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«Review»

# Egg Consumption and Human Health: A Comprehensive Review of the Effects on Serum Lipids, Antioxidant Status, and Cardiovascular Outcomes

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Eggs are a highly nutritious food and an excellent source of carotenoids, lutein and zeaxanthin, which contribute to antioxidant defenses and ocular health. However, eggs have been viewed skeptically because of their impact on serum cholesterol levels. This review summarizes the evidence from clinical trials, observational studies, and worldwide ecological studies relating egg consumption to serum lipid profiles, antioxidant status, and cardiovascular outcomes. Recent meta-analyses on egg consumption have reported an increase in serum cholesterol but limited or no impact on atherosclerosis and cardiovascular disease risk. Clinical studies have reported that the additional consumption of an egg per day for 4 weeks improved high-density lipoprotein-cholesterol levels and decreased oxidized low-density lipoprotein levels. Most recently, a cross-sectional study of Japanese patients who underwent coronary angiography reported no significant association between egg intake and the prevalence of coronary artery disease or multi-vessel disease. Among patients not receiving lipid-lowering drugs, moderate egg intake (3–4 eggs/week) was associated with a lower prevalence of multi-vessel disease. Furthermore, worldwide ecological analyses have identified a significant negative association between egg intake and the incidence and mortality of ischemic heart disease. Given their high nutritional value, relatively low cost, and the evidence presented, eggs could contribute to healthy diets in many countries worldwide.

**Key words:** antioxidant, cardiovascular health, carotenoids, cholesterol, egg

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## Introduction

Eggs are known for their high nutritional value; however, whether they represent a healthy option varies by country and individual. Because eggs are a major source of dietary cholesterol, limiting egg consumption has often been recommended as a means of preventing hypercholesterolemia. However, multiple lines of evidence suggest that dietary cholesterol has a limited effect on blood cholesterol levels and atherosclerosis risk. Eggs are rich in high-quality proteins, phospholipids, and antioxidant carotenoids, such as lutein and zeaxanthin, which exert beneficial effects on lipid metabolism and oxidative stress, two major risk factors for cardiovascular disease (CVD).

The relationship between egg consumption and heart disease has been extensively studied. In Japan, a large cohort study published in 2006 showed that daily or nearly daily egg consumption did not increase the incidence of coronary heart disease[1]. Conversely, a recent US study associated high egg consumption with increased CVD risk and all-cause mortality[2]. Hence, the evidence remains inconclusive.

This review aims to integrate clinical, observational, and ecological evidence to provide a comprehensive perspective on the role of egg consumption in cardiovascular health, with a particular focus on the Japanese population.

## Egg Intake and Nutritional Value of Eggs

According to the Global Dietary Database, a comprehensive international resource compiled by experts in epidemiology and

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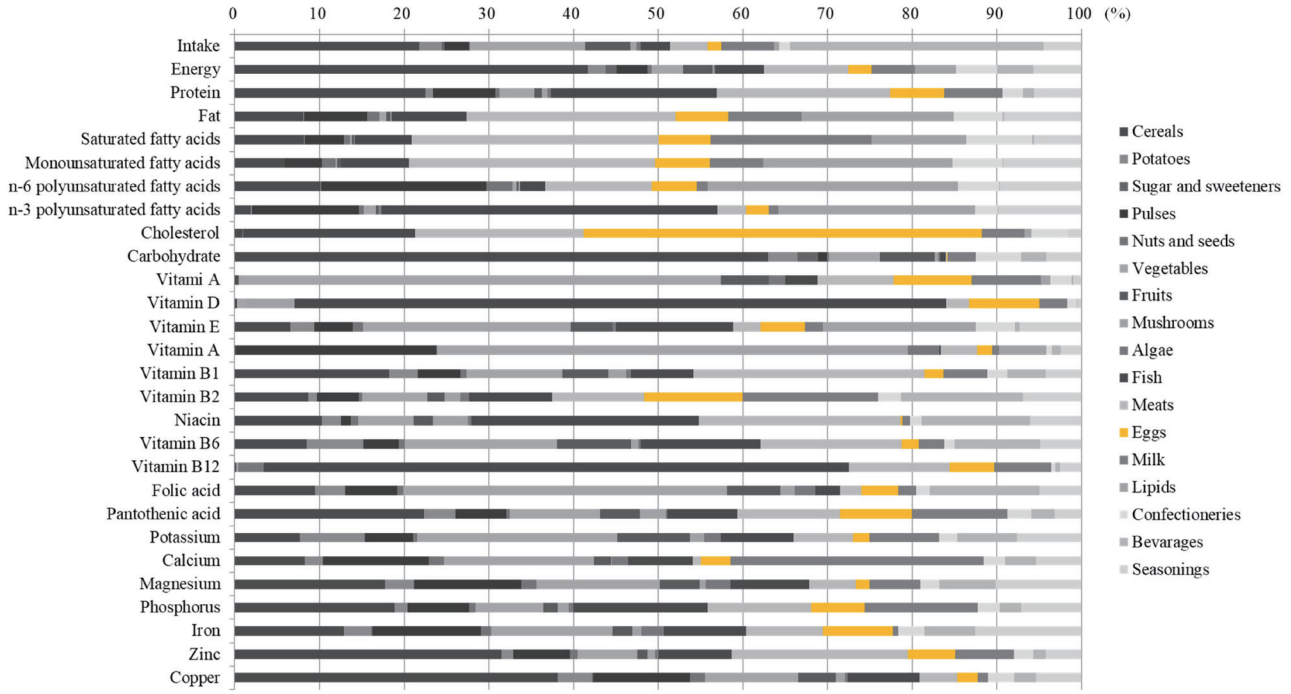


Fig. 1. **Impact of egg consumption on nutrient intake in Japan.** Dietary intake data were obtained from the National Health and Nutrition Survey in 2019. The bar chart illustrates the percentage contribution of each food source to the intake of a specific nutrient. The eggs are highlighted in yellow.

nutrition, the median egg intake varies widely across regions and populations[3]. Based on data from 142 countries in 2018, the global mean and median egg intakes were estimated at 21.5 g/day and 18.7 g/day, respectively. The distribution was broad, with the 5th to 95th percentile ranging from 3.5 to 45.1 g/day. The highest regional average intake estimate was observed in the Middle East and North Africa, with a regional summary of country-level medians of 36.1 ± 22.1 g/day, and a range of 6.9 to 106.1 g/day. In contrast, Sub-Saharan Africa reported the lowest regional average intake estimate (6.9 ± 4.6 g/day)[4]. Japan ranks among the higher-consuming countries, with a median intake of 39.6 g/day, which is well above the global mean. These disparities may reflect cultural, economic, and dietary factors.

Eggs are widely recognized as a nutritionally dense food. A single medium-sized egg provides approximately 6 g of high-quality protein containing all nine essential amino acids in optimal ratios for human health. In addition to protein, eggs are rich in fat-soluble vitamins such as vitamin A, D, E, and K, and water-soluble B vitamins. Eggs are a natural source of bioactive and potentially beneficial compounds[5]. The yolk contains cholesterol that regulates cell membrane fluidity and stability. According to the Japan National Health and Nutrition Survey of 2019, eggs contribute to approximately 50% of the dietary cholesterol intake[6]. **Figure 1** shows the percentage contribution of each food group to the intake of various nutrients. Eggs contribute to the intake of protein, vitamins, and minerals. The yolk contains carotenoids, such as lutein and zeaxanthin, which contribute to antioxidant defense and ocular health. The lutein and zeaxanthin content in eggs depends on the feed given to laying hens. The level of lutein ranges from 167 to 216 μg/egg yolk, and that of zeaxanthin ranges from 85 to 185 μg/egg yolk[5,7,8]. Fukushima et al. recently published a Japanese carotenoid content database, which indicated that eggs contained 270 μg of lutein and 230 μg of zeaxanthin per 100 g. Eggs were identified as the third major source of lutein intake (8.1% of total) and the primary source of zeaxanthin intake (52.3% of total) among Japanese women[9]. These findings suggest that eggs are a significant dietary source of both carotenoids.

## Egg Consumption and Blood Lipids

Eggs are a prominent source of dietary cholesterol, and their impact on blood lipid profiles has been extensively investigated in clinical trials and observational studies. However, the findings of these studies have been inconsistent, particularly regarding serum cholesterol levels and cardiovascular risk.

A meta-analysis of 28 randomized controlled trials (RCTs) reported that egg consumption resulted in only modest increases of 5.60 mg/dL for total cholesterol (TC), 5.55 mg/dL for low-density lipoprotein cholesterol (LDL-C), and 2.13 mg/dL for high-density lipoprotein cholesterol (HDL-C) levels. Increased egg consumption had no significant effect on the LDL-C/HDL-C and TC/HDL-C ratios[10]. These ratios are clinically relevant

because elevated LDL-C/HDL-C and TC/HDL-C values are established markers of atherosclerotic risk. A 2020 meta-analysis of 66 RCTs reported similar findings: consuming more than one egg per day increased TC, LDL-C, and HDL-C, while the LDL-C/HDL-C ratio remained unchanged[11]. In contrast, another 2020 meta-analysis of 17 RCTs associated egg intake with increases in LDL-C and the LDL-C/HDL-C ratio[12], suggesting potential variability depending on study design and population characteristics.

Despite these mixed results, a consistent pattern has emerged: egg consumption tends to increase LDL-C and HDL-C levels, but the balance between them, reflected in the LDL-C/HDL-C ratio, tends to remain stable. This suggests that the potential atherogenic effect of elevated LDL-C levels may be offset by the cardioprotective role of HDL-C. Across several analyses, the estimated increase in TC is approximately 2.2–2.5 mg/dL for every 100 mg/day increase in dietary cholesterol, roughly equivalent to a 2–3% rise in serum cholesterol per egg consumed[13,14]. This effect is relatively modest compared to the impact of other dietary components such as saturated fatty acids[15]. This limited response may be attributed to the physiological feedback mechanisms that regulate cholesterol absorption, synthesis, and excretion. A meta-analysis demonstrated that the LDL-C response to dietary cholesterol was significantly attenuated when the background diet was low in saturated fat (P/S > 0.7) as opposed to a higher saturated fat content (P/S ≤ 0.7)[16].

These findings suggest that although eggs influence lipid parameters, the magnitude and clinical relevance of these changes are context-dependent and may not warrant blanket dietary restrictions, especially in individuals with healthy dietary habits (high P/S ratio).

## Impact of Daily Egg Supplementation on Lipid Profiles and Antioxidant Status in Japanese Adults

To investigate the physiological effects of egg consumption, two intervention studies were conducted in Japanese populations with distinct lipid profiles. The first study, conducted in healthy Japanese adults, reported that the additional consumption of an egg per day for 4 weeks significantly increased HDL-C levels and decreased the LDL-C/HDL-C ratio. Malondialdehyde-modified LDL (MDA-LDL) is an oxidized form of LDL, and the MDA-LDL/LDL-C ratio reflects the LDL oxidation degree. In this study, this ratio decreased, and the resistance of LDL to oxidation improved, suggesting a favorable shift in lipoprotein quality toward reduced oxidative susceptibility[17].

The second study targeted moderately hypercholesterolemic Japanese males and examined the effects of adding one egg per day to their habitual diet on serum lipid levels. After 4 weeks, no significant alterations in TC and LDL-C levels were observed. At 2 and 4 weeks, serum MDA-LDL levels was decreased, whereas LDL resistance to oxidation significantly improved. The same time points showed a significant increase in serum lutein + zeaxanthin levels. A significant inverse relationship was observed between serum lutein + zeaxanthin content and MDA-LDL ($r = -0.48$, $p = 0.0001$), whereas a significant positive relationship was observed with LDL oxidation lag time ($r = 0.28$, $p < 0.05$) (**Figure 2**)[18].

In the two studies mentioned above, the lack of increase in serum cholesterol could be attributed to the relatively low amount of loaded cholesterol and changes in the absorption and reverse transport of cholesterol caused by egg components. Egg white protein has been observed to suppress cholesterol absorption in animal experiments and clinical trials[19,20]. Another explanation may be the Japanese dietary pattern, particularly its high P/S ratio. The addition of one egg per day for 12 weeks significantly increased serum lutein + zeaxanthin levels, while lowering oxidized LDL levels, suggesting that egg-derived carotenoids may attenuate oxidative stress and improve lipoprotein quality[17,18]. These results highlight the role of lutein and zeaxanthin as key bioactive compounds in eggs. Lutein is more readily absorbed from eggs than from other sources, such as lutein supplements and spinach[21]. The capacity of these carotenoids to limit the oxidative modification of lipoproteins may represent an important mechanism by which egg consumption supports cardiovascular health, particularly in the Japanese population with its high baseline egg intake.

## Egg Consumption and Cardiovascular Health

The relationship between dietary cholesterol intake, particularly from eggs, and cardiovascular outcomes has been extensively investigated through observational studies and intervention trials. Although some studies have linked an increased risk of CVD with higher cholesterol or egg consumption[2,22–26], others have reported no association or even a protective effect[27–30]. Although much of the existing evidence comes from studies conducted in high-income countries, three large international prospective cohort studies involving approximately 177,000 individuals across 50 countries on six continents observed no significant association between egg intake and blood lipid levels, mortality, or major cardiovascular events[31].

A 2015 systematic review and meta-analysis, which included 17 cohort studies and 19 clinical trials, observed no significant association between dietary cholesterol intake and CVD risk, despite modest increases in TC and LDL-C levels[32]. More recently, a 2020 meta-analysis concluded that consuming up to one egg per day was not associated with an increased CVD risk and might even lower the risk in Asian populations[33]. An umbrella review reported no significant association between egg consumption and major health outcomes, including cancer, CVD, and metabolic disorders, while noting a possible protective effect against stroke[34].

Current evidence does not support a definitive link between egg consumption and risk of CVD. Methodological heterogeneity and population differences complicate interpretation; however, the consistent finding across studies is that egg intake does not promote CVD.

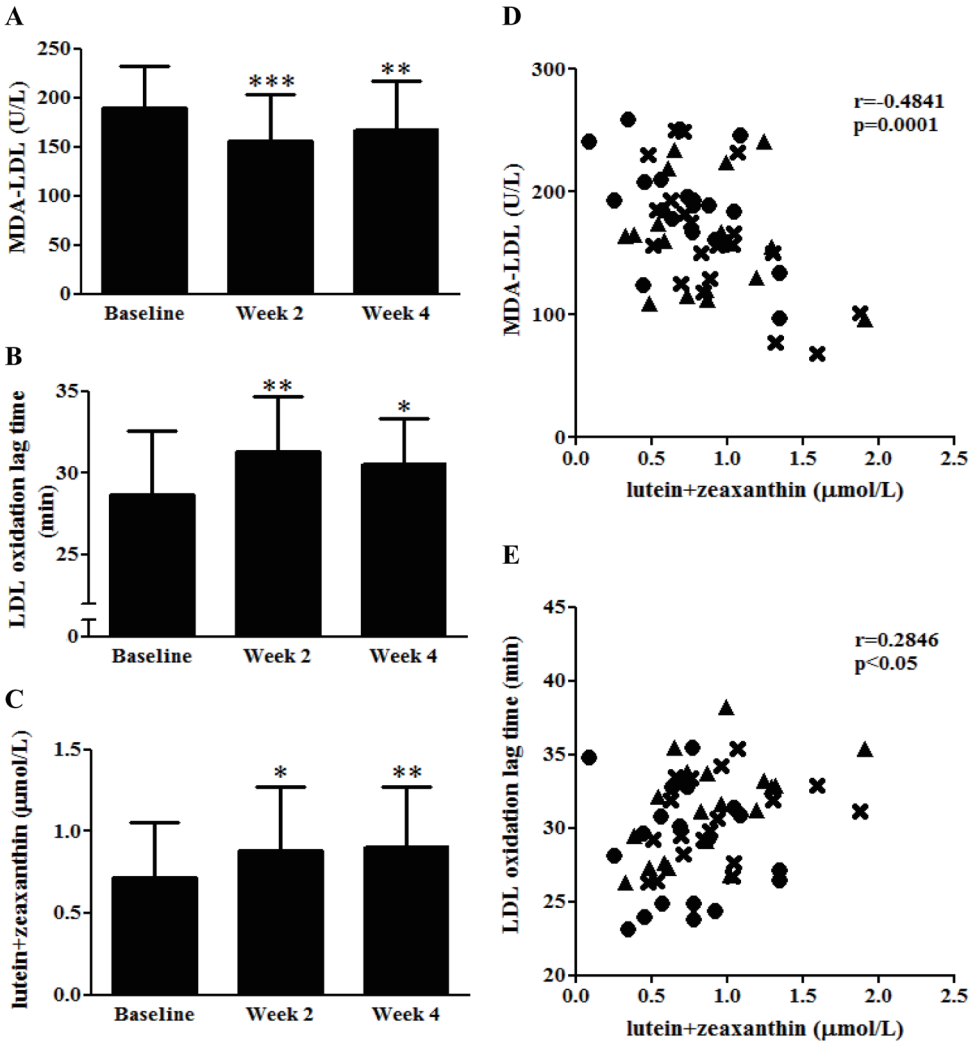


Fig. 2. **Serum parameters at baseline, week 2, and week 4 in moderately hypercholesterolemic Japanese males consuming one egg per day in addition to their habitual diet.** (A) Malondialdehyde-modified low-density lipoprotein (MDA-LDL) concentration, (B) LDL oxidation lag time, and (C) serum lutein + zeaxanthin concentration. Values represent the mean ± SD (n = 19); ***p < 0.001, **p < 0.01, *p < 0.05 compared to baseline using Tukey's test after repeated analysis of variance (ANOVA). (D, E) Pearson correlation between lutein + zeaxanthin concentration and MDA-LDL concentration (D) and LDL oxidation lag time (E). ●: baseline, ▲: week 2, and ×: week 4. (Reprinted from Kishimoto et al., 2017, copyright (2017), with permission from Elsevier)

## Observational Analysis of Egg Intake and Coronary Artery Disease in Japanese Patients Undergoing Coronary Angiography

Recently, a cross-sectional study was conducted involving Japanese patients who underwent coronary angiography for suspected coronary artery disease (CAD)[35]. Among the 795 participants, CAD was diagnosed in 506 individuals, of whom 299 had multi-vessel disease (MVD). The prevalence of CAD and MVD did not differ significantly among the three categories of egg intake: <3 eggs/week, 3–4 eggs/week, and ≥1 egg/day. Multivariate analyses adjusted for atherosclerotic risk factors and dietary intake revealed no significant association between egg consumption and CAD or MVD. The odds ratios (ORs) in the 3–4 eggs/week and ≥1 egg/day groups, compared to the <3 eggs/week group, were 0.91 [95% confidence interval (CI): 0.62–1.34] and 1.06 (95% CI: 0.67–1.67) for CAD, and 0.79 (95% CI: 0.55–1.15) and 1.22 (95% CI: 0.80–1.87) for MVD, respectively. In a subgroup analysis of 504 patients not receiving lipid-lowering drugs, those consuming 3–4 eggs/week had a significantly lower

prevalence of MVD than those consuming <3 eggs/week ($p < 0.05$). In this subgroup, multivariate analysis showed an OR of 0.56 (95% CI: 0.33–0.96) for MVD in the 3–4 eggs/week group, whereas no significant association was observed in the ≥1 egg/day group (OR: 1.21, 95% CI: 0.69–2.13). These findings suggest that the consumption of ≥1 egg/day is not associated with an increased risk of CAD or MVD in Japanese patients undergoing coronary angiography.

## Ecological Evidence Linking Egg Intake and Ischemic Heart Disease

An ecological study using data from multiple countries investigated the association between egg intake and the incidence (IHDi) and mortality (IHDd) of ischemic heart disease (IHD). Country-level egg intake (g/day/capita) was obtained from the Global Dietary Database[3], and age-standardized IHDi and IHDd rates were obtained from the 2019 Global Burden of Disease Database[36]. The analysis included 142 countries with populations exceeding one million, for which complete data were available from 1990 to 2018. Linear mixed models were used to assess the relationship between egg intake and IHD outcomes, accounting for inter- and intra-country variations over time. The results demonstrated a significant inverse association between egg intake and IHDi ($-0.253 \pm 0.117$, $p < 0.05$) and IHDd ($-0.359 \pm 0.137$, $p < 0.05$). Accordingly, higher egg intake may be associated with globally lower IHDi and IHDd rates[4].

## Conclusions and Perspectives

Eggs are a nutritionally rich food, providing high-quality protein, essential micronutrients, and bioactive compounds such as lutein and zeaxanthin. Although traditionally viewed with caution due to their cholesterol content, accumulating evidence from clinical trials, observational studies, and ecological analyses suggests that egg consumption does not adversely affect cardiovascular health in most populations.

Intervention studies in Japanese adults have reported beneficial effects on HDL-C levels and resistance to LDL oxidation. The antioxidant properties of egg-derived carotenoids, particularly lutein and zeaxanthin, play a key role in modulating oxidative stress and enhancing lipoprotein quality. These mechanisms may help explain the neutral or favorable cardiovascular effects observed, despite modest increases in serum cholesterol levels.

Given the wide variation in egg consumption across regions and the cultural importance of eggs in many diets, including Japan, where intake is relatively high, future studies should continue to explore population-specific responses, genetic factors, and dietary patterns. Longitudinal studies and mechanistic investigations are essential to clarify the role of eggs in chronic disease prevention and provide evidence-based dietary guidelines.

In conclusion, current evidence supports the inclusion of eggs in a balanced diet, particularly when consumed in moderation. Their nutritional and functional properties warrant continued attention in clinical nutrition and public health.

## Author Contributions

YK analyzed the data and wrote the manuscript. NS analyzed the data and revised the manuscript.

## Conflicts of Interest

The authors declare no conflict of interest.

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