



Position Statement for Healthcare Professionals

Eggs, Plasma Cholesterol and Lipoproteins

Updated May 2012

Research conducted over the past 50 years shows egg consumption has only a small effect on raising total plasma cholesterol levels in most healthy people. Three meta-analyses have been conducted investigating the effects of eggs or dietary cholesterol on serum cholesterol levels.

The most recent meta-analysis of 17 human experimental studies published in 2001 found on average, increasing dietary cholesterol from eggs by 100mg daily, equivalent to half a 60gram egg or 3-4 eggs a week, results in the serum lipid changes shown in Table 1 ¹.

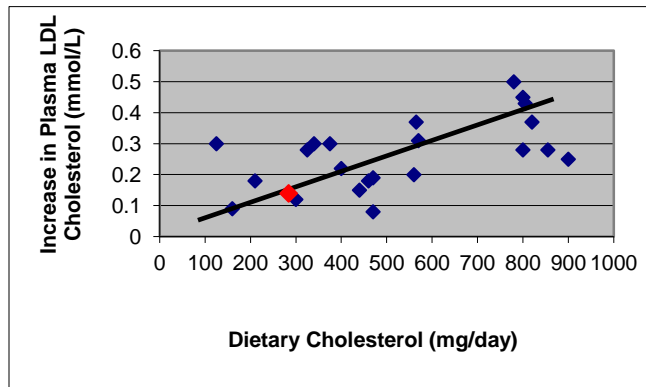
Table 1: Predicted changes in serum total cholesterol concentration, induced by a 100mg/day increase in dietary cholesterol from eggs alone ¹

Serum cholesterol concentration	Predicted change (95% CI)
Total cholesterol (mmol/L)	0.056 +/- 0.005 (0.046, 0.065)
HDL cholesterol (mmol/L)	0.008 +/- 0.001 (0.005, 0.010)
LDL cholesterol (mmol/L)	0.050 +/- 0.004 (0.042, 0.058)

These results are consistent with a meta-analysis on the plasma lipid and lipoprotein responses to dietary fat and cholesterol published in 1997 showing a 100mg decrease in dietary cholesterol results in a 0.057mmol/L decrease in plasma cholesterol translating to an approximate 1% decrease in the average population cholesterol concentration ².

A third meta-analysis of the effects of dietary cholesterol on serum cholesterol found higher baseline intakes of dietary cholesterol attenuated the increase in serum cholesterol seen with increasing intakes ³. However, subsequent studies have shown this occurs only at baseline cholesterol intakes greater than 1,000 – 1,200mg per day ^{4,5}. While the predicted changes in serum cholesterol induced by a 100mg per day increase in dietary cholesterol from eggs would be expected to diminish with higher baseline intakes, only three of the 17 studies included in the Weggemans et al meta-analysis involved subjects with a cholesterol intake greater than 1,000mg daily. Linear regression models were therefore used in the analysis showing the following serum LDL changes with increasing dietary cholesterol intake up to 1,000mg a day (Figure 1).

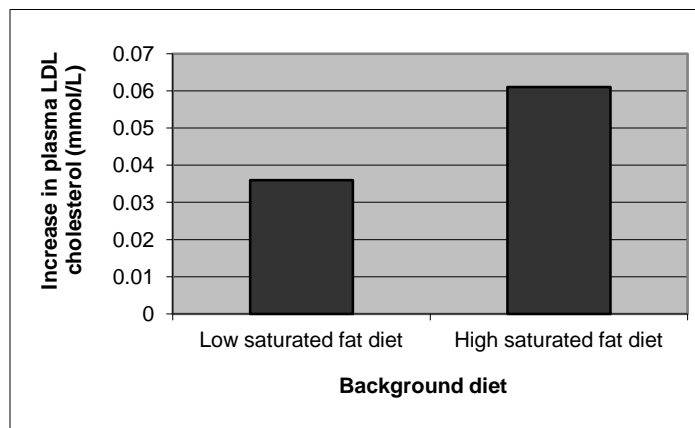
Figure 1: Predicted changes in serum LDL cholesterol induced by a 100mg/day increase in dietary cholesterol from eggs alone ¹



The red diamond indicates the average Australian intake of cholesterol from the 1995 National Nutrition Survey (297.9milligrams).

The changes in plasma cholesterol levels outlined in Table 1 and Figure 1 represent maximal estimates because the increase in plasma LDL cholesterol in response to increased egg consumption is attenuated when the background diet is low in saturated fat ⁶. This finding was confirmed in the meta-analysis when studies were divided into two groups: those with a background diet relatively high in saturated fat, and those with a background diet relatively low in saturated fat. As demonstrated in Figure 2, adding 100mg of cholesterol to a high saturated fat diet caused an increase in LDL cholesterol of 0.061 +/- 0.006mmol/L, whereas adding the same quantity of cholesterol to a low saturated fat diet caused an increase in LDL cholesterol of only 0.036 +/- 0.004mmol/L. The effect on LDL cholesterol from an increase in dietary cholesterol from eggs is therefore 1.7 times greater when the background diet is high in saturated fat compared to a low saturated fat background diet. This finding reinforces the recommendations from heart associations worldwide to reduce dietary saturated fat as a key strategy for reducing serum cholesterol levels. Dietary saturated fat has a significant effect on serum cholesterol levels with research showing that for every 1% increase in total daily kilojoules from saturated fatty acids, serum LDL cholesterol rises by about 2% ⁷.

Figure 2: Change in LDL cholesterol with an additional 100mg dietary cholesterol from eggs (independent of saturated fat)



Since 2001 several additional studies have been published investigating the impact of eggs on serum cholesterol. One study showed that the consumption of two eggs daily for six weeks had no effect on serum total cholesterol or on endothelial function in healthy adults⁸. Another study reported that adding four eggs a day to a low-fat diet for four weeks increased HDL cholesterol levels in all subjects, and increased inflammatory markers and non-HDL cholesterol levels in lean insulin-sensitive subjects but not in lean or obese insulin-resistant subjects⁹. A third study showed the consumption of three eggs per day for one month among 42 postmenopausal women and men aged sixty years and over with healthy lipoprotein profiles increased both plasma LDL and HDL cholesterol levels, however the LDL:HDL and TC:HDL ratios did not change¹⁰. A 2006 study among 33 men and women aged 60 years and over found that eating one egg a day for five weeks did not cause an increase in blood cholesterol levels¹¹. In 2006, the Japan Public Health Center-based study reported an inverse correlation between egg consumption and mean total cholesterol levels in people with normal and high baseline serum cholesterol levels ($TC \geq 5.8\text{mmol/L}$). Those who ate eggs daily had lower total serum cholesterol levels than those who ate eggs less than once per week ($P < 0.0001$)¹².

A study that included 3 eggs per day as part of a carbohydrate restricted diet in overweight/obese men aged 40-70 years undergoing a 12 week weight loss intervention showed no change in LDL cholesterol levels, a reduction in plasma triglycerides, and a significant increase in HDL cholesterol and lutein levels compared to the control (egg substitute) group¹³.

The Weggemans et al study also showed a small increase in HDL cholesterol with increasing cholesterol intake from eggs. The National Heart Foundation of Australia and the American Heart Association recognise low HDL as a major risk factor for coronary heart disease^{14,15}. HDL cholesterol is an independent risk factor for cardiovascular disease and higher levels are found to be cardio-protective¹⁶. Emerging evidence reveals many protective functions of HDL-cholesterol and therefore its importance in relation to cardiovascular disease should not be understated¹⁶.



Another study of 45 healthy but overweight/obese males and females aged 18-55 years showed energy restricted diets that included zero or two eggs per day for 12 weeks were equally effective for weight loss and reductions in plasma cholesterol arising as a result of a decrease in LDL levels. These results occurred despite the fact that dietary cholesterol was increased by more than two fold in the egg-fed group to an average 582mg per day and decreased in the non-egg-fed group, who were advised to exclude eggs from their diet. This indicates that increasing dietary cholesterol by consuming 2 eggs a day produces no increase in total and LDL cholesterol when accompanied by energy restriction and moderate weight loss ¹⁷.

A review ¹⁸ aimed to dispel the public misconception that eggs and dietary cholesterol significantly increase blood cholesterol and subsequent changes to dietary recommendations. The article concluded that while dietary cholesterol can raise "bad" LDL cholesterol, the effect is small compared to that of saturated fat. Furthermore eggs increase good "HDL" cholesterol. However, despite this evidence and changes to dietary recommendations, the myth surrounding eggs and heart disease still exists among the public.

Body weight may also affect the response to dietary cholesterol. The Chicago Western Electric Study, a prospective cohort study of 1,903 middle-aged men, showed a change in intake of dietary cholesterol was positively associated with a change in serum cholesterol for men in the lowest tertile of body mass index ($< 24.2\text{kg/m}^2$) but not for men in the highest tertile ($> 26.6\text{ kg/m}^2$) ¹⁹. This has since been supported by studies conducted in obese insulin-resistant postmenopausal women consuming up to four eggs per day showing no change in LDL cholesterol levels ²⁰. More recently, a study found that cholesterol absorption was highest in lean insulin sensitive participants whereas cholesterol synthesis was highest in lean insulin resistant and obese insulin resistant subjects. The authors suggest that for lean insulin-sensitive subjects a low intake of dietary cholesterol should be emphasized but the focus for insulin resistant individuals should be weight loss to decrease cholesterol overproduction by the body²¹.

Overall, the increase in total and LDL cholesterol levels seen with increased dietary cholesterol intake from eggs is small, however it is greater when the background diet is high in saturated fat. The effect may be attenuated even further in overweight, insulin-resistant people.

Apolipoproteins

A number of studies have assessed the effect of changes in dietary cholesterol intake from eggs on apolipoprotein levels with varying results. Some have shown no change in apolipoprotein B (the main apolipoprotein of LDL and VLDL levels which are considered important risk factors for cardiovascular disease) with increased dietary cholesterol from eggs ²²⁻²⁵ while others have shown an increase ²⁶⁻³⁰. Most studies have found no change in apolipoprotein A-1 (the main protein of HDL) with increased intakes of dietary cholesterol from eggs ^{22-24,26,27,29,30}.

Hyper-responders

It has been estimated that 15-25% of the population are hyper-responders to dietary cholesterol ⁵. In those individuals plasma cholesterol levels increase by 0.06-0.22mmol/L for each 100mg of dietary cholesterol consumed ^{5,31-33}. It used to be thought that people with hyperlipidemia were more likely to be hyper-responders and that restriction of dietary cholesterol intake was prudent in this group. However, research shows that despite hyper-responders experiencing an almost three fold greater response to dietary cholesterol compared to the remainder of the population ⁵, the LDL:HDL ratio is not significantly changed ^{32,34,35}. How these findings translate into changes in cardiovascular disease risk remains to be shown by randomised controlled trials.



Herron et al showed female hyper-responders to dietary cholesterol experienced an increase in LDL and HDL cholesterol levels with the addition of 640mg per day of dietary cholesterol from eggs (equivalent to 3.5 eggs a day) but there was no change in the LDL:HDL ratio ³⁵. Similar results were shown in men, where although there was an increase in the LDL:HDL ratio with the addition of 640mg dietary cholesterol from eggs, the ratio correlated with a low risk of coronary heart disease according to the clinical guidelines of the National Cholesterol Education Program Adult Treatment Panel ³⁶. Another study found hyper-responders had a consistently lower LDL:HDL ratio compared to hypo-responders before, during and after an experimental period which involved the consumption of three eggs a day for 28 days in addition to their habitual diet ³⁴. The studies by Herron et al also showed an increase in dietary cholesterol from eggs enhances reverse cholesterol transport pathways in hyper-responders that mobilise the excess cholesterol to the liver, the major site of cholesterol elimination from the body ^{32,35}.

Research showed that among 42 postmenopausal women and men aged sixty years and over with healthy lipoprotein profiles ³¹, consumption of three eggs per day for one month increased both plasma total, LDL and HDL cholesterol levels for hyper-responders ($P < 0.0001$) but not hypo-responders. Hyper-responders who consumed eggs had on average 20% higher total cholesterol (5.4mmol/L versus 4.5mmol/L), 26% higher LDL cholesterol (3.4mmol/L versus 2.7mmol/L), 10% higher HDL cholesterol (1.5mmol/L versus 1.4mmol/L) and 2% higher triglycerides (1.1mmol/L versus 1.08mmol/L) compared to the control group following egg consumption. Among hyper-responders, there was a significant increase in the larger, less atherogenic LDL particles during the egg treatment period.

Overall in hyper-responders, while increased egg consumption affects plasma lipids to a greater extent than in hypo-responders, further research is required to determine how this translates into cardiovascular disease risk.

High risk groups

People with hypercholesterolemia have been shown to demonstrate the same degree of response to increased dietary cholesterol from eggs as the remainder of the population ^{1,37,38} however studies in this area are limited. In a study of 33 patients with hyperlipidemia (a combination of subjects with hypercholesterolemia, combined hyperlipidemia and hypertriglyceridemia), the addition of either two or seven eggs a week to a reduced fat, high fibre diet resulted in no change to total cholesterol, LDL, HDL or triglycerides after eight weeks ³⁸. While this study showed no negative effects of egg feeding in combined hyperlipidemic subjects (those with high triglyceride and total cholesterol levels), the numbers were small (three out of 33 subjects).

In contrast, another study showed patients with combined hyperlipidemia exhibited greater increases in plasma cholesterol levels with increased egg intake compared with hypercholesterolemic patients ³⁷. In this study, combined hyperlipidemic subjects following the American Heart Association Step 1 diet for six weeks showed an increase in LDL cholesterol levels of 0.31mmol/L ($P < 0.001$) with the addition of two eggs a day and an increase in HDL cholesterol levels of 0.08mmol/L ($P = 0.02$), compared to a non-significant increase in LDL cholesterol levels in hypercholesterolemic subjects and a similar significant increase in HDL cholesterol levels (0.10mmol/L $P = 0.003$).



People with type 2 diabetes are another high risk group for cardiovascular disease. A recent study in people with diabetes found that when subjects consumed 2 eggs per day versus 100g of lean animal protein there was no difference in LDL cholesterol but HDL cholesterol increased in the egg group³⁹. One study in people with insulin resistance showed the increase in LDL cholesterol that occurred with ingesting four eggs a day over four weeks was less in people with insulin resistance compared to insulin sensitive subjects²⁰.

Guidelines Relating to Cholesterol and Egg Consumption

The NHF 2009 Position Statement on Dietary Fat⁴⁰ states there is good evidence that an increase in the consumption of saturated fatty acids is associated with an increase in risk of CHD, and moderate evidence that dietary cholesterol increases total cholesterol and LDL-C but substantially less so than saturated and trans fatty acids. They recommended that within a low saturated fat diet, individuals may consume six eggs per week without adversely affecting CVD outcomes

Conclusions

The Egg Nutrition Council concludes the following:

- Reducing saturated fat intake is the primary dietary strategy recommended for reducing serum cholesterol levels.
- In a healthy Western population, there is insufficient evidence to excessively restrict egg intake as part of a healthy diet. Eggs should be considered in a similar way as other protein rich foods and selected as part of a varied diet that is low in saturated fat and contains a variety of cardio-protective foods such as fish, wholegrains, fruits, vegetables, legumes and nuts. Substituting eggs for other animal protein foods in the diet may result in even smaller changes to LDL cholesterol than predictive equations as the net dietary cholesterol increase is smaller.
- Research supports the inclusion of around 6 eggs a week as part of a healthy diet.
- Further research is required to fully assess the effects of egg consumption in those with coronary heart disease, hyperlipidemias (especially combined hyperlipidemias), or type 2 diabetes. However, prudent advice is that the inclusion of eggs in the context of a diet low in saturated fat and containing known cardio-protective foods is not associated with increased risk.

This statement is for healthcare professionals only.

As diet-induced changes in total cholesterol and lipoproteins vary considerably between individuals, the Egg Nutrition Council recommends individual discussion of the recommendations regarding egg intake with their health care professional.

Useful links:

Egg Nutrition Centre

<http://www.enc-online.org/>



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