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Egg intake has no adverse association with blood lipids or glucose in adolescent girls

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Abstract

Objective: Longitudinal data on cardiometabolic effects of egg intake during adolescence are lacking. The current analyses aim to evaluate the impact of usual adolescent egg consumption on lipid levels, fasting glucose, and insulin resistance during late adolescence (ages 17–20 years).

Methods: Data from 1392 girls, ages 9–10 at baseline and followed for 10 years, in the National Heart Lung and Blood Institute's National Growth and Health Study were used to examine the association between usual egg intake, alone and in combination with other healthy lifestyle factors, on late adolescent lipid levels, fasting glucose, and insulin resistance, measured as HOMA-IR. Diet was assessed using three-day food records during eight examination cycles. Girls were classified according to usual weekly egg intake, ages 9–17 years: < 1 egg/week (n=361), 1–< 3 eggs/week (n=703), and ≥ 3 eggs/week (n=328). Analysis of covariance modeling was used to control for confounding by other behavioral and biological risk factors.

Results: Girls with low, moderate, and high egg intakes had adjusted LDL-C levels of 99.7, 98.8, 95.5 mg/dL, respectively (p=0.0778). In combination with higher intakes of fiber, dairy, or fruits and vegetables, these beneficial effects were stronger and statistically significant. There was no evidence that ≥ 3 eggs/week had an adverse effect on lipids, glucose, or HOMA-IR. More active girls who consumed ≥ 3 eggs/week had the lowest levels of insulin resistance.

Conclusion: These results suggest that eggs may be included as part of a healthy adolescent diet without adverse effects on glucose, lipid levels, or insulin resistance.

INTRODUCTION

For many years, egg consumption has been thought to be linked with higher levels of total and LDL-cholesterol (LDL-C) as well as increased coronary heart disease (CHD) risk. As a result, Americans have been advised to avoid consuming eggs, particularly egg yolks. However, evidence to support such advice is weak [1, 2] and higher egg intake has been reported to have favorable effects on HDL-C levels and composition [3]. In fact, the absence of an adverse effect of egg consumption on CHD risk is thought to be due, at least in part, to these beneficial effects on HDL which may mediate any concurrent adverse effects on LDL [4]. In one of the few studies to examine cardiometabolic effects of egg consumption in younger populations, children aged 8 to 12 years eating two whole eggs daily for 30 days (vs. an equivalent amount of egg whites) lowered their diastolic blood pressure, maintained their LDL to HDL ratio, and generated fewer atherogenic small, dense LDL particles [5].

While some population-based studies have indicated an increased risk of cardiovascular disease (CVD) among the subset of adults with type 2 diabetes mellitus (T2DM) who have higher egg intakes, this has not generally been the case among those without diabetes [6, 7]. Other studies, including randomized clinical trials, have observed no detrimental effects of egg consumption on cardiometabolic risk (CMR) among those with or without diabetes [8–10]. Thus, while some uncertainty remains in these studies of adults, there is very little evidence from studies of children on the effects of egg consumption on cardiometabolic outcomes.

Questions also remain about the effects of egg consumption on fasting glucose and risk of T2DM. Data from a randomized crossover study of adults showed lower post-prandial glucose and insulin concentrations following an egg-based breakfast compared with a bagel breakfast [11]. However, data on the long-term effects of egg intake on glucose concentrations are lacking in both children and adults.

Finally, the effects of egg consumption on CMR may differ based on overall dietary patterns. Since egg intake is often associated with higher intakes of saturated fat and low intakes of dietary fiber, the potentially detrimental effects of these other factors on cardiometabolic health could also explain an apparent adverse effect of eggs [12]. The objective of this study was to examine the association of usual egg intake with lipids and glucose concentrations among adolescent girls and to stratify these associations by other lifestyle patterns including diet and physical activity.

MATERIALS AND METHODS

Study Population

The National Heart, Lung, and Blood Institute's Growth and Health Study (NGHS) enrolled 2,379 black and white girls at 9–10 years of age and followed these girls for 10 years. Subjects were recruited from three clinical centers: University of Cincinnati Children's Hospital Medical Center, University of California at Berkeley, and Westat Inc./Group Health Association in Rockville, MD. They were assessed annually for development of obesity and other CMR factors. The current analyses uses data from the 1392 girls for whom lab data

were available at the two final exams. We compared the baseline characteristics of the girls who were excluded from the study with the 1392 who were included and found no meaningful differences between the groups in baseline BMI, sedentary behaviors, or dietary habits.

Dietary Data

Dietary data from three day food records (two weekdays and one weekend day) were collected during eight of the 10 exam years (1–5, 7, 8, and 10). A study dietitian instructed the subjects on the use of standard household measures to estimate portions consumed. Additional information on details such as specific recipes were obtained from a parent if necessary. Food records were reviewed by a study dietitian to determine reliability based on a standard protocol. Records deemed reliable were then entered into the Nutrition Data System for Research (NDSR) of the University of Minnesota in accordance with system guidelines [13]. As NDSR is updated regularly to reflect trends in food composition and availability, nutrient information was derived using the NDS nutrient database relevant to the year of the data collection.

Researchers from Boston University further linked the NDS food codes with those in the United States Department of Agriculture's (USDA) "Pyramid Serving Database for USDA Survey Food Codes, Version 2" [14]. The subjects' consumption of eggs and other food was derived from whole foods, composite foods, and mixed dishes. For example, total egg intake includes whole eggs, eggs in a mixed dish (e.g., quiche), and eggs in baked goods. For each subject, the mean for all days of dietary data collected between the ages of 9 and 17 years was calculated and used in the analysis to enhance precision of estimated dietary intake.

Outcome Measures

Data on fasting glucose and lipids were analyzed at a Johns Hopkins University laboratory associated with the Center for Disease Control's Lipid Standardization Program [15]. The Cholesterol CHOD-PAP method (Boehringer-Mannheim Diagnostics, city, state, country) was used to assess total cholesterol (TC) and HDL-C, while triglycerides were determined enzymatically (Abbott A-Gent Triglycerides Reagent Set, city, state, country). LDL-C was calculated using a modified Friedewald equation: $[LDL-C] = [TC] - [HDL-C] - [triglycerides]/6.5$ [16]. Finally, insulin resistance was calculated using the homeostasis model assessment of insulin resistance (HOMA-IR)[17]. For all lab variables, the means at the end of follow-up were averaged from ages 17–20 years.

Potential Confounders

Potential confounders including race (self-described as black or white), socioeconomic status (categorized as low, moderate, or high based on income and parent education), age (years) at time of dietary assessment, physical activity (METS), television/video watching (hours/day), height, BMI, waist circumference, percent of energy from carbohydrates, and other dietary factors were explored. High SES was based on an income of \$40,000 or more and a parent with more than a high school education while low SES included families with an income of < \$10,000 (regardless of education) and those earning up to \$20,000 with a high school education or less. All other families were categorized as middle SES. Physical

activity was self-reported at visits 1, 3, 5 and 7–10 by means of the validated Habitual Activity Questionnaire (HAQ) with the score being calculated by multiplying an estimate of the metabolic equivalent (MET) for each recorded activity by weekly frequency of participation and number of weeks per year in which the child participated [18]. To assess television/video watching, girls were asked to report their usual number hours engaged in these activities in a typical week. The final analytic models retained those factors that led to a 5% change in estimated effects (race, age at time of diet assessment, baseline height, and percent of energy from carbohydrates).

Statistical Analysis

All cut-off values were determined through sensitivity analyses with a goal of identifying the optimal logical cutpoint and the optimal analytical power. For analyses related to the various lipid and glucose outcomes, mean egg consumption during early to mid-adolescence (ages 9–17 years) was categorized as follows: < 1.0 egg per week (n=361), 1.0–3.0 eggs per week (n=703), and > 3.0 eggs per week (n=328). For the analyses examining the combined intakes of eggs and other foods designed to reflect a healthy dietary pattern, egg intake was dichotomized using cutoff values of < 3.0 versus ≥ 3.0 eggs per week. Dietary fiber was classified as < 12 versus ≥ 12 grams per day, dairy intake as < 2 versus ≥ 2 cups per day, and fruit and vegetable intakes as < 1.75 versus ≥ 1.75 cup equivalents per day. Finally, the effects of egg consumption on lipid and glucose-related outcomes in combination with level of usual physical activity were also estimated. For these analyses, egg intake was combined with level of physical activity after dichotomizing activity as a metabolic equivalent score (METs) of < 20 versus ≥ 20 METs per week. Analysis of covariance models were used to calculate adjusted fasting lipid concentrations, fasting glucose concentration, and HOMA-IR in later adolescence (17–20 years of age). All analyses were completed using Statistical Analysis Systems software, version 9.4 (SAS Institute, Cary, NC).

RESULTS

Table 1 shows the characteristics of the girls according to their usual intake of eggs between 9 and 17 years of age. Girls who consumed < 1.0 egg per week were less likely to watch television, tended to report lower energy intake, and had lower energy-adjusted intakes of fat and saturated fat than those in the other two categories of intake. Those consuming ≥ 3.0 eggs per week had a higher percentage of energy from protein and fat as well as lower energy-adjusted intakes of carbohydrates and fiber.

Table 2 shows the associations between egg consumption over 9–17 years of age and mean concentrations of lipids, fasting glucose, and HOMA-IR in late adolescence (ages 16–17 years). Overall, there was an inverse linear trend between egg intake and TC and a similar but borderline statistically significant inverse trend egg consumption and LDL-C. There were no adverse associations of egg consumption with other lipid outcomes or with glucose or HOMA-IR.

Table 3 shows the associations of eggs combined with indicators of healthy diet on lipids, glucose, and HOMA-IR. After cross-classifying dichotomous egg intake with other markers of a healthy diet pattern, there were no adverse associations of egg consumption observed.

Girls who consumed 3.0 eggs per week combined with higher intakes of fiber, dairy, or fruits and vegetables had the lowest mean TC, LDL-C, and the LDL:HDL ratio. Further, girls with higher intakes of dietary fiber also tended to have lower HOMA-IR values.

Finally, Table 4 shows the association between lifestyle patterns defined on the basis of egg consumption and physical activity levels on lipid and glucose-related outcomes. Girls who were more physically active and who also consumed more eggs had non-statistically significant reductions in HOMA-IR while the associations with lipids and glucose were weaker.

DISCUSSION

In this study, there was no adverse association between higher egg intakes during ages 9–17 years and fasting lipids, fasting glucose, or insulin resistance as measured by HOMA-IR in late adolescence (age 17–20 years). In fact, egg consumption as a part of a healthy diet pattern was associated with lower TC, LDL-C and a lower LDL to HDL ratio. In addition, more active girls who consumed more eggs tended to have lower insulin resistance. These results imply that in contrast to some earlier recommendations eggs do not adversely affect cardiometabolic risk in adolescent girls and may be included as part of a healthy diet.

To our knowledge, there is only one other study of egg intake and lipid-related outcomes in children or adolescents and our results are consistent with that intervention [5]. Another trial of 38 young adults showed that consuming up to 3 eggs per day had beneficial effects on HDL, LDL:HDL, LDL and plasma choline [19]. Our findings are also consistent with a review of several epidemiologic studies of adults in which no adverse effect was observed between egg intake and TC [20]. In another review, researchers concluded that there were no adverse effects of egg consumption on TC or triglycerides in healthy and in hyperlipidemic adults [21]. Further, randomized clinical trials in different populations have shown that dietary cholesterol from eggs may increase both LDL-C and HDL-C in those who are susceptible to plasma cholesterol increases, without changing the LDL to HDL ratio [4].

To the best of our knowledge, there are no previous studies in the pediatric population on the association between egg consumption and glucose or insulin levels. In adults, cross-sectional analyses have found no relation between egg intake and insulin resistance [22]. However, some meta-analyses suggest a link between egg consumption and risk of diabetes [23, 24]. A more recent meta-analysis indicated a 39% higher risk of T2DM associated with higher egg consumption in studies carried out in the U.S. and a non-statistically significant 11% reduction in T2DM risk in non-U.S. studies [25]. This contradictory finding may suggest that differences in other diet and lifestyle factors may be responsible. Two other meta-analyses had similar findings, with U.S. studies having a small adverse association of higher egg consumption with diabetes risk, while non-U.S. studies found the opposite [26, 27]. In one of these studies which separated results by study quality, the studies deemed to be of higher quality were more likely to have null results [26]. The observed differences in dietary patterns associated with egg intake across studies could be a result of decades-long public health campaigns in the U.S. focused on reducing egg consumption due to high dietary cholesterol content [9]. Thus, we theorize that uncontrolled confounding, most likely from

other dietary factors, may explain some of the conflicting finding on egg intake and cardiometabolic outcomes.

Given the limited observed impact of eggs on blood lipids, it is even less clear how eggs might impact T2DM risk. One possibility is through effects of egg consumption on the production of trimethylamine-N-oxide (TMAO), a known risk factor for atherosclerosis. Recent studies have shown that dietary choline from eggs can be converted in the gut to trimethylamine and then oxidized to TMAO in the liver [28]. In a recent randomized clinical trial, higher egg consumption was associated with increases in both plasma and urinary TMAO; however, this did not result in increased inflammation or oxidation of LDL [29].

Eggs are an important sources of beneficial nutrients in the diet, including protein, B-vitamins, choline, and anti-oxidant vitamins known to protect against inflammation, oxidation, and atherosclerosis [30]. In this study, we found that egg consumption had no adverse association with lipids, glucose, or insulin resistance among adolescent females. In fact, the overall association with lipids tended to be somewhat beneficial. These results provide support for moderate egg consumption, particularly as a part of a healthy diet pattern, during the critical adolescent years of growth.

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Table 1.

Baseline characteristics of girls according to mean weekly egg intake

Baseline characteristics	Egg Intake per Week ¹			p-value ²
	0 to <1.0	1.0 to <3.0	3.0	
	n=361	n=703	n=328	
	Mean (SD)	Mean (SD)	Mean (SD)	
Age (years)	10.0 ± 0.6	10.0 ± 0.6	10.1 ± 0.6	0.4989
Height (cm)	141.0 ± 7.2	141.3 ± 7.7	143.1 ± 8.6	0.0004
Body mass index (kg/m ²)	18.5 ± 3.5	18.6 ± 4.0	18.9 ± 4.0	0.315
Activity score (METS) ¹	20.4 ± 10.4	19.5 ± 9.5	19.2 ± 10.1	0.2196
Television/video (hrs/day) ¹	4.3 ± 1.9	4.5 ± 2.2	5.1 ± 2.0	<0.0001
Dietary intakes				
Energy intake (kcal/day)	1751 ± 318	1886 ± 349	2051 ± 391	<0.0001
% energy from protein	14.0 ± 2.0	14.0 ± 1.8	14.5 ± 1.8	<0.0001
% energy from carbohydrate	53.3 ± 4.9	51.9 ± 4.7	49.4 ± 4.7	<0.0001
% energy from fat	33.7 ± 4.1	35.1 ± 3.8	37.0 ± 3.8	<0.0001
% energy from saturated fat	12.5 ± 1.8	12.9 ± 1.6	13.3 ± 1.6	<0.0001
Dairy (cup eq/day)	1.7 ± 0.8	1.7 ± 0.7	1.6 ± 0.7	0.3763
Eggs (ounce eq/week)	0.5 ± 0.3	1.9 ± 0.6	4.6 ± 1.6	<0.0001
Fiber (grams/day)	11.0 ± 3.2	11.6 ± 3.0	12.1 ± 3.2	<0.0001
Fiber (grams/1,000 kcal)	6.3 ± 1.5	6.2 ± 1.3	5.9 ± 1.3	0.0015
FV (cup eq/day)	3.2 ± 1.2	3.4 ± 1.2	3.7 ± 1.3	<0.0001
	Column %	Column %	Column %	
Race (%)				
White	58.70%	49.20%	28.10%	<0.0001
Black	41.30%	50.80%	71.90%	
Socioeconomic status (%) ³				
Low	15.50%	20.90%	27.70%	0.0007
Middle	45.20%	40.50%	42.70%	
High	39.30%	38.60%	29.60%	

¹ Mean values from ages 9–17² P-values were derived from analysis of covariance (for means) and chi-square tests (for categorical variables)³ High SES required a family income of \$40,000 and at least 1 parent with > high school education; low SES included all families with an income of < \$10,000 (regardless of education) and those earning up to \$20,000 who had a high school education or less. All remaining families were categorized as middle SES.

Table 2.

Lipid and glucose-related outcomes in late adolescence (ages 17–20 years) according to average weekly egg intake

Egg Intake ¹ (per wk)	n	TC (mg/dL)	LDL-C (mg/dL)	LDL:HDL	Log Triglycerides	Glucose (mg/dL)	HOMA-IR
<i>Adjusted mean (± s.e.)²</i>							
<1.0	361	166.4 ± 1.70	99.7 ± 1.56	1.98 ± 0.04	4.31 ± 0.02	88.0 ± 0.72	2.61 ± 0.16
1.0 to <3.0	703	164.4 ± 1.19	98.8 ± 1.10	1.95 ± 0.03	4.29 ± 0.02	87.6 ± 0.51	2.58 ± 0.12
3.0	328	161.3 ± 1.81	95.5 ± 1.67	1.89 ± 0.04	4.29 ± 0.02	88.1 ± 0.77	2.50 ± 0.17
<i>p-trend</i>		<i>0.0481</i>	<i>0.0775</i>	<i>0.1672</i>	<i>0.4572</i>	<i>0.9048</i>	<i>0.6671</i>

Abbreviations: TC = total cholesterol; LDL-C = low-density lipoprotein cholesterol; HDL = high-density lipoprotein cholesterol; HOMA-IR = homeostatic model assessment of insulin resistance

¹ Egg intake is based on mean consumption from 9–17 years of age

² Adjusted for race, age (at time of diet assessment), % energy from carbohydrates, and baseline height.

Table 3.

Lipid levels, glucose, and HOMA-IR in 17–20 year old girls according to earlier adolescent egg-based dietary patterns

Diet Pattern ¹ (9–17 yrs)	N	TC (mg/dL)		LDL-C (mg/dL)		LDL: HDL		Log triglycerides		Glucose (mg/dL)		HOMA-IR	
		mean ± s.e. ²	p-value	mean ± s.e. ²	p-value	mean ± s.e. ²	p-value	mean ± s.e. ²	p-value	mean ± s.e. ²	p-value	mean ± s.e. ²	p-value
Eggs/Fiber													
Lower/Lower	682	166.4 ± 1.21	-	100.3 ± 1.11	-	1.99 ± 0.03	-	4.31 ± 0.02	-	87.3 ± 0.51	-	2.64 ± 0.12	-
Lower/Higher	382	162.4 ± 1.68	0.050	96.7 ± 1.54	0.061	1.90 ± 0.04	0.085	4.27 ± 0.02	0.134	88.7 ± 0.71	0.118	2.50 ± 0.16	0.474
Higher/Lower	175	162.7 ± 2.47	0.179	97.0 ± 2.27	0.185	1.93 ± 0.06	0.389	4.31 ± 0.03	0.890	88.0 ± 1.05	0.517	2.81 ± 0.24	0.507
Higher/Higher	153	160.3 ± 2.58	0.032	94.3 ± 2.37	0.022	1.85 ± 0.06	0.053	4.28 ± 0.03	0.437	88.1 ± 1.10	0.491	2.17 ± 0.25	0.089
Eggs/Dairy													
Lower/Lower	746	166.2 ± 1.17	-	100.1 ± 1.08	-	1.97 ± 0.03	-	4.30 ± 0.02	-	87.9 ± 0.50	-	2.62 ± 0.11	-
Lower/Higher	318	162.0 ± 1.88	0.061	96.5 ± 1.74	0.079	1.92 ± 0.05	0.394	4.30 ± 0.02	0.985	87.4 ± 0.80	0.616	2.52 ± 0.18	0.671
Higher/Lower	249	162.8 ± 2.09	0.153	96.5 ± 1.93	0.105	1.89 ± 0.05	0.195	4.30 ± 0.03	0.916	88.0 ± 0.89	0.899	2.54 ± 0.20	0.731
Higher/Higher	79	157.8 ± 3.59	0.027	93.0 ± 3.30	0.041	1.87 ± 0.09	0.305	4.29 ± 0.05	0.862	88.6 ± 1.53	0.677	2.40 ± 0.35	0.556
Eggs/FV													
Lower/Lower	503	166.1 ± 1.42	-	100.4 ± 1.30	-	2.00 ± 0.03	-	4.30 ± 0.02	-	87.2 ± 0.60	-	2.59 ± 0.14	-
Lower/Higher	561	164.1 ± 1.37	0.315	97.8 ± 1.27	0.162	1.92 ± 0.03	0.094	4.29 ± 0.02	0.867	88.2 ± 0.58	0.236	2.59 ± 0.13	0.986
Higher/Lower	124	163.3 ± 2.91	0.395	96.6 ± 2.68	0.195	1.92 ± 0.07	0.323	4.37 ± 0.04	0.075	87.1 ± 1.24	0.940	2.53 ± 0.28	0.856
Higher/Higher	204	160.4 ± 2.26	0.033	95.0 ± 2.08	0.029	1.87 ± 0.06	0.054	4.25 ± 0.03	0.119	88.7 ± 0.96	0.207	2.48 ± 0.22	0.671

Abbreviations: FV = fruits and vegetables; TC = total cholesterol; LDL-C = low-density lipoprotein cholesterol; HDL = high-density lipoprotein cholesterol; HOMA-IR = homeostatic model assessment of insulin resistance

¹ Lower vs. higher egg intake = <3 per week vs. 3 eggs per week; Lower vs. higher fiber intake = <12 vs. 12 grams per day; Lower vs. higher dairy intake = <2 vs. 2 servings per day; Lower vs. higher fruit and vegetable intake = <1.75 vs. 1.75 cup equivalents per day

² Adjusted for race, age (at time of diet assessment), % energy from carbohydrates, and baseline height

Table 4.

Independent and combined effects of egg intake and physical activity on lipid levels, glucose, and HOMA-IR in 17–20 year old girls

Eggs/Physical Activity ¹	n	Total chol (mg/dL)		LDL-C (mg/dL)		LDL: HDL		Log triglycerides		Glucose (mg/dL)		HOMA-IR	
		mean ± s.e. ²	p-value	mean ± s.e. ²	p-value	mean ± s.e. ²	p-value	mean ± s.e. ²	p-value	mean ± s.e. ²	p-value	mean ± s.e. ²	p-value
Lower/Lower	596	166.1 ± 1.30	-	99.7 ± 1.19	-	1.95 ± 0.03	-	4.30 ± 0.02	-	87.9 ± 0.55	-	2.71 ± 0.13	-
Lower/Higher	468	163.6 ± 1.51	0.210	98.3 ± 1.39	0.463	1.97 ± 0.04	0.609	4.29 ± 0.02	0.881	87.6 ± 0.64	0.695	2.42 ± 0.15	0.129
Higher/Lower	199	161.4 ± 2.32	0.073	94.4 ± 2.13	0.033	1.83 ± 0.06	0.070	4.29 ± 0.03	0.844	88.4 ± 0.98	0.650	2.74 ± 0.22	0.908
Higher/Higher	129	161.7 ± 2.80	0.157	97.2 ± 2.58	0.392	1.97 ± 0.07	0.748	4.29 ± 0.04	0.906	87.8 ± 1.19	0.939	2.17 ± 0.27	0.070

Abbreviations: TC = total cholesterol; LDL-C = low-density lipoprotein cholesterol; HDL = high-density lipoprotein cholesterol; HOMA-IR = homeostatic model assessment of insulin resistance

¹ Lower vs. higher egg intake = <3 per week vs. 3 eggs per week; Lower vs. higher physical activity = <20 METS per week vs. 20 METS per week.

² Adjusted for race, age (at time of diet assessment), % energy from carbohydrates, and baseline height