

# The Role of Eggs in Healthy Diets

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## KEY TAKEAWAYS

- Eggs can be part of a healthy diet.
- Epidemiologic evidence and clinical trials have found no links between egg intake and increased risk for heart disease.
- Eggs are a good source of high-quality protein.
- Eggs, in addition to numerous vitamins and

minerals, contain compounds including choline, lutein, and zeaxanthin with functions that go beyond nutrition as they protect against chronic disease.

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## DISCLOSURES

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## HISTORICAL OVERVIEW OF THE ROLE OF EGGS IN DIETARY RECOMMENDATIONS

Dietary cholesterol has been a controversial issue since the 1960s when the upper limit for cholesterol intake was set at no more than 300 mg/day. It is now recognized that this arbitrary number was not based on data derived from epidemiologic studies or clinical interventions but more on limited information that existed at the time.<sup>1</sup> The 2015 Dietary Guidelines for Americans have now changed that historical perspective by removing the upper limit of dietary cholesterol among healthy populations<sup>2</sup> following the conclusions reached by numerous other countries, which had long ago realized that cholesterol from the diet does not increase the risk for cardiovascular disease (CVD).<sup>3</sup> Because of these early recommendations in the United States, eggs, with their high content of dietary cholesterol (about 180 mg in a large egg), have been regarded as the icon that exemplifies dietary cholesterol and hence, by association, heart disease risk. Despite new dietary guidelines, the perception of the dangers of egg consumption are, for many people, still based on outdated information. More recent data suggest that eggs do not increase the risk for heart disease and should be considered a valuable component of a healthy diet.

## EFFECTS OF EGGS ON CARDIOVASCULAR RISK: EPIDEMIOLOGIC FINDINGS

There are a number of epidemiologic studies that have shown a lack of association between eggs and cardiovascular risk.<sup>3-7</sup> In a recent updated cohort comprised of a number of individuals including 83,349 women from the Nurses'

Health Study (NHS), 90,214 women from NHS II, and 42,055 men from the Health Professional Follow-Up who were free of CVD, type 2 diabetes, and cancer at baseline, it was found that moderate egg consumption was not associated with increased cardiovascular risk (pooled relative risk 0.98, 95% confidence interval [CI] 0.93 to 1.03, heterogeneity test [I<sup>2</sup>] = 62.3%).<sup>4</sup> Similarly, a current meta-analysis of 39 studies that included 2 million individuals arrived at the same conclusion: intake of 2 eggs per day is not associated with cardiovascular risk (relative risk = 0.96, 95% CI: 0.91 to 1.00).<sup>5</sup> More importantly, a recent publication on 3 large international prospective studies that included 177,000 individuals from 50 countries and 6 continents showed a statistical trend that egg intake was not related to plasma lipids, mortality (hazard ratio [HR]: 1.04; 95% CI: 0.94 to 1.15; *P*-trend = 0.38), or CVD events (HR: 0.92; 95% CI: 0.83 to 1.01; *P*-trend = 0.20).<sup>6</sup> A meta-analysis of randomized clinical trials, with some limitations, has further confirmed the lack of association between biomarkers of heart disease and egg intake by showing no association between egg consumption and inflammatory markers including C-reactive protein (CRP) (95% CI: -0.43 to 0.90; *P* = 0.48), interleukin-6 (IL-6) (95% CI: -0.71, 1.11; *P* = 0.50), and tumor necrosis factor alpha (TNF- $\alpha$ ) (CI: -0.87 to 0.10; *P* = 0.12).<sup>7</sup> Interestingly, egg intake has been associated with lower cardiovascular risk in Asian populations<sup>3,8</sup> and with lower mortality among patients with hypertension.<sup>9</sup> Although controversy exists in the literature related to egg consumption and risk for diabetes, a recent epidemiologic analysis conducted by Harvard investigators reported no correlation between egg intake and risk of diabetes (95% CI: 0.99 to 1.15; I<sup>2</sup> = 69.8%),<sup>10</sup> an

important finding due to the strong correlation between diabetes and risk for heart diseases. Thus, from an epidemiologic point of view, recent cohort studies and a large meta-analysis have not reported an association between egg intake and cardiovascular risk.

### EFFECTS OF EGGS ON PLASMA LIPIDS, LIPOPROTEINS, AND INFLAMMATORY BIOMARKERS IN DIVERSE POPULATIONS

The low-density lipoprotein (LDL)/high-density lipoprotein (HDL) ratio has been recognized as a key biomarker of coronary heart disease risk.<sup>11</sup> Clinical interventions conducted in the last 20 years have unequivocally shown that egg intake consistently results in increases in HDL cholesterol and either maintenance or decreases in the LDL/HDL

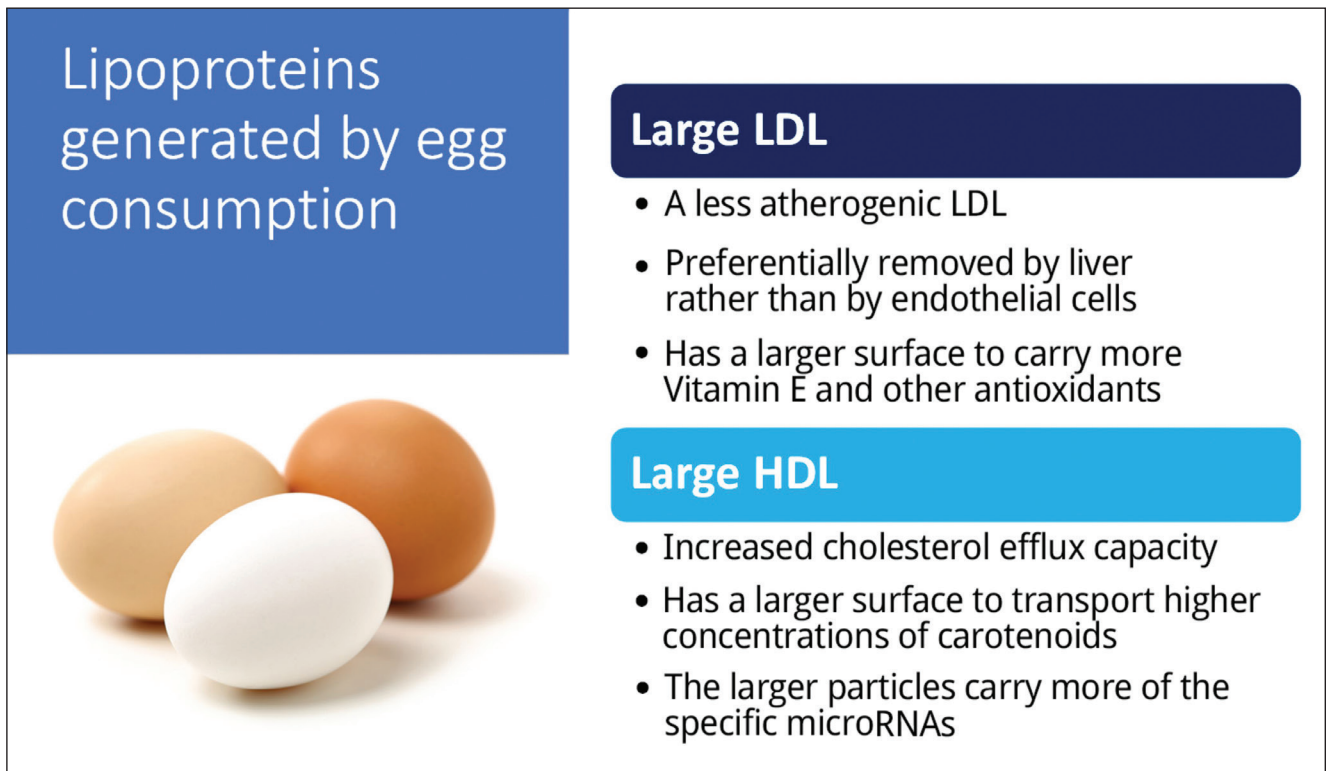
ratio.<sup>12-28</sup> **TABLE 1** illustrates different clinical interventions with diverse populations including children, young adults, elderly people, overweight-obese adults, individuals with metabolic syndrome, and patients with diabetes, which clearly demonstrate that consumption of 2-3 eggs per day for extended periods results in no effects or an improvement in the LDL/HDL ratio.

Another important metabolic alteration induced by eggs is the reduction of concentrations of atherogenic lipoproteins. Eggs have been shown to contribute to the formation of large LDL,<sup>12</sup> a less atherogenic lipoprotein compared to small LDL. Small LDL has been recognized as more atherogenic because of its limited ability to transport sufficient antioxidants and its capability to penetrate the arterial wall where it becomes oxidized. At that point, the

**TABLE 1. Changes in LDL cholesterol, HDL cholesterol, and LDL/HDL ratio compared to alternative treatment (egg substitute [sub], oatmeal [OM], 0 eggs or a choline supplement [CholS]) either in crossover- or parallel-design studies**

Type of study	Populations and comparisons	Number of eggs and time	LDL	HDL	LDL/HDL
Crossover <sup>19</sup>	Children	2 eggs/d 4 wk	Increased	Increased	No change
Crossover <sup>20</sup>	Young women compared to sub	3 eggs/d 4 wk	Increased	Increased	No change
Crossover <sup>21</sup>	College students compared to OM	2 eggs/d 4 wk	Increased	Increased	No change
Crossover <sup>22</sup>	Elderly compared to sub	3 eggs/d 4 wk	Increased	Increased	No change
Crossover <sup>23</sup>	Patients > 60 years	4 eggs/wk 4 wk	No change	Increased	Decreased
Parallel <sup>24</sup>	College students compared to 0 eggs	3 eggs/d 4 wk	No change	Increased	Decreased
Parallel <sup>25</sup>	Adult men and women compared to bagel	2 eggs/d 8 wk	No change	No change	No change
Parallel <sup>26</sup>	Obese/overweight men compared to sub	3 eggs/d 12 wk	No change	Increased	Decreased
Parallel <sup>15</sup>	Metabolic syndrome compared to sub	3 eggs/d 12 wk	No change	Increased	Decreased
Parallel <sup>27</sup>	Metabolic syndrome compared to CholS	2 eggs/d 12 wk	No change	No change	No change
Parallel <sup>18</sup>	Diabetic patients compared to OM	1 egg/d 5 wk	No change	No change	No change
Parallel <sup>28</sup>	Diabetic patients compared to low cholesterol	2 eggs/d 12 wk	No change	Increased	Decreased

FIGURE 1. Lipoproteins generated by egg consumption and their benefits



The large LDL is considered a less atherogenic lipoprotein than small LDL<sup>12</sup> since it is removed from circulation by the liver rather than by macrophages.<sup>29</sup> By being a larger particle, it has the ability to carry more Vitamin E and other antioxidants.<sup>29</sup> The large HDL has been shown to have increased cholesterol efflux capacity<sup>13,14</sup> and being a larger particle, it has the ability to carry more lutein and zeaxanthin,<sup>15</sup> carotenoids that have been shown to have antioxidant properties and to protect against age-related macular degeneration.<sup>23</sup> The large HDL also carries more specific microRNAs with hormonal properties.

**Abbreviations:** LDL = low-density lipoprotein; HDL = high-density lipoprotein, RNAs = ribonucleic acids.

oxidized LDL is taken up by the macrophages in an unregulated manner leading to foam cell formation and the beginning of the atherosclerotic process.<sup>29</sup> The elevation in the number of large LDLs induced by eggs also leads to higher plasma antioxidants characteristically transported by this lipoprotein.

Recent evidence has been presented that HDL functionality may be more important than circulating concentrations of HDL cholesterol.<sup>30</sup> Functionality of HDL refers to its cholesterol efflux capacity, a major function in reverse cholesterol transport, specific micro ribonucleic acids (microRNAs) in HDL that provide hormonal properties, and the antioxidants transported by this lipoprotein.<sup>30</sup> Larger HDL particles have been identified as biomarkers of cholesterol efflux capacity while high concentrations of small HDL particles have been identified as a marker of diabetes.<sup>31</sup> Consumption of eggs leads to the formation of large HDL particles with increased phosphatidyl choline content, which has been demonstrated to enhance reverse chole-

sterol transport in cell studies<sup>13,14</sup> and to be a better carrier for lutein and zeaxanthin, carotenoids present in eggs.<sup>15</sup>

**FIGURE 1** illustrates the lipoproteins that are increased by egg intake and their properties. Egg intake generates large LDL that is not easily oxidized because it carries more antioxidants and will most likely be removed by the liver via apoB-100. Eggs also generate large HDL that is involved in a more efficient HDL efflux. Large HDL also transports more carotenoids and microRNAs with hormonal properties in plasma.

Other studies have demonstrated that eggs reduce inflammatory markers including IL-6, CRP, serum amyloid A, TNF- $\alpha$ , and liver enzymes in patients with metabolic syndrome<sup>16,17</sup> or those with diabetes.<sup>18</sup> This reduction is possibly due to the high number of antioxidants present in eggs.

#### BENEFITS OF EGGS ACROSS THE LIFESPAN

Eggs do not increase the biomarkers of heart disease including LDL cholesterol, the LDL/HDL ratio, or inflammatory

TABLE 2. Protective effects of eggs against chronic disease

Disease	Protective effects
Coronary heart disease <sup>13-16,28</sup>	<ul style="list-style-type: none"> <li>• Generation of HDL particles with efficient cholesterol efflux capacity</li> <li>• Lowering of systemic inflammation</li> </ul>
Age-related macular degeneration (AMD) <sup>23,36</sup>	<ul style="list-style-type: none"> <li>• Eggs contain highly bioavailable lutein and zeaxanthin, 2 carotenoids selectively captured by the eye that protect against AMD</li> </ul>
Cognitive failure <sup>33</sup>	<ul style="list-style-type: none"> <li>• Eggs are a good source of choline, which has been shown to improve cognitive function</li> </ul>
Protein malnutrition <sup>40,41</sup>	<ul style="list-style-type: none"> <li>• Highly bioavailable protein</li> </ul>

markers<sup>14-16</sup>; in contrast, there are numerous benefits associated with egg consumption. Eggs are a source of highly bioavailable protein that has all essential amino acids and can be utilized by individuals across the life spectrum.<sup>32</sup> Eggs are a major source of choline, which is a metabolite that plays an important role in liver health, is an intrinsic part of cell membranes and lipoproteins, and is a precursor of the neurotransmitter acetylcholine. Evidence also suggests that choline can protect against decline in cognitive function.<sup>33</sup> Further, dietary choline from eggs does not increase the chronic concentrations of trimethylamine oxide (TMAO)<sup>30,34</sup> a metabolite recognized as a biomarker of heart disease.<sup>35</sup> Eggs contain highly bioavailable lutein and zeaxanthin,<sup>14,30</sup> carotenoids that accumulate in the retina and protect against age-related macular degeneration.<sup>36</sup> Lutein and zeaxanthin are also potent carotenoids that are mainly transported by HDL<sup>14</sup> and that have been shown to exert antioxidant and anti-inflammatory effects in various organs.<sup>37,38</sup> Further, a role of lutein in cognitive function has been recently recognized.<sup>39</sup> A brief description of the protective role of eggs against chronic disease is presented in **TABLE 2**.

## SUMMARY AND CONCLUSIONS

Eggs have been historically considered as food with a high cholesterol content. Strong evidence from rigorously conducted epidemiologic analyses<sup>4,10</sup> and from well-controlled clinical trials<sup>16-31</sup> indicates that eggs do not increase the biomarkers for heart disease or negatively alter the lipoprotein profile, when consumed in moderation (ie, <3 eggs daily). Eggs are, in fact, worthy of consideration as a component of a healthy diet due to their high concentrations of vitamins E and D and selenium<sup>40</sup> and their high-quality protein.<sup>41,42</sup> Additionally, they are a good source of choline<sup>24,34</sup> and of the highly bioavailable carotenoids, lutein and zeaxanthin,<sup>15,23</sup> shown to be protective antioxidants against age-related macular degeneration,<sup>23,38</sup> fatty liver, and the development of atherosclerosis in animal studies.<sup>43</sup> ●

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