healthy weight • Appropriate supplementation – iron and folic acid are recommended during first 3 months after delivery • Breastfeeding support • Nutritious weaning foods • Interpregnancy spacing and contraception • Chronic disease screening and management (type 2 diabetes, blood pressure)

Abbreviations: IUD, intrauterine device; BMI, body mass index; GPs, general practitioners; PUFAs, polyunsaturated fatty acids; GDM, gestational diabetes mellitus.
[a] Time spent on computers, video games, and watching television.

With the caveat that dietary habits and food availability differ regionally and locally, it is still possible to advise on an overall diet that is healthy or "prudent" and to identify aspects of diet that are unhealthy. An adequate diet is one that supplies nutrient and metabolic needs without excess or shortage. A key message should be that calories do not equal nutrients—healthy diets must include foods with high nutrient density (high nutrient value per calorie), such as pulses, legumes, vegetables, and fruits, and limit those that are energy rich but nutrient poor, such as sweets, sugar-sweetened beverages, and saturated fats.

4.2.1. Healthy dietary patterns

While attention to specific potential nutrient deficiencies is important, it is equally important to consider the overall quality of the dietary pattern, and the complexity of the diet. Diets that are consistently associated with lower risk of disease are those containing vegetables, fruits, whole grains and nuts, and those low in saturated fats and high in fiber, such as the "Mediterranean diet" or the "Prudent diet" [67]. However, the naming of diet patterns involves subjectivity—numerous so-called healthy patterns differ from each other in nutrient and food composition [68,69]. Overall, healthy diets rely heavily on plant sources (including vegetables, fruits, nuts, seeds, and whole grains) and unsaturated fats (from vegetable oils and fish), along with poultry, low-fat dairy products, eggs, with red and processed meat consumed in lower proportions. A reduction of total fat is not a prerequisite of a healthy diet, but the ratio of unsaturated (mono- and polyunsaturated) to saturated fats should be high; synthetic trans-fats should be avoided altogether. Such a dietary pattern was found to be associated with the lowest risk of all-cause mortality, and specifically from cardiovascular disease and cancer [70] (see Regional Case Study 3: Southern Europe).

Unhealthy dietary patterns are common in high-resource countries. A study in Ireland identified 50% of pregnant women as having an "unhealthy" pattern among 285 pregnant women

Regional Case Study 3: Thinking Nutrition First in Southern Europe

The Mediterranean diet

Many studies contrast "healthy" diets with the typical "Western" diet, characteristic of the USA, as an example of an unhealthy eating pattern. One diet that is considered particularly healthy in terms of reduced cardiovascular and metabolic risks is the traditional dietary pattern of the Mediterranean region of Southern Europe (Spain, Portugal, Italy). The Mediterranean diet is characterized by higher intakes of fruit, vegetables, vegetable oil, fish, whole grains, pasta, and rice, and lower intakes of meat, potatoes, and fatty sauces, in contrast with the Western diet, which relies more heavily on refined grains, meat, potatoes, high-fat dairy products, processed snacks and sweets, and low intakes of vegetables and fruit. The basic components of Mediterranean and Western diets are shown in the Table below.

Mediterranean diet		Western diet	
Component	Frequency	Component	Frequency
Vegetables	High	Refined grains	High
Wholegrain cereals (bread, pasta, rice, etc)	High	Meat and meat products	High
Fruit	High	Potatoes/french fries	High
Legumes, nuts (especially walnuts)	Moderate	High-fat dairy products	Moderate
Low-fat dairy products	Moderate	Poultry, fish, eggs	Moderate
Poultry, fish, eggs	Moderate	Sugary beverages	High
Meat and meat products	Low	Processed, salty snacks	High
Pastries, sweets	Low	Pastries, sweets	High
Sauces	Low	Sauces/spreads	High
Saturated fats	Low	Vegetables	Low
Main added fat source = olive oil (extra virgin)		Main added fat source = butter, vegetable oil	

The Mediterranean diet pattern, characterized by low total fat (<30% of energy), low saturated fat (<10% of energy), high complex carbohydrate (but relatively low total carbohydrate), and high dietary fiber intake, is generally considered healthy for all people, and has been recommended as a good preconception and pregnancy diet. The intake of pulses, green leafy vegetables, cereals, and fruit that is associated with best adherence to the Mediterranean diet provides a relatively high intake of folate [73], which is particularly important in the preconception period. Following a Mediterranean diet also increases the likelihood of achieving adequate intakes of zinc, B vitamins, vitamin A, vitamin E, magnesium, and vitamin C [74].

Following a Mediterranean diet pattern, in addition to regular physical exercise, may help women to achieve and maintain a healthy weight prior to and during pregnancy. An association has been observed between the degree of adherence to the Mediterranean diet and the increase in BMI during pregnancy—women with high adherence gained less weight, and their weight gain was more likely to be within the Institute of Medicine's recommended range [75].

Adherence to a diet similar to the Mediterranean pattern has been proposed as beneficial for fetal growth in pregnancy [76,77]. Low adherence was associated with lower birthweight and lower placental weight [77], and an increased likelihood of delivering an infant with hyperinsulinemia [78]. A Mediterranean diet is likely to supply adequate levels of most micronutrients and limit the need for supplementation for all but a few critical nutrients for the preconception and pregnancy period and beyond.

whose dietary intakes were assessed in early pregnancy. The unhealthy pattern was characterized by high intakes of white bread, processed meats, and high energy beverages. Women in this group had lower educational attainment and higher BMI than those in the "healthy" diet group [71].

The WHO defines a healthy diet as one in which the proportion of energy intake from total fat does not exceed 30%, with unsaturated fats (e.g. those found in fish, avocado, nuts, sunflower, canola, and olive oils) being preferable to saturated fats (e.g. those found in fatty meat, butter, palm and coconut oil, cream, cheese, ghee, and lard) [72]. Industrial trans-fats (found in processed food, fast food, snack food, fried food, frozen pizza, pies, cookies, and margarines and spreads) are not considered part of a healthy diet. Intake of fruits and vegetables (excluding potatoes and other starchy roots) should be at least 400 g per day, and intake of dietary fiber should be more than 25 g per day. Free sugars should comprise less than 10% of energy intake. Free sugars are those that are added to foods by the manufacturer, cook, or consumer; they can also be found in sugars naturally present in honey, syrups, fruit juices, and fruit concentrates (Box 3).

4.2.2. Assessing dietary diversity

Dietary diversity is recognized as a measure of diet quality, and is strongly associated with nutrient adequacy [79]. Women in LMICs are more likely to have unvarying diets based on a few staple foods, and are thus at risk of micronutrient malnutrition. Population groups that are most affected by micronutrient deficiencies are those that subsist on refined cereal grain or tuber-based diets. Such diets provide energy and protein but often lack some critical micronutrients, and the protein in the diet does not contain the appropriate amino acid balance. To ensure optimal nutrition, whenever possible it is preferable to encourage the inclusion of foods in the diet that have high micronutrient density, rather than relying on supplementation or fortification schemes, although these may be necessary in some situations. Pregnant and lactating women have increased needs for some micronutrients relative to their energy needs, so will require increased micronutrient density diets.

Box 3
The composition of a healthy diet for adults as defined by WHO.

- Fruits, vegetables, legumes (e.g. lentils, beans).
- Nuts and whole grains (e.g. unprocessed maize, millet, oats, wheat, brown rice).
- At least 400 g (5 portions) of fruit and vegetables per day (potatoes, sweet potatoes, cassava, and other starchy roots are not classified as fruits or vegetables).
- Less than 10% of total energy from free sugars, equivalent to 50 g (or around 12 level teaspoons), but possibly less than 5% of total energy for additional health benefits.
- Less than 30% of total energy from fat, with preference for unsaturated fats:
  - Saturated fats less than 10% of total energy.
  - Polyunsaturated fats 6%−10% of total energy
- Less than 5 g of salt (equivalent to approximately one teaspoon, which contains 2 g sodium) per day and use of iodized salt.

The United Nations Subcommittee on Nutrition (UNSCN) and the Food and Agriculture Organization (FAO) Women's Dietary Diversity Project have developed a dichotomous indicator of diet quality referred to as the "Minimum Dietary Diversity Index for Women (MDD-W)" [80]. The MDD-W predicts the micronutrient adequacy of women's diets based on a threshold consumption of a minimum of 15 g per day of at least 5 of 10 different food groups (see Box 4). This index may be useful for assessing the micronutrient density of women's diets in LMICs.

4.3. Recommendations for adolescent girls and women prior to pregnancy

- FIGO emphasizes the importance of optimizing the nutritional status of adolescent girls and women and encouraging the adoption of good dietary and lifestyle habits before pregnancy.

A central theme of these recommendations is the importance of ensuring the nutritional health of adolescent girls and women as early as possible in their lives, preferably well before they become pregnant. Promoting these recommendations will also require a focus on adolescent boys and young men, although this is not the focus of these guidelines. If good dietary habits are established and specific nutrient needs are addressed in this period, the modifications required for a successful pregnancy will be minimal. Therefore the following recommendations about nutrient requirements throughout the reproductive cycle are given in most detail for the prepregnancy period, with additional information relating specifically to pregnancy and breastfeeding given in those sections respectively.

Nutritional assessment and pregnancy planning should be incorporated into routine health care for adolescents and women or reproductive age. Nutritional status influences linear growth, age at menarche, and fertility, as well as a woman's ability to go through pregnancy and breastfeeding without compromising her own nutritional well-being and health status. This is particularly important for adolescent girls who are still growing themselves.

Starting in adolescence, a number of factors should be assessed at routine physical examinations, as indicated in Table 1. Effort should be made at this stage in the life course to

Box 4
Minimum Dietary Diversity Index for Women (MDD-W) food groups.

Intake of ≥15 g/day of each of 5 or more of the following food groups is indicative of micronutrient adequacy:

1. All starchy staple foods.
2. Beans and peas.
3. Nuts and seeds.
4. Dairy.
5. Meat, poultry, and fish.
6. Eggs.
7. Vitamin A-rich dark green leafy vegetables.
8. Other vitamin A-rich vegetables and fruits.
9. Other vegetables.
10. Other fruits.

educate young girls and adolescents about what constitutes a healthy diet and adequate physical activity, and why these are important for the woman's health in general, and in particular for her reproductive years. This education should involve capacity building of healthcare providers but also education for teachers, parents, and social and cultural organizations, in order to promote a whole community approach to improving nutrition.

If prospective parents seek prepregnancy counselling, there is an opportunity to discuss and address issues of lifestyle and nutrition in addition to any specific medical problems. However, many pregnancies, and especially those that occur at a younger age, are unplanned, and pregnancies may not be recognized until after the first trimester. The first prenatal visit is relatively late to address some risk factors, such as folic acid intake, alcohol use, and other diet and lifestyle factors that can affect very early development of the fetus. Rates of unplanned pregnancy remain at approximately 50% in many contexts, with the most socioeconomically disadvantaged groups tending to have even higher rates in addition to the most risk factors for poorer outcomes, and less access to health care at all life stages.

Recent evidence suggests that interventions to change behaviors during pregnancy are often only minimally effective [81]. Overweight and obesity, in particular, are difficult to modify once a woman is pregnant. Prevention should occur early in life and be emphasized during adolescent health checks. Ideally, nutrition and health education should begin in the primary school years and continue through high school. Regular physical activity should be encouraged and excessive sedentary activities discouraged.

For all women of reproductive age, advice should be given about specific nutrients that may be lacking in their diets, and early pregnancy care should be encouraged, stressing the need to see a healthcare provider as soon as possible for nutritional advice and supplements once pregnant.

4.3.1. Preconception bodyweight and BMI

- FIGO recommends that attention be paid to preconception body weight and BMI as modifiable risk factors with important effects on a woman's nutritional status:
  - Underweight women may be lacking in a number of important nutrients, and their diets should be carefully assessed and supplemented as required.
  - Overweight or obese women may have poor diets that are high in energy but low in nutritional value.

Attention to a woman's BMI prior to pregnancy is important; both low and high BMIs are associated with poorer pregnancy outcomes, and there is growing evidence that this may also be true for paternal BMI. Fertility is also decreased in both females and males who are significantly underweight or overweight [82–86]. Healthy weight is associated with a BMI between 18.5 and 25 kg. Body weight measurement alone is not a substitute for BMI, although in some low-resource settings height measuring scales are still not available.

4.3.1.1. Underweight

Women who are underweight (BMI <18.5) prior to/at the beginning of pregnancy have diminished energy reserves and may be deficient in important nutrients (e.g. iron, iodine, vitamin A, B vitamins, folate, calcium, and zinc), weakening their immune systems and putting them at risk of infections and other diseases [25], and reducing their capacity to cope with the demands of pregnancy. Underweight women and those of short stature have a higher chance of spontaneous abortion and of having smaller babies and shorter gestational length [87]. A recent analysis found that prepregnancy underweight contributes to a 32% higher risk of preterm birth [88]. Infants born to underweight women are more likely to experience poor fetal growth, including low birthweight and intrauterine growth restriction, smaller head circumference, and lower ponderal index, all of which are associated with higher infant morbidity [89]. While poor fetal growth is rarely a direct cause of death, it can contribute indirectly to neonatal deaths, particularly those due to birth asphyxia and infections (sepsis, pneumonia, and diarrhea), which together account for 60% of neonatal deaths [25]. There may be long-term consequences of this periconceptional undernutrition for the infant, including a substantially increased risk of NCDs later in life [90–92].

4.3.1.2. Overweight and obesity

Obesity prior to pregnancy is a risk factor for adverse pregnancy and neonatal outcomes. Women who are obese have higher rates of infertility compared with women with healthy BMI, and also experience higher rates of contraceptive failure and thus unplanned pregnancy [93]. During pregnancy, mothers who are obese are more likely to develop complications including gestational diabetes mellitus and pre-eclampsia, to require cesarean delivery or assisted delivery, and to have a postpartum period complicated by infection or blood clot [94]. Being obese at the start of pregnancy is associated with fetal macrosomia and large-for-gestational-age infants [95], and the risk of complications increases as the prepregnancy BMI increases [96,97]. Children of obese mothers are more likely to have birth defects, experience trauma at birth, have higher rates of infant mortality, and are themselves at higher risk of becoming obese as they develop [98,99]. Weight loss is generally not recommended during pregnancy, so it is best for overweight women to lose their excess weight well before conception. Severe dieting around the time of conception is discouraged, as this may have adverse effects on the embryo. As noted elsewhere, despite their high energy intake, women who are overweight or obese may still have poor diet quality and be deficient in key nutrients. The growing problem of maternal obesity is illustrated in Regional Case Study 4: North America.

4.3.2. Nutrient status and possible deficiencies

- FIGO recommends that micronutrient deficiencies are recognized and rectified through interventions, including dietary diversity, consumption of fortified foods, and supplementation as appropriate.

Assessment of a woman's nutritional status is the key to providing appropriate advice about diet and the need for supplementation before and during pregnancy. Depending on the resources, it is advisable to screen women at least for anemia, and to adjust the iron supplementation dose for either prophylactic or therapeutic purposes. The risk of other specific nutritional problems resulting from a diet of low nutrient density should also be assessed. These deficiencies may be region or population specific.

Other aspects of health influence nutritional status, and need to be taken into account. For example, infection and malnutrition are linked: malnutrition can make a woman more susceptible to infection, and infection also contributes to malnutrition. Thus, particular attention should be paid in situations with a high burden of infection, such as HIV, tuberculosis, and malaria. Malnutrition is one of the major complications of HIV/AIDS

Regional Case Study 4: Thinking Nutrition First in North America

Confronting the obesity epidemic

North America is a region of the world with one of the highest prevalences of obesity. In the USA, more than one-third of all adults are obese, with higher rates among African-American and Hispanic ethnic groups. Canada's rates of obesity are lower at about 25% but are rising, with especially high rates among the First Nations populations. Mexico has rapidly transitioned over the past few decades from a region where undernutrition, vitamin and mineral deficiencies, and stunting were paramount to overtaking the USA in rates of obesity.

An environment that promotes food intake and discourages physical activity both encourages excess weight gain and opposes efforts at weight loss [100]. Large portion sizes, ready availability of sugar-sweetened beverages, and "food deserts"—geographical areas lacking in fresh fruit, vegetables, and other healthy food choices [101]—all contribute to the problem, especially in many ethnic minority populations.

Achieving a healthy weight before pregnancy is of great importance.

Obesity confers significant risks for mothers and their children, both during pregnancy and beyond. Children born to obese mothers are themselves at risk of obesity and NCDs, continuing the intergenerational cycle of disease. While the epidemic of obesity continues in North America and throughout the world, efforts to mitigate its harmful effects are ongoing. In 2009, the US Institute of Medicine published guidelines on healthy gestational weight gain within each weight category. Evidence suggests that dietary and lifestyle interventions in pregnancy can reduce maternal gestational weight gain and improve outcomes for both mother and baby [102].

One example of a successful local program, the "Balance after Baby" program, was modelled after the Diabetes Prevention Program. Investigators enrolled 75 women in the Boston area with a pregnancy complicated by gestational diabetes, and randomized them to an internet-based lifestyle modification program or usual clinical care. Women who received the intervention lost a mean of 2.8 kg from 6 weeks to 12 months postpartum, whereas the control group gained an average of 0.5 kg [103]. Because this program was delivered remotely through a website and lifestyle coach, its cost to implement was low and it has the potential for broader dissemination.

infection and a significant factor in advancing the disease's status in individuals. HIV infection can compromise nutrition through malabsorption and altered metabolism, with a number of consequences including weight loss and increased risk of vitamin and mineral deficiencies. The situation for malaria is somewhat complex: iron deficiency anemia is considered to protect against falciparum malaria, and iron supplementation increases susceptibility to clinically significant malaria. Thus, WHO recommends that iron supplementation should be accompanied by effective measures to prevent, diagnose, and treat falciparum malaria [54].

Ideally, most aspects of nutrition can be addressed by diet, with supplementation required for only a few nutrients, except in certain cases as outlined below. However, in many low-resource settings, access to an appropriate variety of nutrient-rich foods is not always possible, and the provision of vitamins and minerals through supplementation or fortification is sometimes required. In many countries in Latin America, for example, the usual diet does not always provide the required amount of iron, folic acid, and calcium, and some scientific organizations and health authorities of these countries recommend multiple micronutrient supplementation for all pregnant women.

Every effort should be made to educate and assist women to establish good dietary habits before pregnancy and to emphasize that the same habits should be maintained through pregnancy, with attention to specific nutrient requirements along the way. Nutrients of particular importance, or for which there is a high risk of deficiency in some populations, are listed below (see also Box 5 and Table 2).

4.3.2.1. Energy, macronutrients, and fiber

A healthy diet is made up of macronutrients in balanced proportions and a total energy intake sufficient to balance energy expenditure (for physical activity, and growth in children and adolescents). The macronutrients supplying energy in the diet are protein, fats, and carbohydrates; fiber contributes to digestive health and glucose homeostasis. Optimizing the balance of these nutrients and ensuring adequate intake of fiber is best accomplished before pregnancy, and then maintained throughout gestation.

Protein

It is important to establish good dietary habits in terms of protein intake prior to pregnancy, as the ratio of protein to nonprotein energy in diet affects not only the woman's body composition, but may influence her child's body composition and future metabolic health [104]. Both very low and excessively high protein diets may be associated with restricted fetal growth. The general recommendation is for adolescent girls and women to consume approximately 46 g protein per day, which would

Box 5

Common nutrient deficiencies in adolescent girls and women that may require supplementation.

- *Iron* – in all women, particularly in adolescent girls after menstruation starts, and in pregnancy.
- *Iodine* – required early in pregnancy and often lacking in diets if iodized salt is not used.
- *Folate* – required before conception and in early pregnancy; dietary intake is usually insufficient. All women of reproductive age are advised to consume 400 μg/day as supplements or fortified foods.
- *Vitamin B12* – dietary intake may be very low in vegetarian diets and absent in vegan diets.
- *Calcium* – frequently lacking in diets low in dairy products; higher requirement in adolescents during growth spurt.
- *Vitamin D* – food sources are minimal unless fortified, and inadequacy is very common, especially in women with minimal sun exposure, or darkly pigmented skin.

Table 2
FIGO recommendations on adolescent, preconception, and maternal nutrition: Specific nutritional requirements before conception, and increases for pregnancy and lactation, based on Institute of Medicine recommended dietary allowance and adequate intake guidelines.[a]

Nutrient	Daily intake requirement			Function	Food sources	Risk factors for deficiency/ consideration for supplementation
	Pre-pregnant	Pregnant	Lactating			
Protein	60 g	71 g		Building blocks for structural and functional components of cells	Meat, poultry, fish, eggs, dairy products, legumes, grains, nuts, seeds	Protein energy malnutrition
Omega-6 PUFAs	11–12 g	13 g	13 g	Component of structural membrane lipids, involved in cell signaling, precursor of eicosanoids	Nuts, seeds, vegetable oils (corn, sunflower, soybean). For arachidonic acid: poultry, eggs, fish	Fat intake mainly from saturated fat sources
Omega-3 PUFAs	1.1 g	1.4 g	1.3 g	Neurological development, growth, precursor of eicosanoids	Fish oils, fatty fish, flaxseed oil, nuts (e.g. walnuts)	Low intake of fatty fish, fat intake from saturated fat sources
Carbohydrates	130 g	175 g	210 g	Fuel for growth	Starchy vegetables, grains, sugars	Protein energy malnutrition
Folate	400 µg	400–600 µg	600 µg	Neurological function, erythropoiesis, neural tube formation, brain development	Liver[b], yeast extract, green leafy vegetables, legumes, citrus fruits, fortified breakfast cereals	Family history of neural tube defects, low folate diet[c]
Vitamin B12	2.4 µg	2.6 µg	2.8 µg	Neurological function, erythropoiesis, neural tube formation, brain development	Milk/dairy products, meat (especially liver[b]), poultry, fish, and eggs	Vegan/vegetarian diets, malabsorption disorders, communities where undernutrition is prevalent
Vitamin A (as retinol activity equivalents)	700 µg	750–770 µg	1300 µg	Vision, immunity, growth, organ and limb development, red blood cell production	Yellow and orange vegetables, cod liver oil, eggs, dairy (sources of vitamin A precursors: carotenoids)	Endemic in some areas. Zinc deficiency may interfere with vitamin A metabolism
Vitamin D	≥600 IU[d]	≥600 IU[d]	≥600 IU[d]	Immune function, bone growth, calcium and phosphorus balance, insulin secretion, blood pressure regulation	Fatty fish, eggs, dairy	Limited sun exposure, low dietary intake, obesity
Vitamin B6	1.3 mg	1.9 mg	2.0 mg	Multiple enzyme function – protein metabolism, neurological function	Poultry, fish (especially tuna), meats, legumes, potatoes and other starchy vegetables, noncitrus fruits, nuts, and seeds	Alcoholism, poor diet, systemic inflammation
Iodine	150 µg	220 µg	290 µg	Thyroid adaptation to pregnancy, brain development	Seaweed, seafoods, iodized salt	Endemic iodine deficiency due to low soil content
Iron	15–18 mg	27 mg	9 mg	Hemoglobin synthesis, organ function	Meat, poultry, fish, seafood, molasses, prunes, lentils, kidney beans, yeast extract, tofu, cashew nuts	Malaria infection/endemic area[e], vegetarian diet, malnutrition
Calcium[f]	1000–1300 mg	1000–1300 mg	1000–1300 mg	Muscle function, skeletal development, nerve impulse transmission, hormone secretion	Dairy products, tofu, sardines, beans, Chinese cabbage, oranges, figs, kale, broccoli	Low intake of dairy products; vegan diet, adolescent growth spurt
Selenium	55 µg	60 µg	70 µg	Fertility, fetal growth, prevention of oxidative stress	Plant foods (e.g. wheat) grown in selenium-rich soil; animals fed on selenium-rich plant foods	Low regional soil selenium content
Zinc[f]	8–9 mg	11–12 mg	12 mg	Immune function/infection resistance, growth, neurodevelopment	Oysters, other shellfish, red meat, nuts legumes, poultry, eggs, seeds (sesame, pumpkin, sunflower)	Protein-energy malnutrition, diets low in animal protein and/or high in phytates (whole grains). Iron and calcium supplements decrease zinc absorption
Choline	400–425 mg	450 mg		Membrane function, nerve impulse transmission, brain development, neural tube formation	Liver[b], eggs, beef, fish, seafood, milk, wheat germ	Vegan/vegetarian diets
Biotin	25–30 µg	30 µg		Immune function, neurological function	Egg yolk, legumes (particularly soybeans and lentils), sunflower seeds, milk, cheese, chicken, pork, beef, and some fruits and vegetables.	High consumption of egg whites
Copper	890–900 µg	1000 µg		Immune function, connective tissue formation, iron metabolism, central nervous system function	Organ meats, grains, shellfish (oysters), nuts, seeds, and cocoa products	Iron and zinc supplementation reduces copper absorption

[a] Source: Institute of Medicine [107,119,132,136,141].
[b] Liver is very high in vitamin A and high consumption is not recommended in the periconceptional period because it poses a teratogenic risk.
[c] Most women in the reproductive years should be supplemented with folate 400 µg/day to decrease the risk of neural tube defects, but attention should be paid to vitamin B12 status—excess folate from supplements may mask/exacerbate the effects of vitamin B12 deficiency.
[d] Intakes of between 1000 and 2000 IU/day are likely to be beneficial and not harmful.
[e] Malaria causes iron delocalization rather than deficiency, so supplementation may not be helpful unless malaria prophylaxis/treatment is used in conjunction.
[f] The intake range indicates adult versus adolescent requirements. Adolescents require the higher intake; adults the lower intake.

account for approximately 12% of energy intake in a 2000 kcal per day diet [105]. Intake of protein comprising more than 25% of total energy intake is not recommended.

Fat

Fat is important in the maternal diet. For women of reproductive age, fats should contribute between 15% and 30% of their daily energy intake, although the intake of saturated fats and trans-fats (hydrogenated fats and oils) should be limited in favor of sources of long-chain polyunsaturated fatty acids (PUFAs) such as fish oils and olive oil. Highly active individuals who consume diets rich in vegetables, fruits, and legumes and wholegrain cereals can consume up to 35% of their energy intake from fats without risk of unhealthy weight gain or increasing risk of NCDs.

PUFAs are important for a woman's own mental and physical health and are critical for fetal brain development. There are two essential PUFAs: linoleic acid (LA; the parent omega-6 [*n*-6] fatty acid) and alpha-linolenic acid (ALA; the parent omega-3 [*n*-3] fatty acid). LA and ALA are converted to more physiologically active, long-chain PUFAs (LA to the *n*-6 PUFA arachidonic acid [AA] and ALA to *n*-3 PUFAs eicosapentenoic acid [EPA] and docosahexenoic acid [DHA]) in the body. LA is found in many vegetable oils, and AA is present in animal foods such as poultry, fish, and eggs. Conversion of LA to AA is quite efficient, but conversion of ALA to EPA and DHA is not. It is therefore beneficial to consume EPA and DHA directly from foods—particularly from fatty fish.

Diets providing PUFAs in the range 6%–10% of daily energy intake are considered adequate, with an optimal balance between intake of *n*-6 PUFAs and *n*-3 PUFAs of 5%–8% and 1%–2% of daily energy intake, respectively [72]. Most Western diets have a ratio of *n*-6 to *n*-3 fats that is considered to be too high (exceeding 10:1), so increasing the intake of *n*-3 PUFAs from fish, and decreasing intake of *n*-6-rich vegetable oils is recommended. Although vegetarian and vegan diets are usually low in saturated fats, they are also very low in DHA and EPA and typically have a higher *n*-6:*n*-3 ratio than that of omnivorous diets [106]. To balance this, it is suggested that vegetarians should try to increase consumption of ALA from sources such as olive oil, walnuts, and flaxseed oil, and decrease LA intake from other vegetable oils. Processed foods contain high amounts of saturated fats, trans-fats, and *n*-6 fatty acids, and should be limited or avoided in any type of diet.

Carbohydrates

Carbohydrates are an important source of fuel for the body, and are needed for organs and muscles to function properly. They should make up the remainder of total energy intake, after taking into account appropriate amounts of protein and fat. The type and content of carbohydrate (high- versus low-glycemic sources) influences insulin action and blood glucose concentration, and thereby can affect the degree of insulin resistance. Glycemic index (GI) refers to the grouping of carbohydrate sources based on the degree of blood glucose elevation that occurs after they are consumed. The greater the level of processing and refining, the higher the glucose index of a particular carbohydrate. Low-GI carbohydrates are preferable for a healthy diet, and include wholegrains, unprocessed rice, beans, most fruits, nontuberous vegetables, nuts, and dairy products. High-GI foods include processed grains (flour, bread, cereals), tuberous vegetables (potatoes, carrots), baked goods, soft drinks, snack foods, ripe bananas, and some tropical fruit [107].

Fiber

Recommendations for a healthy diet often include increasing intakes of fiber-rich fruits, vegetables, and whole grains. Fiber in the diet affects intestinal health, and has a beneficial effect on the postprandial insulin response. Observational data suggest that dietary fiber may act as a protective factor against type 2 diabetes [108], cardiovascular disease [109], stroke [110], and some types of cancer [111]. Fiber-rich ingredients such as wheat bran, beta-glucans from oats and barley, and soluble fiber from prebiotics are also recommended to ensure an adequate intake of dietary fiber [112].

4.3.2.2. Micronutrients

Folate

Folate is important in women for the prevention of macrocytic anemia, and is implicated in maintaining cardiovascular health and cognitive function. It is also critical for normal fetal development. Folate insufficiency before pregnancy is a proven risk factor for the development of NTDs and other congenital malformations in the fetus. Because the embryonic processes affected by folate occur very early in pregnancy, it is essential for women of reproductive age to maintain adequate folate levels before conception. In women with low folate status, supplementation after pregnancy does not achieve protective levels before the critical period of neural tube closure [113].

Dietary sources of folate include legumes, green leafy vegetables, citrus fruits, and juices, and breads and cereals that contain flour enriched with folic acid. However, intake from these sources is often too low, even in high-income countries [114]. Synthetic folic acid used for supplementation and food fortification has higher bioavailability than folate from food sources. To ensure protection against NTDs, all women of reproductive age are advised to consume 0.4 mg (400 μg) of synthetic folic acid daily, obtained from fortified foods and/or supplements. Because obesity affects the body distribution and metabolism of folate, and is itself an independent risk factor for NTDs, obese women may benefit from higher doses [115]. If the woman has a history of NTDs, or risk factors for these defects (including BMI >35), folate supplementation should be increased further to 4 mg per day. For women with diabetes, or those who are receiving an anticonvulsant treatment, a higher daily dose of 5 mg folic acid, in addition to dietary advice to increase food folate intake, is recommended, and should be continued until 12 weeks of pregnancy, after which the dose of folic acid should be reduced back to the standard recommended dose of 0.4 mg per day [116,117].

Vitamin B12

Vitamin B12 is critical for normal neurological function and red blood cell formation, and like folate, low levels can lead to macrocytic anemia in women [118]. Vitamin B12 deficiency can also cause peripheral neuropathies and neuropsychiatric problems. In conjunction with folate, vitamin B12 maintains plasma homocysteine at healthy levels, which is important for cardiovascular health [119]. Importantly, high folate intakes can mask the adverse effects of low vitamin B12. While adolescent girls and women should be advised to consume adequate folate/folic acid, their vitamin B12 status also needs to be considered in this context. Low vitamin B12 status is an important risk factor for fetal NTDs, so adequate levels of this vitamin should be achieved and maintained before conception [120,121]. Under normal circumstances, dietary vitamin B12 is accumulated and stored in the liver, such that deficiency appears only after long periods of insufficient intake or as a result of malabsorption disorders. However, as vitamin B12 is only found in animal-derived foods (meat and dairy products), women who follow strict vegetarian diets are at risk of deficiency, and in these women preconceptional supplementation with at least 2.4 μg per day of vitamin B12 is recommended. Vitamin B12 levels may be low in women in LMICs or cultures in which standard diets include minimal or no animal products [122,123].

Vitamin D

Vitamin D has multiple critical functions in maternal health and fetal development. It plays a key role in maintaining bone integrity via calcium regulation, but also influences a number of extra-skeletal processes including immune function and blood glucose homeostasis. A woman's vitamin D requirements increase in pregnancy because the fetus is entirely dependent on the maternal pool of vitamin D for growth and development, therefore it is important to achieve and maintain adequate status for this nutrient prior to conception. Most vitamin D is synthesized endogenously in skin exposed to sunlight. Food sources of vitamin D include milk, orange juice, fatty fish, egg yolks, liver, and cheese, but these contain only low amounts of the vitamin. Inadequate vitamin D status resulting from low dietary intakes and/or sun-avoidance behaviors is more prevalent than is generally recognized—insufficiency or deficiency of this essential vitamin may affect up to 1 billion people worldwide, and is particularly common in women of reproductive age [124]. In high-income countries, dietary intakes tend to be below recommended levels [114]. Its importance for maternal health and fetal development suggest that supplementation with at least 400 IU per day may be necessary prior to conception. However, it should be noted that 400IU of vitamin D in the form of supplements is not as effective in achieving adequate vitamin D status as exposure to sunlight. Higher supplement levels may be required by vegetarians, dark-skinned individuals, or those who live in environments with minimal sun exposure or who cover their skin extensively with clothing or sunscreen.

Other B vitamins (thiamine, riboflavin, niacin, vitamin B6, pantothenate, biotin) and choline

In addition to folate and vitamin B12, other B vitamins are important for women's health prior to pregnancy for proper metabolism and nerve and muscle function. These vitamins are essential for fetal growth and brain development. They are widely distributed in foods, and women with a substantially varied diet consisting of poultry, fish, meats, eggs, starchy vegetables, legumes, nuts, and fruits will obtain sufficient quantities from their diet. However, refining of wheat and rice removes much of the B vitamins they contain, and populations with diets based on polished, unfortified grains may be at risk of subclinical deficiency. Deficits of B vitamins tend to occur together, based on dietary patterns, rather than in isolation. Refugee and displaced populations may be at risk of deficiency if cereal foods used in aid are not fortified. B-vitamin supplementation is recommended in such cases.

Choline is an essential nutrient involved in cell membrane function and neurotransmission, and deficiency can result in organ dysfunction. In pregnancy, it is essential for growth and development of the fetus, and is particularly important for the developing brain [125]. Folate and vitamin B12 interact with choline in common biochemical reactions, and during folate deficiency, choline becomes a limiting nutrient. Periconceptional deficiency of choline, like folate and vitamin B12, is associated with increased risk of fetal NTDs [126]. Multivitamin supplements containing choline (approximately 450 mg per day) may be helpful to maintain adequate choline status and protect against NTDs, though many available formulations do not contain choline.

Iron

Iron is essential for blood production, and is present in the body mostly as a component of the oxygen-carrying protein hemoglobin. Iron also facilitates oxygen use and storage in muscle as a component of myoglobin. A lack of iron leads to anemia and affects physical working capacity, brain function, and behavior.

Iron deficiency is the most widespread nutritional disorder in the world, affecting the health of more than one billion people worldwide, and 29% of all nonpregnant women [43]. In high-income countries, many women in the preconception period have low iron stores as a result of menstrual blood losses and/or poor diet. In low-resource settings, iron-deficiency anemia is especially prevalent, and is often exacerbated by infectious diseases, including schistosomiasis and hookworm, which cause intestinal blood loss [127]. Iron deficiency is also exacerbated by malaria, which causes iron to be shifted from hemoglobin storage forms, but this in fact may be protective as it limits critical nutrients to the infectious agent [128]. Most iron deficiency in girls and women is caused by inadequate intake, poor iron absorption, and/or menstrual blood loss. If women are deficient in iron when they become pregnant, their iron stores will be depleted further, sometimes with grave consequences for the woman, including increased risk of death from postpartum hemorrhage. Improving the iron status of girls and women preconceptionally should therefore be a priority in women's health.

The main dietary sources of heme iron (iron in hemoglobin and myoglobin—the most easily absorbed form) are meat, poultry and fish. Non-heme iron is obtained from cereals, pulses, legumes, fruits, and dark green vegetables. Most diets derive a higher proportion of iron content from non-heme iron than haem iron, although absorption of non-haem iron is less efficient and can be inhibited by phytates present in some of the same foods. It is difficult for many women to obtain enough iron from their diets to have sufficient stores for pregnancy. In regions where anemia is highly prevalent (>20% of women), intermittent supplementation (once weekly) with 60 mg elemental iron is recommended for all menstruating women, in combination with folic acid. It should be noted, however, that excess iron, although unlikely with this iron dose, may be harmful and that supplemental iron may predispose to malaria infection. In malaria endemic areas, iron supplementation should be given in conjunction with malaria prevention and treatment measures [54].

Iodine

Iodine is essential for healthy thyroid function, and increased requirements during pregnancy put women with poor preconception iodine stores at risk of pathological thyroid dysfunction once pregnancy commences. The developing fetal brain is very sensitive to iodine deficiency, and because the bulk of fetal neocortical proliferation occurs early in gestation, iodine deficiency at the beginning of pregnancy also increases the risk of neurodevelopmental delay in the child [129]. This highlights the importance of ensuring adequate iodine nutrition in women of reproductive age.

Food sources of iodine can vary greatly in their iodine content, depending mainly on the natural iodine content of the soil they are grown in, or the content of the food eaten by animal sources. Parts of Europe, the Eastern Mediterranean, Africa, the Himalayas, the Andes, and the Western Pacific are affected by suboptimal iodine in foods, but in other areas it is present in excess, possibly harmful levels [45,130,131]. Seaweed (e.g. kelp, nori, kombu, wakame) is an excellent source of iodine, though the content can vary greatly [132]. In many areas, iodization of salt is universally implemented to combat deficiency in the population, though in some a reduction in the availability of iodized salt has resulted in an increase in moderate iodine deficiency, which can affect the outcomes of pregnancy. At preconception health checks, girls and women should be asked about their use of iodized salt and informed of the importance of adequate iodine nutrition to ensure optimal thyroid function both before and during pregnancy. If iodine nutrition is inadequate, supplementation may be considered for women of reproductive age as a daily oral dose of iodine (150 μg per day) or a single yearly oral dose of iodized oil (400 mg per year) [45].

Calcium

Calcium is important for a woman's preconception health for vascular function, muscle contraction, nerve transmission, and glandular secretion of hormones. Ionized calcium for these functions is stored in and mobilized from the skeleton in a tightly regulated manner for optimal physiological functioning. Calcium is critical for skeletal integrity and growth, and is therefore particularly important for adolescent girls during phases of rapid bone development. While the skeleton is growing and maturing, it accumulates calcium at an average rate of 150 mg per day [133]. Calcium is mobilized from the maternal skeleton during pregnancy for fetal bone growth and development, therefore adequate intake before pregnancy is important to ensure adequate skeletal stores. Low calcium intake is also implicated in hypertensive disorders in pregnancy (see item 4.4.1.2).

The main dietary source of bioavailable (absorbable) calcium is dairy products, and in high-income countries (with the exception of Japan), intake is generally adequate in adults [114]. However, many societies have limited access to dairy products or otherwise do not regularly consume them for cultural reasons. In such situations, leafy green vegetables, sardines/anchovies, soy products, some traditional foods such as nixtamalized (alkali-soaked) maize flour, and fortified cereals can be important sources of calcium [134,135].

All women should be encouraged to achieve or maintain a dietary calcium intake of between 1.0 and 1.3 g per day before pregnancy [136], in order to build adequate body calcium stores and prevent bone loss once pregnancy commences. Adolescent girls should aim for the upper end of the recommended intake range, and some with low intakes may benefit from supplementation.

Selenium

Selenium is an important micronutrient for growth and reproductive function. Selenium-containing proteins are involved in thyroid hormone metabolism, and thus thyroid function is sensitive to selenium in the diet; selenium deficiency can also exacerbate the effects of iodine deficiency. Inadequate selenium status has been associated with infertility. Plant foods, especially wheat, and animals that have eaten selenium-containing foods, are the major sources of dietary selenium. Selenium status varies depending on the selenium content of the soil on which the plants are grown. For example, selenium deficiency occurs in rural areas of China and is common in Europe, but is uncommon in the USA [137]. Recommendations for selenium intake in adolescent girls and nonpregnant women range from 55–65 μg per day, which is often not met in areas where soil selenium is low.

Zinc

Zinc is important in the preconception period for optimal reproductive health and immune function. Zinc status affects growth, therefore adolescent girls are particularly vulnerable to the effects of dietary deficiency, especially if they become pregnant. Good sources of zinc include oysters and other shellfish, and red meat, but it is also found in nuts, legumes, poultry, eggs, whole grains and seeds, some fruits, and dairy products. Mild to moderate zinc deficiency is common in populations with low consumption of zinc-rich foods such as red meat and seafood, and high consumption of grains containing phytates, which inhibit zinc absorption. Deficiency often accompanies general protein/energy malnutrition, and is common in Sub-Saharan Africa and South Asia, and parts of Central and South America [138]. Iron supplementation also inhibits zinc absorption [139], and zinc supplementation may be advised in women taking iron supplements preconceptionally. Recent evidence suggests that zinc supplementation may have a modest effect on reducing the risk of preterm birth, particularly in low-income areas with high perinatal mortality [140].

4.3.3. Preconception lifestyle and exposures

- FIGO strongly recommends that hazardous exposures and behaviors such as smoking, alcohol intake, or use of recreational drugs are avoided prior to conception, and definitely should be avoided in pregnancy because of the risk of detrimental effects on fetal nutrition, growth, and development.

Diet is only one part of a healthful lifestyle. Maintenance of a healthy bodyweight and cardiovascular health relies on an energy balance equation that includes an appropriate intake of energy through the diet counterbalanced by energy expenditure through physical activity.

Tobacco smoking and the use of alcohol will ultimately affect not only the woman's health, but will also contribute to an unhealthy lifestyle that can affect later pregnancies, forming habits that can be difficult to break. Chronic or frequent heavy alcohol use during pregnancy confers significant risk of fetal alcohol spectrum disorders, manifestations of which include facial abnormalities, growth deficiency, and nervous system defects [142]. Yet alcohol consumption remains common among pregnant women, as a continuation of prepregnancy behavior. Smoking and exposure to second-hand smoke are among the most important preventable risk factors for adverse pregnancy outcomes such as preterm birth and low birth weight [143]. Maternal smoking has also been linked to offspring obesity in later life. Women who were exposed to cigarette smoke in utero were at significantly higher risk of obesity in adulthood, and gestational diabetes in their own pregnancies [144]. The importance of measures to discourage these behaviors in adolescence, and in any case before pregnancy begins, cannot be overemphasized.

4.4. Recommendations for pregnant women

- FIGO strongly recommends that pregnant women have early access to prenatal care to receive appropriate nutrition counselling and interventions, and treatment for conditions that jeopardize their pregnancy outcome, such as malaria, tuberculosis, HIV, gastrointestinal infections, and NCDs.

If a woman's diet is healthy prior to conception, she should not need to change it substantially in early pregnancy, although attention should be paid to some nutrients that are needed in higher amounts at various pregnancy stages (see Table 1 and Figure 5). Those nutrients of particular importance in the preconception period (discussed above) are also needed in pregnancy—some in increased amounts as pregnancy progresses. Certain situations such as baseline undernutrition, young maternal age, multiple pregnancy, short interpartum period, malabsorptive disorders, or parasitic infections, may increase the requirements for some nutrients. Depending on the context, specific additional folate, vitamin B12, iron (hemoglobin, ferritin), and vitamin D status may need to be measured.

4.4.1. Nutrient requirements in pregnancy

4.4.1.1. Energy, macronutrients, and fiber

The ratio of macronutrients in the diet should not need to change during pregnancy, unless prepregnancy nutrition is poor or inappropriate. Women should be advised that their energy intake needs in the beginning of pregnancy do not increase from prepregnancy levels; they should focus on eating well for pregnancy, and not eating more. For women with BMI in the normal range and above (BMI ≥25), no increase in energy is needed until later in pregnancy, when a greater intake is required to make up for energy deposited in maternal and fetal tissues. The Food and Agriculture Organization/World Health Organization/ United Nations University recommended that during pregnancy women increase their energy intake by 85 kcal per day in the first trimester, 285 kcal per day in the second trimester, and 475 kcal per day in the third trimester, based on calculated energy costs [145]. The US Institute of Medicine recommends an increase of 340 and 452 kcal per day in the second and third trimesters, respectively. Pregnancy places increased metabolic demands on the woman, and her ability to meet those needs may be partly determined by concurrent demands (Box 6).

Protein

Protein needs increase during pregnancy to account for increased tissue formation for the fetus, placenta, and maternal tissues. Guidelines from the US Institute of Medicine suggest an intake of 1.1 g protein per kilogram bodyweight per day [105]; if women are gaining weight appropriately throughout their pregnancy, their protein intake should thus increase. Overall the recommended increase in protein intake is 10−25 g per day above the prepregnancy recommendation of 60 g per day, though there is no significant increased need in the first trimester. The WHO recommends an increase of 1, 9, and 31 g per day in the first to third trimesters, respectively [146]. Protein supplementation studies have produced varying/conflicting results. Balanced protein/energy supplementation, in which protein accounts for no more than 25% of total dietary energy, can improve maternal and infant outcomes in undernourished women, including reducing the risks of preterm birth, stillbirth, and fetal growth restriction [147]. However, high-protein supplementation does not appear to be beneficial, and may be harmful to the fetus.

Fats

The requirement for fats in pregnancy can be met by typical Western diets, but the quality of the diet with respect to types of fats is a concern. As for before pregnancy, fats should represent 15%–30% of a woman's overall energy intake, although intake of saturated fats should be limited (reducing consumption of fried fast foods and processed snacks) and PUFA intake should be maintained or increased by consuming 1–2 meals per week of oily fish (avoiding large predatory fish that may be high in mercury or other contaminants e.g. swordfish, marlin, tuna, shark, orange roughy, king mackerel, bigeye or Ahi tuna, and tilefish). PUFA status (especially omega-3 fatty acid status) declines during pregnancy and can be improved by supplementation [148].

Carbohydrates

Carbohydrates provide essential fuel (primarily glucose) for both mother and fetus during pregnancy, and should continue to be the largest source of energy in the diet. As advised in the prepregnancy period, it is important to choose complex carbohydrates with a low GI, and to avoid excess added sugar in the diet. Low GI diets in pregnancy are associated with less excessive gestational weight gain and improved glucose tolerance [149]. Low GI diets also attenuate the pregnancy-related rise in insulin resistance [150], and in women with GDM, appear to be associated with less insulin use and lower birthweight [151]. Low GI diets should therefore be considered in women at risk of excessive gestational weight gain and glucose intolerance. In addition, positive benefits of a maternal low GI diet have been noted on infant adiposity [152]. An increase in carbohydrate intake of around 45 g per day is recommended—to 175 g per day during pregnancy, compared with 130 g per day in nonpregnant women.

Fiber

Dietary fiber remains important during pregnancy to reduce constipation, and may help to reduce the risk of gestational diabetes and pre-eclampsia [153,154]. The recommendation for total dietary fiber intake during pregnancy is 28 g per day,

Box 6

Nutritional and situational demands that may impact a pregnant woman.

Nutritional challenges of pregnancy:

- *Anemia/iron deficiency* – supplementation commonly required.
- *Low folate status* – folic acid supplementation should continue.
- *Iodine deficiency* – if uncorrected before pregnancy, supplementation required.
- *Vitamin D deficiency* – high-risk groups (low sun exposure) require supplementation.
- *Low vitamin B12 status* – a concern with vegetarian diets, particularly if folate status is high.

Situations affecting a woman's ability to meet the nutrient demands of pregnancy:

- *Young mothers* – higher demand for nutrients if their own growth is not complete.
- *Hard physical labor* - increases nutrient and fluid requirements.
- *Multiple pregnancy* - increases nutrient demand.
- *Short interpartum interval* - limited opportunity for repletion of nutritional reserves, particularly iron.
- *Parasitic infection or malabsorption disorder* – decreases nutrient absorption and utilization.

which is unchanged from the prepregnancy requirement, but higher than typical intakes for many women. Women whose prepregnancy diet was low in fiber should be encouraged to increase the fiber content by adding more fruits, vegetables, and whole grains to their diet in place of refined grains and simple sugars.

4.4.1.2. Micronutrients

Folate, vitamin B12, vitamin B6, and choline

Both folate and vitamin B12 are required in early pregnancy for protection against NTDs, and supplements taken before conceiving should be continued. During pregnancy, folate and vitamin B12 help prevent megaloblastic anemia. These vitamins, along with choline, serve as sources of methyl donors in epigenetic DNA methylation, and therefore can have long-lasting effects on offspring health if present in inadequate supply in the maternal diet.

Folate, vitamin B12, vitamin B6, and choline work together to regulate the levels of circulating homocysteine, which is linked to cardiovascular disease and other adverse effects if present in elevated levels. Vitamin B6 is involved in this pathway as a cofactor for homocysteine metabolizing enzymes. In pregnancy, elevated homocysteine can increase the risk of placental vascular disorders, preterm birth, low birth weight, and small-for-gestational-age infants [121,155,156]. All of these micronutrients are required to keep homocysteine levels low [157], and affect levels of DNA methylation, thereby epigenetically influencing gene expression (Figure 6).

Recent evidence suggests that continuing supplementation with 400 μg per day of folic acid though the second and third trimesters may prevent the increase in homocysteine concentration that normally occurs in late pregnancy [158], which could be important in women likely to have a short interpregnancy interval.

Vitamin B12 deficiency is common in women who consume minimal or no animal-based foods. In India, women with low vitamin B12 but adequate or high folate levels give birth to babies who are thin but adipose, and at increased risk of insulin resistance and diabetes later in life [159]. If deficiency for vitamin B12 exists before conception, it will become more extreme during pregnancy, leaving the woman even further in deficit and affecting future pregnancies as well as her own health.

Because there is an intersection of the pathways of folate and choline in homocysteine metabolism, choline becomes a limiting nutrient during folate deficiency [160], and conversely, when choline supply is low the demand for folate is increased [161]. An adequate intake of choline therefore should also be assured during pregnancy. Although food sources of choline are plentiful, pregnant women may be at risk of inadequate intakes, particularly if they consume vegetarian or vegan diets. Choline is derived from the lipid portion of foods; eggs in particular are a good source of choline, and should not be restricted in pregnancy.

Mild to moderate vitamin B6 deficiency remains common, despite its wide availability in foods, even in high-income countries such as the USA [162]. A diet similar to the Mediterranean diet is recommended during pregnancy to provide a variety of sources for vitamin B6 and other B-complex vitamins.

Other B vitamins

As in the preconception period, B vitamins from a balanced and varied diet are necessary for maintaining optimal maternal health in pregnancy, and are essential for fetal growth and brain development. Deficiencies that are not obvious in the woman can have effects on the fetus; for example, a recent study has

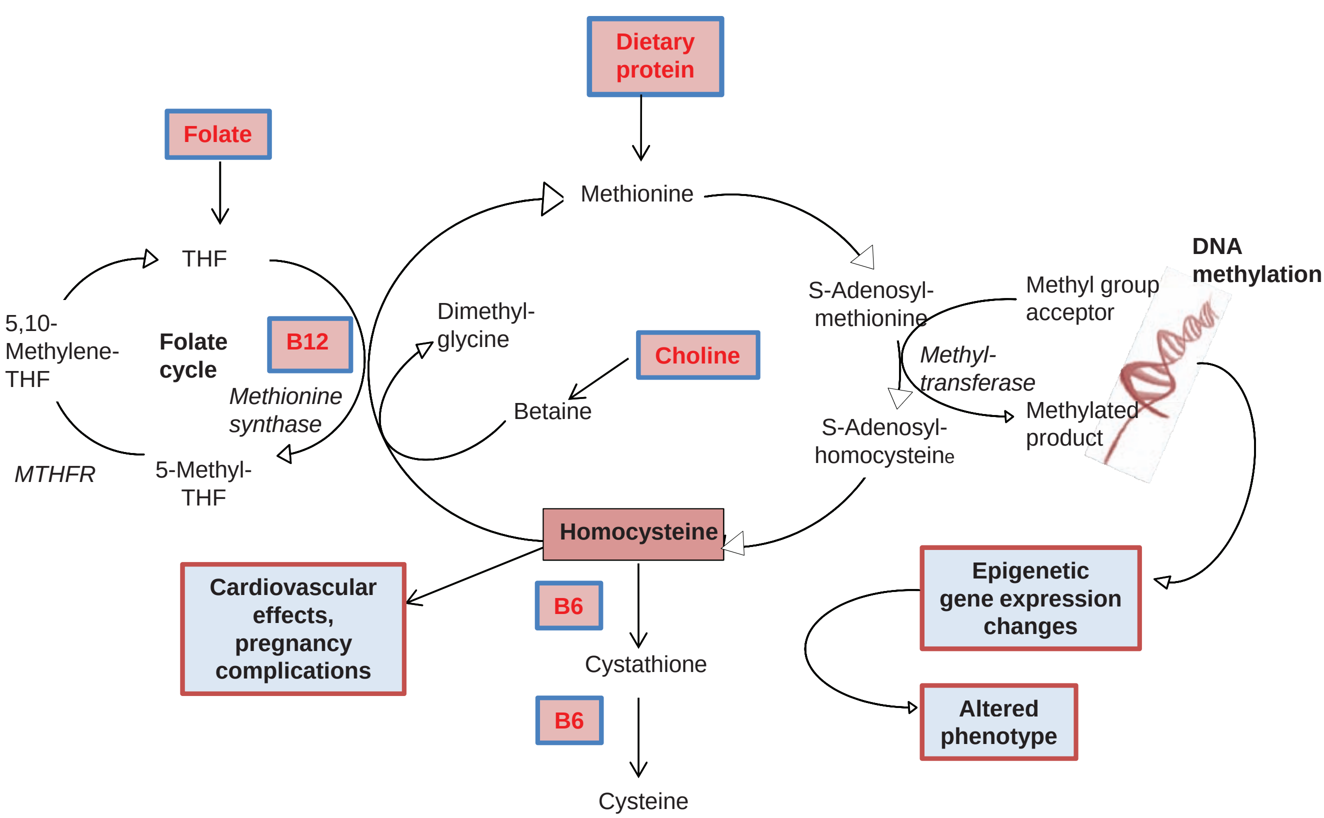

Figure 6 Dietary factors influencing homocysteine metabolism and DNA methylation. Folate, vitamin B6, vitamin B12, choline, and methionine from dietary protein all interact to maintain appropriate levels of homocysteine and regulate DNA methylation. Epigenetic processes including such DNA methylation modify phenotypic outcomes, with long-term effects on health and disease

confirmed earlier observations that marginal biotin deficiency is common in human pregnancy, and there is evidence that biotin intake of at least 2−3 times the recommended adequate intake may be needed to meet the requirement for pregnancy [163]. A varied diet including green vegetables and whole, unprocessed foods should ensure adequate B vitamins, although these may be lacking in countries where diets are based around staple polished grains, and in regions with high prevalence of general malnutrition.

Vitamin D

Vitamin D is essential in pregnancy for immune and nervous system function [164], and for maintaining maternal calcium homeostasis [165]. During pregnancy, the fetal skeleton accumulates calcium from maternal stores, mediated by maternal vitamin D (calcitriol). The importance of vitamin D for fetal skeletal development is well recognized—maternal deficiency can result in childhood rickets, craniotabes (soft skull bones), and osteopenia in the newborn [166]. In addition to skeletal effects, women with very low vitamin D status face increased risks of other adverse pregnancy outcomes and possible long-term effects on their own health and that of their offspring [167]. Infants born to vitamin D deficient mothers are more likely to have low birth weight [168,169], and may be at increased risk of newborn hypocalcemia and possible cardiac failure [170]. There may also be an increased risk of developing allergies in childhood [171]. Because vitamin D insufficiency is common, supplementation should be continued throughout pregnancy in high-risk women (vegetarians, dark-skinned individuals, or those who live in environments with minimal sun exposure or who cover their skin extensively with clothing or sunscreen). The dose of the vitamin D supplement should be at least 400 IU per day, and the total intake should be in the range of 1000–2000 IU per day from dietary and supplemental sources (See Regional Case Study 5: Northern Europe).

Vitamin A

Vitamin A is important in women's health to ensure proper function of the visual and immune systems, and is also crucial for reproductive function. During pregnancy, adequate vitamin A status is required for fetal growth and development. During pregnancy, either excess or deficiency of vitamin A can cause birth defects, typically involving abnormal development of the eyes, skull, lungs, and heart [172]. Vitamin A deficiency during pregnancy results in maternal night blindness and increased risk of maternal mortality, and is associated with poor pregnancy outcomes including preterm birth, intrauterine growth restriction, and low birth weight. Pro-vitamin A carotenoids in the diet are found in darkly colored fruits and vegetables, oily fruits, and red palm oil, whereas pre-formed vitamin A (retinol and retinyl esters) is found in fatty acids of animal products.

In high-income countries, vitamin A intakes tend to be above recommended levels [114], but deficiency is common in some LMICs because of limited intake of dairy products and carotene-rich vegetables and fruits. Regions with the highest prevalence of vitamin A deficiency (serum retinol <0.7μmol/L) among pregnant women are the Western Pacific (prevalence 21.5%), Southeast Asia (17.3%), Eastern Mediterranean (16.1%), and Africa (13.5%) [44], where supplementation is recommended in late pregnancy in endemically vitamin A deficient communities. However, vitamin A is teratogenic at high maternal intakes in early pregnancy, so in areas where deficiency is not endemic, supplementation is specifically cautioned against, as is consumption of high amounts of liver, which contains a high concentration of pre-formed vitamin A.

Iron

Iron deficiency can cause maternal anemia, which in severe cases increases the risk of death during childbirth. When maternal iron status is suboptimal, fetal iron needs are also compromised [173]. Iron deficiency in pregnancy is associated with increased risk of low birth weight and preterm delivery, which in turn are associated with stunting later in life. The requirement for iron during pregnancy increases more from prepregnancy levels than for any other nutrient. The fetus accumulates the majority of iron stores in the third trimester, and during this period an additional 9–12 mg of iron is required above prepregnancy needs, totaling an additional 1000–1240 mg during gestation

Regional Case Study 5: Thinking Nutrition First in Northern Europe

Vitamin D in pregnancy

The main source of vitamin D in humans is through cutaneous synthesis in the presence of sunlight. Vitamin D can also be acquired to a lesser extent from the diet, principally in oily fish and fortified dairy products. However, consumption of certain dietary sources of vitamin D (such as liver, undercooked eggs, and tuna fish) is restricted during pregnancy, thereby even further reducing pregnant women's chances of meeting recommended intakes from food alone. There is a paucity of data relating to dietary sources, status, and intake of vitamin D intake in pregnancy in the Western world. However, it has been reported that the prevalence of maternal vitamin D deficiency during pregnancy has increased in recent years, with a concurrent rise in the incidence of childhood rickets. This is particularly evident in countries in Northern Europe, such as Ireland, where the main cause of poor vitamin D status is lack of sunlight exposure for much of the year. Ireland lies on a latitude between 51−55°N where the population must rely on the limited dietary sources of vitamin D for much of the year.

In a prospective observational study, dietary intakes of vitamin D ranged from 1.9−2.1 μg per day during pregnancy—80% below the current recommendation. The principal food groups contributing to vitamin D intake were meat, eggs, and breakfast cereal. Oily fish, the best dietary source of vitamin D, was consumed by less than 25% of women [188]. Measurement of serum 25(OH) vitamin D revealed a high prevalence of hypovitaminosis D ranging from 33% to 97%, with a marked seasonal variation. Among those with a winter pregnancy, a correlation was found between pregnancy vitamin D levels and fetal length [189].

Vitamin D levels were also assessed in immigrant women from the Middle East, and North and Sub-Saharan Africa. These groups had vitamin D levels below those of white women, indicating that these women are at particular risk of vitamin D deficiency in pregnancy [190].

The high prevalence of maternal hypovitaminosis D during winter months in northern latitudes may have detrimental effects on fetal skeletal growth. These data on dietary intakes and on serum 25 (OH) vitamin D levels highlight the need for vitamin D supplementation during pregnancy in vulnerable populations.

[174]. Despite homeostatic regulatory mechanisms that operate during pregnancy to increase iron absorption in mid- to late pregnancy, the prevalence of iron deficiency and iron-deficiency anemia is very high, affecting over 38% of pregnant women, totaling 32 million women worldwide. Pregnant adolescents, women carrying multiple fetuses, or those who are pregnant after a short interpartum period are at particularly high risk of iron-deficiency anemia. Iron deficiency puts mothers at risk of poor outcomes in the event of postpartum hemorrhage.

A recent survey found that iron intakes by pregnant women were below nutrient recommendations in all high-income countries except for the UK [114]. Women who consume little or no animal-source food generally have low iron stores, and are likely to benefit from supplementation with low-dose iron. In regions where anemia is highly prevalent (>20%), daily supplementation with 60 mg elemental iron is recommended, in combination with folic acid (see below) [47]. In areas of lower prevalence, intermittent use of iron supplements (120 mg, once weekly) is recommended to improve gestational outcomes and avoid the development of maternal anemia [175]. In malaria endemic areas, iron supplementation should be given in conjunction with malaria prevention and treatment measures. In women with multiple micronutrient deficiencies, supplementation with iron alone may adversely impact the absorption of other nutrients such as zinc and copper, so additional nutrient supplementation may be helpful [176].

Iodine

Iodine is critical for maternal and fetal thyroid function and fetal neurological development, and a women's need for supplementation should be assessed early in pregnancy in known iodine-deficient areas where salt iodization is not implemented or iodized salt is not consumed. In women with adequate iodine intake before conception (approximately 150 μg per day) the increased demand for thyroid hormones during pregnancy are met by homeostatic adaptation to hormonal output by the thyroid gland, but if a woman enters pregnancy with low iodine stores, hypothyroidism can develop [177]. Much of the fetal neocortical proliferation occurs early in gestation, so women who are hypothyroxinemic because of low iodine stores at the beginning of pregnancy are at risk of neurodevelopmental delay in their offspring [129].

It has been suggested that even with use of iodized salt and eating seafood 2–3 days per week, a woman's daily iodine intake would be in the order of 100–150 mg per day—approximately half the amount recently recommended during pregnancy and lactation [178]. In areas of endemic iodine deficiency or where soil iodine is low and women do not consume iodized salt, iodine supplementation should be considered for pregnant women as early as possible in pregnancy, at a daily oral dose of iodine (200−250 μg per day) or a single oral dose of iodized oil (400 mg, once per year) [45]. FIGO's recommendation, from its Working Group on Best Practice in Maternal−Foetal Medicine (best practice advice on thyroid disease in pregnancy, currently in progress), is to screen for thyroid function in the first trimester in countries where women have an iodine deficient diet, and in symptomatic patients.

Calcium

Calcium supplementation has the potential to reduce adverse gestational outcomes, in particular by decreasing the risk of developing hypertensive disorders during pregnancy, which are associated with maternal death and preterm birth. In high-income countries where calcium intake is high/adequate, supplementation during pregnancy is generally not required, though the bone health of adolescents with low calcium intake may benefit from taking a prenatal calcium supplement. In women at high risk for hypertensive disorders, an overall protective effect of supplemental calcium on pre-eclampsia has been demonstrated in populations with low calcium intake [179,180]. Calcium supplementation (1500–2000 mg per day) during pregnancy was found to reduce the risk of all gestational hypertensive disorders in women with low baseline calcium intakes, and this level of supplementation is now recommended by the WHO for these regions, implemented from 20 weeks of pregnancy until the end of pregnancy [181]. However, there is some evidence that excessive calcium supplementation in pregnancy may lead to long-term deficits in maternal bone mineral content in women previously accustomed to low-calcium diets [182]. Lower dose supplements (500−600 mg per day) may also be effective and could be considered in settings where high-dose supplementation is not feasible [183]. The effect of such lower doses on bone mineral content has not yet been determined.

Selenium

Selenium is important in pregnancy for fetal growth and thyroid metabolism, and insufficiency may increase risks of early pregnancy loss, pre-eclampsia, and gestational diabetes [137,184]. Selenium plays an important role in prevention of oxidative stress through selenoproteins such as glutathione peroxidase, and this role may contribute to suboptimal pregnancy outcomes associated with insufficiency. The Institute of Medicine RDA for selenium in pregnancy is 65 μg per day [141].

Zinc

Zinc is required for fetal growth, immune function, and neurological development; daily zinc requirements increase by up to 40% during pregnancy. Inadequate zinc intake often accompanies general protein/calorie malnourishment, but is also seen in individuals consuming poor quality diets. Regular consumption of zinc-rich or zinc-fortified foods during pregnancy is necessary to meet the requirement. Much of the world's population is at risk of zinc deficiency because of inadequate zinc content in the food supply. Deficiency is particularly common in Sub-Saharan Africa and South Asia [138]. Zinc supplementation in high-risk populations has been shown to reduce the incidence of preterm delivery, and increases growth and weight gain in infants and children [185,186]. Fortification of flour with zinc has been recommended in some areas [187].

4.4.2. Gestational weight gain

- FIGO recommends that healthcare professionals take action to recommend and monitor appropriate gestational weight gain in relation to prepregnancy BMI. In resource-constrained settings, gestational weight gain monitoring should not occur at the expense of assessments such as blood pressure measurement, urine testing for protein, and abdominal examination.

A significant proportion of women in high-income countries exceed recommended gestational weight gain guidelines. Excessive weight gain is associated with higher fetal weights and fetal adiposity in the third trimester, higher infant birthweight and higher maternal insulin resistance than women with normal gestational weight gain [191]. Gestational weight gain is a particularly important issue for women who are obese at the start of pregnancy. Whilst prepregnancy BMI is the major determinant of adverse pregnancy outcomes, obese pregnant women who put on excessive weight during pregnancy have even higher risk, and tend to retain more weight postpartum, leading to a higher BMI in subsequent pregnancies. Counselling interventions have been shown to be somewhat effective in reducing gestational weight gain in obese women, but evidence that lifestyle interventions alone can prevent adverse outcomes is currently lacking [192]. Lessons learned from weight control programs outside pregnancy may also help promote better weight control in pregnancy [193].

It is equally important to consider weight gain in undernourished women with low prepregnancy BMIs. Underweight women who do not gain sufficient weight in pregnancy are at risk of poor obstetric outcomes [194] and more likely to have babies that are affected by fetal growth restriction and stunting [195], putting them at risk of metabolic disorders and disadvantages later in life.

Currently, the most accepted guidance on gestational weight gain are those of the US Institute of Medicine (Table 3), which are derived from studies in high-income countries in which mean maternal height is similar to that in the USA. For other regions, these guidelines may be inappropriate [196]. Alternatives that include the influence of maternal height to guide weight gain proportionally may be considered for LMICs. A reference table of weight-for-height by week of pregnancy has been devised on theoretical grounds, based on the premise that the average increment of weight during pregnancy is 20% of the prepregnant weight [197]. However, the table does not establish upper cut-off limits to avoid excess weight gain in settings where the obesity epidemic is also reaching LMICs. Here, it may be advisable to use the so-called Rosso and Mardones (RM) chart, which can diagnose mothers at risk of delivering either small for gestational age or large babies and sets weight gain goals for each individual mother [198]. The RM chart takes into account the importance of height in LMICs and is presently being used in several Latin American countries [196]. In low-resource settings, routine weighing of women throughout pregnancy should not be conducted at the expense of other assessments such as blood pressure measurement, urine testing for protein, and abdominal examination.

4.4.2.1. Energy intake and physical activity

- FIGO recommends that pregnant women exercise moderately for at least 30 minutes per day. Most women should increase their dietary energy intake by approximately 340–450 kcal per day during the second and third trimester. Extreme exercise or hard physical labor should be avoided during late pregnancy.

Maintenance of a healthy bodyweight and cardiovascular health relies on an energy balance that includes an appropriate intake of energy through the diet counterbalanced by energy expenditure through basal metabolism, physical activity, growth, and repair. In mid- to late pregnancy, extra dietary energy is required not only for growth of fetal and maternal tissues, but also to offset increases in basal metabolism and the higher energy cost of physical activity in the pregnant state. The total energy cost of pregnancy, based on an average gestational weight gain of 12.0 kg, has been calculated as 374, 1200, and 1950 kJ per day for the first, second, and third trimesters, respectively [200]. Population-specific differences in lifestyle and body sizes need to be accounted for in making recommendations for physical activity and energy intake, but in general, an additional 340–450 kcal are required during the second and third trimester. Thirty minutes or more of moderate physical activity (e.g. brisk walking, swimming, yoga, low-impact aerobics, cycling) per day on most, if not all, days of the week is desirable. Extreme exercise in late pregnancy, however, is associated with lower birth weight and the possibility of long-term adverse consequences in the offspring. Women should be counselled against such extreme forms of exercise during the later stages of pregnancy and advised to take a more moderate approach. Hard physical labor is also likely to be detrimental [201], as is prolonged squatting (e.g. weeding crops), and these activities should be reduced or avoided where possible, particularly in late pregnancy. This may be difficult for women who are constrained by the demands of a subsistence livelihood. Education of the family and community on this issue is important.

4.4.2.2. Specific recommendations for obese pregnant women

An obese pregnant woman should be advised that a healthy diet and being physically active will benefit both her and her unborn child during pregnancy and will also help her to achieve a healthy weight after giving birth. She should be advised to seek information and advice on diet and activity from a reputable source. Any myths about what and how much to eat during pregnancy should be dispelled; for example, as for all women, obese women should be advised that there is no need to “eat for two” or to drink full-fat milk. It should be explained that energy needs do not change greatly in the first 6 months of pregnancy, and increase only slightly in the last 3 months. Screening for GDM and blood pressure to detect gestational hypertension should be routinely performed in all obese pregnant women and appropriate treatment initiated, including diet alone and/or appropriate hypoglycemic therapy (e.g. insulin). As for all women with GDM, obese women (with or without GDM) should be advised to restrict calorie intake to 25 kcal per kg per day or less and to take moderate exercise of at least 30 minutes daily. Obese women (especially if complicated with GDM) should be advised to choose carbohydrates from low GI sources, lean proteins including oily fish, and a balance of polyunsaturated fats and monounsaturated fats. Restriction of energy intake to between 1800 and 2000 kcal per day, with an intake of carbohydrates between 150 and 180g per day, has been shown to reduce fasting

Table 3
Gestational weight gain recommendations according to the revised US Institute of Medicine guidelines.[a]

		Weight gain		
Body composition	BMI	1st trimester (total)	2nd and 3rd trimesters	Total GWG
Underweight	<18.5	1.0–3.0 kg	0.44–0.58 kg/wk	12.5–18.0 kg
Normal weight	18.5–25	1.0–3.0 kg	0.35–0.5 kg/wk	11.5–16.0 kg
Overweight	25–30	1.0–3.0 kg	0.23–0.33 kg/wk	7.0–11.5 kg
Obese	≥30	0.2–2.0 kg	0.17–0.27 kg/wk	5.0–9.0 kg

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); GWG, gestational weight gain.
[a] Source: Institute of Medicine [199].

insulin levels and deterioration of glucose metabolism in late pregnancy in obese women [201,202], which predisposes to developing type 2 diabetes after pregnancy. Recommendations for management of pregnancy in overweight and obese women are also given by the American College of Obstetricians and Gynecologists [202].

4.4.3. Exposures to avoid

- FIGO calls for action to reduce exposure of adolescents and pregnant women to mercury, arsenic, lead, and cadmium, which can be ingested via food and water. These heavy metals can have detrimental effects on fetal growth and development.

There are a number of food-related issues of concern for pregnant women. To avoid possible infection with pathogens that may cause fetal harm (e.g. *Listeria monocytogenes, Toxoplasma gondii*, *Salmonella enterica*), all pregnant women, regardless of their diet, are advised to be vigilant about how their food is washed, cooked, and stored. Foods that are likely sources of these contaminants, and which should be avoided during pregnancy, are listed in Table 4.

Fungal contamination of food during processing, storage, or transport in conditions favorable for mold growth can expose women to teratogenic mycotoxins such as aflatoxin [203]. The most common source of contamination is rice, corn, wheat, and ground nuts. Exposure is common in Sub-Saharan Africa and East and Southeast Asia [204].

Excessive intake of vitamin A or retinoic acid early in pregnancy is known to be teratogenic in humans, causing craniofacial, central nervous system, thymic, and heart defects in the fetus [172]. As vitamin A is stored in the liver of animals, eating high amounts of liver, especially during early pregnancy, should be avoided.

Although fish consumption during pregnancy is recommended for provision of omega-3 PUFAs and other nutrients, some types of fish are high in contaminants such as methylmercury—a neurotoxicant to which the fetus is particularly vulnerable [205]. Fish that are likely to contain modest levels of mercury (e.g. bass, carp, Alaskan cod, halibut, Mahi Mahi, freshwater perch, monkfish, sea trout, snapper) should be limited to 1–2 meals per week [206]. Fish may also be exposed to environmental pollutants such as polychlorinated biphenyls (PCBs) that may affect neurological development [207], so awareness of local conditions where fish are caught is important [208].

Caffeine in coffee and soft drinks consumed by the woman passes freely through the placenta to the fetus where it can accumulate [209,210]. High maternal caffeine consumption (>300 mg per day) is associated with an increased risk of fetal growth restriction [211–214], and is suggested to increase risks of spontaneous abortion [215,216] and stillbirth [217]. The common advice to limit caffeine intake to 200 mg per day (approximately two medium cups of filtered coffee) during pregnancy continues to be justified based on the available data. In late pregnancy, women should avoid high intakes of herbal teas and polyphenol-rich foods, which have been associated with effects on the fetal ductus arteriosus brought about by inhibition of prostaglandin synthesis [218].

Storing and cooking foods in plastic containers containing bisphenol A (polycarbonate plastics) should be avoided during pregnancy, as a precaution to prevent potential endocrine-disrupting effects on the fetus [219–221].

4.5. Recommendations for the postpregnancy period

- FIGO recommends that the period that follows birth is used to improve the nutritional status of both mother and child. FIGO endorses the WHO recommendation of exclusive breastfeeding for the first 6 months of the infant's life.

A mother needs to maintain healthy eating habits after birth and during lactation to rebuild her own body stores that were depleted in pregnancy. Throughout the course of breastfeeding, these stores need to be conserved and replenished. Nutrients are prioritized to breast milk during lactation, often at the expense of maternal reserves if the diet is inadequate.

A woman's good health and nutrition is critical to her ability to produce adequate breast milk and to care for her infant, and if her reserves are depleted, the effects can carry into subsequent

Table 4
Foods to avoid during pregnancy.

Food	Risk in pregnancy	Comment/advice
Liver	Excess vitamin A – teratogenic	Limit consumption, particularly in early pregnancy
Fish with mercury[a]	Fetal brain damage/developmental delay	Avoid large predatory fish
Fish exposed to pollutants (PCBs)[b]	Birth defects	Check with local health authorities whether locally-caught fish is safe to eat
Cold deli meat	Listeriosis	Reheat cold meats until steaming hot
Cold smoked seafood[c]	Listeriosis	Reheat until steaming hot
Soft cheese[d]	Listeriosis	Avoid unless made from pasteurized milk
Pâté (including vegetable)	Listeriosis	Avoid all refrigerated pâtés. Canned or shelf-safe pâtés can be eaten
Unwashed fruits and vegetables	Toxoplasmosis	Peel or wash fruits and vegetables thoroughly before eating
Undercooked or raw meat, poultry, or seafood	Toxoplasmosis, Salmonella	Cook food thoroughly and eat while hot
Raw egg[e]	Salmonella	Avoid

Abbreviation: PCBs, polychlorinated biphenyls.
[a] Predatory fish: swordfish, marlin, tuna, shark, orange roughy, king mackerel, bigeye or Ahi tuna, tilefish.
[b] From contaminated rivers and lakes (locally caught, not from supermarket): bluefish, striped bass, salmon, pike, trout, walleye.
[c] Deli or cold packaged. Canned or shelf-safe smoked seafood is safe to eat.
[d] Cheeses made from unpasteurized milk: brie, camembert, roquefort, feta, gorgonzola, Mexican style cheeses (queso blanco and queso fresco).
[e] Includes homemade dressings made with raw eggs, e.g. caesar, hollandaise, and also homemade ice creams or custards. Commercially available dressings, custards, and ice creams are made with pasteurized eggs and are considered safe to eat.

Regional Case Study 6: Thinking Nutrition First in East Asia

Managing cultural beliefs about maternal nutrition and care

A woman's dietary intake before and during pregnancy and through lactation is influenced by her social and cultural environment. East Asia is an example of a region where strong cultural beliefs significantly influence the behavior of pregnant women and some may hinder optimal maternal nutrition. Pregnant mothers in some countries of East Asia are characterized by comparatively high maternal age and low birth rate, and hence there is a relatively high proportion of primigravid women. A cultural issue impacting pregnant women is that a large proportion of them receive nutritional advice from parents, who often live nearby and are in close communication. The fact that parts of East Asia, including China, have gone through rapid economic development over the last few decades, with the older generation having endured hardship in the past when adequate nutrition was not often assured, means that mothers often advise their daughters to "eat for two," leading to risk of excessive weight gain during pregnancy. The older generation may not be supportive of breastfeeding, owing to the mistaken belief that infant formula may be superior. In addition, tradition and cultural beliefs also play a major role in determining what a pregnant mother may consider as a suitable diet, extending to different "confinement diets" in the postnatal and nursing period.

In some Chinese communities it can be common to employ the services of a natal caretaker or *doula*, who may not be supportive of breastfeeding. The *doula* would typically help the mother to bottle feed the infant and prepares all meals for the mother for 1–2 months after delivery, with strict advice on appropriate food items based on cultural beliefs. Providing expectant mothers with a more balanced view of nutrition is therefore essential. This can be accomplished on a local level as has been done in Hong Kong, for example, where a network of maternal−child health centers delivers integrated education and care for mothers from early pregnancy into childhood for the offspring. As such it provides a one-stop solution for provision of maternal nutrition information, prenatal care, breastfeeding education and support, infant nutrition, and childhood immunization and health care.

Importantly, educational material provided by the maternal–child health centers on pregnancy contains information on dietary advice during pregnancy, as well as appropriate gestational weight gain targets for the local population, thereby highlighting these concepts to women from early pregnancy.

In different parts of East Asia, there are also community health centers that may advise young women on reproductive health, family planning, and contraception, etc. These represent another key opportunity to partner in order to provide education on the importance of optimal nutrition and health for women anticipating pregnancy.

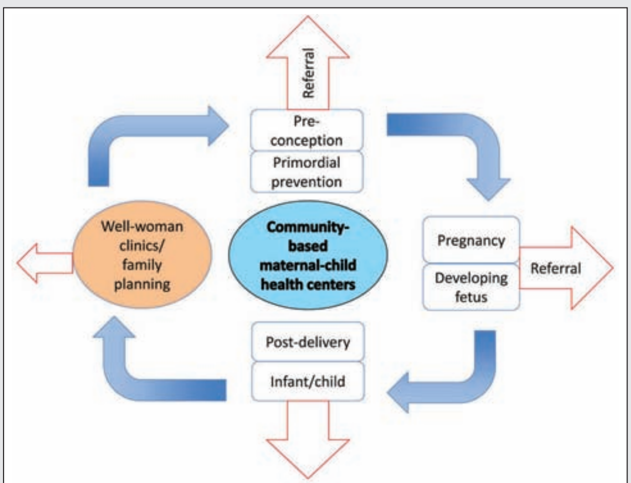

Figure 7. Utilizing maternal–child care centers and well-women/family planning clinics to provide nutritional information and monitoring. Community-based maternal–child care centers can be a useful model to deliver nutritional information to the expectant mother throughout pregnancy as well as addressing the nutritional needs of the developing fetus, infant, and young child. These community-based services will complement that provided by specialists, obstetricians, and pediatricians, who play a key role in reinforcing these messages and highlighting the importance of maternal and early-life nutrition, setting the background for improved life-long dietary behavior. These services need to work closely with well-woman/family planning clinics to deliver a cohesive and consistent message on nutrition and pregnancy.

pregnancies as well. This may create challenges, as in some cultures quite distinct confinement diets are the norm during the first month after birth. It is in the best interest of new mothers, their infants, and their future pregnancies to maintain an optimal diet during this time (See Regional Case Study 6: East Asia).

If maternal nutrition is good, the infant requires little other than breast milk during the first 6 months of life. In low-income countries with suboptimal hygiene, breastfeeding is the safest feeding option, preventing infection both by avoiding contaminated water or foods, and by provision of protective components, including secretory IgA antibodies and lactoferrin in breast milk [222]. In high-income countries, breastfeeding helps to reduce infections including otitis media and gastrointestinal infection [223]. Breastfeeding may also have positive health benefits on cardiometabolic risk factors later in life [224].

Breastfeeding is contraindicated in only a few circumstances, which include cases of maternal HIV-1 or human T-cell lymphotropic virus (HTLV) type I or type II infection, or herpes simplex lesions on the breast [225]. In some low-resource settings, continued breastfeeding by HIV-infected women is recommended because the risk of morbidity and mortality from other infections or malnutrition outweighs the risk of HIV transmission to the infant [226].

Nonbreastfeeding women should be guided to continue to eat a healthy diet but reduce their energy intake from late pregnancy levels in order to facilitate postpartum weight reduction.

4.5.1. Nutrient needs during lactation

4.5.1.1. Energy, macronutrients, and fiber

The energy cost of milk production translates to an increased requirement for energy during breastfeeding, part of which can be met by mobilization of fat stores laid down during pregnancy [200]. Women who had low gestational weight gain, or who were underweight at the start of pregnancy, require some additional energy intake (approximately 500 kcal per day) above the requirement in pregnancy in order to meet the demands of breastfeeding. Overweight or obese women do not require extra energy, and can safely restrict their energy intake by the same amount without affecting the growth of their infants.

The proportions of macronutrients required do not differ during lactation from those of nonlactating women. Lactating women can acquire all of the essential amino acids from high-quality protein sources such as meat, fish, eggs, and milk. For vegetarian women, plant protein sources including legumes, nuts, fruits, starchy root vegetables, and cereals should be combined to ensure that all essential amino acids are consumed. Complex carbohydrates and fiber should be consumed in similar proportions as in the pregnancy diet.

The fat component of breast milk is strongly influenced by the type and amount of fat in the maternal diet. Long-chain PUFAs such as docosahexaenoic acid (DHA) are important for infant brain and visual development, and their levels in breast milk are highly dependent on maternal dietary intake. Preterm infants miss out on accretion of DHA that normally occurs during late pregnancy, and mothers of such infants may require supplementation to increase the DHA levels in their milk [227]. Women should be encouraged to continue to eat 2–3 portions of fatty fish per week during lactation to ensure an adequate supply of essential fatty acids.

Lactating women should continue to choose foods high in fiber and low in refined sugars to facilitate appropriate postpartum weight loss and reduce cardiovascular and metabolic health risks.

4.5.1.2. Micronutrients

There is fairly clear evidence that the breast milk content of certain micronutrients cannot be altered by maternal intake, whereas others can [228]. Specifically, the breast milk content of the B vitamins thiamin, riboflavin, vitamin B6, vitamin B12, and choline, as well as vitamin A, vitamin D, and iodine is substantially reduced by maternal depletion, and can be increased by supplementation. Fetal storage of most of these nutrients is relatively low, and the infant relies on breast milk to acquire the necessary quantities. Continued use of a multivitamin supplement throughout lactation can achieve the goal of adequate intake. The concentration of other micronutrients including folate, calcium, iron, copper, and zinc is relatively unaffected by maternal intake or status. Maternal supplementation or increased intake of these nutrients does not affect the breast milk, but benefits the mother if her nutrient status is depleted [229].

Folate

Folate is concentrated in breast milk at the expense of maternal stores, so most breastfed infants receive sufficient folate, except in cases of severe maternal folate deficiency. Women who may get pregnant again should continue to consume 400 μg folic acid per day as a supplement, although they should also ensure adequate vitamin B12 intake to avoid the risk of masking deficiency for this vitamin, and possible associated neurological damage [230].

Vitamin B6

Infant growth and weight gain are correlated with vitamin B6 intake in breast milk, the composition of which responds to changes in maternal vitamin B6 intake [231,232]. Very low intake puts infants at risk of seizures. Supplementation is not generally required in women consuming a varied diet, but those at risk of low intakes can be supplemented with 2.5 mg per day of pyridoxine hydrochloride to provide adequate vitamin B6 levels in breast milk to support the growth of their breastfed infants [232].

Vitamin B12

Breast milk acquires vitamin B12 via the mother's intake of animal-source foods (meat and fish) [233]. Lactating vegetarian and vegan women require supplementation to ensure adequate vitamin B12 levels in their milk, or alternatively, their breastfed infants should receive vitamin B12 supplementation to prevent the potentially severe effects of deficiency.

Vitamin D

Vitamin D is likely to be in limited supply in the breast milk of many women, unless they were receiving adequate supplementation during pregnancy. Supplementation at the often-recommended level of 400 IU per day has only a modest impact on maternal blood vitamin D levels, and the Endocrine Society suggests that much higher supplementation levels (≥1000 IU per day) are required for lactating women [234], but this remains controversial. Supplementation of infants with 400 IU per day orally is a recommended alternative because adequate levels of vitamin D in breast milk cannot be assured without high-dose maternal supplementation [235].

Vitamin A

Vitamin A in breast milk is derived mainly from maternal fat stores, but is also sensitive to dietary intake. Uptake of vitamin A by the breastfeeding infant is much higher than during pregnancy, and therefore women with low dietary intakes of foods rich in pro-vitamin A carotenoids (darkly-colored vegetables and fruits) or pre-formed vitamin A (liver, dairy products, eggs) may be at risk of depletion of their body stores during lactation. Consumption of these foods should be encouraged for lactating women, as postpartum supplementation with vitamin A appears to have minimal effect on maternal or infant morbidity [236].

Iron

The requirement for iron in non-anemic women decreases after birth, because very little is transferred to breast milk, but women who entered pregnancy with low iron stores or developed anemia during pregnancy need to maintain similar iron intake to allow for recovery of iron stores after pregnancy. Infants accumulate sufficient stores in late gestation to carry them through the first 4–6 months of life, despite limited intake from breast milk [237]. Delayed umbilical cord clamping (not earlier than 1 minute after birth) is recommended for improved maternal and infant health and nutrition outcomes [238]. Preterm, low birth weight infants or those born to women with diabetes or obesity may have low iron stores at birth, and may require supplementation [239,240].

Iodine

Iodine is required in breast milk for optimal thyroid function and neurological development in the infant. As with zinc, iodine is concentrated in breast milk at the expense of maternal stores, necessitating an additional 50–70 μg per day intake over the pregnancy requirement of 200–220 μg per day to protect against maternal deficiency [241]. Iodine status varies greatly by region and depending on the availability of iodized salt. Most women utilizing iodized salt have an acceptable iodine status for lactation. Recent evidence suggests that in regions of moderate to severe iodine deficiency, infant iodine status benefits more from supplementation of the mother than direct supplementation of the infant [242].

Calcium

The concentration of calcium in the maternal plasma is tightly regulated by homeostatic mechanisms during lactation, and is unrelated to dietary intake. The maternal plasma concentration does not reflect total body calcium, which is mobilized from bone to maintain plasma levels. Unless calcium stores are very low, the mobilization of calcium from the maternal skeleton that occurs during lactation recovers adequately after weaning, but adolescents whose own bones are still growing may have poor recovery of bone mineral density after lactation. Young breastfeeding mothers require 1300 mg of calcium per day, and should be advised how to maintain this intake in their diets to ensure their own long-term bone health [136].

Zinc

Maternal zinc inadequacy during lactation is common in regions where protein–energy malnutrition is prevalent, putting women's health at risk, particularly with regard to infections. Lactating women are advised to consume adequate levels of zinc in their diets, or take a multivitamin supplement containing zinc. Zinc is critical for infant and child development, reflected in the fact that the prevalence of zinc deficiency correlates with the prevalence of stunting in children under 5 years of age [139]. To satisfy the high zinc demand in the infant, the trace element is preferentially secreted into breast milk from maternal tissues. Dietary or supplementary zinc does not greatly influence the level in breast milk, which declines over the course of lactation irrespective of maternal consumption [243].

4.5.2. Weaning/complementary foods

Breastfeeding should be encouraged for as long as possible as the most healthy option for both mothers and babies. The duration of lactation may depend, among other factors, on the nutritional status of both the mother and infant—well-nourished women are able to breastfeed longer and their milk will have better nutrient density than that of malnourished women. However, the concentrations of many nutrients in breast milk decline rapidly between 6 and 12 months of lactation, and human milk may not then be sufficient to meet the growing infant's requirements. The transition from exclusive breastfeeding to family foods, referred to as complementary feeding, typically covers the period from 6 to 18–24 months of age, and is a very vulnerable period. It is the time when malnutrition starts in many infants, contributing significantly to the high prevalence of malnutrition in children under 5 years of age worldwide. It is also a time when aspects of the child's food preferences, e.g. for sweet foods, are established. In addition to the infant requirement for iron-rich foods, a variety of nutritious foods (with the right texture) should be slowly introduced to the weaning infant during this period. If the typical diet is limited in vitamins and minerals, the infant may require fortified foods or multiple micronutrient powders to supplement their diet [244]. Some of the foods a woman has eaten during lactation affect the flavor of her milk and influence the infant's acceptance of new flavors when complementary foods are introduced, so a healthy and varied diet should continue to be encouraged throughout lactation. Women who have established good eating habits before, during, and after pregnancy are more likely to encourage the same in their infants and children.

4.5.3. The importance of the interpregnancy interval

In addition to being a critical nutritional period for women in terms of lactation, the time between pregnancies is important for women to replenish their nutrient stores both for their own health and that of any future offspring. This time is referred to as the interpregnancy interval—the elapsed time between delivery of an infant and conception of a subsequent pregnancy. Conceiving again after a short interval limits the woman's ability to go through pregnancy and breastfeeding periods in optimal health and has consequential effects on the health of her baby. In cases of undernutrition, repletion of maternal nutrient stores is critical, and requires sufficient time after lactation is complete. Nutritional deficiencies for folate and iron are of particular concern, and contribute to maternal and fetal anemia, low birth weight, congenital malformations, and fetal and maternal death. If pregnant women are not taking folic acid supplements, their folate levels begin to decline in mid-pregnancy and remain low during lactation, as maternal stores are further drained to supply folate to breast milk [245]. Women should therefore be advised to continue to take folic acid supplements and/or consumed fortified foods, particularly if they are likely to conceive another pregnancy.

For women with high gestational weight gain, short interpregnancy intervals do not provide sufficient time for the body to return to its normal metabolic state, and confer a higher risk of maternal obesity entering the next pregnancy, with its attendant risks [246]. Interventions to limit excessive weight gain and to lengthen the interpregnancy interval are recommended in such situations. The WHO recommends at least a 24-month interval between pregnancies for best maternal and infant outcomes [247]. There is a U-shaped association between birth spacing and maternal and perinatal outcomes—both very short and very long intervals having some associations with negative health outcomes. The risk of adverse perinatal outcomes including prematurity, low birth weight, and small size for gestational age was highest for birth-to-pregnancy intervals shorter than 18 months.

4.6. Specific considerations for adolescents

It is estimated that there are 1.8 billion people aged 10–24 years in the world today, making up approximately one-quarter of the world's total population. Adolescence is the second most critical period of growth in the life cycle after infancy. About 20%–25% of full adult height is gained between the ages of 10 and 19 years.

Adolescents are typically considered a low-risk group for poor health, but this view overlooks the fact that many later-life health problems can be avoided by focusing on health, nutrition, and lifestyle during the adolescent period. Adolescents may also be at higher risk of unhealthy behaviors, accidents, and sexually transmitted infections and in many societies they are increasingly likely to be overweight or obese. Attention to the health, well-being, and nutritional status of adolescent girls is central to ensuring their own optimal physical growth, cognitive function, school performance, and overall quality of life, but also helps avoid the development of chronic disease and prepares them for the possibility of future childbearing. Adolescent girls have unique health needs that differ from both children and adults. They require sexual and reproductive health education and counselling and nutrition education and support to make positive lifestyle choices. Interventions in early adolescence may have far-reaching impact, because lifelong habits are often established in this period. Adolescent girls, when adequately supported and nourished, can be agents of positive change for their future families and communities [248].

4.6.1. Social factors in the reproductive health of adolescent girls

The reproductive health and fitness of adolescent girls is affected not only by physiological factors such as poor diet and maternal/fetal competition for nutrients, but also by socioeconomic and lifestyle risk factors that are common in this age group. Adolescents with high-risk lifestyles including drug use, excessive alcohol consumption, and tobacco smoking are among those more likely to become pregnant. In some societies, early marriage and adolescent pregnancy are the norm. More than 30% of girls in LMICs marry before they are 18 years old, including around 14% before the age of 15. A recent study in India found that more than 60% of all married women were married before the age of 18, and 34% gave birth before the age of 18 [249]. The Indian population is reflective of those of other LMICs where early marriage and early age at childbirth in general are common, particularly in lower socioeconomic groups.

Early marriage and childbearing have negative impacts on maternal and infant survival, health, and future outlook, with 15–19-year-olds being twice as likely to die from pregnancy-related causes compared with women in their twenties. Most of these deaths occur in LMICs. Approximately 16 million adolescent women between 15 and 19 years of age give birth each year, with the highest rates occurring in Sub-Saharan Africa [250]. Increasing education and prolonging years of schooling help girls postpone marriage and childbearing.

4.6.2. Dietary issues

Adolescence is a high-risk period for weight gain, coinciding with changes in eating behaviors and physical activity, and with less reliance on parental choices and food provision. Adolescents are more likely than adults to consume micronutrient-poor, energy-dense diets that are high in fat and added sugar, which can lead to overweight and obesity. A high intake of sugar in pregnant adolescents has been associated with increased adiposity in their infants [251]. Adolescent girls should be made aware of the impact of excessive gestational weight gain from high fat diets and be encouraged to select a variety of foods specifically including fruits and vegetables. The well-known effects of obesity in pregnancy and adiposity in infants emphasize the importance of addressing this issue as early as possible in order to reduce the intergenerational cycle of weight gain and NCDs [252].

On the other hand, an increasing focus on body shape during adolescence can fuel a drive for thinness, which is generally accomplished by reducing food intake rather than by increasing physical activity. This can reach extreme levels, leading to eating disorders such as anorexia nervosa. Undernutrition in adolescent girls can affect fetal development, especially when the girl is still growing and there may be competition for essential nutrients that are deficient in her diet. Pregnancy and lactation can further deplete nutrient stores and cause a cessation of linear growth in undernourished adolescents [253].

4.6.3. Common nutrient deficiencies in adolescent girls

Nutritional deficits common in adolescents can be harmful to the developing fetus. Pregnant adolescents are at risk of insufficient intake of several essential nutrients from diet alone, even in situations of adequate or excessive energy intakes, and prenatal supplements do not always meet adolescent requirements [254].

Iron

Iron requirements typically exceed intake by a greater amount in pregnant adolescents than in adult pregnant women [255]. Low body iron stores are more prevalent, and anemia is particularly common in pregnant adolescents, increasing the risks of spontaneous abortion, stillbirth, premature birth, low birthweight, and perinatal mortality. Targeting the vulnerable adolescent period specifically with regard to iron deficiency before childbearing is of critical importance in many regions of the world. Adolescent girls should be informed of the importance of consuming iron-rich foods, and should be offered iron supplements if they are at risk of deficiency [256].

Folate

Adolescent mothers are less likely to have consumed folic acid supplements preconceptionally, but should be encouraged to do so as soon as possible in early pregnancy. In addition to NTD risk, low folate in adolescents increases the risk of small for gestational age birth [257].

Calcium and vitamin D

Pregnant adolescents require a higher calcium intake to compensate for the dual demands of the fetus and their own continued bone growth, though dietary intakes of calcium tend to be below recommended levels in this age group. Low dietary calcium intake may be cultural, or in some cases results from replacing the main source of calcium—milk—with soft drinks [166]. Although calcium supplementation is not generally required for pregnant women who consume a healthy diet, young women whose bones are still growing do benefit from additional calcium and vitamin D in the form of supplements to help reduce bone loss [258]. Pregnancy in adolescence is also a risk factor for gestational hypertensive disorders, and calcium supplementation may be beneficial in this regard [181].

Magnesium

Adolescent pregnancy is a risk factor for poor bone mineralization, and lower magnesium content in breast milk has been observed in adolescent mothers compared with adult mothers [259]. Prenatal supplements may not provide sufficient magnesium for pregnant adolescents [254].

Zinc

Zinc is crucial for and utilized during growth phases, making adolescents particularly susceptible to the effects of zinc deficiency, particularly in late pregnancy when the fetus is also undergoing rapid growth. Supplemental zinc may be warranted in this age group.

4.6.4. Breastfeeding issues in adolescents

In high-income countries, adolescent mothers are less likely than adults to initiate breastfeeding, and are more likely to terminate breastfeeding early [260]. In the USA, approximately 60% of women younger than 20 years old initiate breastfeeding, compared with almost 80% of women over 30 years, and only approximately 20% of young mothers continue breastfeeding for 6 months. Young mothers, particularly those from socioeconomically disadvantaged households or with lower educational attainment, are more likely to introduce inappropriate complementary foods, and this needs attention.

Interventions are required that specifically target adolescents to encourage breastfeeding initiation and continuation in this age group, noting the health advantages for both baby and mother—including faster return to prepregnancy weight. Issues of self-esteem, self-confidence, and reintegration into their peer group need to be considered.

5. Regional considerations

Poor maternal nutrition is a global problem with challenges that differ by region and country, and according to resources and population needs. Locally targeted solutions are required, and it is important for healthcare providers to identify common nutrition problems in the community. For example, in those areas where consumption of dairy products is low, the requirement for calcium will be difficult to meet. Diets based on refined grains as staple foods may be lacking in B vitamins. Other regional nutritional concerns include specific micronutrient deficiencies (e.g. iron, iodine, vitamin A, vitamin D, selenium), protein energy malnutrition, transition to Western obesogenic diets, and cultural beliefs that hinder optimal maternal nutrition and health. Some of these issues are illustrated in the regional case studies. As examples, Figures 8–11 illustrate the regional specificity and extent of specific nutrient deficiencies for iron, retinol/vitamin A, and iodine, and the prevalence of obesity.

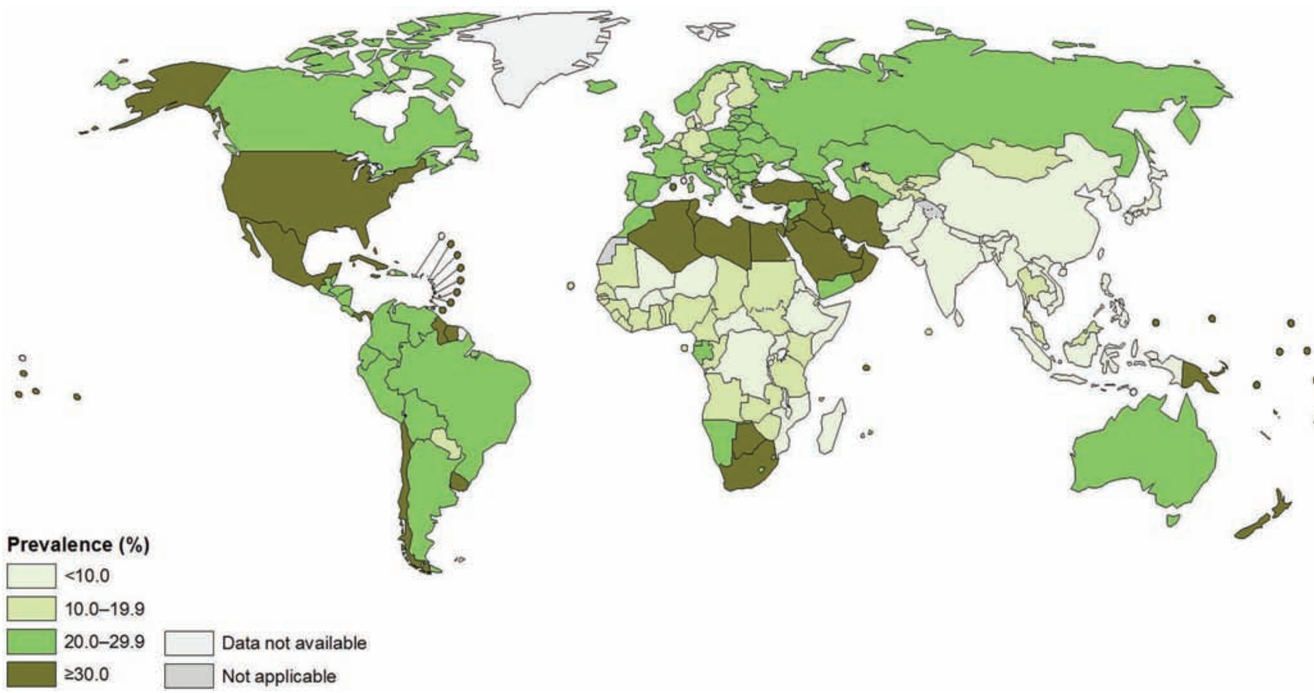

Figure 8 Prevalence of obesity in females aged 18+, 2014 (age standardized estimate). Reprinted with permission from WHO [261]. Copyright WHO (2015).

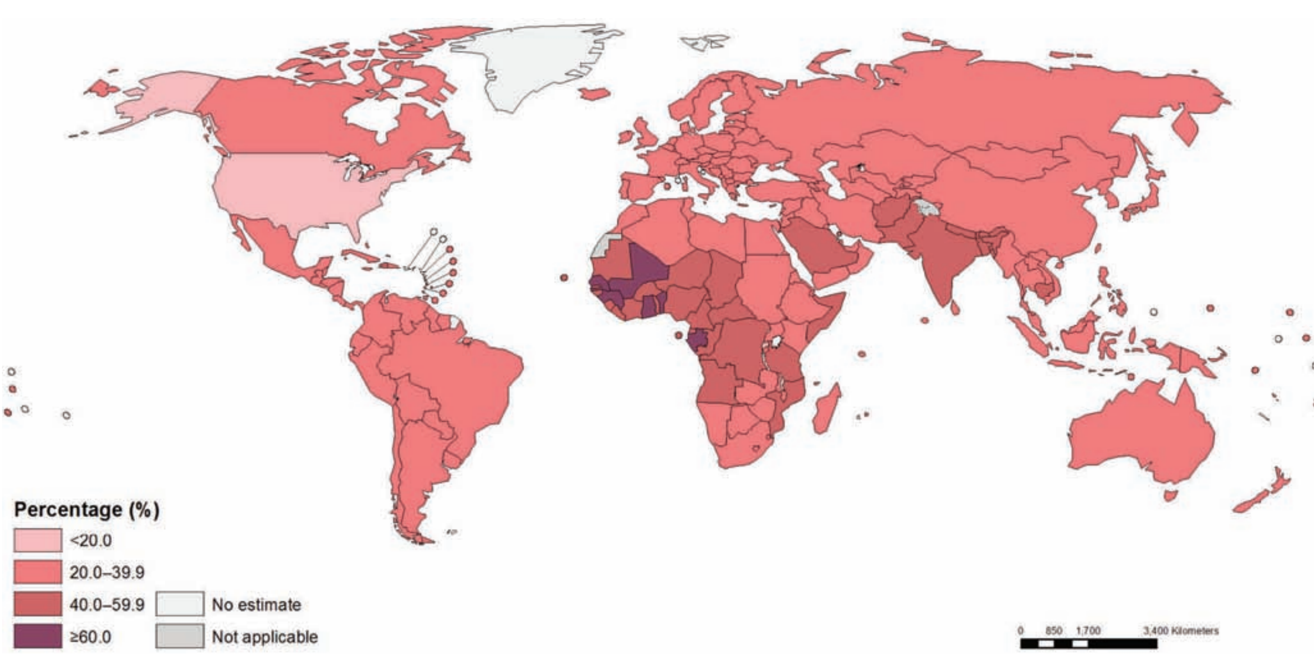

Figure 9 Global estimates of the prevalence of anemia in pregnant women aged 15–49 years, 2011. Reprinted with permission from WHO [262]. Copyright WHO (2015).

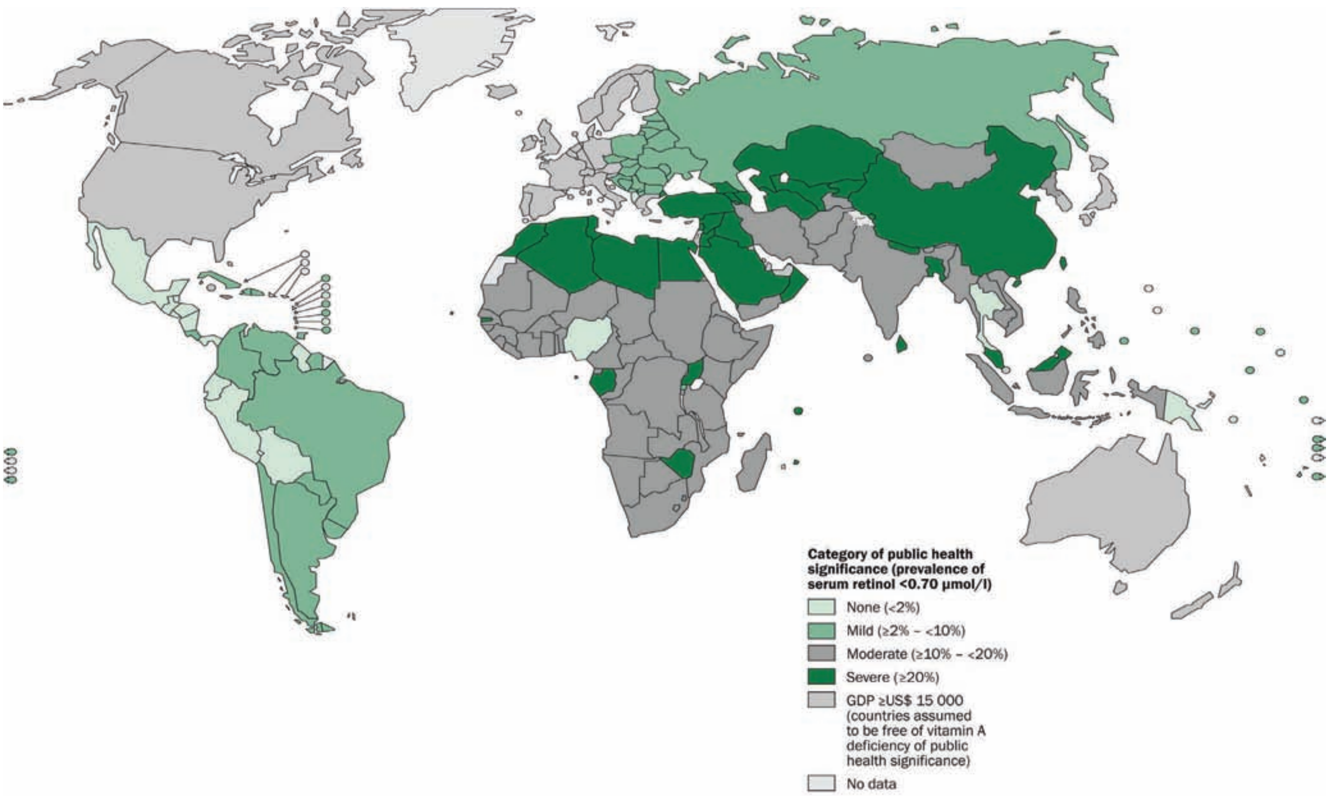

Figure 10 Prevalence of serum retinol <0.7 μmol/L in pregnant women. Countries and areas with survey data and regression-based estimates. Reprinted with permission from WHO [263]. Copyright WHO (2009).

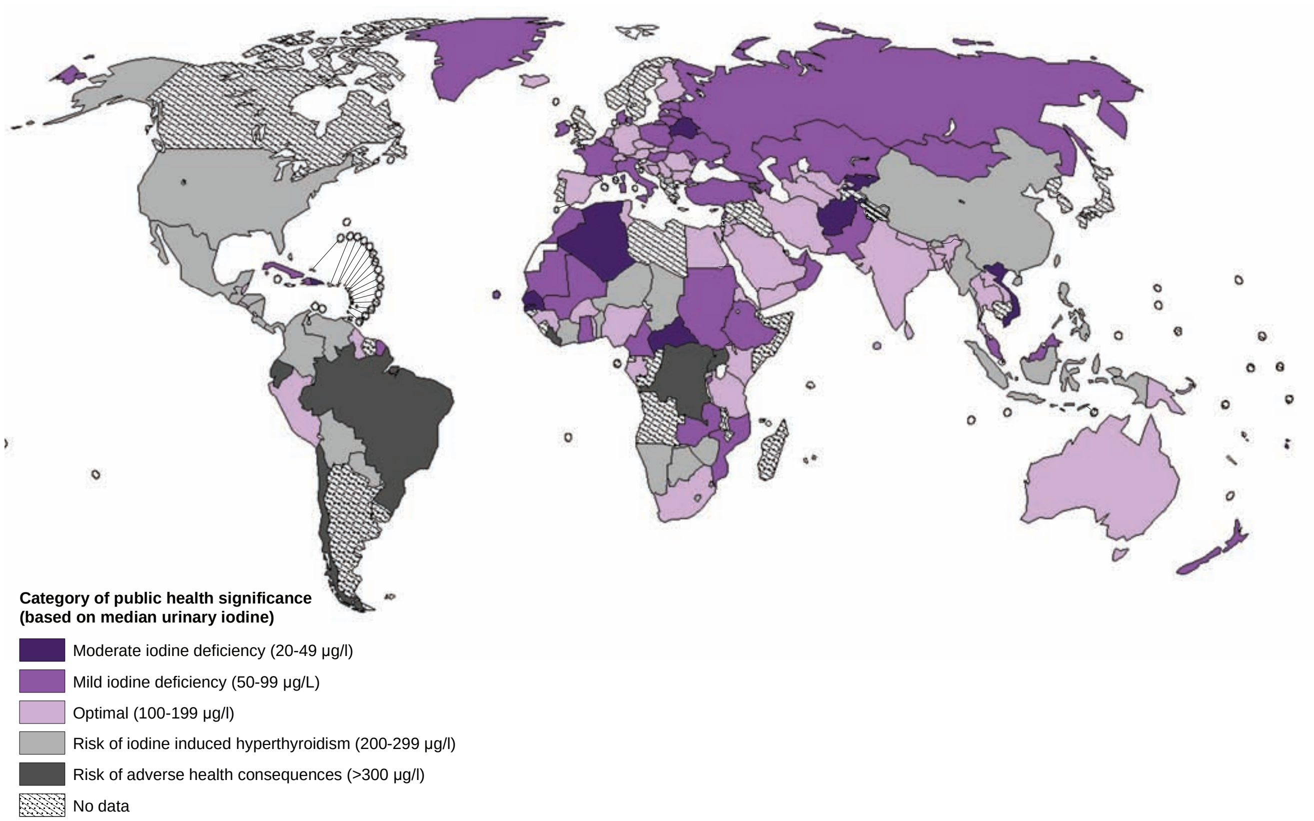

Figure 11 Degree of public health significance of iodine nutrition based on median urinary iodine: 1993–2006. Reprinted with permission from WHO [264]. Copyright WHO (2009).

6. Barriers and opportunities

6.1. Addressing barriers to dietary change

Maternal nutrition is now gaining importance on international agendas, as evidenced by the United Nations-backed "Scaling Up Nutrition" initiative (http://scalingupnutrition.org/), the Rome Declaration of the Second International Conference on Nutrition [20], and by the recognition of the central importance of the "first 1000 days" (a timeframe from conception through the first two years of life) for optimum development of every child (http://www.thousanddays.org). When considering approaches to improving the nutritional status of adolescents and women, it is also important to consider the context, and to recognize that in many settings, achieving nutrition's full impact on health and development will require a multisectoral approach. There are a number of "nutrition-sensitive" interventions, such as agriculture, education, social welfare, public health (access to safe water, vaccination, etc), and women's empowerment, that together could have a greater impact on improving nutrition than dietary change/supplementation alone. Understanding potential barriers to improved nutrition, and identifying opportunities for joined-up approaches is thus critical. WHO member states have agreed upon a series of priority actions [265] to be jointly implemented with international partners to achieve the 2025 global nutrition targets [5], which emphasize the importance of improving the nutritional status of women of reproductive age.

6.2. Addressing women's rights and access to good nutrition

- FIGO supports the adoption of gender-sensitive policies to improve access to adequate and nutritious food for girls, adolescents, and women.

The ability to improve the nutritional status of adolescents and women worldwide relies on reducing the specific gender-based constraints facing girls and women, particularly in relation to food security. In many parts of the world, cultural norms apportion higher power to males, including male offspring, translating to differential caregiving practices that can favor boys over girls, and intra-household food allocation practices that can disadvantage girls and women. Women are thus disproportionately affected by poor nutrition and micronutrient deficiencies, particularly when food availability or access is tenuous.

Women in situations of inadequate food access are often anemic and suffer other micronutrient deficiencies, which greatly affect their own lives and their ability to cope with pregnancy. For example, one of the largest causes of maternal death, namely postpartum hemorrhage, is not usually due to catastrophic blood loss but to the mother's underlying anemia, which leaves her with little reserve to cope with even a small loss of blood after delivery. There has been a range of reports produced on the human rights issues relating to adolescent and women's health [266–269], but there is still much to be done in this respect.

6.3. Recommendations for health policy makers

Good nutrition for adolescents and women starts with food security, food availability, and education. FIGO recommends that health policy makers:

- Invest in promoting healthy nutrition in adolescents and young women from before pregnancy, through pregnancy and childbirth, and during the care of the infant and child.
- Develop practical policies to encourage women and their families to access better diet and adopt healthy behaviors.
- Invest in dietary educational resources and support for healthcare providers, school teachers, community pharmacists, and social and cultural organizations to provide whole-of-community initiatives—especially to reach young women before pregnancy.
- Promote food fortification or supplementation of specific nutrients in specific situations. Because initiating fortification schemes is a long process, planning and integration between public and private sectors are required. Supplementation may be necessary in vulnerable groups.
  - Promote use of iodized salt.
  - Promote iron plus folic acid supplementation.
  - Promote multiple micronutrient supplementation when appropriate.
  - Consider ready-to-use therapeutic foods (balanced protein energy supplementation) as appropriate.
  - Promote adequate calcium status in adolescents and women.
  - Promote adequate vitamin D status in adolescents and women.
- Devise and implement government-funded food and nutrition programs to fill gaps in women's nutrition intake.
- Implement and monitor programs to reduce/remove barriers to attaining good nutrition for adolescent girls and women by:
  - Addressing discriminatory laws and social and cultural norms to enhance women's empowerment.
  - Improving access to educational and employment opportunities.
  - Ensuring school feeding programs to reduce hunger and micronutrient deficiencies in children; for girls in particular, such programs also raise school attendance.
- Establish functional monitoring systems to track progress on the achievement of global nutrition and NCD targets.
- Implement government initiatives to promote and support breastfeeding.

6.4. Recommendations for healthcare providers

FIGO recommends that:

- All healthcare providers should be aware of maternal nutritional issues and should take the opportunity to discuss them with patients/members of the public at every opportunity. **Think Nutrition First.**
- Nutrition education, counselling, and screening begin in early adolescence:
  - School health clinic nutritional screening.
  - Community programs for out-of-school youth.
  - Detect iron deficiency and other micronutrient deficiencies.
- Processes are devised and implemented to ensure that nonpregnant women, who are less likely to see a physician regularly for prevention and health education, have access to advice and health care in the adolescent, preconception, and pregnancy periods to ensure that they have healthy nutrition.
- Healthcare providers need to know when supplementation is required because adequate micronutrient intakes are often not achieved through food-based approaches.

7. Summary and conclusions

7.1. Focus on women's nutrition for a better future

To guarantee the best possible future for any society, it is essential to ensure healthy nutrition for adolescent girls and women of reproductive age such that, when a woman is ready to reproduce, her own good health and nutrition will provide a favorable environment for the development of her future offspring.

Women's nutrition and health can play a role in the intergenerational transmission of human health capital, ensuring future health, happiness, longevity, and economic progress. Investing in adolescent, preconception, and maternal nutrition will provide a range of cumulative benefits, delivering improvements in health across multiple sectors of society.

- FIGO makes specific recommendations to achieve this goal, and advocates concerted action by a range of stakeholders including donors and international organizations to enact them. FIGO maintains that THINKING NUTRITION FIRST should be a priority in all countries.

8. References

[1] World Health Organization. Global status report on noncommunicable diseases 2010. Geneva, Switerland: WHO; 2011.
[2] World Health Organization. Noncommunicable diseases country profiles 2014. Geneva, Switzerland: WHO; 2014.
[3] United Nations. Millenium Development Goals and Beyond 2015. http://www.un.org/millenniumgoals/.
[4] World Health Organization. Global action plan for the prevention and control of noncommunicable diseases 2013–2020. Geneva, Switzerland: WHO; 2013.
[5] World Health Organization. Global Targets 2025. http://www.who.int/nutrition/global-target-2025/en/
[6] Morton SB. Maternal nutrition and fetal growth and development. In: Gluckman PD, Hanson MA, eds. Developmental Origins of Health and Disease. Cambridge, UK: Cambridge University Press; 2006:98–129.
[7] Scholl TO. Perinatal nutrition: Maternal nutrition and pregnancy outcome. In: Duggan C, Watkins JB, Walker WA, eds. Nutrition in pediatrics basic science, clinical applications. Hamilton, Ontario, Canada; and Lewiston, NY, USA: B.C.Decker; 2008.
[8] Velazquez MA, Fleming TP. Maternal diet, oocyte nutrition and metabolism and offspring health. In: Coticchio G, Albertini DF, De Santis L, eds. Oogenesis. New York, USA: Springer; 2013.
[9] West-Eberhard MJ. Phenotypic plasticity and the origins of diversity. Annu. Rev. Ecol. Syst 1989;20:249–78.
[10] Gluckman PD, Hanson MA, Low FM. The role of developmental plasticity and epigenetics in human health. Birth Defects Res C Embryo Today 2011;93(1):12–18.
[11] Waterland RA, Kellermayer R, Laritsky E, Rayco-Solon P, Harris RA, Travisano M, et al. Season of conception in rural gambia affects DNA methylation at putative human metastable epialleles. PLoS Genet 2010;6(12):e1001252.
[12] Dominguez-Salas P, Moore SE, Baker MS, Bergen AW, Cox SE, Dyer RA, et al. Maternal nutrition at conception modulates DNA methylation of human metastable epialleles. Nat Commun 2014;5:3746.
[13] Drake AJ, Reynolds RM. Impact of maternal obesity on offspring obesity and cardiometabolic disease risk. Reproduction 2010;140(3):387–98.
[14] Purcell SH, Moley KH. The impact of obesity on egg quality. J Assist Reprod Genet 2011;28(6):517–24.
[15] Radford EJ, Ito M, Shi H, Corish JA, Yamazawa K, Isganaitis E, et al. In utero effects. In utero undernourishment perturbs the adult sperm methylome and intergenerational metabolism. Science 2014;345(6198):1255903.
[16] Young SS, Eskenazi B, Marchetti FM, Block G, Wyrobek AJ. The association of folate, zinc and antioxidant intake with sperm aneuploidy in healthy non-smoking men. Hum Reprod 2008;23(5):1014–22.
[17] Colagar AH, Marzony ET, Chaichi MJ. Zinc levels in seminal plasma are associated with sperm quality in fertile and infertile men. Nutr Res 2009;29(2):82–8.
[18] Hammiche F, Laven JS, Twigt JM, Boellaard WP, Steegers EA, Steegers-Theunissen RP. Body mass index and central adiposity are associated with sperm quality in men of subfertile couples. Hum Reprod 2012;27(8):2365–72.
[19] World Health Organization. Health topics: Nutrition. http://www.who.int/topics/nutrition/en/
[20] Food and Agriculture Organization, World Health Organization. Second International Conference on Nutrition. Conference Outcome Document: Rome Declaration on Nutrition. ICN2 2014/2. October 2014. http://www.fao.org/3/a-ml542e.pdf
[21] Misra A, Vikram NK. Insulin resistance syndrome (metabolic syndrome) and obesity in Asian Indians: evidence and implications. Nutrition 2004;20(5):482–91.
[22] Yajnik CS, Deshmukh US. Maternal nutrition, intrauterine programming and consequential risks in the offspring. Rev Endocr Metab Disord 2008;9(3):203–11.
[23] Misra A, Singhal N, Sivakumar B, Bhagat N, Jaiswal A, Khurana L. Nutrition transition in India: secular trends in dietary intake and their relationship to diet-related non-communicable diseases. J Diabetes 2011;3(4):278–92.
[24] Victora CG, Adair L, Fall C, Hallal PC, Martorell R, Richter L, et al. Maternal and child undernutrition: consequences for adult health and human capital. Lancet 2008;371(9609):340–57.
[25] Black RE, Allen LH, Bhutta ZA, Caulfield LE, de Onis M, Ezzati M, et al. Maternal and child undernutrition: global and regional exposures and health consequences. Lancet 2008;371(9608):243–60.
[26] Oken E, Gillman MW. Fetal origins of obesity. Obes Res. 2003;11(4):496–506.
[27] Gluckman PD, Seng CY, Fukuoka H, Beedle AS, Hanson MA. Low birthweight and subsequent obesity in Japan. Lancet 2007;369(9567):1081–2.
[28] Painter RC, Osmond C, Gluckman P, Hanson M, Phillips DI, Roseboom TJ. Transgenerational effects of prenatal exposure to the Dutch famine on neonatal adiposity and health in later life. BJOG 2008;115(10):1243–9.
[29] Freedman DS, Khan LK, Serdula MK, Dietz WH, Srinivasan SR, Berenson GS. The relation of childhood BMI to adult adiposity: the Bogalusa Heart Study. Pediatrics 2005;115(1):22–7.
[30] Maffeis C, Tato L. Long-term effects of childhood obesity on morbidity and mortality. Horm Res 2001;55(Suppl 1):42–5.
[31] Reilly JJ, Kelly J. Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. Int J Obes (Lond) 2011;35(7):891–8.
[32] Popkin BM. Global nutrition dynamics: the world is shifting rapidly toward a diet linked with noncommunicable diseases. Am J Clin Nutr 2006;84(2):289–98.
[33] Antony AC. Vegetarianism and vitamin B-12 (cobalamin) deficiency. Am J Clin Nutr 2003;78(1):3–6.
[34] Craig WJ. Nutrition concerns and health effects of vegetarian diets. Nutr Clin Pract 2010;25(6):613–20.
[35] Combs GFJr. Selenium in global food systems. Br J Nutr 2001;85(5):517–47.
[36] Food and Agriculture Organization of the United Nations, World Health Organization. Human vitamin and mineral requirements. Report of a joint FAO/WHO expert consulation, Bangkok, Thailand. Rome, Italy: FAO; 2001.
[37] Pearce EN, Andersson M, Zimmermann MB. Global iodine nutrition: Where do we stand in 2013? Thyroid 2013;23(5):523–8.
[38] Andrieu E, Darmon N, Drewnowski A. Low-cost diets: more energy, fewer nutrients. Eur J Clin Nutr 2006;60(3):434–6.
[39] Townsend MS, Peerson J, Love B, Achterberg C, Murphy SP. Food insecurity is positively related to overweight in women. J Nutr 2001;131(6):1738–45.
[40] Scheier LM. What is the hunger-obesity paradox? J Am Diet Assoc 2005;105(6):883–4, 886.
[41] Laraia BA, Bodnar LM, Siega-Riz AM. Pregravid body mass index is negatively associated with diet quality during pregnancy. Public Health Nutr 2007;10(9):920–6.
[42] Rifas-Shiman SL, Rich-Edwards JW, Kleinman KP, Oken E, Gillman MW. Dietary quality during pregnancy varies by maternal characteristics in Project Viva: a US cohort. J Am Diet Assoc 2009;109(6):1004–11.
[43] Stevens GA, Finucane MM, De-Regil LM, Paciorek CJ, Flaxman SR, Branca F, et al. Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995–2011: a systematic analysis of population-representative data. Lancet Glob Health 2013;1(1):e16–25.
[44] World Health Organization. Global prevalence of vitamin A deficiency in populations at risk 1995–2005. WHO Global Database on Vitamin A Deficiency. http://www.who.int/vmnis/database/vitamina/table4/en/
[45] World Health Organization, UNICEF, ICCIDD. Assessment of iodine deficiency disorders and monitoring their elimination: A guide for programme managers, Third edition, 2007 (updated 1st September 2008). Geneva, Switzerland: WHO; 2007.
[46] von Grebmer K, Saltzman A, Birol E, Wiesmann D, Prasai N, Yin S, et al. Global Hunger Index: The Challenge of Hidden Hunger. Bonn, Washington, D.C., USA and Dublin: International Food Policy Research Institute, and Concern Worldwide; 2014.
[47] World Health Organization. Guideline: Daily iron and folic acid supplementation in pregnant women. Geneva, Switzerland: WHO; 2012.
[48] Bhutta ZA, Haider BA. Maternal micronutrient deficiencies in developing countries. Lancet 2008;371(9608):186–7.
[49] UNICEF, World Health Organization, United Nations University. Composition of a multi-micronutrient supplement to be used in pilot programmes among pregnant women in developing countries: report of a United Nations Children's Fund (UNICEF), World Health Organization (WHO) and United Nations University workshop. http://www.who.int/iris/handle/10665/75358 - sthash.z47fFqPF.dpuf
[50] World Health Organization, World Food Programme, United Nations Children's Fund. Preventing and controlling micronutrient deficiencies in populations affected by an emergency: Multiple vitamin and mineral supplements for pregnant and lactating women, and for children aged 6 to 59 months. Geneva, Switzerland: WHO, WFP, UNICEF; 2006.
[51] World Health Organization. United Nations Children's Fund, Reaching optimal iodine nutrition in pregnant and lactating women and young children. Geneva, Switzerland: WHO, UNICEF; 2007.
[52] Public Health Committee of the American Thyroid Association, Becker DV, Braverman LE, Delange F, Dunn JT, Franklyn JA, et al. Iodine supplementation for pregnancy and lactation-United States and Canada: recommendations of the American Thyroid Association. Thyroid 2006;16(10):949–51.
[53] National Health and Medical Research Council. NHMRC Public Statement: Iodine Supplementation for Pregnant and Breastfeeding Women. Canberra, Australia: Australian Government; 2010.
[54] World Health Organization. WHO Guideline: Intermittent iron and folic acid supplementation in menstruating women. Geneva, Switzerland: WHO; 2011.
[55] Codex Alimentarius Commission. General Principles for the Addition of Essential Nutrients to Foods, CAC/GL 09-1987 (amended 1989, 1991). Rome, Italy: FAO/WHO; 1994.
[56] Horton S, Shekar M, McDonald C, Mahal A, Krystene Brooks J, et al. Scaling up nutrition: what will it cost?. Washington, D.C., USA: World Bank; 2010.
[57] Martorell R, Ascencio M, Tacsan L, Alfaro T, Young MF, Yaw Addo O, et al. Effectiveness evaluation of the food fortification program of Costa Rica: impact on anemia prevalence and hemoglobin concentrations in women and

children. Am J Clin Nutr 2015;101(1):210–7.

[58] Blencowe H, Cousens S, Modell B, Lawn J. Folic acid to reduce neonatal mortality from neural tube disorders. Int J Epidemiol 2010;39(Suppl 1):i110–i121.

[59] Williams J, Mai CT, Mulinare J, Isenburg J, Flood TJ, Ethen M, et al. Updated estimates of neural tube defects prevented by mandatory folic Acid fortification - United States, 1995–2011. MMWR Morb Mortal Wkly Rep 2015;64(1):1–5.

[60] World Health Organization. Guideline: fortification of food-grade salt with iodine for the prevention and control of iodine deficiency disorders. Geneva, Switzerland: WHO; 2014.

[61] De-Regil L, Jefferds MD, Pena-Rosas JP. Point-of-use fortification of foods with micronutrient powders containing iron in children of preschool and school age (Protocol). Cochrane Database Syst Rev 2012;(2):CD009666.

[62] Home Fortification Technical Advisory Group. http://www.hftag.org

[63] MRC Vitamin Study Research Group. Prevention of neural tube defects: results of the Medical Research Council Vitamin Study. Lancet 1991;338(8760):131–7.

[64] Lopez-Camelo JS, Castilla EE, Orioli IM, INAGEMP (Instituto Nacional de Genética Médica Populacional), ECLAMC (Estudio Colaborativo Latino Americano de Malformaciones Congénitas), Folic acid flour fortification: impact on the frequencies of 52 congenital anomaly types in three South American countries. Am J Med Genet A 2010;152A(10):2444–58.

[65] Hertrampf E, Cortes F. National food-fortification program with folic acid in Chile. Food Nutr Bull 2008;29(2 Suppl):S231–7.

[66] World Health Organization. Recommendations on Wheat and Maize Flour Fortification Meeting Report: Interim Consensus Statement. Geneva, Switerland: WHO; 2009.

[67] Fardet A, Boirie Y. Associations between food and beverage groups and major diet-related chronic diseases: an exhaustive review of pooled/meta-analyses and systematic reviews. Nutr Rev 2014;72(12):741–62.

[68] Newby PK, Tucker KL. Empirically derived eating patterns using factor or cluster analysis: a review. Nutr Rev 2004;62(5):177–203.

[69] Skerrett PJ, Willett WC. Essentials of healthy eating: a guide. J Midwifery Womens Health 2010;55(6):492–501.

[70] Heidemann C, Schulze MB, Franco OH, van Dam RM, Mantzoros CS, Hu FB. Dietary patterns and risk of mortality from cardiovascular disease, cancer, and all causes in a prospective cohort of women. Circulation 2008;118(3):230–7.

[71] McGowan CA, McAuliffe FM. Maternal dietary patterns and associated nutrient intakes during each trimester of pregnancy. Public Health Nutr 2013;16(1):97–107.

[72] World Health Organization and Food and Agriculture Organization of the United Nations. Diet, nutrition and the prevention of chronic diseases, in WHO Technical Report Series. Geneva, Switzerland: WHO; 2003.

[73] Monteagudo C, Mariscal-Arcas M, Palacin A, Lopez M, Lorenzo ML, Olea-Serrano F. Estimation of dietary folic acid intake in three generations of females in Southern Spain. Appetite 2013;67:114–8.

[74] Castro-Quezada I, Roman-Vinas B, Serra-Majem L. The Mediterranean diet and nutritional adequacy: a review. Nutrients 2014;6(1):231–48.

[75] Silva-del Valle MA, Sanchez-Villegas A, Serra-Majem L. Association between the adherence to the Mediterranean diet and overweight and obesity in pregnant women in Gran Canaria. Nutr Hosp 2013;28(3):654–9.

[76] Knudsen VK, Orozova-Bekkevold IM, Mikkelsen TB, Wolff S, Olsen SF. Major dietary patterns in pregnancy and fetal growth. Eur J Clin Nutr 2008;62(4):463–70.

[77] Timmermans S, Steegers-Theunissen RP, Vujkovic M, den Breeijen H, Russcher H, Lindemans J. The Mediterranean diet and fetal size parameters: the Generation R Study. Br J Nutr 2012;108(8):1399–409.

[78] Gesteiro E, Rodríguez Bernal B, Bastida S, Sánchez-Muniz FJ. Maternal diets with low healthy eating index or Mediterranean diet adherence scores are associated with high cord-blood insulin levels and insulin resistance markers at birth. Eur J Clin Nutr 2012;66(9):1008–15.

[79] Foote JA, Murphy SP, Wilkens LR, Basiotis PP, Carlson A. Dietary variety increases the probability of nutrient adequacy among adults. J Nutr 2004;134(7):1779–85.

[80] Arimond M, Wiesmann D, Becquey E, Carriquiry A, Daniels MC, Deitchler M, et al. Simple food group diversity indicators predict micronutrient adequacy of women's diets in 5 diverse, resource-poor settings. J Nutr 2010;140(11):2059S–69S.

[81] Dodd JM. Dietary and Lifestyle Advice for Pregnant Women Who Are Overweight or Obese: The LIMIT Randomized Trial. Ann Nutr Metab 2014;64(3–4):197–202.

[82] Frisch RE. Body fat, menarche, fitness and fertility. Hum Reprod 1987;2(6):521–33.

[83] Jensen TK, Andersson AM, Jørgensen N, Andersen AG, Carlsen E, Petersen JH, et al. Body mass index in relation to semen quality and reproductive hormones among 1,558 Danish men. Fertil Steril 2004;82(4):863–70.

[84] Sallmen M, Sandler DP, Hoppin JA, Blair A, Baird DD. Reduced fertility among overweight and obese men. Epidemiology 2006; 17(5):520–3.

[85] Balen AH, Anderson RA. Impact of obesity on female reproductive health: British Fertility Society, Policy and Practice Guidelines. Hum Fertil (Camb) 2007;10(4):195–206.

[86] Jokela M, Elovainio M, Kivimaki M. Lower fertility associated with obesity and underweight: the US National Longitudinal Survey of Youth. Am J Clin Nutr 2008;88(4):886–93.

[87] Ehrenberg HM, Dierker L, Milluzzi C, Mercer BM. Low maternal weight, failure to thrive in pregnancy, and adverse pregnancy outcomes. Am J Obstet Gynecol 2003;189(6):1726–30.

[88] Dean SV, Lassi ZS, Imam AM, Bhutta ZA. Preconception care: nutritional risks and interventions. Reprod Health 2014;11(Suppl 3):S3.

[89] Ronnenberg AG, Wang X, Xing H, Chen C, Chen D, Guang W, et al. Low preconception body mass index is associated with birth outcome in a prospective cohort of Chinese women. J Nutr 2003;133(11):3449–55.

[90] Stein AD, Kahn HS, Rundle A, Zybert PA, van der Pal-de Bruin K, Lumey LH. Anthropometric measures in middle age after exposure to famine during gestation: evidence from the Dutch famine. Am J Clin Nutr 2007;85(3):869–76.

[91] Hult M, Tornhammar P, Ueda P, Chima C, Bonamy AK, Ozumba B, et al. Hypertension, diabetes and overweight: looming legacies of the Biafran famine. PLoS One 2010;5(10):e13582.

[92] Zheng X, Wang Y, Ren W, Luo R, Zhang S, Zhang JH, et al. Risk of metabolic syndrome in adults exposed to the great Chinese famine during the fetal life and early childhood. Eur J Clin Nutr 2012;66(2):231–6.

[93] Murthy AS. Obesity and contraception: emerging issues. Semin Reprod Med 2010;28(2):156–63.

[94] The American College of Obstetricians and Gynecologists, Obesity in pregnancy. ACOG Committee opinion 549. Washington, D.C.: ACOG; 2013.

[95] Chu SY, Callaghan WM, Kim SY, Schmid CH, Lau J, England LJ, et al. Maternal obesity and risk of gestational diabetes mellitus. Diabetes Care 2007;30(8):2070–6.

[96] Yu CK, Teoh TG, Robinson S. Obesity in pregnancy. BJOG 2006;113(10):1117–25.

[97] Nohr EA, Vaeth M, Baker JL, Sørensen TIa, Olsen J, Rasmussen KM. Combined associations of prepregnancy body mass index and gestational weight gain with the outcome of pregnancy. Am J Clin Nutr 2008;87(6):1750–9.

[98] Meehan S, Beck CR, Mair-Jenkins J, Leonardi-Bee J, Puleston R. Maternal obesity and infant mortality: a meta-analysis. Pediatrics 2014;133(5):863–871.

[99] Perng W, Gillman MW, Mantzoros CS, Oken E. A prospective study of maternal prenatal weight and offspring cardiometabolic health in midchildhood. Ann Epidemiol 2014;24(11):793–800

[100] Hill JO, Peters JC. Environmental contributions to the obesity epidemic. Science 1998;280(5368):1371–4.

[101] American Nutrition Association, USDA defines food deserts. Nutrition Digest 2010;37(2).

[102] Thangaratinam S, Rogozinska E, Jolly K, Glinkowski S, Roseboom T, Tomlinson JW, et al. Effects of interventions in pregnancy on maternal weight and obstetric outcomes: meta-analysis of randomised evidence. BMJ 2012;344:e2088.

[103] Nicklas JM, Zera CA, England LJ, Rosner BA, Horton E, Levkoff SE, et al. A web-based lifestyle intervention for women with recent gestational diabetes mellitus: a randomized controlled trial. Obstet Gynecol 2014;124(3):563–70.

[104] Blumfield ML, Hure AJ, MacDonald-Wicks LK, Smith R, Simpson SJ, Giles WB, et al. Dietary balance during pregnancy is associated with fetal adiposity and fat distribution. Am J Clin Nutr 2012;96(5):1032–41.

[105] Institute of Medicine, Food and Nutrition Board. Dietary reference intakes for energy, carboyhdrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids. Washington, D.C., USA: Institute of Medicine; 2005.

[106] Sanders TA, Roshanai F. Platelet phospholipid fatty acid composition and function in vegans compared with age- and sex-matched omnivore controls. Eur J Clin Nutr 1992;46(11):823–31.

[107] Clapp JF 3rd. Maternal carbohydrate intake and pregnancy outcome. Proc Nutr Soc 2002;61(1):45–50.

[108] Weickert MO, Pfeiffer AF. Metabolic effects of dietary fiber consumption and prevention of diabetes. J Nutr 2008;138(3):439–42.

[109] Threapleton DE, Greenwood DC, Evans CE, Cleghorn CL, Nykjaer C, Woodhead C, et al. Dietary fibre intake and risk of cardiovascular disease: systematic review and meta-analysis. BMJ 2013;347:f6879.

[110] Threapleton DE, Greenwood DC, Evans CE, Cleghorn CL, Nykjaer C, Woodhead C, et al. Dietary fiber intake and risk of first stroke: a systematic review and meta-analysis. Stroke 2013;44(5):1360–8.

[111] Liu L, Wang S, Liu J. Fiber consumption and all-cause, cardiovascular, and cancer mortalities: A systematic review and meta-analysis of cohort studies. Mol Nutr Food Res 2015;59(1):139–46.

[112] Champ M, Hoebler C. Functional food for pregnant, lactating women and in perinatal nutrition: a role for dietary fibres? Curr Opin Clin Nutr Metab Care 2009;12(6):565–74.

[113] World Health Organization. Optimal serum and red blood cell folate concentrations in women of reproductive age for prevention of neural tube defects: Guideline. Geneva, Switzerland: WHO; 2015.

[114] Blumfield ML, Hure AJ, Macdonald-Wicks L, Smith R, Collins CE. A systematic review and meta-analysis of micronutrient intakes during pregnancy in developed countries. Nutr Rev 2013;71(2):118–32.

[115] Wang M, Wang ZP, Gao LJ, Gong R, Sun XH, Zhao ZT. Maternal body mass index and the association between folic acid supplements and neural tube defects. Acta Paediatr 2013;102(9):908–13.

[116] National Institute for Health and Care Excellence (NICE). Diabetes in pregnancy: management of diabetes and its complications from preconception to the postnatal period. http://www.nice.org.uk/guidance/ng3/

chapter/1-recommendations. February 2015.
[117] Blumer I, Hadar E, Hadden DR, Jovanovič L, Mestman JH, Murad MH, et al. Diabetes and pregnancy: an endocrine society clinical practice guideline. J Clin Endocrinol Metab 2013;98(11):4227–49.
[118] Dali-Youcef N, Andres E. An update on cobalamin deficiency in adults. QJM 2009;102(1):17–28.
[119] Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes and its Panel on Folate, Other B Vitamins, and Choline. Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline. Washington, D.C., USA: National Academies Press; 1998.
[120] Schorah CJ, Smithells RW, Scott J. Vitamin B12 and anencephaly. Lancet 1980;1(8173):880.
[121] Furness D, Fenech M, Dekker G, Khong TY, Roberts C, Hague W. Folate, Vitamin B12, Vitamin B6 and homocysteine: impact on pregnancy outcome. Matern Child Nutr 2013;9(2):155–166.
[122] Koebnick C, Hoffmann I, Dagnelie PC, Heins UA, Wickramasinghe SN, Ratnayaka ID, et al. Long-term ovo-lacto vegetarian diet impairs vitamin B-12 status in pregnant women. J Nutr 2004;134(12):3319–26.
[123] Elmadfa I, Singer I. Vitamin B-12 and homocysteine status among vegetarians: a global perspective. Am J Clin Nutr 2009;89(5):1693S–1698S.
[124] Holick MF, Chen TC. Vitamin D deficiency: a worldwide problem with health consequences. Am J Clin Nutr 2008:87(4):1080S–6S.
[125] Boeke CE, Gillman MW, Hughes MD, Rifas-Shiman SL, Villamor E, Oken E. Choline intake during pregnancy and child cognition at age 7 years. Am J Epidemiol 2013;177(12):1338–47.
[126] Shaw GM, Carmichael SL, Yang W, Selvin S, Schaffer DM. Periconceptional dietary intake of choline and betaine and neural tube defects in offspring. Am J Epidemiol 2004;160(2):102–9.
[127] Shaw JG, Friedman JF. Iron deficiency anemia: focus on infectious diseases in lesser developed countries. Anemia 2011;2011:260380.
[128] Prentice AM. Iron metabolism, malaria, and other infections: what is all the fuss about? J Nutr 2008;138(12):2537–41.
[129] Berbel P, Mestre JL, Santamaría A, Palazón I, Franco A, Graells M, et al. Delayed neurobehavioral development in children born to pregnant women with mild hypothyroxinemia during the first month of gestation: the importance of early iodine supplementation. Thyroid 2009;19(5):511–9.
[130] World Health Organization. Iodine deficiency in Europe: a continuing public health problem. Geneva, Switzerland: WHO and UNICEF; 2007.
[131] Torheim LE, Oshaug A, Barikmo I, Dahl L, Henjum S. Environmental implication of iodine in water, milk and other foods used in Saharawi refugees camps in Tindouf, Algeria. J Food Comp Anal 2011;24(4–5):637–41.
[132] Institute of Medicine (US) Panel on Micronutrients. Dietary Reference Intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. Washington, D.C., USA: The National Academies Press; 2001.
[133] Nordin BEC. Calcium in health and disease. Food, Nutrition and Agriculture, 1997. http://www.fao.org/3/a-w7336t/W7336t05.pdf
[134] Ho SC, Leung PC, Swaminathan R, Chan C, Chan SS, Fan YK, et al. Determinants of bone mass in Chinese women aged 21–40 years. II. Pattern of dietary calcium intake and association with bone mineral density. Osteoporos Int 1994;4(3):167–75.
[135] Weaver CM, Heaney RP, Nickel KP, Packard PI. Calcium bioavailability from high oxalate vegetables: Chinese vegetables, sweet potatoes and rhubarb. J Food Sci 1997;62:524–5.
[136] Institute of Medicine (US) Committee to Review Dietary Reference Intakes for Vitamin D and Calcium. Dietary Reference Intakes for Calcium and Vitamin D. Washington, D.C., USA: The National Academies Press; 2011.
[137] Mistry HD, Broughton Pipkin F, Redman CW, Poston L. Selenium in reproductive health. Am J Obstet Gynecol 2012;206(1):21–30.
[138] Wessells KR, Brown KH. Estimating the global prevalence of zinc deficiency: results based on zinc availability in national food supplies and the prevalence of stunting. PLoS One 2012;7(11):e50568.
[139] Sandstrom B. Micronutrient interactions: effects on absorption and bioavailability. Br J Nutr 2001;85 Suppl 2:S181–5.
[140] Ota E, Middleton P, Tobe-Gai R, Mahomed K, Bhutta ZA. Zinc supplementation for improving pregnancy and infant outcome. Cochrane Database Syst Rev 2015;2:CD000230.
[141] Institute of Medicine, Food and Nutrition Board. Dietary Reference Intakes for VItamin C, Vitamin E, Selenium and Carotenoids. Washington, D.C., USA: The National Academies Press; 2000.
[142] O'Leary CM, Nassar N, Kurinczuk JJ, de Klerk N, Geelhoed E, Elliott EJ, et al. Prenatal alcohol exposure and risk of birth defects. Pediatrics 2010;126(4):e843–50.
[143] Shea AK, Steiner M. Cigarette smoking during pregnancy. Nicotine Tob Res 2008;10(2):267–78.
[144] Mattsson K, Källén K, Longnecker MP, Rignell-Hydbom A, Rylander L. Maternal smoking during pregnancy and daughters' risk of gestational diabetes and obesity. Diabetologia 2013;56(8):1689–95.
[145] FAO/WHO/UNU Expert Consultation. Human energy requirements, in FAO Food and Nutrition Technical Report Series 1. Rome, Italy: Food and Agriculture Organization, World Health Organization, and United Nations University; 2001.
[146] World Health Organization. Protein and amino acid requirements in human nutrition: Report of a Joint WHO/FAO/UNU Expert Consultation, in WHO Technical Report Series 935. Geneva, Switzerland: WHO; 2007.
[147] Ota E, Tobe-Gai R, Mori R, Farrar D. Antenatal dietary advice and supplementation to increase energy and protein intake. Cochrane Database Syst Rev 2012;9:CD000032.
[148] Carlson SE. Docosahexaenoic acid supplementation in pregnancy and lactation. Am J Clin Nutr 2009;89(2):678S–84S.
[149] Walsh JM, McGowan CA, Mahony R, Foley ME, McAuliffe FM. Low glycaemic index diet in pregnancy to prevent macrosomia (ROLO study): randomised control trial. BMJ 2012;345:e5605.
[150] Walsh JM, Mahony RM, Culliton M, Foley ME, McAuliffe FM. Impact of a low glycemic index diet in pregnancy on markers of maternal and fetal metabolism and inflammation. Reprod Sci 2014;21(11):1378–81.
[151] Viana LV, Gross JL, Azevedo MJ. Dietary intervention in patients with gestational diabetes mellitus: a systematic review and meta-analysis of randomized clinical trials on maternal and newborn outcomes. Diabetes Care 2014;37(12):3345–55.
[152] Donnelly JM, Walsh JM, Byrne J, Molloy EJ, McAuliffe FM. Impact of maternal diet on neonatal anthropometry: a randomized controlled trial. Pediatr Obes 2015;10(1):52–6.
[153] Zhang C, Liu S, Solomon CG, Hu FB. Dietary fiber intake, dietary glycemic load, and the risk for gestational diabetes mellitus. Diabetes Care 2006;29(10):2223–30.
[154] Qiu C, Coughlin KB, Frederick IO, Sorensen TK, Williams MA. Dietary fiber intake in early pregnancy and risk of subsequent preeclampsia. Am J Hypertens 2008;21(8):903–9.
[155] Hogeveen M, Blom HJ, den Heijer M. Maternal homocysteine and small-for-gestational-age offspring: systematic review and meta-analysis. Am J Clin Nutr 2012;95(1):130–6.
[156] Bergen NE, Jaddoe VW, Timmermans S, Hofman A, Lindemans J, Russcher H, et al. Homocysteine and folate concentrations in early pregnancy and the risk of adverse pregnancy outcomes: the Generation R Study. BJOG 2012;119(6):739–51.
[157] Mason JB, Miller JW. The effects of vitamins B12, B6, and folate on blood homocysteine levels. Ann N Y Acad Sci 1992;669:197–203;discussion 203–4.
[158] McNulty B, McNulty H, Marshall B, Ward M, Molloy AM, Scott JM, et al. Impact of continuing folic acid after the first trimester of pregnancy: findings of a randomized trial of Folic Acid Supplementation in the Second and Third Trimesters. Am J Clin Nutr 2013;98(1):92–8.
[159] Deshmukh U, Katre P, Yajnik CS. Influence of maternal vitamin B12 and folate on growth and insulin resistance in the offspring. Nestle Nutr Inst Workshop Ser 2013;74:145–54;discussion 154–6.
[160] Kim YI, Miller JW, da Costa KA, Nadeau M, Smith D, Selhub J, et al. Severe folate deficiency causes secondary depletion of choline and phosphocholine in rat liver. J Nutr 1994;124(11):2197–203.
[161] Jacob RA, Jenden DJ, Allman-Farinelli MA, Swendseid ME. Folate nutriture alters choline status of women and men fed low choline diets. J Nutr 1999;129(3):712–7.
[162] U.S. Centers for Disease Control and Prevention. Second National Report on Biochemical Indicators of Diet and Nutrition in the U.S. Population 2012. Atlanta (GA) USA: National Center for Environmental Health; 2012.
[163] Perry CA, West AA, Gayle A, Lucas LK, Yan J, Jiang X, et al. Pregnancy and Lactation Alter Biomarkers of Biotin Metabolism in Women Consuming a Controlled Diet. J Nutr 2014; 144(12):1977–84.
[164] Rosen CJ, Adams JS, Bikle DD, Black DM, Demay MB, Manson JE, et al. The nonskeletal effects of vitamin D: an Endocrine Society scientific statement. Endocr Rev 2012;33(3):456–92.
[165] Ritchie LD,Fung EB, Halloran BP, Turnlund JR, Van Loan MD, Cann CE, et al. A longitudinal study of calcium homeostasis during human pregnancy and lactation and after resumption of menses. Am J Clin Nutr 1998;67(4):693–701.
[166] Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes. Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride. Washington, D.C., USA: The National Academies Press; 1997.
[167] Lucas RM, Ponsonby AL, Pasco JA, Morley R. Future health implications of prenatal and early-life vitamin D status. Nutr Rev 2008;66(12):710–20.
[168] Leffelaar ER, Vrijkotte TG, van Eijsden M. Maternal early pregnancy vitamin D status in relation to fetal and neonatal growth: results of the multi-ethnic Amsterdam Born Children and their Development cohort. Br J Nutr 2010;104(1):108–17.
[169] Gernand AD, Simhan HN, Klebanoff MA, Bodnar LM. Maternal Serum 25-Hydroxyvitamin D and Measures of Newborn and Placental Weight in a U.S. Multicenter Cohort Study. J Clin Endocrinol Metab 2013;98(1):398–404.
[170] Maiya S,Sullivan I, Allgrove J, Yates R, Malone M, Brain C, et al. Hypocalcaemia and vitamin D deficiency: an important, but preventable, cause of life-threatening infant heart failure. Heart 2008;94(5):581–4.
[171] Mulligan ML, Felton SK, Riek AE, Bernal-Mizrachi C. Implications of vitamin D deficiency in pregnancy and lactation. Am J Obstet Gynecol 2010;202(5):429 e1–9.
[172] Rothman KJ, Moore LL, Singer MR, Nguyen US, Mannino S, Milunsky A.

Teratogenicity of high vitamin A intake. N Engl J Med 1995;333(21):1369–73.
[173] Scholl TO. Maternal iron status: relation to fetal growth, length of gestation, and iron endowment of the neonate. Nutr Rev 2011;69 Suppl 1:S23–9.
[174] Bothwell TH. Iron requirements in pregnancy and strategies to meet them. Am J Clin Nutr 2000;72(1 Suppl):257S–264S.
[175] World Health Organization. WHO Guideline: Intermittent iron and folic acid supplementation to non-anaemic pregnant women. Geneva, Switzerland: WHO; 2012.
[176] Shah PS, Ohlsson A. Knowledge Synthesis Group on Determinants of Low Birth Weight and Preterm Births, Effects of prenatal multimicronutrient supplementation on pregnancy outcomes: a meta-analysis. CMAJ 2009;180(12):E99–108.
[177] Liberman CS, Pino SC, Fang SL, Braverman LE, Emerson CH. Circulating iodide concentrations during and after pregnancy. J Clin Endocrinol Metab 1998;83(10):3545–9.
[178] Glinoer D. The importance of iodine nutrition during pregnancy. Public Health Nutr 2007;10(12A):1542–6.
[179] Hofmeyr GJ, Lawrie TA, Atallah AN, Duley L. Calcium supplementation during pregnancy for preventing hypertensive disorders and related problems. Cochrane Database Syst Rev 2010;(8):CD001059.
[180] Imdad A, Jabeen A, Bhutta ZA. Role of calcium supplementation during pregnancy in reducing risk of developing gestational hypertensive disorders: a meta-analysis of studies from developing countries. BMC Public Health 2011;11 Suppl 3:S18.
[181] World Health Organization. Guideline: Calcium supplementation in pregnant women. Geneva, Switzerland: WHO; 2013.
[182] Jarjou LM, Sawo Y, Goldberg GR, Laskey MA, Cole TJ, Prentice A. Unexpected long-term effects of calcium supplementation in pregnancy on maternal bone outcomes in women with a low calcium intake: a follow-up study. Am J Clin Nutr 2013;98(3):723–30.
[183] Hofmeyr GJ, Lawrie TA, Atallah AN, Duley L, Torloni MR. Calcium supplementation during pregnancy for preventing hypertensive disorders and related problems. Cochrane Database Syst Rev 2014;6:CD001059.
[184] Mistry HD, Wilson V, Ramsay MM, Symonds ME, Broughton Pipkin F. Reduced selenium concentrations and glutathione peroxidase activity in preeclamptic pregnancies. Hypertension 2008;52(5):881–8.
[185] Brown KH, Peerson JM, Baker SK, Hess SY. Preventive zinc supplementation among infants, preschoolers, and older prepubertal children. Food Nutr Bull 2009;30(1 Suppl):S12–40.
[186] Hess SY, King JC. Effects of maternal zinc supplementation on pregnancy and lactation outcomes. Food Nutr Bull 2009;30(1 Suppl):S60–78.
[187] Brown KH, Hambidge KM, Ranum P, Zinc Fortification Working Group. Zinc fortification of cereal flours: current recommendations and research needs. Food Nutr Bull 2010;31(1 Suppl):S62–74.
[188] McGowan CA, Byrne J, Walsh J, McAuliffe FM. Insufficient vitamin D intakes among pregnant women. Eur J Clin Nutr 2011;65(9):1076–8.
[189] Walsh JM, Kilbane M, McGowan CA, McKenna MJ, McAuliffe FM. Pregnancy in dark winters: implications for fetal bone growth? Fertil Steril 2013;99(1):206–11.
[190] Toher C, Lindsay K, McKenna M, Kilbane M, Curran S, Harrington L, et al. Relationship between vitamin D knowledge and 25-hydroxyvitamin D levels amongst pregnant women. J Hum Nutr Diet 2014;27(3):261–9.
[191] Walsh JM, McGowan CA, Mahony RM, Foley ME, McAuliffe FM. Obstetric and metabolic implications of excessive gestational weight gain in pregnancy. Obesity (Silver Spring) 2014;22(7):1594–600.
[192] Phelan S, Phipps MG, Abrams B, Darroch F, Schaffner A, Wing RR. Randomized trial of a behavioral intervention to prevent excessive gestational weight gain: the Fit for Delivery Study. Am J Clin Nutr 2011;93(4):772–9.
[193] Phelan S, Jankovitz K, Hagobian T, Abrams B. Reducing excessive gestational weight gain: lessons from the weight control literature and avenues for future research. Womens Health (Lond Engl) 2011;7(6):641–61.
[194] Triunfo S, Lanzone A. Impact of maternal under nutrition on obstetric outcomes. J Endocrinol Invest 2014 [Epub ahead of print].
[195] Neumann CG, Harrison GG. Onset and evolution of stunting in infants and children. Examples from the Human Nutrition Collaborative Research Support Program. Kenya and Egypt studies. Eur J Clin Nutr 1994;48 Suppl 1:S90–102.
[196] Scott C, Andersen CT, Valdez N, Mardones F, Nohr EA, Poston L, et al. No global consensus: a cross-sectional survey of maternal weight policies. BMC Pregnancy Childbirth 2014;14:167.
[197] Gueri M, Jutsum P, Sorhaindo B. Anthropometric assessment of nutritional status in pregnant women: a reference table of weight-for-height by week of pregnancy. Am J Clin Nutr 1982;35(3):609–16.
[198] Mardones F, Rosso P. A weight gain chart for pregnant women designed in Chile. Matern Child Nutr 2005;1(2):77–90.
[199] Institute of Medicine and National Research Council Committee to Reexamine IOM Pregnancy Weight Gain Guidelines. Weight gain during pregnancy: reexamining the guidelines. Rasmussen KM, Yaktine AL, eds. Washington, DC, USA: National Academies Press; 2009.
[200] Butte NF, King JC. Energy requirements during pregnancy and lactation. Public Health Nutr 2005;8(7A):1010–27.
[201] Tafari N, Naeye RL, Gobezie A. Effects of maternal undernutrition and heavy physical work during pregnancy on birth weight. Br J Obstet Gynaecol 1980;87(3):222–6.
[202] American College of Obstetricians and Gynecologists, Obesity in pregnancy. Committee Opinion No. 549. Obstet Gynecol 2013;121:213–17.
[203] Denning DW, Allen R, Wilkinson AP, Morgan MR. Transplacental transfer of aflatoxin in humans. Carcinogenesis 1990;11(6):1033–5.
[204] Yu MC, Yuan JM. Environmental factors and risk for hepatocellular carcinoma. Gastroenterology 2004;127(5 Suppl 1):S72–8.
[205] Harada M, Congenital Minamata disease: intrauterine methylmercury poisoning. Teratology 1978;18(2):285–8.
[206] American Pregnancy Association. Mercury levels in fish. http://americanpregnancy.org/pregnancyhealth/fishmercury.htm
[207] Stewart P, Reihman J, Gump B, Lonky E, Darvill T, Pagano J. Response inhibition at 8 and 9 1/2 years of age in children prenatally exposed to PCBs. Neurotoxicol Teratol 2005;27(6):771–80.
[208] Stewart P, Darvill T, Lonky E, Reihman J, Pagano J, Bush B. Assessment of prenatal exposure to PCBs from maternal consumption of Great Lakes fish: an analysis of PCB pattern and concentration. Environ Res 1999;80(2 Pt 2):S87–S96.
[209] Eteng MU, Eyong EU, Eka OU, Umoh IB, Ebong PE, Ettarh RR. Caffeine and theobromine levels in selected Nigerian beverages. Plant Foods Hum Nutr 1999;54(4):337–44.
[210] Aden U. Methylxanthines during pregnancy and early postnatal life. Handb Exp Pharmacol 2011;(200):373–89.
[211] Klebanoff MA, Levine RJ, Clemens JD, Wilkins DG. Maternal serum caffeine metabolites and small-for-gestational age birth. Am J Epidemiol 2002;155(1):32–7.
[212] Vlajinac HD, Petrović RR, Marinković JM, Sipetić SB, Adanja BJ. Effect of caffeine intake during pregnancy on birth weight. Am J Epidemiol 1997;145(4):335–8.
[213] Bracken MB, Triche EW, Belanger K, Hellenbrand K, Leaderer BP. Association of maternal caffeine consumption with decrements in fetal growth. Am J Epidemiol 2003;157(5):456–66.
[214] Care Study Group, Maternal caffeine intake during pregnancy and risk of fetal growth restriction: a large prospective observational study. BMJ 2008;337:a2332.
[215] Klebanoff MA, Levine RJ, DerSimonian R, Clemens JD, Wilkins DG. Maternal serum paraxanthine, a caffeine metabolite, and the risk of spontaneous abortion. N Engl J Med 1999;341(22):1639–44.
[216] Cnattingius S, Signorello LB, Annerén G, Clausson B, Ekbom A, Ljunger E, et al. Caffeine intake and the risk of first-trimester spontaneous abortion. N Engl J Med 2000;343(25):1839–45.
[217] Wisborg K, Kesmodel U, Bech BH, Hedegaard M, Henriksen TB. Maternal consumption of coffee during pregnancy and stillbirth and infant death in first year of life: prospective study. BMJ 2003;326(7386):420.
[218] Zielinsky P, Busato S. Prenatal effects of maternal consumption of polyphenol-rich foods in late pregnancy upon fetal ductus arteriosus. Birth Defects Res C Embryo Today 2013;99(4):256–74.
[219] Braun JM, Yolton K, Dietrich KN, Hornung R, Ye X, Calafat AM, et al. Prenatal bisphenol A exposure and early childhood behavior. Environ Health Perspect 2009;117(12):1945–52.
[220] Donohue KM, Miller RL, Perzanowski MS, Just AC, Hoepner LA, Arunajadai S, et al. Prenatal and postnatal bisphenol A exposure and asthma development among inner-city children. J Allergy Clin Immunol 2013;131(3):736–42.
[221] Veiga-Lopez A, Luense LJ, Christenson LK, Padmanabhan V. Developmental programming: Gestational bisphenol-A treatment alters trajectory of fetal ovarian gene expression. Endocrinology 2013;154(5):1873–1884
[222] Hanson LA, Korotkova M, Lundin S, Håversen L, Silfverdal SA, Mattsby-Baltzer I, et al. The transfer of immunity from mother to child. Ann N Y Acad Sci 2003;987:199–206.
[223] Ip S, Chung M, Raman G, Chew P, Magula N, DeVine D, et al. Breastfeeding and maternal and infant health outcomes in developed countries. Evid Rep Technol Assess (Full Rep) 2007;(153):1–186.
[224] Owen CG, Whincup PH, Cook DG. Breast-feeding and cardiovascular risk factors and outcomes in later life: evidence from epidemiological studies. Proc Nutr Soc 2011;70(4):478–84.
[225] Lawrence RM. Circumstances when breastfeeding is contraindicated. Pediatr Clin North Am 2013;60(1):295–318.
[226] Coutsoudis A. Breastfeeding and HIV. Best Pract Res Clin Obstet Gynaecol 2005;19(2):185–96.
[227] Lapillonne A, Jensen CL. Reevaluation of the DHA requirement for the premature infant. Prostaglandins Leukot Essent Fatty Acids 2009;81(2–3):143–50.
[228] Allen LH. B vitamins in breast milk: relative importance of maternal status and intake, and effects on infant status and function. Adv Nutr 2012;3(3):362–9.
[229] Allen LH. Maternal micronutrient malnutrition: effects on breast milk and infant nutrition, and priorities for intervention. SCN News 1994;(11):21–4.
[230] Scientific Committee for Food. Tolerable upper intake levels for vitamins and minerals. Brussels, Belgium: European Food Safety Authority; 2006.
[231] Kang-Yoon SA, Kirksey A, Giacoia G, West K. Vitamin B-6 status of breast-fed neonates: influence of pyridoxine supplementation on mothers and neonates. Am J Clin Nutr 1992;56(3):548–58.
[232] Chang SJ, Kirksey A. Vitamin B6 status of breast-fed infants in relation to

pyridoxine HCl supplementation of mothers. J Nutr Sci Vitaminol (Tokyo) 2002;48(1):10–7.
[233] Emmett PM, Rogers IS. Properties of human milk and their relationship with maternal nutrition. Early Hum Dev 1997;49 Suppl:S7–28.
[234] Holick MF, Binkley NC, Bischoff-Ferrari HA, Gordon CM, Hanley DA, Heaney RP, et al. Evaluation, treatment, and prevention of vitamin D deficiency: an Endocrine Society clinical practice guideline. J Clin Endocrinol Metab 2011;96(7):1911–30.
[235] Braegger C, Campoy C, Colomb V, Decsi T, Domellof M, Fewtrell M, et al. Vitamin D in the healthy European paediatric population. J Pediatr Gastroenterol Nutr 2013;56(6):692–701.
[236] Oliveira-Menegozzo JM, Bergamaschi DP, Middleton P, East CE. Vitamin A supplementation for postpartum women. Cochrane Database Syst Rev 2010;(10):CD005944.
[237] McMillan JA, Landaw SA, Oski FA. Iron sufficiency in breast-fed infants and the availability of iron from human milk. Pediatrics 1976;58(5):686–91.
[238] World Health Organization. Guideline: Delayed umbilical cord clamping for improved maternal and infant health and nutrition outcomes. Geneva, Switzerland: WHO; 2014.
[239] Baker RD, Greer FR. Committee on Nutrition American Academy of Pediatrics, Diagnosis and prevention of iron deficiency and iron-deficiency anemia in infants and young children (0–3 years of age). Pediatrics 2010;126(5):1040–50.
[240] Phillips AK, Roy SC, Lundberg R, Guilbert TW, Auger AP, Blohowiak SE, et al. Neonatal iron status is impaired by maternal obesity and excessive weight gain during pregnancy. J Perinatol 2014;34(7):513–8.
[241] WHO Secretariat, Andersson M, de Benoist B, Delange F, Zupan J. Prevention and control of iodine deficiency in pregnant and lactating women and in children less than 2-years-old: conclusions and recommendations of the Technical Consultation. Public Health Nutr 2007;10(12A):1606–11.
[242] Bouhouch RR, Bouhouch S, Cherkaoui M, Aboussad A, Stinca S, Haldimann M, et al. Direct iodine supplementation of infants versus supplementation of their breastfeeding mothers: a double-blind, randomised, placebo-controlled trial. Lancet Diabetes Endocrinol 2014;2(3):197–209.
[243] Donangelo CM, King JC. Maternal zinc intakes and homeostatic adjustments during pregnancy and lactation. Nutrients 2012;4(7):782–98.
[244] World Health Organization, Department of Child and Adolescent Health and Development (CAH). Guiding principles for feeding non-breastfed children 6–24 months of age. Geneva, Switzerland: WHO; 2005.
[245] Conde-Agudelo A, Rosas-Bermudez A, Castaño F, Norton MH. Effects of birth spacing on maternal, perinatal, infant, and child health: a systematic review of causal mechanisms. Stud Fam Plann 2012;43(2):93–114.
[246] Davis EM,Babineau DC, Wang X, Zyzanski S, Abrams B, Bodnar LM, et al. Short inter-pregnancy intervals, parity, excessive pregnancy weight gain and risk of maternal obesity. Matern Child Health J 2014;18(3):554–62.
[247] World Health Organization. Report of a WHO Technical Consultation on Birth Spacing. Geneva, Switzerland: WHO; 2006.
[248] Temin M, Levine R. Start with a girl: A new agenda for global health. Washington, D.C., USA: Center for Global Development; 2009.
[249] Goli S, Rammohan A, Singh D. The Effect of Early Marriages and Early Childbearing on Women's Nutritional Status in India. Matern Child Health J 2015;[Epub ahead of print].
[250] World Health Organization. Adolescent pregnancy, Fact sheet No.364. http://www.who.int/mediacentre/factsheets/fs364/en
[251] Whisner CM, Young BE, Pressman EK, Queenan RA, Cooper EM, O'Brien KO. Maternal diet but not gestational weight gain predicts central adiposity accretion in utero among pregnant adolescents. Int J Obes (Lond) 2015;39(4):565–70.
[252] Todd AS, Street SJ, Ziviani J, Byrne NM, Hills AP. Overweight and obese adolescent girls: the importance of promoting sensible eating and activity behaviors from the start of the adolescent period. Int J Environ Res Public Health 2015;12(2):2306–29.
[253] Rah JH, Christian P, Shamim AA, Arju UT, Labrique AB, Rashid M. Pregnancy and lactation hinder growth and nutritional status of adolescent girls in rural Bangladesh. J Nutr 2008;138(8):1505–11.
[254] Lee S, Young BE, Cooper EM, Pressman E, Queenan RA, Guillet R, et al. Nutrient inadequacy is prevalent in pregnant adolescents, and prenatal supplement use may not fully compensate for dietary deficiencies. ICAN: Infant, Child, & Adolescent Nutrition 2014;6(3):152–159.
[255] Soares NN, Mattar R, Camano L, Torloni MR. Iron deficiency anemia and iron stores in adult and adolescent women in pregnancy. Acta Obstet Gynecol Scand 2010;89(3):343–9.
[256] Kurz KM, Galloway R. Improving adolescent iron status before childbearing. J Nutr 2000;130(2S Suppl):437S–439S.
[257] Baker PN, Wheeler SJ, Sanders TA, Thomas JE, Hutchinson CJ, Clarke K, et al. A prospective study of micronutrient status in adolescent pregnancy. Am J Clin Nutr 2009;89(4):1114–24.
[258] Diogenes ME, Bezerra FF, Rezende EP, Taveira MF, Pinhal I, Donangelo CM. Effect of calcium plus vitamin D supplementation during pregnancy in Brazilian adolescent mothers: a randomized, placebo-controlled trial. Am J Clin Nutr 2013; 98(1):82–91.
[259] Lipsman S, Dewey KG, Lonnerdal B. Breast-feeding among teenage mothers: milk composition, infant growth, and maternal dietary intake. J Pediatr Gastroenterol Nutr 1985;4(3):426–34.
[260] Sipsma HL, Magriples U, Divney A, Gordon D, Gabzdyl E, Kershaw T. Breastfeeding Behavior Among Adolescents: Initiation, Duration, and Exclusivity. J Adolesc Health 2013;53(3):394–400.
[261] World Health Organization. Health Statistics and Information Systems. http://gamapserver.who.int/mapLibrary/Files/Maps/Global_Obesity_2014_Female.png. Published 2015.
[262] World Health Organization. The Global Prevalence of Anaemia in 2011. Geneva: WHO; 2015.
[263] World Health Organization. Global prevalence of vitamin A deficiency in populations at risk 1995–2005. WHO Global Database on Vitamin A Deficiency. Geneva: WHO; 2009.
[264] World Health Organization. Vitamin and Mineral Nutrition Information System (VMNIS). Micronutrients Database. Database on Iodine Deficiency. http://www.who.int/vmnis/iodine/status/summary/median_ui_2007_color.pdf. Published 2009.
[265] World Health Organization. Comprehensive implementation plan on maternal, infant, and young child nutrition. Geneva, Switzerland: WHO; 2014.
[266] Viner RM, Ozer EM, Denny S, Marmot M, Resnick M, Fatusi A, et al. Adolescence and the social determinants of health. Lancet 2012;379(9826):1641–52.
[267] World Health Organization. Health for the world's adolescents: a second chance in the second decade: summary. http://apps.who.int/adolescent/second-decade/files/1612_MNCAH_HWA_Executive_Summary.pdf
[268] World Health Organization. Every Woman, Every Child: A Post-2015 Vision: 3rd Report of the Expert Review Group on Information and Accountability for Women's and Children's Health. http://apps.who.int/iris/bitstream/10665/132673/1/9789241507523_eng.pdf
[269] Bustreo F, Hunt P. Women's and children's health: evidence of impact of human rights. Geneva, Switzerland: WHO; 2013.