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Lifecycle 1: Maternal and Infant Nutrition

Section 1: Pregnancy

Overview Fetal Nourishment
Nutrient Needs Macronutrients
Maternal Concerns

Section 2: Nutrient Needs

Fat-soluble Vitamins Water-soluble Vitamins
Minerals/Trace Elements Maternal Diet

Section 3: Lactation

Overview Lactation Physiology
Milk Synthesis Milk Composition
Beneficial Components Quantity/Quality

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Growth and Development Nutrients for Growth
Micronutrients Nutrition Assessment

Section 5: Special Needs

Preterm Concerns Malabsorption
Special Needs

Maternal and Infant Nutrition

OVERALL PROGRAM OBJECTIVES:

After completing this module on Maternal and Infant Nutrition, you should be able to:

Cite maternal and fetal nutrient requirements in pregnancy and maternal requirements during lactation.

Describe the physiology of nutrient transfer from mother to fetus.

Characterize nutritional consequences of placental insufficiency.

Assess and advise pregnant or lactating women on their dietary needs and habits.

Describe human milk production, regulation, nutritional composition, and benefits.

Relate nutrient requirements during early infancy to growth and development.

Explain feeding and nutritional concerns for low birth weight infants.

Section 1: Overview

Importance of preconceptional nutrition

Optimal preconceptional nutrition lowers risk of birth defects.

The embryo is particularly vulnerable during the first few weeks when organs are formed. Severe birth defects may be caused by low intakes of vitamins needed for DNA synthesis, especially folate, vitamin B12 and B6, often in conjunction with genetic variants affecting vitamin metabolism. Excess retinol intake, on the other hand, increases the risk for heart and other organ defects.

Nutrient source for fetus

Nutrients are provided by chorionic fluid first, later via placenta.

During the first weeks the embryo gets all nutrients from fluids secreted by the chorion into the chorionic sac which envelops the embryo. Glucose, amino acids, vitamins and other essential compounds are absorbed by the embryo's yolk sac, by both passive and active transport mechanisms. Towards the end of the first trimester the placenta takes over the maternal-fetal exchange of nutrients, fluids and gases.

NOTES:

Section 1: Pregnancy continued

Meeting fetal nutrient needs

Maternal diet and nutrient stores together provide for fetal needs.

Pregnancy increases the requirement for some, but not all, nutrients; folate and iron needs increase dramatically. Energy needs increase only during the second and third trimester by 10-15 % (about 300 kcal/day). Maternal stores (especially iron and B12) are important to cover some of the additional nutrient needs of pregnancy. Lack of sufficient energy, protein and micronutrients can interfere with fetal brain and other organ development. Regardless of pre-pregnancy weight, all pregnant women need to gain some weight during pregnancy. The average recommended weight gain is between 25-35 lbs (11-16 kg).

Glucose is primary energy source

Most nutrient energy is transferred to the fetus as glucose.

Glucose is the main fetal energy source, transported across the placenta following the concentration gradient. Maternal endocrine adaptation causes moderate insulin resistance and hyperglycemia which favors glucose transfer to the fetus. Glucose transport across placenta is not insulin sensitive.

NOTES:

Amino acid transfer

Placental syntrophoblast controls amino acid transfer to fetus.

Maternal amino acids are partially metabolized in the syntrophoblast layer of the placental membrane and are transferred with several specific transporters.

Fat transfer

Receptors mediate fatty acid and lipid transfer to the fetus.

Fatty acids, cholesterol and other lipophilic substances enter the syntrophoblast via specific receptors and are secreted into fetal blood with newly synthesized lipoproteins. Docosahexaenoic acid (DHA) and other essential fatty acids are especially critical for brain growth.

NOTES:

Section 2: Nutrient Needs

Retinol generation

Retinol is generated by cleavage of specific dietary carotenoids.

The three forms of fat-soluble vitamin A have distinct functions: retinal (vision), retinol (transport, storage and cellular action), retinoic acid (cell differentiation and proliferation). Once they are taken up into enterocytes, beta-carotene and a few other carotenoids can be cleaved enzymatically to form retinol. Retinol deficiency causes night blindness and skin disease, slows fetal growth during pregnancy. High maternal intake of preformed retinol may cause fetal organ malformations.

Transport of vitamins A and D

Some fat soluble vitamins (A & D) are transported via specific proteins to the fetus.

The 1:1:1 complexes of retinylesters, retinol-binding protein and transthyretin from maternal blood are taken up by specific receptors into the syntrophoblast and then secreted into fetal blood. Vitamin D complexed with vitamin D-binding protein is transported in a similar manner across the placenta. Vitamin E and vitamin K are taken up with lipoproteins from maternal circulation and secreted into fetal blood with newly synthesized lipoproteins.

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Riboflavin function

Riboflavin optimizes folate, niacin, pyridoxine utilization.

Many vitamins are transferred to the fetus for fetal stores in the latter part of pregnancy, although they may play important developmental roles throughout gestation. The flavin nucleotides FAD and FMN are part of many flavoproteins with roles in oxidative phosphorylation and other redox reactions, including the activation of folate, niacin, and pyridoxine (B6). Riboflavin (B2)-rich foods include dairy products and fortified cereals. Symptoms of B2 deficiency include skin changes and anemia. A specific riboflavin-carrier protein is needed for transfer across the placenta.

Iron absorption

Deficiency and pregnancy increase intestinal iron absorption.

Intestinal absorption of both heme and non-heme iron increases with pregnancy, and when iron stores are low. Iron is absorbed best when eaten in a meal with fruits or vegetables (containing ascorbate and organic acids), and less well when eaten with phytate-rich whole grain foods or black tea.

NOTES:

Section 2: Nutrient Transfer continued

Minerals & trace elements

Minerals and trace elements like iodine are critical to fetal development.

Many minerals and trace elements are transferred to the fetus for fetal stores in the latter part of pregnancy, although they may play important developmental roles throughout gestation. The production of thyroid hormones is dependent on adequate maternal iodine intake. Iodine deficiency can lead to birth defects, slow mental development (cretinism), enlarge the thyroid gland (goiter), and cause fetal death (stillbirth). While not a common concern in the US due to fortification of salt, it is a major public health concern in underdeveloped countries. Another good source of iodine is seafood.

Dietary assessment

Dietary patterns should be examined for adequacy or other problems.

Prospective mothers often have many concerns about adequate nutrition and the effect of pregnancy on their bodies, including food aversions or cravings, constipation, and sweetener or salt use. Excessive alcohol or caffeine use, hyperemesis, pica and veganism are important nutritional concerns which should be addressed. Vegan diets often lack iron, B12, vitamin D, zinc and calcium, which can be obtained in fortified foods or via supplementation.

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Section 3: Lactation

Advantages of breastfeeding

Breastfeeding offers unique advantages beyond nutrition to the infant.

Breastfeeding (BF) is the gold standard in infant feeding. It affords many benefits to the infant, including optimal nutrition, reduced incidence and severity of infectious gastrointestinal disease, as well as some respiratory and ear infections. BF protects against food allergies, and improves mental, cognitive, and visual development, especially in pre-term infants. BF can be continued through most illnesses, procedures, and while on most medications. The longer the duration of breastfeeding, the more benefits conferred. Current guidelines recommend breastfeeding for the first six months to 1 year of life.

Milk production

Milk production is not significantly affected by maternal diet.

For women consuming a varied diet, milk production is not significantly affected by diet. Volume and protein content remain surprising constant across populations. Milk components are synthesized from maternal diet and stores in the mammary epithelium and secreted into the alveoli. Except for a few components (vitamins/trace elements, fatty acid profile) maternal diet does not greatly influence milk composition. Fatty acid composition is dependent upon maternal intake. Lactating women need additional calories, ~500 kcal/day, and adequate fluids. The increase in RDA for several nutrients are usually met by the increased intake.

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Section 3: Lactation continued

Human milk

Generally, human milk is the only nutrition an infant needs until 4 to 6 months. With the exception of vitamin K, and possibly vitamin D, a full-term infant can generally meet all nutritional requirements from human milk, along with the infant's own stores. No additional fluids or foods are needed during the first 4 to 6 months. Vitamin D content of human milk may be inadequate for some infants, especially if they are dark-skinned or have limited exposure to sunlight, and may require supplementation. If the lactating mother is vegan, supplemental Vitamin B12 is suggested for the mother. Any breastfed infant with limited exposure to sunlight may need vitamin D supplements.

Requirements for effective nursing

Effective nursing requires proper infant positioning and latching-on.
Positioning: various positions allow for comfortable nursing; the head should be at breast level, and the infant in a flexed/relaxed position. The infant's head turns toward the breast and opens the mouth when the nipple tickles the lips or cheek (the rooting reflex).
Latch-on: With mouth wide open, the infant is pulled onto the breast, inserting nipple and ≥ 1/2 " of the areola. Lips are flanged open to form a seal, with the tongue curled around the base of the areola. Suckling initiates let-down and milk transfer occurs.

NOTES:

Section 3: Lactation continued

Hormones involved in lactation

Prolactin, oxytocin, and feedback-inhibitor of lactation (FIL) are the hormones of lactation.

Prolactin functions to ready the breast during pregnancy, and then to initiate and maintain milk supply. Infant suckling stimulates its release post-partum; infants must be fed on demand to ensure an adequate milk supply, especially while breastfeeding is being established. Suckling also stimulates the release of oxytocin which acts on the myoepithelial cells surrounding the alveoli; contraction ejects milk droplets into the ducts, so that it can be removed from the breast. Without enough suckling, milk production will decrease and eventually stop in part due to local mechanisms (FIL), and in part due to decreased prolactin.

Influences on milk production

Milk production is based on principles of supply and demand.

Initially, hormones of pregnancy start the milk manufacturing process, i.e. it is controlled internally. Shortly after birth, it switches so that milk removal is the controlling factor. Milk production, especially early on, is related to frequency and amount of feeding. For this reason, infants should be fed on demand. During growth spurts, infants feed more frequently which signals the breast to make more milk. In addition, regular, frequent feedings can reduce complications in the mother, such as engorgement.

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Section 4: The Term Infant

Appropriate infant food

The most appropriate food for an infant is human milk.

Infants require 93-120 Kcal/kg/day, the highest requirements of the lifecycle, and must nurse several times a day to meet these needs. They require 86-103 ml/kg/day of fluid; which can be easily met via intake of human milk or formula. At birth, low secretion of digestive enzymes makes digesting solids foods or cow's milk impossible. Low renal capacity means high protein intake can cause renal overload and induce osmotic diuresis and water loss. After 4-6 months an infant's kidneys will mature enough to handle the high solute loads caused by solid foods.

Optimal macronutrient intake

Infant feedings must be lipid- and carbohydrate-rich.

Energy for growth and development comes from carbohydrate, protein, and fat metabolism: 45-50% as lipids and 40-50% as carbohydrates (mainly lactose in human milk which also promotes beneficial intestinal flora and calcium and magnesium absorption). Glucose metabolism is the primary energy pathway of the term infant. Optimal protein intake is relatively low. Intake of 150-200 ml of breast milk/kg/d provides adequate protein; 25-40% of human milk protein is secretory IgA and lactoferrin. Insufficient calories cause protein to be sacrificed for energy.

NOTES:

Section 4: The Term Infant continued

Essential nutrients

Some nutrients are essential for infants, but not adults.

Not all metabolic pathways are fully developed at birth, particularly premature infants or those with inborn errors of metabolism. Certain amino acids (carnitine, cysteine, histidine, tyrosine, choline, and taurine) and some fatty acids (DHA and others) need to be provided in the diet since those substances usually derived by interconversion can be deficient in an infant. Infants also have low levels of the enzymes required to metabolize aromatic amino acids, such as phenylalanine and tyrosine.

Vitamins and minerals

Vitamins and minerals are important for growth: excess or deficits can be detrimental.

Healthy term infants in developed countries are at low risk for vitamin and mineral deficiency. Although important for growth, excesses or deficits can be detrimental. Healthy term infants are born with iron stores sufficient for the first 6 months of life, but infants born to mothers suffering from anemia during pregnancy may have stores for only three months. Milk of vegan mothers lis ikely to be deficient in B12 because of low maternal intake. Infants need limited sun exposure to ensure adequate levels of vitamin D.

NOTES:

Section 4: The Term Infant continued

Assessing nutritional status of infants

Low weight, length and head circumference point to nutritional deficiencies.
Growth charts track body weight to measure of nutritional status and detect protein-energy malnutrition (PEM); length and head circumference are also good measures. Infants are categorized as small, appropriate, or large for their gestational age of Preterm (<37 weeks), Term (37-42 weeks), or Post-term (>42 weeks). Infants may lose up to 10% of their birth weight in the first few days of life without cause for alarm. Evaluate a weight loss >10% or beyond 10 days and not regained by 3 weeks.

Infant formulas

Infant formulas are the only acceptable human milk substitute for the young infant.
When a mother does not breastfeed, iron-fortified infant formulas are the only acceptable human milk substitutes. These resemble human milk in all major constituents to promote normal development and growth. There are several categories of formula, differing in their source of protein, allergenic potential, or other special formulation. Cow's milk should never be given to an infant under 1 year of age.

NOTES:

Section 5: Special Needs

Impact of immaturity on the gut

Immaturity limits feeding and assimilation capacity.

The fetus develops its full capacity to absorb nutrients from the gut and to excrete waste product through the kidneys only during the last few weeks of pregnancy. The small size of stomach and intestine limits feeding volume. At the same time, renal excretion of urea and retention of minerals are limited.

Immaturity influences nutrient requirements

Immaturity increases nutrient needs, and impairs nutrient utilization.

On a per weight basis newborn infants with low birth weight have increased nutrient needs, because the normal rate of growth before birth is greater than after birth, and because they did not have time to build up needed nutrient stores. The relatively immature gut and kidneys are less effective for nutrient transfer than a healthy placenta, and some metabolic pathways for the conversion of nutrients (e.g., DHA, vitamin D) are not fully active, yet.

NOTES:

Section 5: Special Needs continued

The benefits of enteral feeding

Enteral feeding promotes gut maturity, and protects against infection.
Until late in pregnancy there is only a partial barrier that blocks normal gut bacteria from penetrating the intestinal wall and reaching the blood stream. Feeding even small amounts promotes the full function of this intestinal barrier. Normal bacterial colonization of the lower gut requires feeding and provides nutrients (vitamin B12 and K, biotin, and others).

Slow infant growth

Underfeeding, malabsorption and genetic disorders slow infant growth.
When infants grow slower than predicted by the appropriate growth charts, the underlying cause must be sought with great consequence. Inadequate intake should be considered first, often due to faulty breast- or bottle feeding technique. Infections and organic illnesses also are common. Malabsorption and inborn errors of metabolism are much rarer causes.

NOTES:

Malabsorption

Lack of enzymes causes malabsorption of carbohydrate and fat.

When there is a lack of brush-border enzymes, some or all of the lactose in milk or formula may escape digestion. Enteral infection can reduce lactase activity. Food allergies or defects in genetic lactase or sugar transporters are much less common. Dietary fat mixes with bile and pancreatic secretions to generate micelles. When micellar triglycerides are cleaved by lipase+colipase, the fatty acids, bile acids and other micellar compounds can be absorbed. Malabsorption of carbohydrates and fat can lead to flatulence, pain, and diarrhea, as well as poor fat-soluble vitamin uptake.

Protein digestion

Enzymes from stomach, pancreas, and intestinal brush-border digest protein.

Dietary proteins are cleaved by pepsin from the stomach, trypsin, chymotrypsin, elastase, and carboxypeptidase from pancreas, and brush-border aminopetidases and dipeptidases in the small intestine. The precursors of the gastric and pancreatic enzymes have to be activated by cleavage. Infants with pancreas insufficiency typically have poor growth rates.

NOTES:

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