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Review

Nutrition for safer pregnancy, motherhood and infant survival

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Maternal nutrition has long-lasting effects on the health of the offspring. The ability of mother to provide nutrients for her unborn baby is a critical factor for fetal health and its survival. Failure in supplying the adequate amount of nutrients to meet fetal demand can lead to fetal malnutrition. The fetus responds and adapts to under nutrition but by doing so it permanently alters the structure and function of the body. There is growing evidence that maternal nutrition can induce epigenetic and metabolic modifications of the fetus that may underlie the prevalence of many chronic diseases of adulthood. It is now of crucial importance to gain the understanding of the intricacies of nutrition for mothers and the children and the long-term effects on the health of an individual. This review highlighted the causes and effects of malnutrition in pregnant women, nursing mothers and their babies and the basic nutritional requirements needed to correct the deficiency. It enumerated the good nutritional status which is achieved by eating nutritious foods at all times. Finally, recommendations were made for the roles and obligations of the pregnant women and nursing mothers towards safer motherhood and infant survival.

Key words: Nutrition, pregnant women, mother and infant.

INTRODUCTION

Nutrition (also called nourishment or aliment) is the provision of the necessary food materials to cells and organisms to support life (Sizer and Whitne, 2007). Any nutritional disorder caused by inappropriate dietary intake is referred to as malnutrition. Malnutrition can be caused by many factors, most of which relate to poor diet or severe infections, particularly in underprivileged populations. Many common health problems can be prevented or alleviated with a healthy diet. Inadequate diet and disease are closely linked to the general standard of living, the environmental conditions, and whether a population is able to meet its basic needs such as food and health care (ACC/SCN, 2000).

Malnutrition commonly affects all groups in a community, but infants and young children are the most vulnerable because of their high nutritional requirements for growth and development. Another group of concern is pregnant women, given that a malnourished mother is at high risk of giving birth to a low birth weight (LBW) baby who will be prone to growth failure during infancy and early childhood, and be at increased risk of morbidity and early death (Fishman et al., 2004). Malnourished girls, in particular, risk becoming yet another malnourished mother, thus contributing to the intergenerational cycle of malnutrition. In developing countries, poor prenatal conditions are responsible for approximately 23% of all deaths among children younger than 5 years old (de Onis et al., 2004). These deaths are concentrated in the neonatal period (that is, the first 28 days after birth), and most are attributable to LBW (Rice et al., 2000; Shrimpton et al., 2001). Evidence has shown that there is a greater incidence of low births among women who are underweight or stunted prior to conception, or who fail to gain sufficient weight during pregnancy (Shrimpton et al., 2001; Fishman et al., 2004), compared to women with normal weight and weight gain. Although it is rarely the direct cause of death (except in extreme situations, such as famine), child malnutrition was associated with 54% of child deaths (10.8 million children) in developing countries in 2001 (WHO, 2004).

The nutritional status of women and children is particularly important, because it is through women and

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their offspring that the pernicious effects of malnutrition are propagated to future generations. Malnutrition can create and perpetuate poverty in the family which triggers a cycle that hampers economic and social development, and contributes to unsustainable resource use and environmental degradation (WEHAB, 2002). Breaking the cycle of continuing malnutrition, poverty and environmental deterioration is a prerequisite for sustainable development and survival.

This review was aimed at highlighting the causes and effects of malnutrition in pregnant women, nursing mothers and infants, and the basic nutritional requirements needed to correct the deficiency. The goal is to help policy-makers and others quantify the increased risk associated with malnutrition and to enable resources to be deployed more effectively.

CAUSES AND EFFECTS OF MALNUTRITION IN PREGNANT WOMEN, NURSING MOTHERS AND BABIES

Maternal dietary deficiency

To a great extent, the diet can affect the baby's health even before a woman becomes pregnant. The nutritional needs of a pregnant woman vary with the different stages of her pregnancy (Williamson, 2006). The stages are the first trimester (0 to 3 months), second trimester (4 to 6 months) and third trimester (7 to 9 months). The conception and the subsequent weeks afterwards is the time when it is most vulnerable, as it is the time when the organs and systems develop within. The energy used to create these systems comes from the nutrients in the mother's circulation and around the lining of the womb.

During the first trimester, the baby's brain, spinal cord, heart and other organs begin to form (Moore, 2003; Knuppel, 2007). These require additional nutrients. The woman may not be aware that she is pregnant and this means that she may not be eating properly for the fetus to enjoy the nutrients it needs in its early stages of development. In the second trimester, vomiting and loss of appetite tend to disappear allowing for most women to get on well with their normal food. Most women feel more energized in this period, and begin to put on weight as the symptoms of morning sickness subside and eventually fade away.

During the third trimester, the final and the most weight gain throughout the pregnancy takes place. The fetus will be growing the most rapidly during this stage, gaining up to 28 g per day (Knuppel, 2007). There is a large shift of calcium to the baby, which helps to develop and strengthen its bones (Weaver, 2004). Maternal diet during pregnancy influences the quality and the quantity of nutrients in milk during lactation (Bauchner et al., 2006). This is the key to a child's survival especially during the first year of birth. Also the lack of the much needed nutrients makes the infant vulnerable to diseases such as tuberculosis, measles, tetanus, polio, diphtheria, whooping cough and diarrhoea, which kill the majority of babies in the third world (WHO/FAO, 2003). Immunizing factors present in breast milk combat organisms invading the body through the intestinal tract, a feature giving breastfed babies a distinct advantage in areas where infection is a major problem (Heird, 2003). It protects babies from diarrhea and acute respiratory infections, stimulates their immune system and response to other diseases and to vaccination (Bauchner et al., 2006; UNICEF, 2009).

Infant dietary deficiency

Inappropriate feeding practices are a major cause of the onset of malnutrition in young children. Infants usually thrive for the first few months while they are receiving breast milk. At about the age of 4 to 6 months when they are weaned and other foods introduced to them, their physical conditions begin to deteriorate (Butte, 2000). Many infants are breast-fed for a year or more, but this diet eventually becomes inadequate when it is not supplemented with foods that contribute added protein, vitamins and minerals.

Children who are not breastfed appropriately have repeated infections, grow less well, and are almost six times more likely to die by the age of 1 month than children who receive at least some breast milk (Heird, 2003). From the age of 6 months onwards, when breast milk alone is no longer sufficient to meet all nutritional requirements, infants enter a particularly vulnerable period of complementary feeding, during which they make a gradual transition to eating ordinary family foods. The incidence of malnutrition rises sharply during the period from 6 to 18 months of age in most countries, and the deficits acquired at this age are difficult to compensate for later in childhood.

NUTRITIONAL REQUIREMENTS DURING PREGNANCY, LACTATION AND INFANCY

A woman's diet during pregnancy affects the course of pregnancy and the condition of her infant at birth. In addition to her normal nutrients requirements, she must provide adequate nutrients for the fetus. Pioneering studies showed that poorly nourished pregnant women provided with food supplements had a reduced incident of miscarriages, stillbirths and deaths of the newborn (Williamson, 2006; Knuppel, 2007). They also suffered fewer complications during pregnancy, and had less difficulty during labour; the physical condition of the babies was rated good. The essential nutrients can be classified into carbohydrate, protein, fats and oil, vitamins and minerals.

Table 1. Recommended dietary allowance/adequate intake (RDA/AI) for macronutrients in males and females.

Substance	Amount (males)	Amount (females)	Top sources in common measures
Water	3.7 L/day	2.7 L/day	Drinking water, beverages, lettuce, beer
Carbohydrates	130 g/day	130 g/day	Rice, oats, wheat, condensed milk, barley
Protein[a]	56 g/day	46 g/day	Beef, duck, chicken, turkey
Fiber	38 g/day	25 g/day	Legumes, barley, bulgur
Fat	20-35% of calories		Pie crust, white chocolate, trail mix
Linoleic acid, an omega-6 fatty acid (polyunsaturated)	17 g/day	12 g/day	Grape seed oil
Alpha-linolenic acid, an omega-3 fatty acid (polyunsaturated)	1.6 g/day	1.1 g/day	Flaxseed (linseed) oil
Cholesterol	As low as possible		Chicken giblets, turkey giblets, beef liver
Trans fatty acids	As low as possible		
Saturated fatty acids	As low as possible		Cheese, white chocolate, coconut meat
Added sugar	No more than 25% of calories		Condensed milk, white chocolate

[a]Based on 0.8 g/kg of body weight. Source: Food and Nutrition Board (2005).

Energy

Energy intake is important for normal or underweight women during pregnancy in relation to the energy needs of fetus and mother. The pattern and amount of gain in weight as an indication of adequate or inadequate energy intake will affect the well-being of the mother and that of her infant. Carbohydrates form the major part of the diet, providing between 50 and 70% of the energy intake, largely from starch and sucrose. The basic carbohydrates are the monosaccharide sugars, of which glucose, fructose and galactose are the most important nutritionally. Starches are complex carbohydrates found in grains (for example, brown rice, oats, wheat, barley and corn), beans and peas (for example, kidney beans, garbanzo beans, lentils and split peas) and tubers (for example, potatoes and carrots).

The body stores of carbohydrate are mainly in the form of glycogen in the liver and skeletal muscle. The metabolic energy yield of carbohydrates is 17 kJ (4 kcal)/g and proteins 16.8 kJ (4 kcal)/g, while fats contain 37.8 kJ (9 kcal)/g. So diets high in complex carbohydrates are likely to provide fewer calories than diets high in fat. More precisely, monosaccharides yield 15.7 kJ (3.74 kcal), disaccharides 16.6 kJ (3.95 kcal) and starch 17.6 kJ (4.18 kcal)/g. Disaccharides include lactose (found in dairy), maltose (found in certain vegetables and in beer) and sucrose (table sugar). Honey is also a disaccharide. But unlike table sugar, it contains a small amount of vitamins and minerals. It should be noted that honey should not be given to children younger than 1 year old. It may contain the spores that cause botulism. An infant's immune system is not fully developed to fight off this disease (Heird, 2003).

Refined sugars lack vitamins, minerals and fiber. Such sugars can lead to weight gain and should be avoided during pregnancy (Rockville, 2005). It is undesirable for pregnant women to be obese (Astrup, 2008). Many refined foods, such as white flour, sugar and polished rice lack vitamins and other important nutrients. It is healthiest to get carbohydrates, vitamins and other nutrients in as natural a form as possible - for example, from fruit instead of table sugar (Rockville, 2005). Women who were at least 6.4 kg over their ideal weight had problem of high blood pressure and pre-eclampsia (a toxic condition characterized by high blood pressure, excretion of albumin in the urine and oedema) (Lichtenstein et al., 2006).

The recommended dietary allowance/adequate intake (RDA/AI) for macronutrients for adult males and females is shown in Table 1. The RDA for energy is additional 1140 kJ (285 kcal) a day for the first 6 months during pregnancy and 2000 kJ (500 kcal) during lactation over the usual allowances for women (WHO, 2000) (Table 2). Based on the effects on risk of heart disease and obesity, the Institute of Medicine recommended that adults get between 45 to 65% of dietary energy from carbohydrates (Food and Nutrition Board, 2005). The Food and Agriculture Organization and World Health Organization jointly recommended that national dietary guidelines set a goal of 55 to 75% of total energy from carbohydrates, but only 10% directly from sugars (WHO/FAO, 2003).

Requirements for energy and nutrients per unit body weight are higher in infancy than at any other time in life.

Table 2. Additional nutritional requirements for pregnant and lactating women.

Nutrient	Additional requirements (per day)	
	Pregnant women	Lactating women
Total energy (kJ)	1140	2000
Macronutrients		
Protein (g)		
Mixed cereal/pulse diet (g) (for first 6 months)	7.1	18.9
Energy from fat (%)	(20 - 25%) of energy should be derived from fats	
Micronutrients		
Vitamin A (µg RE)	100	350
Vitamin D (µg)	7.5	7.5
Vitamin B_1/Thiamine (mg)	0.1	0.3
Vitamin B_2/Riboflavin (mg)	0.1	0.3
Niacin (mg)	1.1	2.7
Folic acid (µg)	250	100
Vitamin B_{12} (µg)	0.4	0.3
Ascorbic acid (mg)	20	20
Calcium (g)	0.6 - 0.7	0.6 - 0.7
Iron: low 5 - 9% (mg)	60 -120	17
Iodine (µg)	50	50

Source: WHO (2000).

Table 3. Human milk composition.

Age (month)	Energy ($kcal_{th}$/g)[a]	Protein (g/L)[a]	Vitamin A (µmol/L)[b]	Vitamin D (mg/L)[c]	Vitamin B_6 (mg/L)[d]	Calcium (mg/L)[a]	Iron (mg/L)[a]	Zinc (mg/L)[a]
1	0.67	11	1.7	645	0.13	266	0.5	2.1
2	0.67	9	1.7	645	0.13	259	0.4	2
3	0.67	9	1.7	645	0.13	253	0.4	1.5
4	0.67	8	1.7	645	0.13	247	0.35	1.2
5	0.67	8	1.7	645	0.13	241	0.35	1
6	0.67	8	1.7	645	0.13	234	0.3	1
7	0.67	8	1.7	645	0.13	228	0.3	0.75
8	0.67	8	1.7	645	0.13	222	0.3	0.75
9	0.67	8	1.7	645	0.13	215	0.3	0.75
10	0.67	8	1.7	645	0.13	209	0.3	0.5
11	0.67	8	1.7	645	0.13	203	0.3	0.5
12	0.67	8	1.7	645	0.13	197	0.3	0.5

Sources: [a] Michaelsen (2000); [d] Food and Nutrition Board (2000); [b] Food and Nutrition Board (2001); [c] Food and Nutrition Board (2002).

Breast milk is the natural nutritional source for infants younger than 1 year of age. Breast milk contains appropriate amounts of carbohydrate, protein and fat, and provides the digestive proteins (enzymes), minerals, vitamins, antibodies, hormones, antioxidants and other factors infants need to resist infections (Bauchner et al., 2006). Carbohydrates, proteins and lipids are the major contributors to the energy content of human milk (Michaelsen, 2000). Changes in human milk composition are shown in Table 3.

The major type of carbohydrate normally consumed by young infants is lactose, the carbohydrate source in breast milk and cow's milk-based infant formula. Lactose-free infant formulas, such as soy-based infant formulas, provide carbohydrates in the form of sucrose, corn syrup or corn syrup solids. These infant formulas are prescribed to infants who cannot metabolize lactose or galactose. Some specialty infant formulas contain other

Table 4. Recommended daily amounts for essential amino acids in adult humans.

Amino acid	mg per kg body weight	mg per 70 kg	mg per 100 kg	Food sources
Isoleucine	20	1400	2000	Fish, sea foods, meats, poultry, sesame seeds
Leucine	39	2730	3900	Peanuts, wheat germ, almonds, oat, beans, yellow corn, brown rice
Lysine	30	2100	3000	Catfish, chicken, beef, soybean, milk, egg, kidney bean.
Methionine	15	1050	1500	Sesame seeds, Brazil nuts, fish, meats, wheat germ, peanuts
Phenylalanine	25	1750	2500	Beef, poultry, pork, fish, milk, yoghurt, eggs, cheese, soy products
Threonine	15	1050	1500	Cottage cheese, poultry, fish, meat, lentils, sesame seeds
Tryptophan	4	280	400	Egg white, soybeans, cheese , sesame seed, sunflower seed, beef
Valine	26	1820	2600	Cottage cheese, fish, poultry, peanuts, sesame seeds, and lentils
Histidine	10	700	1000	Yam, green plantain, banana, grapes, beef, cheese

Source: FAO/WHO/UNU (2007).

carbohydrates in the form of modified corn starch, tapioca dextrin or tapioca starch. In later infancy, infants derive carbohydrates from additional sources including cereal and other grain products, fruits and vegetables. Infants who consume sufficient breast milk or infant formula and appropriate complementary foods later in infancy will meet their dietary needs for carbohydrates. Sugar alcohols, including sorbitol and mannitol, are also important to consider for infants.

Protein

Protein is a biological macromolecule made up of various α-amino acids that are joined by peptide bonds. The amino acids regarded as essential for humans are phenylalanine, valine, threonine, tryptophan, isoleucine, methionine, leucine, lysine and histidine (Young, 2004). Additionally, cysteine (or sulphur-containing amino acids), tyrosine (or aromatic amino acids) and arginine are required by infants and growing children (FAO/ WHO/UNU, 2007). Cystine and tyrosine are considered essential for the preterm and young term infant because enzyme activities involved in their synthesis are immature (Food and Nutrition Board, 2005). Protein under nutrition produces long-term negative effects on growth and neurodevelopment. Infants who are deprived of adequate types and amounts of food for long periods of time may develop kwashiorkor, resulting principally from a protein deficiency.

The protein content of mature human milk is approximately 8 to 10 g/L (Michaelsen, 2000) (Table 3). The concentration of protein changes as lactation progresses. By the second week postpartum, when the transition from colostrum to mature milk is nearly complete, the concentration of protein is approximately 12.7 g/L (Michaelsen, 2000). This value drops to 9 g/L by the second month and to 8 g/L by the fourth month where it appears to remain until well into the weaning process when milk volumes fall substantially. At this point, protein concentrations increase as involution of the mammary gland progresses. The inter-individual variation of the protein content of human milk is approximately 15% (Gebre-Medhin, 2006).

A nutritionally balanced diet provides adequate protein during pregnancy and lactation. Proteins in animal foods contain sufficient amounts of all the essential amino acids needed to meet protein requirements. In comparison, plant foods contain low levels of one or more of the essential amino acids. However, when plant foods low in one essential amino acid are eaten with an animal food or other plant foods that are high in that amino acid (for example, legumes such as pureed kidney beans [low in methionine, high in lysine] and grain products such as mashed rice [high in methionine, low in lysine]), sufficient amounts of all the essential amino acids are made available to the body (Young and Pellett, 2004). The protein eaten from the two foods would be equivalent to the high-quality protein found in animal products.

The need for protein during pregnancy is greatly increased. About 950 g of protein accumulates in the mother's body during pregnancy, most of which is added during the last 6 months (Williamson, 2006). The RDA is an additional 7.1 g of protein daily for first 6 months over the normal allowance for pregnant women (WHO, 2000) (Table 1). Additional 18.9 g of protein daily over the normal allowance is recommended for a lactating woman. The recommended daily intakes for children aged 3 years and older is 10 to 20% higher than adult levels and those for infants can be as much as 150% higher in the first year of life. Protein needs of infants range between 2.0 to 2.5 g/kg body weight and 1.8 to 2.2 g/kg body weight at the first and second 6 months of life, respectively (WHO/UNICEF, 2003). Table 4 shows the recommended daily amounts for essential amino acids in adult humans.

Dietary sources containing all nine essential amino acids are found in animal foods such as meat, fish, poultry, eggs, milk and milk products such as yoghurt and cheese (Table 4). Soybeans are the only plant protein considered to be containing all nine essential amino acids. Foods lacking one or more of the essential amino acids include beans, peas, nuts, seeds, grain and vegetables.

Essential amino acids are "essential" not because they are more important to life than the others, but because the body does not synthesize them, making it essential to include them in one's diet in order to obtain them. In addition, the amino acids arginine, cysteine, glycine, glutamine, histidine, proline, serine and tyrosine are considered conditionally essential, meaning they are not normally required in the diet, but must be supplied exogenously to specific populations that do not synthesize them in adequate amounts (Reeds, 2000; Fürst and Stehle, 2004).

The standard amino acids are either used to synthesize proteins and other biomolecules or are oxidized to urea and carbon dioxide as a source of energy (Sakami and Harrington, 2003). Like other biological macromolecules such as polysaccharides and nucleic acids, proteins are essential parts of organisms and participate in virtually every process within cells. Many proteins are enzymes that catalyze biochemical reactions and are vital to metabolism. Proteins also have structural or mechanical functions, such as actin and myosin in muscle and the proteins in the cytoskeleton, which form a system of scaffolding that maintains cell shape. Other proteins are important in cell signaling, immune responses, cell adhesion and the cell cycle. All proteins in the human body - enzymes, hair, skin, muscles, glands or the cells of the internal organs - consist of amino acids.

Fats and oil

Lipids are a group of substances including fats, oils and fat-like substances, such as cholesterol. All fats are combinations of saturated and unsaturated fatty acids. They provide essential fatty acids, which are not made by the body and must be obtained from food. Fat is one of the three nutrients (along with protein and carbohydrate) that supply energy to the body. When the body has used up the calories from carbohydrate, it begins to depend on the calories from fat. A minimum amount of dietary fat is necessary to facilitate absorption of fat-soluble vitamins (A, D, E and K) and carotenoids (Beresford et al., 2006). Humans and other mammals have a dietary requirement for certain essential fatty acids, such as linoleic acid (an omega-6 fatty acid) and alpha-linolenic acid (an omega-3 fatty acid) because they cannot be synthesized from simple precursors in the diet (Galli and Risé, 2009; Russo, 2009). Both of these fatty acids are 18-carbon polyunsaturated fatty acids differing in the number and position of the double bonds (Table 5).

During pregnancy and lactation, at least 20 to 25% of energy should be derived from fats (WHO, 2000) (Table 2). Additional requirements of fats are needed for development throughout 9 months pregnancy for the fetal and fat storage. Of most importance is the provision of linoleic acid for the fetal development. During lactation, the overall energy of breast milk is supplied by fat in the diet and maternal stores. Breast feeding is physiologically advantageous to the mother in making use of excess fat stored in the body during pregnancy as well as promoting more rapid restoration of size (Lawrence and Lawrence, 2005).

Breast milk and infant formula are important sources of lipids, including essential fatty acids, during infancy. The lipid content of breast milk varies, but after about the first 2 weeks postpartum, breast milk provides approximately 50% of its calories from lipids (Lawrence and Lawrence, 2005). Infant formulas also provide approximately 50% of their calories as fat. Breast milk provides approximately 5.6 g/L of linoleic acid (Food and Nutrition Board, 2005), while infant formulas currently provide 3.3 to 8.6 g/L. In addition, breast milk provides approximately 0.63 g/L of n-3 polyunsaturated fatty acids (Food and Nutrition Board, 2005) (including α-linolenic acid and docosahexaenoic acid). Manufacturers of infant formulas add blends of vegetable oils, which are high in linoleic acid, to improve essential fatty acid content.

Food sources of lipids in older infant's diet, other than breast milk and infant formula, include meats, cheese and other dairy products, egg yolks and any fats or oils added to home-prepared foods. Most vegetable oils are rich in linoleic acid (safflower, sunflower and corn oils). Alpha-linolenic acid is found in the green leaves of plants, and in selected seeds, nuts and legumes (particularly flax, rapeseed, walnut and soy). Fish oils are particularly rich in the longer-chain omega-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Galli and Risé, 2009; Russo, 2009).

A large number of studies have shown positive health benefits associated with consumption of omega-3 fatty acids on infant development, cancer, cardiovascular diseases and various mental illnesses, such as depression, attention-deficit hyperactivity disorder, and dementia (Galli and Risé, 2009; Riediger et al., 2009). Fatty acids are required for normal brain development, healthy skin and hair, normal eye development, and resistance to infection and disease in infants (Kleinman, 2004a). In contrast, it is now well-established that consumption of trans fats, such as those present in partially hydrogenated vegetable oils, are a risk factor for cardiovascular disease (Mozaffarian and Willett, 2007; Dalainas and Ioannou 2008; Micha and Mozaffarian, 2008).

Trans fats are not routinely used in the preparation of infant formulas (Larque et al., 2001). Trans fatty acids are found in fried foods, commercial baked goods (donuts, cookies and crackers) and processed foods. Foods made with hydrogenated oils should be avoided by pregnant women (Mosca et al., 2007). A few studies have suggested that total dietary fat intake is linked to an increased risk of obesity (Astrup, 2005; Astrup et al., 2008) and diabetes (Ma, 2006; Astrup, 2008). However, a

Table 5. Sources of common fatty acids.

Chemical names and descriptions of some common fatty acids				
Common name	**Carbon atoms**	**Double bonds**	**Scientific name**	**Sources**
Butyric acid	4	0	Butanoic acid	Butterfat
Caproic acid	6	0	Hexanoic acid	Butterfat
Caprylic acid	8	0	Octanoic acid	Coconut Oil
Capric acid	10	0	Decanoic acid	Coconut oil
Lauric acid	12	0	Dodecanoic acid	Coconut oil
Myristic acid	14	0	Tetradecanoic acid	Palm kernel oil
Palmitic acid	16	0	hexadecanoic acid	Palm oil
Palmitoleic acid	16	1	9-hexadecenoic acid	Animal fats
Stearic acid	18	0	Octadecanoic acid	Animal fats
Oleic acid	18	1	9-octadecenoic acid	Olive oil
Ricinoleic acid	18	1	12-hydroxy-9-octadecenoic acid	Castor oil
Vaccenic acid	18	1	11-octadecenoic acid	Butterfat
Linoleic acid	18	2	9, 12-octadecadienoic acid	Grape seed oil
Alpha-Linolenic acid (ALA)	18	3	9, 12, 15-octadecatrienoic acid	Flaxseed (linseed) oil
Gamma-Linolenic acid (GLA)	18	3	6, 9, 12-octadecatrienoic acid	Borage oil
Arachidic acid	20	0	Eicosanoic acid	Peanut oil, fish oil
Gadoleic acid	20	1	9-eicosenoic acid	Fish oil
Arachidonic acid (AA)	20	4	5, 8, 11, 14-eicosatetraenoic acid	Liver fats
EPA	20	5	5, 8, 11, 14, 17 eicosapentaenoic acid	Fish oil
Behenic acid	22	0	Docosanoic acid	Rapeseed oil
Erucic acid	22	1	13-docosenoic acid	Rapeseed oil
DHA	22	6	4,7,10, 13, 16, 19-docosahexaenoic acid	Fish oil
Lignoceric acid	24	0	Tetracosanoic acid	Small amounts in most fats

Source: Food and Nutrition Board (2005).

number of very large studies, including the Women's Health Initiative Dietary Modification Trial, an 8 years study of 49,000 women, the Nurses' Health Study and the Health Professionals Follow-up Study, revealed no such links (Beresford et al., 2006; Howard et al., 2006).

Saturated fats are the biggest dietary cause of high low-density lipoprotein (LDL) levels. Saturated fat should be limited to 10% of energy intake (Lichtenstein et al., 2006). When looking at a food label, pregnant women must pay very close attention to the percentage of saturated fat and avoid or limit any foods that are high in them. Saturated fats are found in animal products such as butter, cheese, whole milk, ice cream, poultry, eggs and fatty meats. They are also found in some vegetable oils -- coconut, palm and palm kernel oils. It should be noted that most other vegetable oils contain unsaturated fat and are healthy. Unsaturated fats help to lower blood cholesterol if used in place of saturated fats (Harvard School of Public Health, 2009). However, unsaturated fats have a lot of calories, so pregnant women still need to limit them. Most (but not all) liquid vegetable oils are unsaturated (the exceptions include coconut, palm and palm kernel oils). Two types of unsaturated fats are monounsaturated fats (olive and canola oils) and polyunsaturated fats (fish, safflower, sunflower, corn and soybean oils) (Table 5).

Vitamins

Vitamins are organic components in food that are needed in very small amounts in human diet for normal growth, maintenance of life and normal reproduction. The vitamins include vitamins A, D, E, and K (fat-soluble vitamins), and folate (folic acid), vitamin B_{12}, biotin, vitamin B_6, niacin, thiamin, riboflavin, pantothenic acid, and vitamin C (ascorbic acid) (water-soluble vitamins).

Vitamins are required in the diet in only tiny amounts, in contrast to the energy components of the diet such as sugars, starches, fats, and oils, which occur in relatively large amounts in the diet.

Using the genetic blueprint inherited from its parents, a fetus begins to develop at the moment of conception, from the nutrients it absorbs. It requires certain vitamins and minerals to be present at certain times. These nutrients facilitate the chemical reactions that produce among other things, skin, bone and muscle. Vitamin needs however increase marginally at the second 6 months of infancy compared with the first. If there is serious deficiency in one or more of these nutrients, a child may develop a deficiency disease. Even minor deficiencies may cause permanent damage (Boy et al., 2009).

Vitamin A

Vitamin A (retinol), a fat-soluble lipid, is either derived directly from animal foods such as liver, egg yolks, cream or butter, or is derived from beta-carotene, a pigment that occurs in leafy green vegetables and in yellow fruits and vegetables. Vitamin A is essential to skeletal growth, normal reproductive function, and the health of the skin and mucous membranes. One form, retinal, is a component of visual purple, a photoreceptor pigment in the retina of the eye. Humans can produce some vitamins from precursors they consume. Examples include vitamin A, produced from beta carotene, and niacin, from the amino acid tryptophan (Kutsky, 2003).

The adequacy of vitamin A and vitamin B_6 in human milk is highly dependent upon maternal diet and nutritional status. In well-nourished populations, the amounts of vitamins A and B_6 in human milk are adequate to meet the requirements for infants during the first 6 months of life. The mature milk of well-nourished mothers contains approximately 1.7 mol/L vitamin A (Michaelsen, 2000) (Table 3).

A deficiency of vitamin A can cause retarded skeletal growth, night blindness, various abnormalities of the skin and linings of the genitourinary system and gastrointestinal tract, and, in children, susceptibility to serious infection. The eye disorders that result from a deficiency of vitamin A can lead to permanent blindness. Severe deficiency can cause death. As with the other fat-soluble vitamins, conditions that lead to an inability to absorb fats, such as obstruction of bile flow or excessive use of mineral oil, can produce a deficiency state. Overconsumption of vitamin A can cause irritability, painful joints, growth retardation, liver and spleen enlargement, hair loss, and birth defects (Heird, (2007).

The Food and Nutrition Board, Institute of Medicine recommended daily dietary allowance for adults is 900 µg (retinol equivalents) for men and women (Food and Nutrition Board, 2001) (Table 6). Additional 100 µg per day are required by pregnant women and 350 µg per day by lactating women (WHO, 2000) (Table 3). The recommended vitamin A intake level for infants aged 0 to 6 months was set at 1.4 µmoles/day, while 1.75 µmol/day was set for infants 6 to 12 months based on the intakes of breastfed infants of well-nourished women (Food and Nutrition Board, 2001).

Vitamin B complex

Commonly grouped as the vitamin B complex are eight water-soluble vitamins.

Thiamine: Thiamine (vitamin B_1 or anti beriberi factor) is a necessary ingredient for the biosynthesis of the coenzyme thiamine pyrophosphate; in this latter form it plays an important role in carbohydrate metabolism. Good sources are yeast, whole grains, lean pork, nuts, legumes and thiamine-enriched cereal products. This vitamin is a factor in the maintenance of appetite, normal intestinal function, and in the health of the cardiovascular and nervous systems.

A deficiency of the vitamin may lead to beriberi. Thiamin deficiency can occur in breastfed infants of thiamin-deficient mothers. However, there have been no recent reports of thiamin deficiency in exclusively breastfed infants regardless of their mother's thiamin status (Food and Nutrition, 2000). The RDA for adults is 1.2 to 1.4 mg/day for men, 1.0 to 1.1 mg/day for women, 0.2 mg/day for infants aged 0 to 6 months and 0.3 mg/day for infants aged 7 to 12 months. Additional 0.1 mg/day is required by pregnant women and 0.1 mg/day by lactating women (WHO, 2000).

Riboflavin: Riboflavin (vitamin B_2 or lactoflavin), a water-soluble vitamin, helps the body to release energy from protein, fat and carbohydrates during metabolism. Deficiency leads to growth inhibition, fissures in the corners of the mouth, inflammation of the tongue showing a reddish purple coloration, skin disease and often severe irritation of the eyes.

Food sources of riboflavin include breast milk, infant formula, organ meats, dairy products, egg yolks, green vegetables (for example, broccoli, asparagus and turnip greens), and whole-grain breads, cereals and fortified or enriched grain products. The RDA for adults is 1.3 to 1.7 mg/day for men and 1.2 to 1.3 mg/day for women. Additional 0.1 mg/day is required by pregnant women and 0.3 mg/day by lactating women (WHO, 2000). 0.2 mg/day is recommended for infants aged 0 to 6 months and 0.3 mg/day for infants aged 7 to 12 months.

Niacin: The B_3 vitamins niacin (nicotinic acid) and niacinamide (nicotinamide) are commonly known as preventives of pellagra. Niacin, a water-soluble vitamin, helps the body release energy from protein, fat and carbohydrates during metabolism. The amino acid tryptophan is the precursor of niacin. The need for niacin is normally met in part by the body's conversion of the amino acid tryptophan in the diet to niacin. Niacin and niacinamide function in the biochemistry of humans and other organisms as components of the two coenzymes nicotinamide adenine dinucleotide (NAD) and NAD phosphate (NADP); these operate in many enzyme-catalyzed oxidation and reduction reactions. However, vitamin B_3 (niacin and niacinamide) is not stored in the human body in significant amounts, so stores may last only a couple of weeks (Food and Nutrition Board, 2004).

The deficiency state in humans causes skin disease, diarrhea, dementia and ultimately death. Lean meats,

Table 6. Recommended dietary allowances (RDA) for vitamins and their food sources.

Vitamin	Chemical name (s)	RDA (Age 19 - 70)	Deficiency disease	Food sources
Vitamin A	Retinol, retinal	900 µg	Night-blindness, hyperkeratosis and keratomalacia[	Liver, egg yolks, leafy green vegetables, yellow fruits
Vitamin B_1	Thiamine	1.2 mg	Beriberi, Wernicke-Korsakoff syndrome	Yeast, whole grains, lean pork, nuts, legumes
Vitamin B_2	Riboflavin	1.3 mg	Ariboflavinosis	Organ meats, dairy products, egg yolks, green vegetables
Vitamin B_3	Niacin, niacinamide	16.0 mg	Pellagra	Lean meats, peanuts and other legumes, and whole-grain
Vitamin B_5	Pantothenic acid	5.0 mg	Paresthesia	Liver, kidney, eggs, and dairy products.
Vitamin B_6	Pyridoxine, pyridoxamine, pyridoxal	1.3 - 1.7 mg	Anemia[peripheral neuropathy	Liver and other organs, meats, corn, whole-grain cereal, seeds
Vitamin B_7	Biotin	30.0 µg	Dermatitis, enteritis	Egg yolk, kidney, liver, tomatoes, yeast
Vitamin B_9	Folic acid, folinic acid	400 µg	Megaloblast and deficiency during pregnancy is associated with birth defects, such as neural tube defects	Liver, yeast, green leafy vegetables, fresh fruits, dried beans, avocados, sunflower seeds, wheat germ.
Vitamin B_{12}	Cyanocobalamin, hydroxycobalamin, methylcobalamin	2.4 µg	Megaloblastic anemia	Liver, kidney, chicken, pork, beef, fish, eggs, and dairy products
Vitamin C	Ascorbic acid	90.0 mg	Scurvy	Citrus fruits, tomatoes, berries, white potatoes and sweet potatoes, fresh green and yellow vegetables
Vitamin D	Cholecalciferol	5.0 - 10 µg	Rickets and Osteomalacia	Irradiated yeast, fish liver oils, fortified milk
Vitamin E	Tocopherols, tocotrienols	15.0 mg	Deficiency is very rare; mild hemolytic anemia in newborn infants	Vegetable oils, green leafy vegetables, wheat germ, some nuts, eggs
Vitamin K	Phylloquinone, menaquinones	120 µg	Bleeding diathesis	Cabbage and spinach

Sources: Food and Nutrition Board (2000); Food and Nutrition Board (2001); Food and Nutrition Board (2002).

peanuts and other legumes, and whole-grain or enriched bread and cereal products are among the best sources of niacin. The recommended daily dietary allowance for adults is 16 to 19 mg niacin equivalents (60 mg of dietary tryptophan to 1 mg of niacin) for men, 13 to 14 mg for women, 2 mg for infants aged 0 to 6 months and 4 mg for infants aged 7 to 12 months. Additional 1.1 mg/day is required by pregnant women and 2.7 mg/day by lactating women (WHO, 2000).

Pantothenic acid: Pantothenic acid (vitamin B_5) is present in perhaps all animal and plant tissues, as well as in many microorganisms. Good sources of it include liver, kidney, eggs and dairy products. It is a component of the important substance coenzyme A, which is involved in the metabolism of many biochemical substances including fatty acids, steroids, phospholipids, amino acids and carbohydrates. The adrenal gland is an important site of pantothenic acid activity. There is no known naturally occurring deficiency state and no known toxicity to pantothenic acid. The estimated safe and adequate daily intake for adults is 5 to 7 mg.

Vitamin B_6 group: Pyridoxine, pyridoxal and pyridoxamine make up the vitamin B_6 group. They all combine with phosphorus in the body to form the coenzyme pyridoxal phosphate, which is necessary in the metabolism of amino acids, glucose and fatty acids. The need for this vitamin is directly related to protein intake; as protein intake increases the need for vitamin B_6 in the diet increases. It helps in the formation of red blood cells and in the maintenance of the central nervous system (Mason, 2007).

The best sources of B_6 vitamins are liver and other organs, meats, corn, whole-grain cereal, seeds, breast milk and infant formula. Deficiency can result in central nervous system disturbances (for example, convulsions in infants) due to the role of B_6 in serotonin and gamma-aminobutyric acid synthesis (Boy et al., 2009). More generally, the effects of deficiency include inadequate growth or weight loss and anemia due to the role of B_6 in the manufacture of hemoglobin.

The RDA for adults is 1.3 to 2.2 mg for men and 2 mg for women. Additional doses are required in pregnancy and by those taking oral contraceptives or the tuberculosis drug. Severe nerve damage has been reported from megadoses (Boy et al., 2009). The daily B_6 intakes of infants 1 to 6 months of age who consume at least 780 ml/day of human milk with a B_6 concentration of 0.13 mg/L should as expected, meet the 0.1 mg/day estimated AI for this age group (Food and Nutrition Board, 2000).

Biotin: Biotin (vitamin B_7) is a vitamin that functions as a coenzyme in the metabolism of carbohydrates, fats and amino acids. Although, it is vitally necessary to the body, only exceedingly small quantities are needed, and since biotin is synthesized by intestinal bacteria, naturally occurring biotin deficiency disease is virtually unknown. The disease state can be produced artificially by including large quantities of raw egg white in the diet; the whites contain avidin, a biotin antagonist. Especially good sources of this widely distributed vitamin include egg yolk, kidney, liver, tomatoes and yeast. There is no known toxicity to biotin. The estimated safe and adequate daily intake for adults is 10 to 30 mg.

Folic acid: Folic acid (pteroylglutamic acid, folacin or vitamin B_9) is a yellowish-orange compound, $C_{19}H_{19}N_7O_6$, of the vitamin B complex group, occurring in liver, yeast, green leafy vegetables, fresh fruits (for example, apples and oranges), dried beans, avocados, sunflower seeds and wheat germ. At times folate is referred to as folic acid. Both are forms of the same B-vitamin, but they come from different sources. Folate occurs naturally in foods while folic acid is a synthetic form of the vitamin that is added to foods and supplements. Derivatives of this vitamin are directly involved in the synthesis of nucleic acids; for this reason cells in the body that are subject to rapid synthesis and destruction are especially sensitive to folic acid deprivation.

Adequate folate intake during the preconception period, the time right before and just after a woman becomes pregnant, helps protect against a number of congenital malformations, including neural tube defects (which are the most notable birth defects that occur from folate deficiency) (Thompson et al., 2001). Neural tube defects produce malformations of the spine, skull and brain including spina bifida and anencephaly. The risk of neural tube defects is significantly reduced when supplemental folic acid is consumed in addition to a healthy diet prior to and during the first month following conception (Mulinare et al., 2008; Milunsky et al., 2009). Folate deficiency during pregnancy may also increase the risk of preterm delivery, infant LBW and fetal growth retardation, as well as increasing homocysteine level in the blood, which may lead to spontaneous abortion and pregnancy complications, such as placental abruption and pre-eclampsia (Scholl and Johnson, 2000).

Women who could become pregnant are advised to eat foods fortified with folic acid or take supplements in addition to eating folate-rich foods to reduce the risk of serious birth defects (Wilton and Foureur, 2010). Supplementation with folic acid has also been shown to reduce the risk of congenital heart defects, cleft lips (Wilcox et al., 2007), limb defects and urinary tract anomalies (Goh and Koren, 2008). Taking 400 µg of synthetic folic acid daily from fortified foods and/or supplements has been suggested. The RDA for folate equivalents for pregnant is 600 to 800 µg, twice the normal RDA of 400 µg for women who are not pregnant (Food and Nutrition Board, 2000). The recommended daily dietary allowance for lactating women is 500 µg (Table 7) and 65 µg for infants ages 0 to 6 months and 80 µg for ages 7 to 12 month (Table 8).

Vitamin B_{12}: Vitamin B_{12} (cobalamin), plays a vital role in the activity of several enzymes in the body. It has an important role in the development of genetic material in the body, and a crucial role in growth and development, production of red blood cells, functioning of the nervous system, and utilization of folic acid. Sources include liver,

Table 7. Recommended dietary allowances for folate in children and adults.

Age (Years)	Males and females (μg/day)	Pregnancy (μg/day)	Lactation (μg/day)
1-3	150	N/A	N/A
4-8	200	N/A	N/A
9-13	300	N/A	N/A
14-18	400	600	500
19+	400	600	500

N/A, Not available. Source: Food and Nutrition Board (2000).

Table 8. Adequate Intake for folate in infants.

Age (Months)	Males and females (μg/day)
0-6	65
7-12	80

Source: Food and Nutrition Board (2000).

kidney, chicken, pork, beef, fish, eggs and dairy products.

Vitamin B_{12} status at birth is strongly associated with the mothers' vitamin B_{12} status and the number of previous pregnancies (Monsen et al*.,* 2001). After birth, the exclusively breastfed infants vitamin B_{12} intake depends on the mother's intake and stores. Concentrations of vitamin B_{12} in breast milk are adequate as long as the maternal diet is adequate. However, infants of breastfeeding mothers who follow strict vegetarian (vegan) diets or eat very few dairy products, meat, or eggs are at risk for developing vitamin B_{12} deficiency. In these infants, vitamin B_{12} status may be abnormal by 4 to 6 months of age (Food and Nutrition Board, 2000).

Signs of vitamin B_{12} deficiency in infancy include failure to thrive, movement disorders, delayed development, sore mouth and tongue, damage to the spinal cord such as numbness, tingling in the limbs, loss of memory and megaloblastic anemia. The Institute of Medicine's Food and Nutrition Board recommended that infants of vegan mothers be supplemented from birth with vitamin B_{12} at the AI for age (0 to 6 months, 0.4 μg/day; 7 to 12 months, 0.5 μg/day) (Food and Nutrition Board, 2000). The recommended daily dietary allowance for adults is 2.4 μg with additional 0.4 μg/day for pregnant women and 0.3 μg/day for lactating women (WHO 2000).

Vitamin C

Vitamin C or ascorbic acid, a water-soluble vitamin, was first isolated from adrenal cortex, oranges, cabbage and lemon juice. Citrus fruits and tomatoes are excellent sources. Other good sources include berries, fresh green and yellow vegetables, and white potatoes and sweet potatoes. The vitamin is readily oxidized and therefore is easily destroyed in cooking and during storage. All animals except humans, guinea pigs and one bat and bird species are able to synthesize ascorbic acid.

Ascorbic acid is necessary for the synthesis of the body's cementing substances: bone matrix, collagen, dentin and cartilage. It is one of many antioxidants. Vitamin E and beta-carotene are two other well-known antioxidants. Antioxidants are nutrients that block some of the damage caused by free radicals, which are by-products that result when the bodies transform food into energy. The buildup of these by-products over time is largely responsible for the aging process and can contribute to the development of various health conditions such as cancer, heart disease and a host of inflammatory conditions like arthritis (Farrell, 2006; Anderson, 2007). Antioxidants also help reduce the damage to the body caused by toxic chemicals and pollutants such as cigarette smoke (Johns and Eyzaguirre, 2000).

Deficiency of vitamin C results in scurvy, the symptoms of which are largely related to inadequate collagen synthesis and defective formation of intercellular materials. Ascorbic acid is metabolized slowly in humans, and symptoms of scurvy are usually not seen for 3 or 4 months in the absence of any dietary vitamin C. The recommended daily allowance for adults is 90 mg and for age (0 to 6 months, 0.4 μg/day; 7 to 12 months, 0.5 μg/day) (Food and Nutrition Board, 2001). Additional 20 mg/day is recommended for both pregnant women and lactating women (WHO 2000).

Vitamin D

Vitamin D is a name given to two fat-soluble compounds: calciferol (vitamin D_2) and cholecalciferol (vitamin D_3). They are now known to be hormones, but continue to be grouped with vitamins because of historical mis-classification. Vitamin D_3 plays an essential role in the metabolism of calcium and phosphorus in the body and prevents rickets in children. A plentiful supply of 7-dehydrocholesterol, the precursor of vitamin D_3, exists in human skin and needs only to be activated by a moderate amount of ultraviolet light (less than a half hour of sunlight) to become fully potent. Rickets is usually caused by a lack of exposure to sunlight rather than a dietary deficiency, although dietary deficiencies can result from malabsorption in the small intestine caused by conditions such as colitis. Rickets can be prevented and its course halted by the intake of vitamin D_2 (found in irradiated yeast and used in some commercial preparations of the vitamin) or vitamin D_3 (found in fish liver oils and in fortified milk).

The vitamin *D* content of human milk is insufficient to meet infant requirements. Infants depend on sunlight exposure or exogenous intakes of vitamin D; if these are inadequate, the risk of vitamin D deficiency rises with age as stores become depleted in the exclusively breastfed infant. Symptoms of vitamin D deficiency in children include bowlegs, knock knees, and more severe (often crippling) deformations of the bones. When deficiency occurs early in infancy, the bone may be too weak to carry the weight of the child resulting in skeletal deformation. In adults deficiency results in osteomalacia, characterized by a softening of the bones. Excessive vitamin D consumption can result in toxicity (Heird, 2007). Symptoms include nausea, loss of appetite, kidney damage, and deposits of insoluble calcium salts in certain tissues.

The recommended daily dietary allowance for cholecalciferol is 5 to 10 µg (200 to 400 IU) depending upon age and the availability of sunlight. Additional 7.5 µg (300 IU)/day is recommended for both pregnant women and lactating women (WHO 2000). Fortified cow's milk supplies 400 IU per quart (422 IU/L). The United States Food and Nutrition Board (Food and Nutrition Board, 2002) recommended 5 µg of vitamin D for infants 0 to 6 months of age, although it also acknowledges that breastfed infants “with habitual small doses of sunshine” do not require supplemental vitamin D. Infants in far northern latitudes or those with minimal sunlight exposure require a minimum of 2.5 µg/day (100 IU) to prevent rickets.

Vitamin E

Vitamin E (tocopherol) occurs in at least eight molecular forms (tocopherols or tocotrienols); in humans the most biologically active form has generally been considered to be alpha-tocopherol, which is also the most common. All forms exist as light yellow, viscous oils. The best sources are vegetable oils. Other sources include green leafy vegetables, wheat germ, some nuts and eggs. Vitamin E can be destroyed through processing and cooking. It is necessary for the maintenance of cell membranes. It is a potent antioxidant; numerous studies have pointed to a protective effect against arterial plaque buildup and cancer. It is helpful in the relief of intermittent claudication (calf pain) and in preventing problems peculiar to premature infants (Heird, 2007). In large doses, it has an anticoagulant effect. The recommended daily dietary allowance for adults is 15 mg (tocopherol equivalents) for men and 8 mg for women, but nutritionists and physicians sometimes recommend higher doses for disease prevention.

Vitamin K

Vitamin K (phylloquinone) consists of substances that are essential for the clotting of blood. Two types of K vitamins have been isolated: K_1, an oil purified from alfalfa concentrates and K_2, synthesized by the normal intestinal bacteria. Both can be derived from the synthetic compound menadione (sometimes called vitamin K_3), a yellow crystalline solid that is as potent in its ability to promote blood clotting as the natural vitamins. The best sources are leafy green vegetables, such as cabbage and spinach, and intestinal bacteria (which produce most of the body's supply of vitamin K). Vitamin K is required for the synthesis in the liver of several blood clotting factors, including prothrombin.

In the deficiency state an abnormal length of time is needed for the blood to clot, and there may be hemorrhaging in various tissues. Deficiency occurs in hemorrhagic disease of the newborn infant, in liver damage, and in cases where the vitamin is not absorbed properly by the intestine. However, vitamin K deficiency in breastfed newborns remains a major worldwide cause of infant morbidity and mortality. Infants have very little stored vitamin K at birth, and the gut is nearly sterile during the first few days of life. As a result, infants can develop a severe bleeding condition known as hemorrhagic disease of the newborn if they do not obtain vitamin K during the first few days of life from an exogenous source, particularly since mother's milk contains little vitamin K and few bacteria other than those it picks up from maternal skin as an infant suckles It can also occur in coumarin therapy or when normal intestinal bacteria are destroyed by extended antibiotic therapy. Coumarin derivatives, used in medicine to prevent blood coagulation in certain cases, act by antagonizing the action of vitamin K. Vitamin K does not treat hemophilia. Deficiency is rarely of dietary origin. The estimated safe and AI for adults is 120 to 140 µg and for infants age (0 to 6 months, 2.0 µg/day; 7 to 12 months, 2.5 µg/day) (Food and Nutrition Board, 2001).

Minerals

Dietary minerals are the chemical elements required by living organisms, other than the four elements carbon, hydrogen, nitrogen and oxygen present in common organic molecules. Examples include calcium, magnesium, potassium, sodium, zinc and iodine (Table 9). The essential minerals for the control of the body processes and good health are phosphorous and calcium which are macro-minerals and iron, and iodine, which are micro-minerals.

Dietary elements are best supplied by ingesting specific foods rich with the chemical element(s) of interest. The elements may be naturally present in the food (for example, calcium in dairy milk) or added to the food (for example, orange juice fortified with calcium; iodized salt, salt fortified with iodine).

Phosphorus

Phosphorus is a component of bones and cells. It also functions in energy processing. In biological contexts, it is

Table 9. Recommended dietary allowance (RDA) for dietary elements and their sources.

Dietary element	RDA/AI	Description	Food sources
Calcium (mg)[a]	1300	Quantity	Milk, canned fish with bones, leafy green vegetables, nuts and seeds
Phosphorus (mg)[a]	1250	Quantity	Meat, fish, milk and milk products, eggs, cereal grains, wheat germ
Magnesium (mg)[a]	420	Quantity	Nuts, soy beans, cocoa mass
Zinc (mg)[b]	11	Trace	Meat, poultry, liver, egg yolks, cheese, yoghurt, legumes, cereals
Iron (mg)[b]	18	Trace	Liver, meat, egg yolk, legumes, apricots, whole grain cereals
Manganese (mg)[b]	2.3	Trace	Leafy green vegetables, fruits, nuts, whole grains
Copper (µg)[b]	900	Trace	Cereals, legumes, livers, fruits, leafy green vegetables, nuts, poultry.
Iodine (µg)[b]	150	Trace	Cray fish, shrimps, crabs, salt water fish, vegetables, legumes, cereals
Molybdenum (µg)[b]	45	Trace	Pork, lamb, beef liver, green beans, eggs, sunflower seeds, cucumbers

Source: [b] Food and Nutrition Board *(*2001); [a] Food and Nutrition Board (2002).

usually seen as phosphate. Phosphorus rich foods include high protein foods such as meat, fish, milk and milk products and eggs. Other sources include cereal grains; especially wheat germ and whole grains. The RDA for phosphorus is 1250 mg (Food and Nutrition Board, 2002) (Table 9).

Calcium

Calcium is needed for healthy muscle, heart and digestive system. It builds bone, supports the synthesis and proper function of blood cells. Foods rich in calcium include milk and milk products, canned fish with bones (salmon, sardines), leafy green vegetables, broccoli, nuts and seeds. Human milk contains 197 to 266 mg/L of calcium with no pronounced changes during lactation Michaelsen, 2000) (Table 3). Based on the estimated calcium intakes of exclusively breastfed infants and an estimated absorption efficiency of >70%, human milk meets the calcium requirements of infants during the first 6 months of life. Children who consume little or no dairy products are at particular risk for calcium deficiency that can interfere with bone growth and development. The RDA for calcium is 1300 mg (Food and Nutrition Board, 2002). Additional 0.6 to 0.7 mg/day is recommended for both pregnant women and lactating women (WHO 2000).

Iron

Iron is required for many proteins and enzymes, notably hemoglobin to prevent anemia. Iron-deficiency anaemia, the late manifestation of chronic iron deficiency, is the most common nutrient deficiency among pregnant women (WHO, 2001). Iron deficiency involves an insufficient supply of iron to the cells following depletion of the body's reserves (Beard, 2000) and its main causes are a diet poor in absorbable iron, an increased requirement for iron (for example, during pregnancy), a loss of iron due to parasitic infections, particularly hookworm, and other blood losses (Crompton and Nesheim, 2002; INACG, 2002).

Pregnancy requires a large intake of iron especially during the last 6 months. During the 300 days of human pregnancy, 400 mg iron enters the fetus and 500 mg enters the placenta (Knuppel, 2007). Because of widespread incidence of anaemia, a dose of ferrous salt containing at least 60 mg of elemental iron may be taken once daily during the second and third trimester of pregnancy and the first six months of lactation (Food and Nutrition Board, 2001; WHO, 2006; Hamrick and Counts, 2008). Sources of iron include liver which is an excellent source, meat, egg yolk, legumes and dried fruits such as apricots. Enriched breakfast cereals and whole grain cereals contain appreciable amounts of iron.

Human milk, which is a poor source of iron and zinc, cannot be altered by maternal supplementation with these two nutrients. The concentration of iron in human milk declines from ~0.4 to 0.5 mg/L in colostrum to ~0.3 to 0.4 mg/L in mature human milk (Michaelsen, (2000) (Table 3) The newborn infant is well endowed with iron stores and a high concentration of haemoglobin. The iron endowment at birth meets the iron needs of the breastfed infant in the first half of infancy, that is, 0 to 6 months. If an exogenous source of iron is not provided, exclusively breastfed infants are at risk of becoming iron deficient during the second half of infancy. The first 3 to 4 months of lactation appear to be the period of most rapid change in the concentrations of most nutrients. Total body iron of infants is relatively stable from birth to 4 months of age, but the proportion of body iron in distinct compartments (for example, red blood cells, myoglobin and stores) shifts dramatically as stores are depleted and demands for iron increase to meet needs imposed from 4 to 12 months of age by expanding red blood cell and myoglobin compartments. In the first 6 to 8 weeks of life, there is a marked decline in haemoglobin from the highest to the lowest observed during development due to the abrupt decrease in erythropoiesis in response to increased postnatal delivery of oxygen to tissues (WHO, 2001).

Table 10. Recommended dietary allowance (RDA) for iron by age and sex.

Age/Group	Life stage	Iron (mg/day)
Infants	0 - 6 months	0.5
	7 - 12 months	1.1
Children	1 - 3 years	7
	4 - 8 years	10
Males	9 - 13 years	8
	14 - 18 years	11
	19 - 30 years	8
	31 - 50 years	8
	51 - 70 years	8
	>70 years	8
Females	9 -13 years	8
	14 -18 years	15
	19 - 30 years	18
	31 - 50 years	18
	51 - 70 years	8
	>70 years	8
Pregnant women	14 - 18 years	27
	19 - 30 years	27
	31 - 50 years	27
Lactating women	14 - 18 years	10
	19 - 30 years	9
	31 - 50 years	9

Source: Food and Nutrition Board (2001).

Iron requirements vary by age, rate of growth, iron stores, increasing blood volume and rate of absorption from food sources (IOM, 2001; WHO, 2001). Iron requirements thus rise markedly around 4 to 6 months of age (WHO, 2001). Because of the considerable iron requirement for growth and the marginal supply of iron in infant diets, iron deficiency is prevalent among infants between 6 and 12 months of age. These requirements are very high relative to infants' energy requirements at this age. Iron requirements are estimated to be 0.5 mg/day for infants from 0 to 6 months of age and 1.1 mg/day for infants 6 to 12 months of age. The recommended daily dietary allowance for pregnant women is 27 mg/day and for lactating woman is 10 mg/day (Food and Nutrition Board, 2001). The RDA for iron by age and sex is shown in Table 10.

Iodine

Iodine is required not only for the synthesis of thyroid hormones, thyroxine and triiodothyronine and to prevent goiter, but also, probably as an antioxidant, for extra thyroidal organs as mammary and salivary glands and for gastric mucosa and immune system (thymus). Food sources of iodine include sea foods such as cray fish, shrimps, crabs and salt water fish. Plant sources include leafy green vegetables, legumes and cereal grains. The RDA for iodine is 150 µg/day (Food and Nutrition Board, 2001). Although a pregnant woman's total iodine level is lower than that of a non-pregnant woman, there may be an increased need for iodine during pregnancy. Additional 50 mg/day is recommended for both pregnant women and lactating women (WHO, 2000).

INFANTS FEEDING

Birth to 4 months of age

During the first 4 to 6 months of life, infants need only breast milk or formula to meet all their nutritional needs (Rockville, 2005; Heird, 2003). The beneficial effects of colostrum in breast milk are especially important; infants should be breastfed on demand from birth. If breast-feeding, a newborn may need to be fed 8 to 12 times per day (every 2 to 4 h), or on demand. By 4 months, the baby is likely to cut back to 4 to 6 times per day. However, the quantity of breast milk consumed at each feeding will increase.

Cow's milk is not recommended for children under 1 year old (Rockville, 2005; Heird, 2003). Cow's milk, goat's milk and soy-based beverages (for example, soy milk) contain relatively little iron or the iron they contain is poorly absorbed by infants. These milks can promote the development of iron-deficiency anemia by causing microscopic gastrointestinal bleeding and nutritionally significant blood loss in infants (Kleinman, 2004b) and disappears by 12 months of age (Jiang et al., 2000). For this reason, cow's milk, goat's milk or soy-based beverages are not recommended for infants less than 12 months old (Kleinman, 2004b).

4 to 6 months of age

At 4 to 6 months of age, an infant should be ready to start the transition to solid foods. Solid feedings with iron-fortified baby rice cereal mixed with breast milk or formula are recommended. Once the baby is eating rice cereal routinely, other iron-fortified instant cereals may be introduced. Some fruit juices, such as prune, apple and pear, contain a significant amount of sorbitol and proportionally more fructose than glucose. Infants can absorb only a portion of the sorbitol (as little as 10%) and fructose in these juices (Lifschitz, 2000). Unabsorbed carbohydrate is in these juices (Lifschitz, 2000). Unabsorbed carbohydrate is fermented in the lower intestine causing diarrhea, abdominal pain, or bloating. These symptoms are commonly reported in infants and toddlers who drink excessive amounts of juice. For this reason, infants up to 6 months of age should not be offered fruit juice.

6 to 8 months

At 6 months of age, infants should start to receive complementary foods in addition to breast milk. These should be safely prepared from locally available foods that are rich in energy and micronutrients to meet the infants' changing nutritional requirements. The baby will begin taking less formula or breast milk once solid foods become a source of nutrition. Furthermore, cereals, pulses and oil do not by themselves readily meet the nutritional needs of young children. After a baby has tried a variety of different baby cereals, plain vegetables such as green peas, potatoes, carrots, sweet potatoes, squash, beans, beets; and plain fruits such as bananas, applesauce, apricots, pears, peaches, and melon should be given (Heird, 2003).

8 to 12 months of age

Breast milk or formula should be offered 3 to 4 times per day at this age. A baby will be ready to try strained or finely chopped meats. For breastfed infants, meats can be started at 8 months of age (breast milk is not a rich source of iron, but infants have adequate iron stores to last until 8 months of age (WHO, 2001) when iron-rich foods such as meats can be given). Eggs may be given 3 to 4 times per week, but only the yolk until the baby is 1 year old. This is in agreement with the National Cholesterol Education Program of the American Academy of Pediatrics (AAP) recommendation which stated that "no restriction of fat and cholesterol is recommended for infants <2 years when rapid growth and development require high energy intakes" (Owen et al., 2002).

The fast growth of infants requires an energy-dense diet with a higher percentage of kilojoules from fat than is needed by older children. Low-fat or nonfat milk, yoghurt, and cheeses are good sources of calcium that should be given. Other foods such as broccoli, cooked greens and canned salmon (with bones) will also provide a source of calcium in the diet.

1 year of age

After a baby is 1 year old, whole milk may replace breast milk or formula. Children under the age of 2 should not be given low-fat milk (2%, 1% or skim) as they need the additional energy from fat to ensure proper growth and development (Heird, 2003). During the complementary feeding period, older infants and young children require foods that are easily digestible. Equally important, complementary foods used during this period should provide adequate amounts of fats and oils (30 to 40% of energy should come from fat) (Heird, 2003). The period from ages 6 to 24 months is the most critical for a young child because of rapid growth and an increasing reliance on complementary food. Therefore, energy derived from protein should be at least 12%. And these young children must have access to foods rich in micronutrients for sufficient growth and development. The 1 year old child should be getting much of their nutrition from meats, fruits and vegetables, breads and grains, and the dairy group, especially whole milk (Heird, 2003).

Providing a variety of foods will help to ensure enough vitamins and minerals. Toddlers do not grow as rapidly as babies do, so their nutritional needs relative to their size decrease during the second year of life. Although they continue to gain weight, they no longer double their weight as infants do (Fishman et al., 2004). Toddlers are becoming more and more active as they learn to crawl and walk. Toddlers and small children will usually eat only small amounts at one time, but will eat frequently throughout the day. Water can be offered between feedings. Feeding sweets or sweetened beverages is not recommended because they will contribute to tooth decay. Salt, sugar, strong spices and caffeine products (soft drinks, coffee, tea and chocolate) are not also recommended (Heird, 2003).

RECOMMENDATIONS

Nutrition before pregnancy

There are foods that may decrease the fertility such as high mercury fish, foods that contain trans fat and consuming too much caffeine. High levels of mercury in the body can cause challenges with fertility and it can be harmful to the developing fetus. Some high mercury fish which should be avoided may include swordfish, mackerel and shark. Trans fat can also be very harmful to fertility. The more trans fat in a woman's diet, the higher her chances of developing ovulatory infertility. Trans fats are found in processed and fried foods that include packaged foods, food fries, donuts, and margarine. Too much caffeine, such as three or more cups a day, can lower fertility and increase the rate of miscarriage (Murkoff, 2010).

As with most situations, the most important factor in pre-pregnancy nutrition is ensuring that the mother is healthy and without any major factors which could worsen the chances of conceiving. Factors such as anorexia or bulimia are thought to be direct links with infertility. The minimum body mass index for conceiving mothers is 20.8. Gaining weight restores fertility and a body fat content of at least 22% is necessary for normal ovulatory function and menstruation (Williamson, 2006).

Potentially harmful determinants during pregnancy

It is advised for pregnant women to pay special attention to food hygiene during pregnancy in addition to avoiding certain foods in order to reduce the risk of exposure to substances that may be harmful to the developing fetus. This can include toxic food components, alcohol, dietary supplements such as vitamin A and food pathogens such as listeria, taxoplasmosis and salmonella (Williamson, 2006).

Excessive amounts of alcohol have been proven to cause fetal alcohol syndrome. The WHO recommended that alcohol should be avoided entirely during pregnancy, given the relatively unknown effects of even small amounts of alcohol during pregnancy (Stratton et al., 2006). Dietary vitamin A is obtained in two forms which contain the preformed vitamin (retinol), that can be found in some animal products such as liver and fish liver oils, and as a vitamin A precursor in the form of carotenes, which can be found in many fruits and vegetables (Williamson, 2006). Intake of retinol, in extreme cases, has been linked to birth defects and abnormalities (Heird, (2007). However, regular intake of retinol is not seen as dangerous. It is noted that a 100 g serving of liver may contain a large amount of retinol, so it is best that it is not eaten daily during pregnancy, something which is also the same with alcohol intake.

Pregnant women are advised to avoid foods in which high levels of the bacteria have been found, such as in soft cheeses. Listeria are destroyed by heat and therefore pregnant women are advised to reheat ready-prepared meals thoroughly. Pregnant women should also wash their fruit and vegetables very thoroughly in order to minimize risk. Salmonella poisoning is most likely to come from raw eggs or undercooked poultry (Williamson, 2006).

Maternal obesity has a significant impact on maternal metabolism and offspring development (Nelson et al., 2010). Insulin resistance, glucose homeostasis, fat oxidation and amino acid synthesis are all disrupted by maternal obesity and contribute to adverse outcomes (Astrup et al., 2008; Nelson et al., 2010). Modification of lifestyle is an effective intervention strategy for improvement of maternal metabolism and the prevention of adverse outcomes (Nelson et al., 2010).

Nutrition after pregnancy

Proper nutrition is important after delivery to help the mother recover, and to provide enough food energy and nutrients for a woman to breastfeed her child. Women having serum ferritin <70 µg/L may need iron supplements to prevent iron deficiency anaemia during pregnancy and postpartum (Milman et al., 2005; Milman et al., 2006).

Conclusion

Good nutrition is essential for the growth and development that occur during pregnancy and infant's first year of life. When mothers and developing infants are fed the appropriate types and amounts of foods, their health is promoted. Positive and supportive feeding attitudes demonstrated by the mothers help infants to be healthy and active. Maternal and infant survival is one of the most important and socially sensitive indicators of human development necessary to perpetuate the family and the society. It is imperative that the utmost attention is given to raising awareness about adequate nutrition for mothers and infants. To this end, a steady flow of financial and structural supports should be allocated to improve access to food and nutrition education for women in order to reduce maternal and infant mortality.

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