Are the Current Dietary Guidelines Regarding Egg Consumption Appropriate?

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Despite being considered a good or excellent source of 11 nutrients (1), egg intake accounted for only 1.3% of the total energy consumed by the average American in 2000 (2). The perception of cholesterol-rich eggs as a “forbidden food” developed in response to the highly publicized 1970s recommendation by the American Heart Association (AHA) to restrict egg consumption and limit dietary cholesterol intake to ≤300 mg/d. The dietary cholesterol guidelines are similar in the most recent AHA report; however, their position regarding egg intake has become more specific (3). This new report states that the intake of one yolk a day would be acceptable, if other cholesterol contributing foods were limited in the diet (3). Although this recommendation may be useful for certain individuals with a history of elevated plasma cholesterol or established coronary heart disease (CHD), it is unwarranted for the vast majority of the population and may actually have negative nutritional implications. This commentary evaluates the controversy and consequences of the dietary recommendations regarding eggs. The elderly high-risk demographic is utilized to illustrate the health benefits of consumption and the functionality of individual egg nutrients.

As a whole food, eggs are an inexpensive and low calorie source of nutrients such as folate, riboflavin, selenium, choline and vitamins B-12 and A. Eggs are also one of the few exogenous sources of vitamins K and D. Furthermore, eggs are a source of high quality protein, and the lipid matrix of the yolk serves to enhance the bioavailability of nutrients such as lutein and zeaxanthin. However, despite these benefits, to gain popular acceptance the controversy surrounding the dietary cholesterol content of eggs must be revisited and revised.

Eggs and cholesterol

Cholesterol is a dietary component that has elicited much public and scientific interest in conjunction with CHD. Extensive research has failed to establish a definite link between dietary cholesterol intake and disease progression (4). Numerous population studies have clearly demonstrated the lack of a relationship between egg intake and CHD (5). A recent study, which examined the intake of 117,000 nurses and health professionals over a 14-y period, found no difference in the relative risk for CHD between those who consumed less than one egg a week and those who ate more than one egg a day (6). Furthermore, clinical studies have clearly shown that plasma compartment changes resulting from dietary cholesterol consumption are regulated by a vast number of genes, which allow for extensive individual variation in response. The classification of individual genetic differences may allow for the future identification of those who would respond favorably to dietary cholesterol restriction and those who are hyporesponsive to intake. It has been suggested that ~70% of humans are hypo-responsive to excess dietary cholesterol consumption (4). In addition, those individuals who hyperrespond generally experience elevations in both LDL-cholesterol (LDL-C) and HDL-cholesterol (HDL-C) (7) allowing for the maintenance of the LDL-C/HDL-C ratio, an important marker for CHD risk (8,9). This evidence suggests that for healthy individuals, the nutritional benefits clearly outweigh the concern surrounding the 213 mg of dietary cholesterol provided by one large egg.

Current recommendations do not benefit the elderly population

By the year 2020, the number of people worldwide over the age of 60 y is expected to reach one billion. This generation, born between 1946 and 1964, will also represent ~25% of the U.S. population. Therefore, the incidence of age-related disease will continue to increase, further burdening the already strained U.S. health care system. It has been estimated that each year the treatment of chronic disease accounts for 75% of all health care costs in the U.S. Furthermore, of the total money spent each year to treat conditions such as CHD, cancer, stroke and diabetes, approximately $33 billion of the medical and $9 billion of the lost productivity costs can be attributed to poor nutrition (10).

Widely accepted risk factors that have been identified for CHD may not be applicable to elderly populations. Although elevated total cholesterol values have been shown to predict CHD risk in middle-aged individuals, this parameter does not seem to be relevant for the elderly demographic (11). The difficulty that surrounds this finding is that the low fat diet is commonly prescribed to many elderly individuals in an attempt to lower elevated total cholesterol concentrations. Unfortunately, restriction of fat and cholesterol from the diet often results in the inclusion of foods high in simple sugars. This change in diet composition can be detrimental, causing increases in triglycerides (TG), which are generally accompa-
nied by low HDL-C levels. Low HDL-C has been identified as the best lipoprotein indicator of CHD risk in elderly individuals (12). Furthermore, the consumption of a diet high in simple sugars can cause changes in lipoprotein metabolism that result in the production of smaller more dense LDL particles (13). These LDL particles, identified as the pattern B subclass, are considered to be more atherogenen than the larger cholesteryl ester-enriched fraction (14). A predominance of LDL particles in this pattern B subclass has been shown to be associated with a threefold increase in CHD risk (14,15), which may be due to the easy entry of the particle into the arterial wall and its high susceptibility to oxidation (14). Oxidized LDL possess increased atherogenicity due to unregulated uptake by macrophages and their role in foam cell production. Furthermore, it has been suggested that the consumption of a low fat diet by elderly individuals may promote insulin resistance. Insulin resistance and obesity are conditions that are accompanied by increased LDL-C and TG, and decreased HDL-C. Studies have shown that these dyslipidemias are inherent to insulin resistance and not attributable to diet because there appears to be a diminished response in these individuals to dietary saturated fat and cholesterol (7). Therefore, because insulin resistance is considered an independent risk factor for CHD (16), energy restriction as opposed to fat and cholesterol limitations appears to be a better treatment option for this population. Contrary to the current recommendations, these findings suggest that low energy (17.5 kJ/large egg) eggs could be included in a heart healthy diet for this population.

**Egg protein and resistance training**

As people age they may experience the loss of skeletal muscle mass, a condition termed sarcopenia (17). Furthermore, it has been well documented that on average adults generally experience a 1.8–2 lb (0.82–0.91 kg) weight gain each year (18). Decreased fat-free mass and elevated fat mass are associated with lower total energy expenditure, lower resting metabolic rate and altered protein metabolism (19), which further increases the risk for the development of chronic diseases such as type II diabetes, osteoporosis and CHD. However, the adoption of resistance training programs for older adults has proven to be effective in increasing skeletal muscle mass (20). In addition, dietary protein may have a profound effect on the results of training. Acute increases in protein intake can effectively reduce the rate of protein breakdown, whereas long-term (1–2 wk) elevations in intake result in an increase in whole-body protein turnover (21). Consumption of a 133-kJ supplement drink, which contained 17 g/100 g protein, by healthy men between the ages of 61–72 who were engaged in a 12-wk resistance training program, significantly (P < 0.01) increased muscle hypertrophy (22). This finding can be further explained by a study that found increased protein intake by aging individuals has an effect on the uptake and utilization of nitrogen during resistance training (23). These results led to the speculation that it may be possible to enhance the skeletal muscle synthesis that is seen with resistance training by modifying the quality of dietary protein consumed. The source of protein in the diet may also have an effect on protein metabolism in older adults. A study by Campbell et al. (24) reported that consumption of an omnivorous diet results in greater increases in fat-free mass after 12 wk of resistance training compared with those increases achieved with a lactoovovegetarian diet. This finding was further explored by Pannemans et al. (25) who determined that values for protein flux, protein oxidation and protein synthesis are not different between elderly women who consume either a high animal or high vegetable protein diet for a period of 2 wk. However, they did find that protein breakdown decreases (although not significantly; P < 0.08) during the high animal protein diet period. The data from these studies suggest that vegetable protein may not efficiently suppress protein breakdown.

The intake of a high protein meal provides a large number of amino acids to the labile protein pool. However, homeostasis of this pool is maintained within narrow limits by increasing protein synthesis, decreasing protein breakdown or elevating the rate of protein oxidation. The productivity of this postabsorptive phase can be enhanced by increasing the concentration of essential amino acids in the pool and this can be achieved by changing the source of dietary protein. Diets high in vegetable protein contribute less essential amino acids to the labile pool; therefore, they are less capable of inhibiting breakdown and initiating synthesis. An analysis of the amino acid composition of both eggs and soy milk resulted in the determination that eggs provide a greater amount of both the essential and branched chain amino acids (Table 1). Although, eggs were found to have lower amino acid content compared with beef, the biological value of egg protein is greater.

**Egg carotenoids and age related macular degeneration (AMD)**

The leading cause of irreversible blindness in the U.S. is AMD (26). This condition develops from long-term oxidative damage caused by the exposure of the eye to intense light. Furthermore, the retina itself has been shown to have a high rate of oxidative metabolism. Lutein and zeaxanthin accumulate in the macular region of the retina (27); therefore, because of their chemical properties, these two carotenoids may function to reduce the risk for development of AMD. As antioxidants, lutein and zeaxanthin may reduce the degree of oxidation or minimize the resulting damage by decreasing the permeability of the membrane to oxygen (28). Epidemiological data support this protective role suggested for lutein and zeaxanthin. Those individuals who consumed a greater number of foods rich in lutein and zeaxanthin had a lower risk for AMD (29), as were those who had the highest level of intake.

| Nutrient composition of whole eggs, soy milk and ground beef[^1][^2] |
|-------------------|-------------------|-------------------|
| **Nutrient**      | **Soy milk**      | **Egg/whole scrambled** | **Beef/ground 85% lean/broiled** |
| Protein           | 3.75 g            | 11.09 g            | 25.93 g           |
| Amino Acids       |                   |                   |                  |
| Valine            | 0.141 g           | 0.678 g           | 1.273 g          |
| Isoleucine        | 0.144 g           | 0.608 g           | 1.145 g          |
| Leucine           | 0.241 g           | 0.954 g           | 2.021 g          |
| Arginine          | 0.214 g           | 0.644 g           | 1.683 g          |
| Methionine        | 0.040 g           | 0.340 g           | 0.668 g          |
| Tryptophan        | 0.043 g           | 0.136 g           | 0.133 g          |

[^2]: 8 fl oz of soy milk = 245 g, 1 large egg = 61 g and 3 oz meat = 85 g.
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(30), or had increased concentrations of the two carotenoids in plasma (31) or in the retina (32). The lipid matrix of the egg yolk has been shown to enhance the bioavailability of lutein and zeaxanthin. One yolk has been found to provide between 200 and 300 μg of these carotenoids (31). In a study that measured the total carotenoid content of several foods, lutein represented 15–47 mol/100 mol of the total found in various dark green leafy vegetables, whereas eggs were found to contain 54 mol/100 mol (33). Furthermore, increased consumption of foods rich in these carotenoids has been directly associated with elevated serum concentrations of lutein and zeaxanthin and increased macular pigment density (34).

Lutein and zeaxanthin intake also may be associated with a decrease in the risk for CHD by reducing arterial plaque formation. The expression of adhesion molecules, which are needed for monocyte association with the artery, may be inhibited by carotenoid consumption (35). In addition, lutein has demonstrated antioxidant function in vivo as a scavenger of peroxynitrite, the reaction product of nitric oxide and superoxide (36). Peroxynitrite, in the presence of LDL, can destroy lipid-protein complexes creating a particle that is more susceptible to uptake by the macrophage scavenger receptor. Studies have shown that the consumption of foods high in lutein can increase the concentration of this carotenoid in the plasma and the LDL particle (37). Furthermore, two epidemiological studies, which examined carotid intima thickness as a measure of CHD, showed that high levels of plasma lutein produce a significant reduction in disease risk (38,39).

**Egg lecithin and choline**

As a polyunsaturated phosphatidylcholine (PPC), lecithin is a functional and structural component of all biological membranes. PPC function as the rate-limiting step in the activation of membrane enzymes such as superoxide dismutase. It has been suggested that ineffective activation of these antioxidant enzymes would lead to increased damage of membranes by reactive oxygen species, which could eventually lead to hearing loss if mitochondrial DNA were affected. A recent study (40) reported that lecithin supplementation for 6 mo safeguards cochlear mitochondrial function and prevents age-related hearing loss in rats.

As a component of egg lecithin, choline is a required nutrient (41) that is essential for normal development of the brain (42). Choline has numerous important physiologic functions that include the synthesis of phospholipids, the metabolism of methyl and cholinergic neurotransmission. Eggs are one of the few food sources that contain high concentrations of choline (43). Studies in rats have demonstrated that supplementation of choline, during embryonic development or immediately following birth, can result in improved memory performance, which is maintained as the animal ages (44). Additional studies in humans are needed to verify these findings and to further determine the importance of dietary choline at differing life stages including pregnancy, infancy and old age.

**CONCLUSION**

If judged as a whole food, and not simply as a source of dietary cholesterol, the positive contribution of eggs to a healthy diet becomes apparent. Because eggs are a conventional food containing nutrients that play fundamental roles beyond basic nutrition, their promotion as a functional food should be considered. This discussion has examined the possible role of egg nutrients in the prevention and treatment of specific symptoms associated with chronic age-related diseases. Furthermore, evidence has been presented showing that the current blanket recommendations regarding dietary cholesterol and egg intake are unwarranted for the majority of people and are not supported by scientific data. The assumptions made by these recommendations are that dietary cholesterol consumption >300 mg/d translates directly into elevated plasma cholesterol levels and the development of CHD in all individuals. These assumptions are clearly flawed. First, a conservative estimate suggests that only 30% of the population would respond to dietary cholesterol. It has been determined that a reduction in dietary cholesterol of 100 mg/d would only slightly decrease plasma total cholesterol levels of those who are responsive. For example, if a responsive individual chose to eat two eggs in one day they would exceed the AHA recommended upper limit for cholesterol intake by 126 mg, which would suggest that they may experience a 0.05–0.07 nmol/L increase in plasma total cholesterol levels. However, as previously mentioned, persons who consume more than one egg a day do not have a greater relative risk for CHD than those who eat only one egg a week. There are populations that may benefit from decreasing dietary cholesterol intake such as those with diabetes who may possess an abnormality in the mechanism by which they transport cholesterol. However, the current recommendation is applied to the general population without taking individual differences into account. Furthermore, the revised guidelines only allow for eggs to be incorporated into a healthy diet if other animal products are consumed. Because this guideline is unrealistic, it further promotes the public message that eggs should be avoided. The reality of the situation is that although egg intake has steadily declined since the original recommendations in the 1970s, CHD is still the leading cause of death in the U.S. today. Clearly, the current guidelines are not benefiting the public as a whole and may actually have negative nutritional implications.

**LITERATURE CITED**

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