Poultry Eggs and Child Health – a Review

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Introduction

Nutritional intakes during childhood should provide for maintenance of current weight and support normal growth and development. Failure to meet the substantial dietary needs in childhood can result in energy and nutrient deficiencies that adversely affect the growth and development process. In addition, impairments in immune functioning, increased morbidity and mortality in childhood can occur. On the other hand, excesses in energy intake or imbalance in nutrient intake also have negative health effects, such as obesity or cardiovascular disease risk factors. Children having unbalanced nutrients will grow up to become stunted, obese and low in academic performance during adulthood. Malnutrition encompasses obesity, stunting, wasting and micronutrient deficiencies. Stunting, severe wasting, and low birth weight due to intrauterine growth restriction together were responsible for 2.1 million deaths (21% of worldwide deaths under 5). Micronutrient deficiencies include iron, zinc, iodine, vitamin A, the B vitamin complex (especially folate and vitamin B12), and vitamin D. Vitamin A and zinc deficiency resulted in about 6% and 4% of under-5 deaths, respectively. Low intakes of micronutrients not only result in the known clinical deficiencies such as anaemia, goitre and eye problems, but also compromise immune function, cognitive development, growth, reproductive performance and work productivity. Therefore, It is important to choose appropriate nutrients to prevent deficiency, to promote adequacy, and to prevent noncommunicable diseases associated with excess intakes (Ahmed et al. 2012, Black *et al.* 2008, Kliegman *et al.* 2011, WHO/FAO 2002).

Because of the rapid rate of growth and metabolic rate during the first years of life, nutrient needs per unit body weight of infants and young children are very high. Given the relatively small amounts of foods that are consumed at 6-24 months, the nutrient density (amount of each nutrient per 100 kcal of food) of the diet needs to be very high. To meet the requirements for nutrients such as iron and zinc, animal-source foods are needed (WHO, 2005). Proteins from animal sources, e.g. meat, poultry, fish, eggs, milk, cheese and yogurt, provide all essential amino acids in adequate amounts and are considered as “complete proteins”. It was found that eggs were the lowest cost sources of protein, vitamin A, vitamin B12, iron, zinc and riboflavin. Therefore, eggs provide optimal nutrition at an affordable cost (Drewnowski, 2010).

The Nutritional Contribution of Eggs

Proteins

Eggs are classified as the “food protein group”. Eggs contain high quality protein, with 100% of chemical score (essential amino acid level in a food protein divided by the level found in an “ideal” food protein), 97% of egg protein being digestible and 94 % of biologic score (a measure of how efficiently dietary protein is turned into body tissue) (WHO/FAO/UNU 2007, McNamara and Thesmar 2005).

Nutritional requirements for optimal health change throughout our life to meet our needs for growth and development and the physiological challenges and modifiable risks associated with diseases throughout life (WHO/FAO 2002, WHO/FAO/UNU 2007). The nutritional value of eggs and the contribution they make to the diet of infant, toddler, children and adolescents are illustrated by Table 1. The data on the nutritional contents are based on a single medium boiled egg excluding the shell. Overall, 12.6% of the weight of the edible portion of the egg is protein and 50 g edible portion of the egg provides nearly half of the recommended daily allowances (RDA) of protein for children aged 1-3, 33.1% for children aged 4-8, 18.5% for adolescents aged 9-13, 12.1% for boys aged 14-18 and 13.7% for girls aged 14-18.

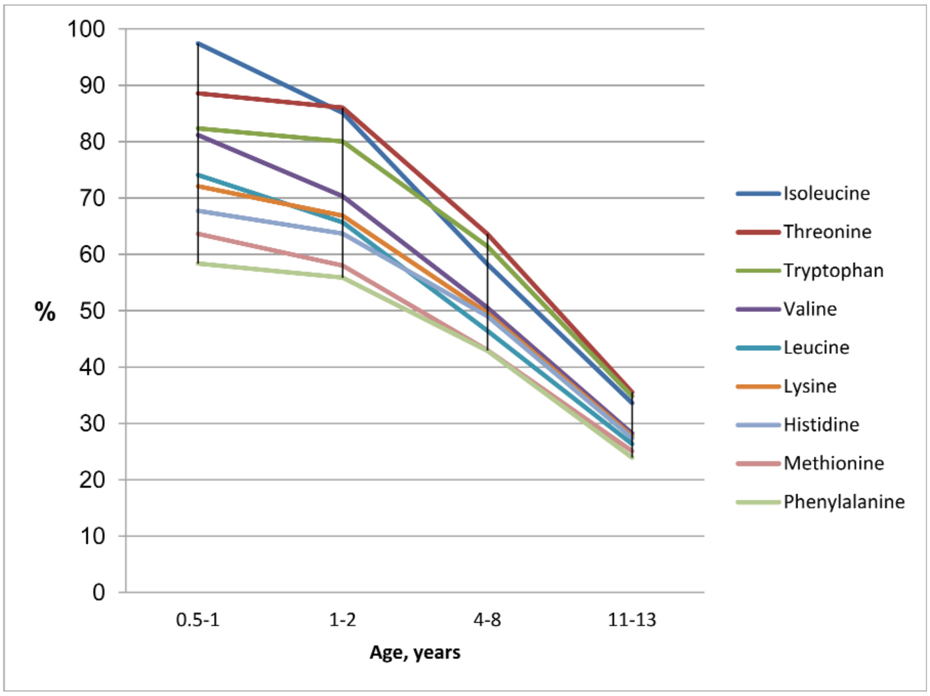
Table 1: Nutrient content of hard-boiled hen eggs in 50 g edible portion without egg shell and contribution to recommended daily intakes for children and adolescents

	Nutrient content (per 50g edible portion)*	Contribution to recommended daily intakes, %**						
		Children			Males		Females	
		6-12 mo&	1-3 y	4–8 y	9–13 y	14–18 y	9–13 y	14–18 y
Water	0.04 L	4.6	2.8	2.2	1.5	1.1	1.8	1.6
Carbohydrates	0.56 g	0.6	0.4	0.4	0.4	0.4	0.4	0.4
Fat	5.31 g	17.7						
Linoleic acid &	0.59 g	12.9	8.5	5.9	5.0	3.7	5.9	5.4
α-Linolenic acid &	0.02 g	3.6	2.6	2.0	1.5	1.1	1.8	1.6
Protein	6.29 g	57.2	48.4	33.1	18.5	12.1	18.5	13.7
Vitamin A	75.0 µg	15.0	25.0	18.8	12.5	8.3	12.5	10.7
Vitamin D	1.10 µg	11.0	7.3	7.3	7.3	7.3	7.3	7.3
Vitamin E	0.52 mg	10.4	8.7	7.4	4.7	3.5	4.7	3.5
Vitamin K	0.20 µg	8.0	0.7	0.4	0.3	0.3	0.3	0.3
Thiamin	0.03 mg	11.0	6.6	5.5	3.7	2.8	3.7	3.3
Riboflavin	0.26 mg	64.3	51.4	42.8	28.6	19.8	28.6	25.7
Niacin	0.03 mg	0.8	0.5	0.4	0.3	0.2	0.3	0.2
Pantothenic Acid&	0.70 mg	38.8	35.0	23.3	17.5	14.0	17.5	14.0
Vitamin B6	0.06 mg	20.3	12.2	10.2	6.1	4.7	6.1	5.1
Folate	22.0 µg	27.5	14.7	11.0	7.3	5.5	7.3	5.5
Vitamin B12	0.56 µg	112.0	62.2	46.7	31.1	23.3	31.1	23.3
Choline&	146.9 mg	97.9	73.5	58.8	39.2	26.7	39.2	36.7
Calcium	25.0 mg	9.6	3.6	2.5	1.9	1.9	1.9	1.9
Copper	7.00 µg	3.2	2.1	1.6	1.0	0.8	1.0	0.8
Iron	0.60 mg	5.5	8.6	6.0	7.5	5.5	7.5	4.0
Magnesium	5.00 mg	6.7	6.3	3.8	2.1	1.2	2.1	1.4
Manganese&	0.01 mg	2.2	1.1	0.9	0.7	0.6	0.8	0.8
Phosphorus	86.0 mg	31.3	18.7	17.2	6.9	6.9	6.9	6.9
Selenium	15.4 µg	77.0	77.0	51.3	38.5	28.0	38.5	28.0
Zinc	0.53 mg	17.7	17.7	10.6	6.6	4.8	6.6	5.9
Potassium&	0.06 g	9.0	2.1	1.7	1.4	1.3	1.4	1.3
Sodium&	0.06 g	16.8	6.2	5.2	4.1	4.1	4.1	4.1

The data followed by symbol "&" were "Adequate Intakes (AIs)". Other data were "Recommended Dietary Allowances (RDAs)"
* Egg, whole, cooked, hard-boiled, 50 g edible portion without egg shell (Adapted from USDA, 2012).
** Calculated from Food and Nutrition Board, Institute of Medicine: 2005

Egg protein is a rich source of all essential amino acids (EAAs) in optimal composition. The EAAs in an egg contribute more than 60 % of the dietary requirement for children aged 6-11 months, nearly half (43-64 %) of dietary requirement for children aged 4-8 years, 24-35 % for children aged 11-13 years (Figure 1).

Figure 1. The contribution of egg for daily requirement of essential amino acids by age, % (Calculated by WHO/FAO/UNU 2007 and USDA, 2012).



Fat

Eggs are low in fat (5.3 g fat/one egg). Overall, 50 g edible portion of a boiled egg has an energy value of 78 kcal (324 kj) and the consumption of one egg daily would contribute only around 5 % of the average energy requirement of a child aged 6 years in a 1400-1600 kcal diet (Kliegman *et al.* 2011, USDA 2012). Most of an egg's total fatty acid composition is monounsaturated (approximately 38%). About a further 13% is polyunsaturated and only 31% is saturated. One egg provides 8.5% of dietary requirement (adequate intake, AI) of linoleic acid for children aged 1-3, 5.0% for boys aged 9-13 and 5.9% for girls aged 9-13 (Table 1). One egg provides 2.6% of AI of α-linolenic acid for children aged 1-3, 1.5% for boys aged 9-13 and 1.8% for girls aged 9-13. Eggs have no trans-fatty acids. Eggs are one of the richest sources of dietary cholesterol, providing 187 mg per 50 g edible portion of boiled egg (USDA 2012).

Vitamins

Eggs contain most of the recognized vitamins with the exception of vitamin C. The egg is a source of all B vitamins. It is a particularly rich source (>10% RDA) of vitamins B12, riboflavin, pantothenic acid and choline thoughout life. One egg provides all requirements of vitamin B12 for infants aged 6-12 months, three-fourth of RDA for children aged 1-3 years and more than half of RDA for children aged 4-8 years. One egg provides nearly half of the requirement of riboflavin up to 9 years of age (Table 1). One egg contains 146.9 mg of choline which is nearly all of AI for infants and three-fourth for children aged 1-3 years and more than half for children aged 4-8 years and two-third of adolescents. Eggs are also rich (>10% RDA) in folate and vitamin B6 for children younger than 9 years. One egg provides more than 20% of the RDA of folate and vitamin B6 for children aged 6-12 months. The egg is also a source of the fat-soluble vitamins A, D, E and some vitamin K. One egg provides around one-fourth of RDA of vitamin A for children aged 1-3.

Minerals

The egg is a highly nutritious food containing several minerals. Eggs contain many of the minerals that the human body requires for health and they are naturally low in salt. One egg (50g edible portion) is a good source (>25% RDA) of selenium throughout life and a source (>10% RDA) of zinc and phosphorous for children up to 9 years of age (Table 1). Eggs provide useful amounts of iron and zinc, which are often low in many children's diets. In particular eggs are an excellent source of iodine (25 µg/egg) (FSA, 2002). One egg provides 48% of RDA of iodine for children aged 4-8 and 36% for children aged 9-13.

Antioxidants

The egg is a source of highly bioavailable forms of the carotenoids, lutein and zeaxanthin. They are antioxidant-like compounds. One egg has been found to provide 177 µg of these carotenoids (USDA, 2012).

Manipulation of egg contents

The enrichment of hen eggs with additional micronutrients would provide new niche markets by improving the nutritional status of children. Enrichment of poultry eggs might be advantageous over the use of supplements because of either low compliance or increased risks of toxicity when relying on supplements, and there are advantages in marketing "naturally" enriched foods (McNamara and Thesmar, 2005; Yalçin *et al.* 2004; Yalçin *et al.* 2009). Some commercially available nutrient enriched eggs contain increased amounts of omega-3 fatty acids, vitamin E, selenium and lutein. Vitamin E levels in eggs have been increased up to 10-25 fold, lutein up to 10 fold, selenium up to 5-9 fold, iodine up to 2-3 fold. Fortified eggs could further yield significant amounts of RDA of n-3 PUFA, DHA, vitamin A, vitamin E, iodine and selenium for children (Shapira, 2009; McNamara and Thesmar, 2005).

Predicted impacts of egg nutrients on child health

Eggs contain essential nutrients and energy to prevent nutritional deficiencies and excesses and provide the right balance of fat and protein to reduce risks for chronic disease (Ruxton *et al.* 2010). High quality protein of eggs has benefits for children and adolescents in aiding growth and development. Decreased egg consumption has been correlated with protein malnutrition in underdeveloped countries (Sullivan *et al.* 2006). Athletes can benefit from higher protein intakes for preservation of lean muscle mass during weight loss (Mettler *et. al.* 2010).

Feeding infant formula containing egg phospholipids was found to reduce the incidence of necrotizing enterocolitis, suggesting that one or more of the compounds of egg phospholipids may enhance the immature intestinal functions of infants (Carlson et al. 1998).

Makrides *et al.* (2002) showed that breast-fed infants who received docosahexaenoic acid (DHA) enriched egg yolks 4 times per week from 6 to 12 months had higher red cell DHA levels at 12 months than did those fed standard egg yolks or no egg yolks. Hoffman *et al.* (2004) reported that breast-fed infants receiving foods containing egg yolk enriched with DHA during 6-12 mo of life had an 83% elevation in red cell DHA levels resulting from an approximately 2-fold greater intake of DHA compared with unsupplemented infants. DHA-supplemented infants had more mature visual evoked potential (VEP) acuity (increase in visual acuity resolution) than control infants at 9 and 12 mo of age. Infants with higher levels of red cell DHA had better visual acuity. Kannass *et al.* (2009) investigated the relationship between maternal DHA levels at birth and toddler free-play attention in the second year. They reported that higher maternal DHA status at birth was associated with enhanced attentional functioning during the second year. Toddlers whose mothers had high DHA at birth exhibited more total looking and fewer episodes of inattention during free-play than toddlers whose mothers had low DHA at birth. These findings are consistent with evidence suggesting a link between DHA and cognitive development in infancy and early childhood (Birch *et. al.* 2007).

The supplementation of infant formulas with egg yolk lipids has been suggested to more closely resemble mother's milk, and Makrides *et al.* (2002) found that while providing essential nutrients, the yolk lipids did not increase plasma cholesterol.

High intake and plasma level of choline in the mother seems to afford reduced risk of neural tube defects (Ueland 2011). Previously, Shaw *et al.* (2004) found that women in the lowest quartile for dietary choline intake had four times the risk of giving birth to a child with a neural tube defect, compared with women in the highest quartile of intake. Konstantinova *et al.* (2008) reported that plasma free choline was positively related to intake of eggs, but not to other choline-rich food items in a Norwegian study. Suarez *et al.* (2012) found that increased folate intake had a protective effect and low serum B12, high serum homocysteine levels and obesity independently contributed to risks for neural tube defects. Chandler *et al.* (2012) reported that higher intakes of folate, thiamin, iron and vitamin A were associated with decreased risk of anencephaly among some ethnic and clinical groups. In addition higher intakes of thiamin, riboflavin, vitamin B6, vitamin E, niacin and retinol were associated with decreased risk of spina bifida. Given a good source for these nutrients, eggs can play important roles in preventing neural tube defects and in the brain development of infants.

Methyl groups for DNA methylation are mostly derived from the diet and supplied through one-carbon metabolism by way of choline, betaine, methionine or folate, with involvement of riboflavin and vitamins B6 and B12 as cofactors. Given the plasticity of DNA methylation in the developing embryo and the established role of one-carbon metabolism in supporting biological methylation reactions, it is plausible that alterations in maternal one-carbon nutrient availability might induce subtle epigenetic changes in the developing embryo and fetus that persist into later life, altering the risk of tumorigenesis throughout life. Retrospective studies investigating the effect of famine or season during pregnancy indicate that variation in early environmental exposure in utero leads to differences in DNA methylation of offspring (Ciappio *et al.* 2011, Dominguez-Salas *et al.* 2012)

Choline has been shown to play an important role in the reduction of homocysteine in the blood (Molloy *et al.* 2005). Elevated maternal homocysteine concentrations are a risk factor for several adverse pregnancy events, including preeclampsia, prematurity and very low birth weight, and have been suggested to have an important role as a marker of pregnancy complications and adverse pregnancy outcomes (Vollset *et al.* 2000, Zeisel and Costa 2009). Similarly, Jiang *et al.* (2013) reported that supplementing the maternal diet with extra choline may improve placental angiogenesis and mitigate some of the pathological antecedents of preeclampsia.

Vitamin B12 works with folate in DNA synthesis and myelin formation and deficiency causes megaloblastic anemia (Stabler, 2013). Vitamin A is essential for growth and eye health (Kliegman *et al.* 2011).

Research evaluating the plasma iron and transferrin saturation in 6-12 month-old children indicated that infants who ate egg yolks had a better iron status than children who did not (Makrides *et al.* 2002). Johner *et al.* (2012) found that milk, salt and eggs were the main contributors to iodine intakes in the diets of 221 German preschoolers aged between 3 and 6 years. Also, the egg is a significant source of phosphorus, required for bone health, and provides some zinc, important for wound healing, growth and fighting infection (Kliegman 2011, USDA 2012).

Eggs and obesity

During the past decades, the number of children who are overweight has increased, which has major health consequences. Being overweight or obese substantially increases the risk of acute health problems and chronic disease. Overweight and obese children and teenagers are more likely to have risk factors for diabetes, cardiovascular disease and liver disease than those who are not overweight (Kliegman 2011). The increase in childhood overweight was due to overconsumption of energy-dense, nutrient-poor foods and beverages and low physical activity patterns (Nicklas *et al.* 2008; Kliegman *et al.* 2011, WHO/FAO 2002). One egg is low in kj, providing around 5 % of the average energy requirement of a child aged 6 years in a 1400-1600 kcal diet, while providing one-third of daily protein requirement (USDA 2012, Kliegman *et al.* 2011). A review of dietary protein in the regulation of food intake has shown that protein makes a stronger contribution to satiety than carbohydrates and fat, and also causes greater suppression of food consumption (Anderson and Moore 2004). The protein in eggs may protect against weight gain by helping to promote satiety and suppress appetite. Consequently, obese children might experience reduced hunger on a higher-protein low-kj diet resulting in better compliance. In addition, egg intake slows the rate of gastric emptying, resulting in a flatter blood glucose response and a lower insulin response (Pelletier *et. al.* 1996). Some researchers concluded that moderate consumption of eggs (one to two eggs per day) should be actively encouraged as part of an energy restricted, weight-losing dietary regimen (Lee and Griffin. 2006). Similarly, Leidy *et al.* (2013) reported that the consumption of "egg- and beef-rich (35 g protein) breakfast" reduced evening snacking of high-fat foods, reduced daily ghrelin and increased daily peptide YY concentrations compared with "breakfast skipping". "High protein breakfast" was found to lead to reductions in hippocampal and parahippocampal activation compared among adolescents with "non-protein breakfast". This study shows that breakfast, rich in protein, might be a useful strategy to improve satiety, reduce food motivation and reward, and improve diet quality in overweight or obese teenage girls.

Eggs and heart health

Previously, there were some controversies regarding the role of dietary cholesterol in determining blood cholesterol levels and coronary heart disease (CHD). However, most studies have shown that saturated fat, not dietary cholesterol, is the major dietary determinant of CHD in healthy populations (Fernandez 2012, Gray and Griffin 2009; Nakamura et al. 2006; Qureshi *et al.* 2007). Egg intake promotes the formation of large LDL and HDL subclasses, which are less atherogenic (Fernandez 2010). Ballesteros et al. (2004) evaluated the effects of consuming two whole eggs per day compared to egg whites only, on plasma lipids and the atherogenicity of the LDL particle in Mexican children aged 10–12 y. They reported that the increases in plasma cholesterol due to dietary cholesterol was present in 1/3 of the children and was associated with increases in both LDL and HDL with no alterations in the LDL-C/HDL-C ratio and there was a shift of LDL size to a less atherogenic particle. Merkens *et al.* (2004) reported an increase in plasma LDL and HDL as a potential beneficial effect of eggs in children suffering from Smith-Lemli-Opitz syndrome, a condition of impaired cholesterol synthesis. In addition, some nutrients such as long chain omega-3 fatty acids, arginine, lutein and zeaxanthin found in eggs also may be associated with protection from CHD or its risk factors (Fernandez 2010, McNamara and Thesmar 2005, Ruxton *et al.* 2010). Recently, Voutilainen *et al.* (2013) also found that regular consumption of eggs did not affect carotid plaque area or risk of acute myocardial infarction in Finnish men.

Immunomodulation

It is well documented that hen eggs contain numerous proteins, peptides and lipids that exert beneficial bioactive effects (Kovacs-Nolan *et al.* 2005). Egg white proteins, including lysozyme, ovomucin, ovalbumin and ovotransferrin, which collectively make up around 73% of total egg white composition, have demonstrated potent immunemodulating activity, antimicrobial, antiviral, anticancer and protease inhibiting activities (Kovacs- Nolan *et al.* 2005), When combined with immunotherapy, lysozyme was effective in improving chronic sinusitis (Asakura et al. 1990) and in normalizing humoral and cellular responses in patients with chronic bronchitis (Sava 1996).

Egg yolk components have been shown to possess a number of novel biological functions including antiadhesive, antimicrobial and antioxidant activity (Kovacs-Nolan *et al.* 2005). Egg yolk antibodies, immunoglobulin Y [IgY] is the functional equivalent of IgG, the major serum antibody in mammals. IgY has been produced against a number of bacteria and viruses and has been shown to bind to and inhibit the infection and disease symptoms, in vitro and in vivo, of gastrointestinal pathogens such as human and bovine rotavirus, bovine coronavirus, *E. coli, Salmonella spp., Yersinia ruckeri, Edwardsiella tarda, Helicobacter pylori*, porcine epidemic diarrhea virus, and infectious bursal disease virus, as well as *S. aureus* and *P. aeruginosa* (Kovacs-Nolan and Mine 2004). The stability of IgY in the orogastrointestinal tract and its safety profile has been well-documented. Therefore, IgY can be used to confer passive immunity as an inexpensive non-antibiotic alternative for the prophylaxis and treatment of a wide variety of infectious diseases. IgY has been used in the treatment or prevention of dental caries, periodontitis and gingivitis, gastritis and gastric ulcer, oral thrush and infant rotavirus diarrhea (Rahman *et. al.* 2013). IgY against *S. mutants* has been shown to prevent oral colonization by mutants streptococci and to reduce dental caries development in humans (Hatta et al. 1997; Nguyen *et al.* 2011). In human studies, orally administered anti-*P. aeruginosa* IgY was found to prevent *P. aeruginosa* colonization in the lungs of cystic fibrosis patients, indicating its use as an alternative to antibiotic treatment (Kollberg *et al.* 2003), and the suppression of *H. pylori* infection in humans was observed following the consumption of a yogurt beverage fortified with IgY against H. pylori urease enzyme (Horie *et al.* 2004). Rahman *et al.* (2012) evaluated the effect of hyperimmune Ig Y (Rotamix IgY) against human rotavirus among pediatric patients receiving standard supportive treatment for rotavirus-associated diarrhea mostly with an enteric non-cholera copathogen in a hospital setting. Rotamix IgY had statistically significant reduction in mean oral rehydration fluid intake ($p=0.004$), mean duration of intravenous fluid administration ($p=0.03$), mean duration of diarrhea from day of admission ($p<0.01$) and mean duration of rotavirus clearance from stool from day of admission ($p=0.05$). Using oral Rotamix IgY for rotavirus-infected children mostly with non-cholera enteric pathogen co-infection appears to be a promising, safe and effective adjunct to management of acute diarrhea in pediatric patients.

Long-term effects of early-life nutrition on adulthood disease susceptibility

Childhood is the best time to establish healthful dietary habits through adulthood. In addition, healthy and balanced nutrient intake during childhood prevents some noncommunicable disease of adults (Kliegman *et al.* 2011, WHO/FAO 2002). Key nutrients found in eggs, such as vitamin D, vitamin B12, folate, selenium, choline, lutein and zeaxanthin, have been associated with disease prevention (Ruxton *et al.* 2010; McNamara and Thesmar 2005)

The egg is one of the few food sources that contain high concentrations of choline. People whose diets supplied the highest average intake of choline (>310 mg of choline daily, found in egg yolk and soybeans), had at least 20% lower levels of inflammatory markers (22% lower concentrations of C-reactive protein, 26% lower concentrations of interleukin-6, 6% lower concentrations of tumor necrosis factor alpha) than subjects with the lowest (<250 mg/day) average intakes (Detopoulou *et al.* 2008). Each of these markers of chronic inflammation has been linked to a wide range of conditions including CHD, osteoporosis, cognitive decline and Alzheimer's, and type-2 diabetes.
A two-stage case-control study showed that consumption of choline and betaine is inversely associated with the risk of breast cancer and the association of choline intake with breast cancer risk is probably modified by folate intake (Zhang *et al.* 2013).

Lutein and zeaxanthin may reduce the degree of oxidation or minimize the resulting damage by decreasing the permeability of the membrane to oxygen. They have been shown to help in the prevention of age-related macular degeneration, a leading cause of blindness in the elderly, and have been associated with lower risk of cataract extraction (Ma and Lin 2010, Solebo *et al.* 2008). Studies have reported significant increases in plasma levels of lutein and zeaxanthin when patients eat at least one egg daily for five weeks (Handelman *et al.* 1999, Goodrow *et al.* 2006). A study by Wenzel *et al.* (2006) developed this further by identifying that eating six eggs weekly for 12 weeks raised serum zeaxanthin levels and increased macular pigment optical density.

An increased intake of omega-3 fatty acids is known to reduce the risk of heart disease, some inflammatory and autoimmune disorders including rheumatoid arthritis and emerging evidence in the treatment of depression and inflammatory bowel disease (Ruxton *et al.* 2010, Kovacs- Nolan *et al.* 2005),

Interestingly, Blesso *et al.* (2013) reported that incorporating daily whole egg intake (3 eggs/day) into a moderately carbohydrate restricted diet provides further improvements in the atherogenic lipoprotein profile and in insulin resistance in individuals with metabolic syndrome.

Healthy eating guidelines for children

When to introduce eggs

In 2001, the World Health Organization (WHO) recommended exclusive breast feeding until 6 months (26 weeks) of age. At about 6 months babies are ready to move on to a complementary food containing eggs (WHO 2002). The European Society for Gastroenterology, Hematology and Nutrition (ESPGHAN) Committee on Nutrition and the American Academy of Pediatrics (AAP) have stated that there is no conclusive evidence supporting delayed introduction of eggs into the infant diet beyond six months of age (Agostoni *et al.* 2008; Greer *et al.* 2008), with the latter suggesting such a delay may even be disadvantageous in prevention of allergy.

Some countries recommend introducing eggs at 4-6 months, whereas other countries recommend 9-12 months. The suggested age for the introduction of egg whites also differs considerably from 4 to 6 months until 9 or 12 months (Israel MOH, 2009; Lin *et al.* 2011, Agostoni *et al.* 2008).

How often and how much to give

The WHO and the Pan American Health Organization (PAHO) recommend that meat, poultry, fish, or eggs should be eaten daily, or as often as possible because they are rich sources of many nutrients such as iron and zinc (Dewey and Lutter 2003; WHO, 2002). The WHO, the National Heart Foundation of Australia, British Heart Foundation, the Heart and Stroke Foundation of Canada and the Irish Heart Foundation, have not put a limit on the number of eggs consumed (Anderson *et al.* 2013; Graham *et al.* 2007; Fernandez and Calle 2010, National Heart Foundation of Australia 2009). The National Heart Foundation of Australia found that up to six eggs a week can be included as part of a healthy balanced diet that is low in saturated fat without increasing the risk of heart disease.

Egg consumption was recommended in Food Based Dietary Guidelines of Thailand, Philippines, China, South Africa, and Vietnam. One of Nine Thai food based dietary guidelines stated that “A regular consumption of fish, lean meat, eggs, legumes and pulses is recommended and eggs may be taken by children every day, while adults can take 3-4 eggs” weekly (Sirichakwal *et al.* 2011). The California food guide contains one egg per day; there is no specific statement for eggs in Japan and Malaysia (Hop *et al.* 2011). Clover with four leaves has been used in Turkey as a food guide (The Ministry of Health of Turkey, 2006). One leaf of clover belongs to the “meat, eggs, legumes” group. In this food guide, daily egg consumption is recommended.

Eggs given to babies or toddlers should be cooked until both the yolk and the white are solid in any fashion: boiled, scrambled, poached or in an omelet.

Religious and vegetarian preferences

The main dietary rules differ between world religions. Most Christians, Sikhs, Muslims and Buddhists eat eggs. The consumption of eggs differs in Hindu and Buddhist and Rastafarian populations. Strict Hindus and Sikhs do not eat eggs, meat, fish and some fats. Some Rastafarians are vegan. Jewish people do not eat eggs with blood spots (BTEC 2006).

A vegetarian diet can lead to low intake of key nutrients such as protein, vitamin B12, selenium, iodine, iron and omega-3s. Lacto ovo vegetarians do not eat meat, poultry or fish, but will eat eggs, and eggs can play a significant role in helping address these potential shortfalls (BTEC 2006).

High risk infants with family history of allergy

It used to be thought that avoidance of foods with documented allergenic potential may delay or prevent some food allergy and atopic dermatitis in high-risk infants with a strong family history of allergy. However, there is no convincing scientific evidence that avoidance or delayed introduction of potentially allergenic foods, such as fish or eggs, reduces allergies, either in infants considered at increased risk for the development of allergy or in those not considered to be at increased risk (Agostoni *et al.* 2008, WHO 2005, Cattaneo *et. al.* 2011).

For this reason, WHO, ESPGAN and AAP concluded that there was no convincing evidence that delaying the introduction of foods beyond 6 months of age had a protective effect on the development of atopic disease, which also included foods that are considered to be highly allergenic, such as fish, eggs and foods containing peanut protein (Greer *et al.* 2008).

Egg allergy is one of the most prevalent food allergies in children (Venter and Arshad 2011). The estimated prevalence varies between 0.5% and 5% in early childhood, less than 0.5% in older children and adults (Tey and Heine 2009). A more recent study suggested that egg allergy is more persistent, predicting resolution in 4% by age 4 years, 12% by age 6 years, 37% by age 10 years, and 68% by age 16 years (Savage *et al.* 2007). In general, the prognosis for children with egg allergy is good (Tey and Heine 2009). Because most children outgrow their egg allergy, periodic reevaluation is recommended. In milder cases advice will be needed after a symptom-free period, so that the careful reintroduction of eggs can be considered, but only with medical support. Prognostic indicators for the development of tolerance to egg include lower level of egg-specific IgE, faster rate of decline of egg-specific IgE level with time, earlier age at diagnosis, milder symptoms, and smaller skin test wheal sizes (Shek *et al.* 2004, Lemon-Mule *et al.* 2008, Ford and Taylor 1982). People who are tolerant to extensively heated egg may be more likely to outgrow the egg allergy (Lemon-Mulé et al. 2008), while those who are allergic to extensively heated eggs are more likely to have severe, and probably lifelong, egg allergy (Caubet and Wang 2011).

It has been observed that more than half of the infants who develop egg allergy begin to have symptoms within minutes of being given an egg. The use of eggs in cakes, custard, mayonnaise and some pasta is well known; their use in bread, in the glazes added to buns or pies, and in some confectionery may not be so obvious. Therefore, food labeling rules are required for prepacked foods to show clearly if they contain egg. However, there are many foods and products that are not covered by FDA allergen labeling laws, so it is still important to know how to read a label for egg ingredients (KFA's Medical Advisory Team 2009).

Salmonella-caused food poisoning

Health safety concerns about eggs center on salmonellosis (salmonella-caused food poisoning). Salmonella from the chicken's intestines may be found even in clean, uncracked eggs. Eggs should be kept refrigerated to prevent deterioration in yolk membrane permeability and minimize growth of any micro-organisms that may be present. Eggs should be stored separately from other foods, preferably in the egg box. Eggs should be brought to room temperature before cooking. Cooked egg dishes should be eaten as soon as possible after cooking and, if not for immediate use, should be stored in the refrigerator. Hands should always be washed before and after handling shell eggs. Salmonellosis is a common cause of food poisoning and is particularly associated with consumption of raw eggs. To avoid salmonella, eggs should be cooked so both white and egg are solid, firm. Properly cooking eggs to a temperature of 63°C for 3 min will destroy salmonella enterica present in an egg. Recipes containing eggs mixed with other foods should be cooked to an internal temperature of 160°F (71°C). Soft-cooked, sunny-side up or raw eggs carry salmonellosis risk. Hard-boiled, scrambled, or poached eggs do not (McNamara and Thesmar 2005; US FDA 2011).

Summary and Conclusion

A healthy, balanced diet and good nutrition are the building blocks of life. Failure to meet the substantial dietary needs and giving unbalanced nutrients in childhood can result in energy and nutrient deficiencies that adversely affect the growth and development process. As a result, these children, having malnutrition (wasted, stunted or obese), impairments in immune functioning, increased morbidity and mortality, might grow up with poor academic performance and short stature. Eggs contain essential nutrients and energy to prevent nutritional deficiencies and excesses and provide the right balance of fat and protein to reduce risks for chronic disease. This article reviews current literature about the impact and value of egg nutrients in child nutrition and health.

The nutrient density of eggs and biological properties of egg components make them a valuable contributor to the overall nutritional balance of the diet and, as an economical source of high quality protein, an important component in the diets of growing children.

Zusammenfassung

Eier und ihre Bedeutung für die Gesundheit von Kindern

Gesunde, ausgewogene Nahrung und gute Ernährung sind die Bausteine des Lebens. Mangelhafte und unausgewogene Ernährung in der Kindheit kann die körperliche und geistige Entwicklung beeinträchtigen. Mangelhaft ernährte Kinder kümmern, bleiben klein oder verfetten, haben ein unterentwickeltes Immunsystem, sind anfällig für Krankheiten und Sterblichkeit und können schwache Leistungen und geringe Körpergröße in der Schule zeigen. Eier enthalten essentielle Nährstoffe und Energie, und ein ausgewogenes Verhältnis von Fett und Eiweiß Energie kann helfen, Risiken chronischer Krankheiten zu reduzieren. In dieser Literaturübersicht wird die Bedeutung von Eiern für eine gesunde Ernährung von Kindern deutlich gemacht. Aufgrund ihrer Nährstoffdichte und günstigen biologischen Eigenschaften von Komponenten sind Eier ein wertvoller und wichtiger Bestandteil einer ausgewogenen Diät und preiswerte Quelle von hochwertigem Eiweiß für die Ernährung wachsender Kinder.

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