

Longitudinal association of egg consumption habits with blood lipids among Chinese adults: results from the Prediction for Atherosclerotic Cardiovascular Disease Risk in China project

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To the Editor: According to guidelines from western countries as well as China, dietary patterns with low intake of cholesterol have been widely recommended for maintaining ideal lipid levels. As one of the major sources of both high-quality protein and dietary cholesterol, eggs have always been the focus in terms of diet. Although increased lipid levels induced by high egg intake have been revealed by randomized controlled trials (RCTs), they may not be sufficient to reflect the impacts of habitual egg intake due to high doses of egg intake of more than 7 eggs/week or even 14 eggs/week. Further, RCTs typically have shorter intervention periods of about 3 months, which may not observe a stable association due to homeostasis in cholesterol metabolism of human beings.^[1,2] Up to now, only three cohorts assessed the associations of egg intake with lipid levels or dyslipidemia, and the findings were still controversial. One recent cohort study has reported the non-significant association between higher egg intake (≥ 7 vs. 1 eggs/week) and lipid profiles. On the other hand, another cohort from Spain found that compared with < 1 egg/week, > 4 eggs/week had no significant influence on total cholesterol (TC) and triglyceride (TG), but significantly decreased high-density lipoprotein cholesterol (HDL-C) levels.^[4] However, none of these cohorts were from

developing countries, and the association between moderate egg intake and lipid profiles has not been well illustrated. Egg consumption in China, a representative of developing countries, is relatively higher, and it may be possible to better explore the appropriate range of egg intake.

This study aimed to explore the longitudinal association of habitual egg consumption with blood lipid indicators, including TC, TG, low-density lipoprotein cholesterol (LDL-C), HDL-C, and non-high-density lipoprotein cholesterol (non-HDL-C), based on the project of Prediction for Atherosclerotic Cardiovascular Disease Risk in China (China-PAR). The China-PAR project investigated the prevalence and incidence of cardiovascular disease and the risk factors in the Chinese general population and detailed descriptions have been published.^[5] Data from 2007 to 2008 visit and 2012 to 2015 visit of the China-PAR project were adopted. After excluding participants who lacked the vital information of egg consumption or lipids or taking lipid-lowering agents, 60,952 subjects were finally included in the current analysis. The study was approved by the Institutional Review Board at Fuwai Hospital (No: 2012-399). Written

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informed consent was obtained from each participant before data collection.

Identical food frequency questionnaires were used to collect information on dietary habits including egg intake through face-to-face interviews and the frequency and amount of different types of foods consumed by each participant in the past year were recorded. The frequency consists of the following categories: no eating, daily, weekly, monthly, and yearly. The amount of food consumption is measured in the traditional Chinese “Jin” and “Liang” units, where 1 “Jin” = 500 g and 1 “Liang” = 50 g. Calculated from the average weight of an egg of about 50 g, egg consumption at two visits was uniformly converted into the number of eggs per week, and this consumption was further divided into the following three groups according to different weekly consumption doses: low (<3 eggs/week), moderate (3–<6 eggs/week), and high (≥6 eggs/week).

After fasting for at least 10 h, blood samples were drawn from participants to measure glucose and lipid levels including TC, TG, and HDL-C. Serum was separated by centrifugation within 3 h and stored at –20 °C for a short time. It was carried by the cold chain to the Fuwai Hospital of the Chinese Academy of Medical Sciences for unified laboratory testing. Different enzymatic methods were employed for the measurement of lipids, including the cholesterol oxidase method for TC, glycerophosphate oxidase method for TG, and direct chemically modified enzyme method for HDL-C. Then, the Friedewald formula was adopted for the calculation of LDL-C: $LDL-C = TC - HDL-C - TG/5$. The estimate of non-HDL-C can be calculated from a standard lipid profile as follows: $non-HDL-C = TC - HDL-C$.

Taking into account the variability of lifestyle and dietary habits, generalized estimating equations (GEE) with unstructured working correlation matrix were applied to evaluate the longitudinal association between each category of egg consumption and lipids indicators (TC, TG, LDL-C, HDL-C, and non-HDL-C) using low (<3 eggs/week) consumption as reference. The effect is expressed as mean difference (MD) with the corresponding 95% confidence interval (CI). For each outcome, model was adjusted for age, gender, urbanization, geographic region, body mass index, current smoker, current drinker, education level, per capita household income, ideal diet score, and ideal dairy intake. In addition, two sensitivity analyses were conducted to further assess the robustness of the main results. All reported *P* values in the current study are two-sided and a significance level of 0.05 was determined. Statistical analysis was performed with SAS software (version 9.4, SAS Institute Inc, Cary, NC, USA).

Among 60,952 participants included in the longitudinal analysis, 23,216 (38.09%) were male and the mean age at the 2007 to 2008 visit was 52.52 ± 11.84 years. The average egg intake of participants was 6.58 eggs/week, and 18,770 (30.79%), 14,907 (24.46%), and 27,275 (44.75%) participants consumed <3, 3 to <6, and ≥6 eggs per week, respectively. In the multivariate adjusted GEE model, significant impacts of egg consumption on lipid

indicators were observed. Compared with those who consumed <3 eggs/week, beneficial impacts of moderate intake of 3 to <6 eggs/week on blood lipid levels were identified. Eating 3 to <6 eggs/week was significantly associated with reduced levels of TC (MD = –0.606 mg/dL, 95% CI: –1.129 to –0.084), TG (MD = –1.465 mg/dL, 95% CI: –2.852 to –0.079), LDL-C (MD = –0.848 mg/dL, 95% CI: –1.318 to –0.377), and non-HDL-C (MD = –1.071 mg/dL, 95% CI: –1.581 to –0.561). In addition, significantly increased HDL-C level (MD = 0.461 mg/dL, 95% CI: 0.240–0.682) was also observed in the moderate egg intake group [Table 1].

However, high intake of ≥6 eggs/week was associated with adverse impacts of most lipid indicators, including TC, LDL-C, and non-HDL-C. Consuming <6 eggs per week contributed to 1.795 mg/dL (95% CI: 1.315–2.275) increase in TC, 1.763 mg/dL (95% CI: 1.337–2.189) increase in LDL-C, and 0.917 mg/dL (95% CI: 0.452–1.381) increase in non-HDL-C compared with <3 eggs/week. Moreover, the decrease in TG levels and the increase in HDL-C levels were maintained at the high intake of ≥6 eggs/week, with the effect values of –4.208 mg/dL (95% CI: –5.485 to –2.931) and 0.815 mg/dL (95% CI: 0.612–1.018), respectively. Besides, the sensitivity analyses by further adjusting for hypertension and diabetes or excluding subjects with metabolic diseases such as diabetes, hypertension, and obesity showed no substantial effect on the overall findings, indicating that the results of the main analysis were robust [Table 1].

Egg yolks have long been a major concern of eating eggs because they contain lots of lipids mainly including cholesterol, TGs, and phospholipids, but they are also rich in protein, vitamins, and carotenoids.^[6] At present, evidence from cohort studies on the health effects of egg intake is still very inadequate. The current study has shown that moderate consumption of 3 to <6 eggs/week had protective influence on blood lipids, and elevated TC, LDL-C, and non-HDL-C levels were observed when consuming ≥6 eggs/week. On the other hand, findings from a study from the Mediterranean cohort were consistent with ours by reporting that egg consumption of >4 eggs/week is associated with lower TG levels.^[4] Meanwhile, a cohort study of 50 countries showed that egg consumption (≥7 *vs.* <1 egg/week) had no significant effect on all lipid levels including TC, TG, LDL-C, and HDL-C.^[3] These inconsistencies may be ascribed to the different ethnic groups, diverse egg consumption levels, and various dietary cultural backgrounds across countries. Maintaining a moderate intake of eggs is crucial for lipid metabolism balance, and it is in accordance with the recommendations for the prevention of cardiovascular and metabolic diseases of eating 3 to <6 eggs per week with no discarding of the yolk in the general population.^[7]

Based on the dietary background of the Chinese population, this study explored the potential appropriate dose range of egg intake and provided evidence for the protective association of moderate habitual egg consumption on blood lipid indicators. Nevertheless, our study may have some potential limitations, which could be taken into

Table 1: Mean differences (95% CIs) on lipid-indicator levels associated with egg consumption.

Lipid indicators (mg/dL)	Egg consumption (number per week)		
	<3	3 to <6	≥6
Multivariable-adjusted			
TC	0 (ref)	-0.606 (-1.129 to -0.084)	1.795 (1.315 to 2.275)
TG	0 (ref)	-1.465 (-2.852 to -0.079)	-4.208 (-5.485 to -2.931)
LDL-C	0 (ref)	-0.848 (-1.318 to -0.377)	1.763 (1.337 to 2.189)
HDL-C	0 (ref)	0.461 (0.240 to 0.682)	0.815 (0.612 to 1.018)
Non-HDL-C	0 (ref)	-1.071 (-1.581 to -0.561)	0.917 (0.452 to 1.381)
Additionally adjusted hypertension and diabetes			
TC	0 (ref)	-0.599 (-1.128 to -0.070)	1.859 (1.373 to 2.345)
TG	0 (ref)	-0.764 (-2.142 to 0.615)	-4.320 (-5.574 to -3.067)
LDL-C	0 (ref)	-0.891 (-1.369 to -0.413)	1.823 (1.390 to 2.256)
HDL-C	0 (ref)	0.457 (0.234 to 0.680)	0.782 (0.577 to 0.987)
Non-HDL-C	0 (ref)	-1.067 (-1.583 to -0.551)	0.983 (0.514 to 1.453)
Excluded subjects with metabolic disease (hypertension, diabetes, and obesity)*			
TC	0 (ref)	-0.889 (-1.561 to -0.216)	1.631 (0.998 to 2.264)
TG	0 (ref)	0.174 (-1.415 to 1.763)	-3.182 (-4.647 to -1.716)
LDL-C	0 (ref)	-1.132 (-1.742 to -0.521)	1.589 (1.024 to 2.155)
HDL-C	0 (ref)	0.241 (-0.050 to 0.531)	0.639 (0.367 to 0.911)
Non-HDL-C	0 (ref)	-1.147 (-1.805 to -0.489)	0.911 (0.299 to 1.522)

Model adjusted for age, gender, urbanization, geographic region, body mass index, current smoker, current drinker, education level, per-capita household income, ideal diet score, and ideal dairy intake. *After excluded subjects with metabolic disease (hypertension, diabetes, and obesity), 33,025 subjects were included in the analyses. CIs: Confidence intervals; HDL-C: High-density lipoprotein cholesterol; LDL-C: Low-density lipoprotein cholesterol; Non-HDL-C: Non-high-density lipoprotein cholesterol; TC: Total cholesterol; TG: Triglyceride.

consideration in future studies. First, we focused on the consumption of whole chicken eggs, while the eggs of other poultry or eggs that are included in mixed dishes such as cake were not considered. Second, different cooking methods of eggs may lead to slight differences in fat and cholesterol content, which was not covered in our questionnaire.

In conclusion, the current study reported the longitudinal association between eggs and blood lipids and found that the moderate intake of eggs (3–<6 per week) was significantly associated with improved lipid metabolism in Chinese adults. Meanwhile, the adverse effects of excessive consumption of eggs on lipid, especially TC, LDL-C, and non-HDL-C, have also been observed. It provides a scientific basis for the optimal range of egg intake and reasonable dietary recommendations.

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Conflicts of interest

None.

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