

## Review

# A Review of Scientific Research and Recommendations Regarding Eggs

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**Key words:** eggs, nutrition, coronary disease, guidelines

For much of the past 40 years, the public has been warned away from eggs because of a concern over coronary heart disease risk. This concern is based on three observations: 1. eggs are a rich source of dietary cholesterol; 2. when fed experimentally, dietary cholesterol increases serum cholesterol and; 3. high serum cholesterol predicts the onset of coronary heart disease. However, data from free-living populations show that egg consumption is not associated with higher cholesterol levels. Furthermore, as a whole, the epidemiologic literature does not support the idea that egg consumption is a risk factor for coronary disease. Within the nutritional community there is a growing appreciation that health derives from an overall pattern of diet rather than from the avoidance of particular foods, and there has been a shift in the tone in recent dietary recommendations away from “avoidance” messages to ones that promote healthy eating patterns. The most recent American Heart Association guidelines no longer include a recommendation to limit egg consumption, but recommend the adoption of eating practices associated with good health. Based on the epidemiologic evidence, there is no reason to think that such a healthy eating pattern could not include eggs.

### Key teaching points:

- Data from free-living populations, as well as the whole epidemiologic literature, does not show that egg consumption is a risk factor for coronary disease.
- Nutrition professionals increasingly understand that the overall pattern of the diet, not the avoidance of particular foods, is most important for health and wellness.
- The American Heart Association’s latest nutrition recommendations do not limit the number of eggs that can be eaten, as long as one’s total cholesterol is limited to no more than 300 milligrams per day.

### The Evolution of Dietary Guidelines in the United States

Over the course of the twentieth century there has been an unprecedented reduction in the burden of premature death in the United States. In 1900, life expectancy was 49.2 years, a century later it was 76.9 years [1]. Over this time span, the leading causes of death have changed from mostly infectious diseases to mostly chronic diseases (Table 1). Dietary guidelines also have evolved over the century motivated both by changing health concerns and advances in nutritional science.

Before the end of World War II dietary advice was aimed at preventing nutritional deficiency [2]. Early guidelines emphasized eating a balance of foods from various groupings without respect to their specific nutrient contents. After World War II the research community attended emerging health concerns, notably heart disease. Early research showed that levels of serum cholesterol were associated with the occurrence of CHD [3], and studies like the Seven Countries Study also showed large variations in the world-wide occurrence of CHD indicating the potential for its prevention [4]. Through the 1960 and 1970’s the evidence showing a causal role for circulating

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Presented in part at the First International Symposium on Eggs and Human Health, Washington, D.C., September 23, 2003.

Financial Disclosure: Dr. Kritchevsky serves on the Egg Nutrition Council’s Scientific Advisory Board.

Abbreviations: CHD = coronary heart disease, RR = relative risk.

Journal of the American College of Nutrition, Vol. 23, No. 6, 596S–600S (2004)

Published by the American College of Nutrition

**Table 1.** Life Expectancy and Top 5 Causes of Death in the United States

Year	1900	1950	2000
Life Expectancy	49.2	68.1	76.9
Top 5 Causes of Death	1. Pneumonia 2. Tuberculosis 3. Diarrhea, Enteritis, and Ulceration of the Intestines 4. Diseases of the Heart 5. Cerebrovascular Disease	1. Diseases of the Heart 2. Malignant Neoplasms 3. Cerebrovascular Disease 4. Accidents 5. Diseases of Early Infancy	1. Diseases of the Heart 2. Malignant Neoplasms 3. Cerebrovascular Disease 4. Chronic Lower Respiratory Disease 5. Accidents
Percent of Deaths Due to Heart Disease	8.0%	36.9%	29.6%

Sources: [1,34,35].

cholesterol levels in the atherosclerotic process strengthened, and evidence for the role of dietary fats and cholesterol in modifying serum levels also emerged [5]. Importantly two groups quantified the extent to which serum cholesterol could be raised by the addition of dietary saturated fat and to a lesser extent dietary cholesterol, and reduced by the addition of polyunsaturated fat [6,7].

The emerging scientific understanding of the role of cholesterol and diet in the atherosclerotic process is reflected in the evolution of dietary guidelines over this time. The American Heart Association Guidelines issued in 1961 (Table 2) recommended reducing total fat, saturated fat, and cholesterol, and increasing intake of polyunsaturated fat [8]. By 1970's dietary recommendations advised the public to avoid saturated fat and cholesterol and specifically to avoid the consumption of eggs. In 1970 the Inter-Society Commission for Heart Disease Resources stated, "Ingestion of two eggs a day . . . will seriously hamper dietary programs aimed at reducing serum cholesterol. Consequently, the public should be encouraged to avoid egg yolk consumption . . ." [9]. This was followed in 1973 by the recommendation from the American Heart Association stated that, "The association noted that dietary cholesterol . . . be limited to no more than 300 mg per day, and recommended that individuals eat no more than 3 egg yolks per week" [10].

The dietary recommendation to avoid eggs is the consequence of the "diet-heart" hypothesis which was formulated based on two observations: dietary cholesterol increases serum cholesterol, and serum cholesterol is associated with heart disease risk. It followed that dietary cholesterol increases heart disease risk [11]. A corollary of the hypothesis is that eggs, being high in cholesterol, also increase heart disease risk.

**Table 2.** American Heart Association Report (1961)

1. Maintain a correct body weight
2. Engage in moderate exercise, e.g., walking to aid in weight reduction.
3. Reduce intake of total fat, saturated fat, and cholesterol. Increase intake of polyunsaturated fat.
4. Men with a strong family history of atherosclerosis should pay particular attention to diet modification.
5. Dietary changes should be carried out under medical supervision.

Source: [8].

However, at the time when these recommendations were formulated there was no empirical evidence directly testing this claim. Since these guidelines were promulgated, considerable additional relevant epidemiological evidence has appeared.

### The Epidemiologic Evaluation of the Role of Eggs in Cardiovascular Disease

Experimental feeding studies have shown that the consumption of an additional egg per day will lead to a modest increase in average serum cholesterol (~1–3%) [12]. However, population-based studies examining the association between egg consumption and serum cholesterol levels show either no association, or, paradoxically, an inverse association. Dawber and colleagues examined the association of egg consumption and serum cholesterol in the Framingham Heart Study [13]. In men, the third with the highest egg consumption ate an average of 9.2 additional eggs/week compared to the third with the lowest consumption. In women, the third with the highest consumption ate an additional 6.7 eggs/week compared to the lowest third. Despite these large differences in egg intake, the differences in mean serum cholesterol between the high and low third were 0 mg/dL in men and –3 mg/dL in women. The association between self-reported diet and serum lipids was assessed at the baseline of the Multiple Risk Factor Intervention Trial [14]. The population consisted of 12,847 men, predominantly white, and at moderate to high risk of coronary disease. Egg consumption was expressed as a percent of total energy consumed. Those with total cholesterol levels <200 mg/dL consumed more eggs as a percent of calories than did participants with cholesterol levels ≥220 mg/dL (2.4% versus 1.9%,  $p < 0.001$ ). Recently, Song and Kerver examined the association between egg consumption and serum cholesterol in more than 20,000 participants in the Third National Health and Nutrition Examination Survey (NHANES III) conducted from 1988–94 [15]. Participants consuming ≤1 egg/week had a higher average serum cholesterol level than those consuming ≥4 eggs/week (197 versus 193 mg/dL,  $p < 0.01$ ).

Epidemiologic data relating directly to egg consumption and cardiovascular disease risk are relatively scarce and have been generally methodologically weak. Many used poor dietary instruments or did not adequately adjust other aspects of the

diet or relevant confounding factors. Dawber and colleagues examined the relationship between egg consumption and incident cardiovascular events in 912 men and women enrolled in the Framingham Study [13]. In men, those in the highest tertile of egg consumption (average = 10.6 eggs/week) had 1.3 fold times the rate of CHD than men in the lowest tertile of consumption (average = 1.4 eggs/week). In women, those in the highest tertile, averaging 7.3 eggs/week, had 1.3 times the rate of CHD than women in the lowest tertile, averaging 0.7 eggs/week. These differences were not statistically significant, and were not adjusted for any risk factors or other dietary habits.

The relationship between dietary intake and CHD mortality was analyzed for 10,802 participants in the Oxford Vegetarian Study [16,17]. During the mean follow-up of 13.3 years, 64 CHD deaths were observed. After adjusting for age, sex, smoking status and social class those eating eggs at least 6 times per week were at 2.47 times the risk of dying from CHD compared to those eating fewer than one egg per week ( $p < 0.01$ ). However, the study did not attempt to adjust for the possible confounding effects of other dietary constituents and probably could not because of the small number of CHD events. This is of concern because of the authors also saw strong associations between total animal fat and cheese consumption and CHD death, factors likely correlated with egg consumption.

In 1960, 25,153 white California Adventists, aged 30–84 years of age, completed a survey asking about the consumption of 4 categories of foods (meat, eggs, cheese and milk) along with other health questions [18]. The mortality experience of the cohort was tracked through death certificates through 1980. A statistical model was used to adjust for the consumption of meat, cheese, milk, and coffee, body weight, marital status, smoking status and age. In men, there was no association between daily egg consumption and CHD death ( $RR = 1.04$ ) compared to no egg consumption. In women, daily egg consumption was associated with an elevated risk of CHD death ( $RR = 1.3, p < 0.05$ ). Consideration of other dietary constituents and other coronary risk factors was not possible due to limitations inherent in the questionnaire. A later study in California Adventists was started in 1976. Fraser reported on the six-year risk of incident coronary events among 26,743 nondiabetic Adventists with no previous history of heart disease [19]. The cohort completed a 51-item food frequency questionnaire. There was no increase in coronary risk among those in the high intake category ( $\geq 3$  eggs/week) compared to those consuming less than one egg/week ( $RR = 1.01$ ). No adjustment for other dietary factors was reported.

The diet of 5,133 Finnish men and women aged 30 to 69 years was assessed from 1969 to 1972 [20]. Over the subsequent 16 years of follow-up 244 participants died from CHD. After accounting for differences in age, there were no baseline differences in egg consumption between those who died from CHD and those surviving to the end of the study.

In the Fukuoka Heart study, 660 cases of non-fatal MI were

identified at 22 hospitals in Fukuoka City Japan from September 1996 to September 1998 [21]. The case-series was matched to 1,277 controls based on age, sex and area of residence. High egg consumption was classified as four or more eggs per week and was compared to consumption of fewer than 2 eggs per week. After adjusting for smoking, alcohol use, work related physical activity, leisure-time physical activity, hyperlipidemia, hypertension, diabetes, angina pectoris and obesity, there was no association between egg consumption and the first occurrence of non-fatal myocardial infarction ( $RR_{men} = 0.9, RR_{women} = 0.8$ ). Other dietary factors were not accounted for in the analysis.

Gramenzi *et al.* reported results from an Italian case-control study that enrolled 287 women aged 22–69 who were admitted for non-fatal myocardial infarction at one of 30 hospitals in northern Italy [22]. The case-series was compared to 649 controls in the same age-range selected from other women admitted to the hospitals participating in the study. Data on the intake of 10 foods and several beverages were collected. Adjusting for age, low egg consumers ( $< 1$  egg/week) and high egg consumers (more than 2 per week) were at similar risk ( $RR = 0.8$ ). No other adjustments were done.

Hu *et al.* published the only study to ever specifically examine the relationship between egg consumption and CHD risk [23]. The two cohorts analyzed included 37,851 men aged 40 to 75 and 80,082 women aged 34 to 59 years free of cardiovascular disease diabetes, hypercholesterolemia, or cancer. These groups were followed for 14 and 8 years, respectively. The associations between egg intake and CHD were examined adjusting for age, body mass index, cigarette smoking, parental history of MI, vitamin supplement use, alcohol consumption, history of hypertension, physical activity, total energy intake, bacon consumption, and, in women, menopausal status and post-menopausal hormone use. Compared to those consuming less than one egg per week, those eating at least 7 eggs/week there had no increased risk of CHD ( $RR_{men} = 1.08, RR_{women} = 0.82$ ). The study was large enough to examine the relationship between egg consumption and heart disease among those with low cholesterol consumption from non-egg sources. This is important because the failure to find an association between egg consumption and CHD risk could be due to the obscuring effects of other sources of dietary cholesterol. That is, if non-egg consumers ate other more high cholesterol foods, and egg consumers ate fewer other high cholesterol foods, it could be that the failure to see a relationship between egg consumption was due to the fact that total cholesterol intake wasn't that much different between egg and non-egg eaters. Furthermore, clinical data indicates that the effect of dietary cholesterol on serum cholesterol is greater at lower total cholesterol intakes, so if an effect of eggs were to be seen it would most likely be apparent among those consuming low levels of total cholesterol [24]. Among the participants with low non-egg cholesterol consumption, the relative risk associated with the consumption of more than one egg per day compared to those

consuming less than one egg per week was 1.05 in men and 0.97 in women. Though excluded from the primary analysis, the authors also looked at the association between egg consumption and CHD in diabetics. In diabetic men, those consuming 1 or more eggs per day had twice the CHD risk as infrequent egg eaters (RR = 2.05; 95% CI = 1.05–3.87). There was no association for men with less frequent intakes. In diabetic women, the relative risk for frequent egg consumers was 1.49 (95% CI, 0.88–2.52). Those consuming 5–6 eggs per week also had an elevated risk.

One study has looked at the role that animal products, including eggs, might play in modulating stroke risk. In 1979, participants in the Hiroshima/Nagasaki Life Span Study who were free of stroke, cancer and heart disease completed risk factor questionnaire including diet items (14,209 men and 22,921 women) [25]. After accounting for sex, age, city, radiation dose, body mass index, smoking status, alcohol use, education, history of diabetes or hypertension, those reporting almost daily egg consumption had a 30% lower rate of stroke death compared to those never consuming eggs (RR = 0.70,  $p < 0.05$ ). Similar associations were seen for dairy product and fish consumption. The association was stronger for hemorrhagic stroke than occlusive stroke.

In summary, eight studies have reported on the egg consumption and CHD risk directly. On the whole they do not support the contention that egg consumption is a risk factor for heart disease. However, the largest by Hu and colleagues is the only one to specifically address issue [23]. It is also the one that used the most well developed dietary instrument and the most sophisticated analytic approach. This study showed no increase in risk associated with egg consumption in the general population. The issue of the role of dietary cholesterol in diabetics requires further examination.

### Guidelines Revisited

The most recent guidelines from the AHA represent a departure from the past [26]. There is a recognition that simply avoiding certain foods or certain nutrients will not lead to better health if the diet as a whole is inadequate. The revised recommendations are centered the selection of healthy foods (Table 3). They recommend limiting foods high in saturated fat and cholesterol, but do not specifically recommend either avoiding or limiting eggs to a certain number. The advisory group recommended that individuals limit their cholesterol intake to under 300 mg/day, but acknowledge that “[t]his target can be readily achieved, even with periodic consumption of eggs and shellfish” [26].

The shift in focus towards healthy eating patterns is part of broader trend in dietary research looking at dietary patterns rather than specific foods or nutrients [27,28]. This is due, in part, to the recognition that diets based on certain cultural patterns of eating (e.g., the Mediterranean pattern) may lead to lower coronary risk than those based on minimizing saturated

**Table 3.** American Heart Association Dietary Guidelines: Revision 2000

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#### Maintaining a Healthy Eating Pattern:

- Consume a variety of fruits and vegetables and grain products, including whole grains.
- Include fat-free and low-fat dairy products, fish, legumes, poultry, and lean meat.

#### Maintaining a Healthy Body Weight:

- Match energy intake to energy needs; limit consumption of foods with high caloric density and/or low nutritional quality, including those with high content of sugar.
- Maintain a level of physical activity that achieved fitness and balances energy expenditure with energy intake; for weight reduction, expenditure should exceed intake.

#### Maintaining a Desirable Blood Cholesterol and Lipoprotein Profile:

- Limit intake of foods with a high content of saturated fatty acids and cholesterol.
- Substitute grains and unsaturated fatty acids from vegetables, fish, legumes, and nuts.

#### Maintaining a Desirable Blood Pressure:

- Limit the intake of salt to <6 g per day.
  - Limit alcohol consumption (no more than 1 drink per day for women and 2 drinks per day for men).
  - Maintain a healthy body weight and dietary pattern that emphasizes vegetables, fruits, and low-fat or fat-free dairy products.
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Source: [26].

fat and cholesterol intake [29,30]. In this context, it should be noted that there are dietary patterns associated with good cardiovascular health in which eggs play a prominent role. Japan has some of the lowest rates of coronary heart disease in the developed world [31]. As Japan has become more affluent the rates of coronary disease have continued to fall [32]. The Japanese diet frequently incorporates eggs, but in the context of a diet relatively low total fat and saturated fat. Interestingly, over the period of declining heart disease rates in Japan, per capita egg consumption increased [33]. Thus, the Japanese experience suggests that egg consumption is consistent with low coronary risk in the context of an otherwise heart healthy diet.

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Received June 30, 2004.