NUTRITION AND HUMAN LIFE STAGES

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Contents

Summary

How nutrition affects human life stages is increasingly seen in a more integrated fashion: inter-generationally, from conception to death, as an interplay between one individual and others (social nutrition), and environmentally (taking account of the various ecological niches in which humans may live). Each of these nutritional dimensions to human growth and development is important. In addition the particular considerations for each stage of life, conception, the fetus, the infant, the child, the adolescent, the adult, and the aged, are reviewed.

The effect of proper nutrition during pregnancy on the health of the infant and of the mother in post-childbearing years has long been recognized. It now appears that maternal and paternal nutrition prior to conception affects the health of the newborn. Infancy, childhood an,d adolescence set the scene for nutritional well-being of adults and families. With the rapid growth in elderly populations, a need has evolved to widen the purview of food and health.

Although it may seem obvious that energy needs decrease with aging, the extent to which this is dependent on inappropriate reduction in physical activity needs to be better understood. Also little is known about whether requirements for specific nutrients are increased or decreased, although the requirement of nutrient density of food eaten is always greater when less food is eaten.

The identification of unique differences in the stages of aging assumes increased significance as it becomes more common for old age to extend well into the ninth decade.

1. Preconceptive and Periconceptive Nutrition

Even before conception, nutritional and other factors, both from maternal and paternal sides, may be playing a role in the determination of the eventual aging in an individual. This is because both spermatogenesis, in the father, and oogenesis, in the mother, may be subject to mutational influences. Maternal nutrition is particularly essential during the pre-, peri- and postnatal years to ensure the proper development and growth of the offspring.

In the paternal situation, the focus of the potential role of nutrition involves sperm, as it will contain the genetic information to be passed on to the offspring. Evidence is now available that smoking, through oxidant effects, can alter the genetic material of sperm in such a way that the risk of hematological malignancy is increased in the child.

Vitamins C & E are potent antioxidants, and both may play an important role in the protection of male germ cells against oxidation and the potential for a genetic mutation which in turn may lead to birth defects and other diseases in the offspring. A paternal diet replete in antioxidant-containing fruits and vegetables may reduce the risk of childhood disease. It may also have longer-term effects when the offspring is adult, depending on the genes affected.

From the maternal point of view, a potential mode of inheritance is through the mitochondria. Mitochondria show a maternal mode of inheritance even though there is currently some debate as to potential inheritance from sperm (mitochondria from the neck and rail of the sperm have been shown to penetrate the ovum). Since the mutation rate is relatively higher in mitochondria than in nuclei, the potential effects of diet to protect or to enhance mutation are also greater in the mitochondrion.

Mitochondrial diseases are characterized by defects in the mitochondria and have been linked to diseases such as diabetes and inherited cardiomyopathies, while some of the defects have been suggested to modify the outcome of diseases such as Alzheimer's Disease.
Given the potential protective role of food antioxidants in genetic defects in sperm, they may also confer similar beneficial effects in mitochondria. Delayed parenthood may also have an effect on both sperm and mitochondrial DNA.

Folate (or folic acid) plays a crucial role in the development of the central nervous system during the early weeks of gestation, which is generally before the pregnancy is confirmed. In a significant number of embryos, an inadequate supply of folate at this time leads to a failure of the primitive neural tube to close and to differentiate normally, and this results in neural tube birth defects (NTD). Folic acid supplementation during the periconceptional period can markedly reduce the occurrence of severe embryonic malformations.

1.2. Nutrition and Gene Expression

Nutrition has marked influences on gene expression, and an understanding of the interaction between nutrients and gene expression is important to provide a basis for determining nutritional requirements on an individual basis. The effects of nutrition can be exerted at many stages between transcription of the genetic sequence and production of a functional protein.

Genes are regulated by complex arrays of response elements that influence the rate of transcription. Nutrients and hormones either act directly to influence these rates or act directly through specialized signalling pathways. Metabolites of Vitamins A & D, fatty acids, some sterols, and zinc are among the nutrients that influence transcription directly. Components of dietary fiber may influence gene expression indirectly through changes in hormonal signalling, mechanical stimuli, and metabolites produced by the intestinal microflora.

2. Fetal Nutrition and Maternal Nutrition during Pregnancy and Lactation

Determination of nutrient needs during pregnancy is complicated because nutrient levels in tissues and fluids are normally altered by hormone-induced changes in metabolism, shifts in plasma volume, and changes in renal function and patterns of urinary excretion. The recommended intakes for pregnant women are generally increased for the support of fetal and infant growth and development along with associated changes in maternal structure and metabolism.

During the period of fetal growth, considerable amounts of nutrients are needed to synthesize fetal tissues and to provide stores of energy and iron for the immediate postnatal period. In a normal pregnancy these nutrients are obtained both from the mother's diet and from her own stores. Maternal metabolism is adjusted through hormones as mediators, redirecting nutrients to highly specialized maternal tissues specific to reproduction (i.e. placenta and mammary glands), and transferring nutrients to the developing fetus or infant. Many nutrients are found at higher levels in the fetal than in the maternal circulation. The ability to concentrate these nutrients enables the fetus to obtain the nutrients even when maternal levels are relatively low.

Fetal growth and development is largely dependent upon the utilization by the fetus of a suitable mix of energy and nutrients, the gene expression of the factors promoting tissue growth, and the hormonal framework. The failure of the materno-placental nutrient supply to match fetal nutrient demand causes restriction of fetal growth. Furthermore, it is now evident from the work of Barker and colleagues that babies who are small or disproportionate at birth, or who have altered placental growth have increased rates of coronary heart disease, hypertension, non-insulin dependent diabetes (NIDDM), insulin resistance syndrome, obesity, and some cancers later in life. These associations are thought to result from fetal programming. In response to maternal and fetal malnutrition, there are adaptive changes, to survive, in fetal organ development. These adaptations may permanently alter adult physiological and metabolism in a way that is beneficial to survival under continued conditions of malnutrition, but detrimental when nutrition is abundant.

This explanation is employed to explain the incidence of impaired glucose tolerance and NIDDM as a result of adaptation to undernutrition in the fetal and infant environment. It is hypothesized that in adapting, the fetus and infant have to be nutritionally thrifty. If poor nutrition continues throughout life, these adaptations are not detrimental. However, if adult nutrition is better, the ability of the pancreas to maintain homeostasis is exceeded, resulting in diabetes.

2.2. Micronutrient Malnutrition during Pregnancy

The most common micronutrient deficiencies are iodine deficiency disorders, iron deficiency anemia, and vitamin A deficiency. Micronutrient deficiencies are caused by inadequate intake of food containing those micronutrients or by their poor absorption or utilization.

2.1.5. Iodine

Iodine deficiency during pregnancy causes brain damage to the fetus that results in a gross intellectual retardation (cretinism), neurological disorders, and growth retardation, which are apparent in childhood. This deficiency is fully preventable and can be corrected before conception or in the early stages of pregnancy. Iodination of salt has been shown to be a low-cost, highly effective means of preventing the deficiency.

2.1.6. Iron

Consequences of iron deficiency anemia are increased maternal mortality and adverse pregnancy outcomes. Anemia is associated with an increased risk of premature delivery and a higher incidence of LBW in infants. Research findings suggest that perinatal mortality was nine times higher for infants delivered by severely anemic mothers compared with normals. The main causes of anemia during pregnancy are dietary factors, parasitic infestations by hookworms, chronic recurrent infections, and in some cases genetic anemia, such as thalassemia.

Dietary causes of iron deficiency anemia are low intake of heme iron (animal origin) or poor bioavailability of non-heme iron (plant origin). This is especially likely if the diet is high in cereals (which are rich in phytic acids and dietary fiber) and if a lot of tea is drunk with meals, or there is a low intake of Vitamin C rich food.

In affluent societies, vegetarians are at risk for iron deficiency during pregnancy and have to be supplemented with iron as soon as pregnancy is confirmed. Prevention of iron deficiency in other groups of the population could be achieved without supplementation by encouraging intake of iron-rich food, such as meat, liver, dark green vegetables, and foods that enhance iron absorption (foods of animal origin, fruits and vegetables rich in vitamin C). Substances that inhibit iron absorption, such as calcium supplements, cow's milk, tea, and coffee should be avoided or taken two hours after meals. Chronic infection and parasitic infestation should be treated. The high physiological requirement for iron in pregnancy is difficult to meet by diet alone. Pregnant women should routinely receive iron supplements in almost all contexts according to international guidelines. Women in areas of high prevalence of anemia

(40% and more) should be supplemented by iron according to the guidelines, for six months during pregnancy and continuing for three months postpartum, to enable woman to build up adequate iron stores. Women with severe and moderate anemia should be treated for three months with therapeutic supplementation and then continue with a preventive supplementation regimen.

2.1.7. Vitamin A

While Vitamin A deficiency can lead to eye damage, supplementation of pregnant or lactating women of childbearing age after two months postpartum is not recommended due to its teratogenic effect. Prevention of Vitamin A and Vitamin C deficiencies can be ensured by regular intake of orange-colored fruits and vegetables and dark green vegetables. In many countries food is fortified by Vitamin A. In affluent societies with a high intake of dairy product, Vitamin A deficiency is extremely rare.

2.1.8. Folic Acid

Folic acid deficiency is another cause of anemia in pregnant women (megaloblastic anemia). Additional folate consumption during periconceptional periods significantly reduces the risk of occurrence of neural tube defects such as anencephaly and spina bifida. Data suggest that poor folate status is related to high blood homocysteine levels, which have been identified as a risk factor for cardiovascular disease (CVD). Folate and vitamin B_{12} requirements are elevated by malaria and other hemolytic conditions. Green leafy vegetables, cruciferous vegetables, legumes, citrus fruits, melons, and organ meats are the principal source of folic acid in a human diet.

2.2. Lactation

Independent of mother’s decision to breastfeed or not, from about 16 weeks of gestation, the breast is fully prepared for lactation. Changes in the hormonal milieu after delivery and the infant’s suckling stimulate the breast to produce and release milk from the first hours after birth. Studies conducted in developed and developing countries demonstrate that the average level of milk production in 3 months of lactation is approximately 750 mL/day to 800 mL/day in women with widely varying dietary intakes and nutritional status. An association between infant’s birth weight and volume of milk intake has been observed.

This appears to be related to the greater sucking strength, frequency, or feeding duration among larger infants—all of which can increase milk volume. Both endocrine and autocrine control mechanisms operate to adjust milk volume in response to infants suckling behavior (i.e. nursing frequency and duration and degree of emptying of the breasts). The relative cost of lactation is much lower for humans than for most other species, possibly in relation to the slow growth rate of the human infant, which is naturally selected to ensure optimal time for the growth, development, and training of the large brain. This low stress of lactation provides women with several mechanisms to protect milk volume and quality, which make lactation performance remarkably unaffected by environmental factors, including maternal nutrition.

Women with much lower than recommended energy and protein intake still produce high-quality milk. However, lactating women with negative energy balance are likely to mobilize their own body reserves, so that the nutrients for milk synthesis are provided by maternal stores or body tissues. The threshold of nutrition status, when the maternal system can no longer sustain lactation, is assumed to be an extreme degree of malnutrition. This condition is likely to be developed in close to a famine situation, when severe food deprivation over a long period is challenging the mother's own survival.

2.3. Breast Milk and Advantages of Breastfeeding

Breast milk is a live dynamic fluid, changeable according to the child's needs. Preterm milk is different from full-term milk; colostrum, the first milk, is different from mature milk; fore milk at the beginning of the feed is different from the hind milk at the end of the same feeding. Breast milk provides easily digested best-quality nutrients with high bioavailability, ensuring the child's optimal growth and development. Feeding on demand, breast milk provides all baby's water needs, so no additional water is required. In many parts of the world, where shortage of water and its contamination are a great problem, breastfeeding is the only source of a clean fluid for infants.

2.3.1. Breast-Milk Composition and its Non-Nutritive Significance

Breast milk is species-specific and in addition to providing well-balanced nutrients it is exceptionally rich and diverse in its non-nutritious components. Compared with other mammalian milks, human milk is low in protein and mineral content and high in lactose. Human infants are born relatively immature and have a slower growth rate. Species-specific to humans,human milk suits the needs for growth, development, and training of the large brain at first, while protein rich cow's milk suits the muscle-skeletal growth of the calf. Energy yield of human milk per gram of nutrient for protein is 17 kJ/g, for carbohydrates is 16 kJ/g, and for fat is 37 kJ/g. On average, mature human milk yields approximately 3150 kJ/L. An intake of 500 g/day of breast milk in the second year of life can cover about 30% of energy, 45% of Vitamin A, and 95% of Vitamin C daily requirements of children.

Major constituents of human milk are lactose, fat, proteins, minerals, and vitamins. Despite the low content of iron in human milk, its bioavailability is exceptionally high (the low iron content may limit the growth of microbes and so protect the infant from gastrointestinal infections). Iron absorption from human milk is about 50%, while from formula or cow's milk it is about 4% to 10%. Exclusively breastfed infants rarely have iron deficiency anemia. Breast milk, and especially colostrum, hasa high content of Vitamin A. Human milk contains enzymes, a number of growth factors, and hormones, which facilitate the infant's growth and development, as well as maturation of its gut and nervous systems. Breastfed infants have optimal visual development and show advanced cognitive development with higher IQ scores and better academic outcomes.

Immunological properties of breast milk help to protect the infant against infection during infancy, but also provide long-lasting active immunity. Breast milk in some cultures is called *white blood*. Cellular components make breast milk a living fluid. Cell numbers are highest in colostrum and gradually decline during the first three months to a steady level. Cellular and humoral factors in breast milk include macrophages, lymphocytes, neutrophils, complement, lysozyme, lactoferrin and prostaglandins, immunoglobulins, oligosaccharides, nucleotides, and others. All of them together contribute to the host-resistant and immunological significance of human milk, providing anti-infective, anti-inflammatory, and anti-protozoan factors, ensuring barrier system, immune-modulating activity, and protecting the young child from acute and chronic disease in childhood. This may be one of the mechanisms for the reduced incidence of necrotizing enterocolitis in breastfed infants.

2.3.5. Breastfeeding Advantages for Mother's and Child's Health

Infants not breastfed have a higher risk of childhood diabetes, childhood lymphomas, celiac disease, Crohn's disease, and are more prone to asthma and other atopic diseases. Exclusively breastfed infants have at least 2.5 times fewer illness episodes than infants fed breast milk substitutes. Infants are as much as 25 times more likely to die from diarrhea in the first 6 moths of life if not exclusively breastfed. Among children under one year, those who are not breastfed are 3 times more likely to die of respiratory infection than those who are exclusively breastfed. Infants exclusively breastfed for 4 or more months have half the mean number of acute otitis media episodes of those not breastfed at all.

Breastfeeding has sound advantages to the mother's health. Early breastfeeding facilitates uterine contraction and decreases postpartum hemorrhage. Lactation amenorrhea combined with exclusive breastfeeding can act as a reliable contraception during the first six months postpartum. It can also ensure the saving of iron stores, as iron loss associated with menstruation is higher compared with lactation. Breastfeeding has protective effects against breast and ovarian cancer and osteoporosis. It helps to reduce mother's weight, especially if lactation lasts more than six months. It gives a woman bonding with her child and increases her self-esteem.

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Biographical Sketches

Mark Wahlqvist has had a combined career in internal medicine and human nutrition with chairs in both these fields over 2 decades. He held the first chair in Human Nutrition in Australia, at Deakin University, for nine years, was Head of Medicine at Monash University at the Monash Medical Centre for twelve years, and also Associate Dean (International), Director of the International Health and Development Unit. He is Professor of Medicine, and Director of the Asia Pacific Health and Nutrition Centre, and the Food and Agriculture Organization (FAO) Centre of Excellence in Food Quality, Safety and Nutrition at Monash University. Among other national and international roles, he chaired the International Union of Nutrition Sciences Committee on Nutrition and Ageing from 1986 to 2001, the Australian Nutrition Foundation from 1995 to 2001, the WHO Western Pacific Dietary Guidelines Committee from 1996 to 1998, was a member of the Nutrition Advisory Panel of the World Health Organization (WHO) since 1988. He was President-Elect of International Union of Nutritional Sciences from 1997 to 2001 and President from 2001. He was also a Board member of the Australian and New Zealand Food Authority from 1996 top 2002, and also Chairman of the Victorian Food Safety Council. He is Editor-in-Chief of the *Asia Pacific Journal of Clinical Nutrition,* and his textbook *Food and Nutrition: Australia, Asia and the Pacific* was launched in 1997, a successor to earlier editions from 1981. His publications amount to some 1000, including almost 500 peer-reviewed scientific papers and 17 books. He has played a major role in national and international nutrition science, education, and policy. His interests in migration studies have been recognized by the 1994 Award of Sweden's Charlotta Medal. He was awarded the Officer of the Order of Australia (AO) on Australia Day, 26th January 2000, for his contribution to the field of nutritional science and public health, and made a Fellow of the Australian Academy of Technology, Science and Engineering in 2002.

Fabien Dalais originates from the island nation of Mauritius. He is an Honorary Lecturer at the Department of Epidemiology & Preventive Medicine, Monash University, Melbourne, Australia. He completed his Ph.D. examining the physiological effects of phytoestrogens with a focus on menopause and heart disease. He has been heavily involved in phytoestrogen research, publishing as well as organizing phytoestrogen related meetings both locally and internationally. Excluding phytoestrogens, his research interest includes the broader field of phytochemicals and their effect on human health. He currently works in the food industry as a product development specialist.

Antigone Kouris-Blazos received a Bachelor of Science in 1984 from Melbourne University (double major in Biochemistry and Microbiology). In 1985 she completed an honors thesis on patient adherence to the diabetic diet, and in 1986 she completed a Post Graduate Diploma in Dietetics at Deakin University. She has worked as a clinical nutritionist for ten years. In 1987 she joined Monash University, Faculty of Medicine, as research dietitian to coordinate an international mortality followup study Food *Habits in Later Life* on 2000 elderly in five countries to identify dietary predictors of survival. In 1993 she completed a Ph.D. thesis investigating dietary contributors to the low mortality, but paradoxically high morbidity, rates of elderly Greek-born Australians. In 1995 she was appointed Lecturer in Human Nutrition and Nutrition Course Coordinator for the Medical curriculum at Monash University. In 1999 she was appointed Lecturer in International Nutrition in the International Health and Development Unit, Faculty of Medicine and Deputy Director of the International Health and Development Unit. Her interest has been in establishing the longevity benefits of traditional Mediterranean and Asian diets and in developing culturally sensitive Food Based Dietary Guidelines in collaboration with the World Health Organization. In 2002 she was appointed Honorary Research Fellow at the Asia Pacific Health and Nutrition Centre, Monash Asia Institute, Monash University and Managing Editor of the Asia Pacific Journal of Clinical Nutrition and www.healthyeatingclub.org.

Gayle Savige started her career as a teacher and while she continues to maintain her interest in education she has since pursued a career in nutritional science. After graduating as a dietitian, she worked in a large geriatric institution before completing her Ph.D. in aged care. She continues to maintain an active interest in successful aging and broadened her interests to include child nutrition. Whilst at Monash University, she utilized her educational and teaching skills to develop an Australian government funded food and nutrition website for children. She recently accepted a position at Deakin University to research the eating behaviors of adolescents.

Gulnara Semenov graduated from Alma-Ata State Medical Institute in 1980 as a medical doctor-pediatrician. From 1981 she has been working at the Kazakhstan Institute of Nutrition, WHO, and UNU collaborative Centre and during 1993 to 1997 as a head of its Breastfeeding promotion Centre. In 1992 she completed her Ph.D. at the same Institute. Additionally she has been trained in breastfeeding management (Wellstart Int, US, and by WHO/UNICEF), community nutrition (Karolinska Institute, Sweden), and in qualitative methods/Rapid Assessment Procedures (University of Connecticut, US). Since 1998 she is an International Board Certified Lactation Consultant, and works as Director of the Lactation Resource Centre of the Nursing Mothers' Association of Australia in Melbourne. As a WHO and UNICEF consultant/trainer, she took part in more than thirty international workshops on breastfeeding management, essential neonatal care, BFHI implementation, International Code of marketing of breastmilk substitutes implementation, and nutrition assessment in Eastern Europe and Central Asia. During 1996–1999, she was a Consultant of the WHO Regional Office for Europe (WHO/EURO) for the Central Asian Republics, Azerbaijan and Kazakhstan Project on Integrated Essential Neonatal Care and Breastfeeding Management (CARAK Project for six countries); and led the BF module of training and development and finalization of the training manual for this project. In 1995 through 1997 she was a Consultant and resource expert for UNICEF Area Office for the Central Asian Republic and Kazakhstan (CARK AO) doing qualitative research in breastfeeding and weaning practice in Uzbekistan, and for the Aral Sea Project for Economic Reconstruction Activities (ASPERA for three countries). In Australia she was involved in the Commonwealth Australia Nursing Mothers' Association of Australia project on Developing an educational kit on breastfeeding for health professionals. She was a member of International and Australian Lactation Consultant Associations, BFHI Australia assessor and educator, member of the Asia Pacific Clinical Nutrition Society, and Research Associate of the Monash

Asia Institute, Monash University, Melbourne. Since 2002, she has been working as an International Health Specialist at the Demographic and Health Research division of ORC Macro International Inc (Calverton, Maryland, USA). She served as a country manager of the 2002 Uzbekistan Health Examination Survey (a nationally representative household based survey with extended modules on adult and child health and biomarkers testing for known risk factors for selected diseases and conditions). Currently, She is a country manager for the 2004 Egypt Service Provision Assessments Survey (a nationally representative sample of about 660 health facilities).

Naiyana "Tikky" Wattanapenpaiboon received a Bachelor's degree in 1984 and a Master's degree in 1987 in Pharmaceutical Sciences from Chulalongkorn University in Thailand. After teaching for three years at the Faculty of Pharmaceutical Science, Khon Kaen University in Thailand, she received an Australian Government scholarship to undertake a Ph.D. degree at the Faculty of Medicine, Monash University, in Melbourne, Australia. She completed her Ph.D. thesis in 1995 with her work on carotenoids, pigments present in fruit and vegetables, and their association with human health. Her interest has been in the area of phytochemicals, where health benefits of compounds found in plants are investigated. She works as a Research Associate in the Asia Pacific Health and Nutrition Centre, Monash Asia Institute, Monash University, Melbourne, Australia.