Nutritional Contribution of Eggs to American Diets

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Key words: eggs, cholesterol, CVD, nutrient, NHANES III, vitamin

Objectives: The main purposes of this study were (1) to assess the nutritional significance of eggs in the American diet and (2) to estimate the degree of association between egg consumption and serum cholesterol concentration.

Methods: Data from the most recent National Health and Nutritional Examination Survey (NHANES III, 1988–94) were utilized to compare the nutritional quality indicators of diets that contained eggs (USDA food grouping system) with those that did not. Nutrient intake (from 24-hour dietary recall), egg intake (from food frequency questionnaire), sociodemographic data and blood cholesterol levels of subjects who met inclusion criteria (n=27,378) were grouped according to the occurrence and frequency of egg consumption and were analyzed using SUDAAN.

Results: Daily nutrient intake of egg consumers (EC) was significantly greater than that of nonconsumers (NC) for all nutrients studied (except dietary fiber and vitamin B6). Eggs contributed $<$ 10% of daily intake of energy and vitamin B6, 10% to 20% of folate and total, saturated and polyunsaturated fat, and 20% to 30% of vitamins A, E and B12 in EC. Compared to EC, NC had higher rates of inadequate intake (defined by Estimated Average Requirements (EAR) or $<$ 70% Recommended Dietary Allowance (RDA)) for vitamin B12 (10% *vs.* 21%), vitamin A (16% *vs.* 21%), vitamin E (14% *vs.* 22%) and vitamin C (15% *vs.* 20%). After adjusting for demographic (age, gender and ethnicity) and lifestyle variables (smoking and physical activity), dietary cholesterol was not related to serum cholesterol concentration. People who reported eating $\geq$ 4 eggs/wk had a significantly lower mean serum cholesterol concentration than those who reported eating $\leq$ 1 egg/wk (193 mg/dL *vs.* 197 mg/dL, $p < 0.01$). More frequent egg consumption was negatively associated with serum cholesterol concentration ($\beta = -6.45$, $p < 0.01$).

Conclusions: In this cross-sectional and population-based study, egg consumption made important nutritional contributions to the American diet and was not associated with high serum cholesterol concentrations.

INTRODUCTION

Since high serum cholesterol levels have been linked to increased risk of cardiovascular disease (CVD) and eggs are relatively high in cholesterol, health professionals have recommended that Americans should limit egg consumption [1,2]. However, a recent study has shown that risk of CVD in men and women does not increase with increasing egg consumption [3]. It also has been suggested that benefits from nutrients in eggs (such as polyunsaturated fat, folate and vitamins A and E) may outweigh the potentially adverse effects of the cholesterolemic compounds in eggs.

The purpose of this research was to explore egg consumption as a risk factor for CVD in the U.S. population. Specific objectives were (1) to estimate mean daily intakes of energy, total, saturated and polyunsaturated fat, cholesterol, dietary fiber, sodium, vitamins E, A, C, B6 and B12 and folate in egg consumers (EC) and nonconsumers (NC), (2) to estimate percentages of nutrients (energy, total, saturated and polyunsaturated fat, cholesterol, vitamins A, E, B6 and B12 and folate) that are contributed by eggs and egg products in the diets of EC, (3) to determine if differences exist between EC and NC in mean nutritional intakes and percentage of people whose nutrient intake is below adequate levels ($<$ EAR or $<$ 70% RDA), (4) to examine

Abbreviations: CVD = cardiovascular disease, EAR = estimated average requirements, EC = egg consumers, HDL = high density lipoprotein, NC = nonconsumers, NCHS = National Center for Health Statistics, NHANES III = Third National Health and Nutrition Examination Survey, RDA = Recommended Dietary Allowance, USDA = United States Department of Agriculture.

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Table 1. Characteristics of Egg Consumers

Categorical Variable	Egg Consumers[1]		Nonconsumers		
	Number	%[2]	Number	%[2]	*p* value[3]
All	6,551	18.7	20,827	81.2	
Gender					
Male	3,466	20.5	9,855	79.5	0.0001
Female	3,085	17.0	10,972	83.0	
Ethnicity					
White, non-Hispanic	1,602	16.7	8,138	83.3	<0.00005
Black, non-Hispanic	1,876	23.3	6,240	76.7	
Mexican-American	2,822	31.8	5,420	68.2	
Other Ethnicity	251	19.6	1,029	80.4	
Age (years)[4]					
< 17	2,604	15.8	9,369	84.2	<0.00005
17–24	607	17.4	2,043	82.6	
25–54	2,001	20.1	5,926	79.9	
55–64	512	19.8	1,299	80.2	
65–74	475	21.0	1,196	79.0	
75+	352	21.6	994	78.4	
Education Level (years)					
≤ 6	558	30.0	930	70.0	<0.00005
7–12	1,409	22.9	3,391	77.1	
13–16	1,638	19.4	5,559	80.6	
17+	311	15.4	1,506	84.6	

[1] Egg consumers are those subjects who reported consuming an egg-group product in the 24 hour recall period of NHANES III.

[2] Rows add to 100% weighted percentage based on US samples (n=27,378).

[3] Level of significance of categorical variable as determined by chi-square analysis.

[4] Education level for adults only (age 17 years and older) (n=15,302).

Table 2. Frequency of Egg and Egg Products Consumed in 24-Hours in the US Population[1]

Food Item	Frequency
Egg omelet or scrambled egg, with additions	4,045
Egg, whole, fried	2,115
Egg, whole, boiled	775
Egg, white only, cooked[2]	110
Egg, whole, raw	103
Egg, whole, poached	73
Egg salad	60
Egg, cheese, and bacon on biscuit	60
Scrambled egg, made from cholesterol-free frozen mixture[2]	52
Egg, cheese, and sausage on biscuit	49
Egg, cheese, and ham on English muffin	39
Egg, deviled	38
Egg, yolk only, cooked	34
Egg, cheese, and sausage on English muffin	34
Egg drop soup	18
Shrimp-egg patty (Torta de Cameron seco)	17
Egg, whole, baked, fat added in cooking	14
Egg, yolk only, raw	13
Egg foo yung, all varieties	13
Huevos rancheros	7
Meringues[2]	7
Egg, whole, pickled	6
Egg, Benedict	3
Egg, white only, raw[2]	3
Quail egg, canned	1
Egg, creamed	1
Egg, cheese, and bacon on English muffin	1
TOTAL[3]	7,691

[1] Subjects of the NHANES III who were identified as egg consumers (n=6,551).

[2] Cholesterol-free egg product.

[3] Includes multiple daily episodes of egg consumption by some subjects.

the difference in serum cholesterol concentration between infrequent and frequent egg consumers after controlling for the potentially confounding effects of demographic (age, gender and ethnicity) and lifestyle variables (smoking and physical activity) and (5) to calculate the regression of serum cholesterol concentration *versus* dietary cholesterol intake after controlling for the effect of the aforementioned variables.

METHODS

Population Database

Subjects were participants in the Third National Health and Nutrition Examination Survey (NHANES III, 1988–94). The National Center for Health Statistics (NCHS) conducted the survey to obtain nationally representative information on the health and nutritional status of the noninstitutionalized population of the United States aged two months or older [4–6]. Food intake data was obtained by asking participants what they had eaten over the previous 24-hour period. Physical examinations (which included blood collection) were conducted in mobile examination centers. Additional details about the conduct of the NHANES III can be obtained by consulting references mentioned above [4–6].

The following were excluded from our statistical analyses: subjects with unreliable dietary recall records as coded by NCHS (n=3,176), pregnant and lactating women (n=457), those taking drugs for hyperlipidemia (n=402) or unspecified heart disease (n=1,224), or those consuming egg white products (n=145). Serum cholesterol data from subjects who reported changing their diet in the past year due to high serum cholesterol level (n=765) were not included.

Smokers were those subjects who responded 'yes' to the question, 'Do you smoke cigarettes now?' Physical activity was reported in total metabolic equivalents per month for all subjects 17 years of age and older. Laboratory tests were performed on whole blood and sera. Serum total cholesterol concentrations were determined in children ≥ 4 years of age and adults. For the analyses involving serum cholesterol concentrations, the food frequency questionnaire was used to estimate the usual intake of eggs.

Study Design

The 24-hour dietary recall records (from NHANES III) and the United States Department of Agriculture (USDA) Survey Nutrient Database were used to determine the average daily

Table 3. Mean Daily Intake[1] of Nutrients in Egg Consumers *Versus* Nonconsumers

Nutrient Intake	All Subjects[2] (n=27,378)	Egg Consumers (n=6,551)	Nonconsumers (n=20,827)	*P* value[3]
Energy (kcal)	2146 ± 16	2373 ± 35	2093 ± 15	0.000
Fat (g)	82 ± 1	100 ± 2	78 ± 1	0.000
Saturated Fat (g)	28.2 ± 0.3	33.7 ± 0.6	26.9 ± 0.3	0.000
Polyunsaturated Fat (g)	16.9 ± 0.3	20.3 ± 0.5	16.2 ± 0.2	0.000
Cholesterol (mg)	273 ± 4	565 ± 9	205 ± 3	0.000
Fiber (g)	15.6 ± 0.1	15.8 ± 0.2	15.5 ± 0.2	0.213
Sodium (mg)	3451 ± 33	3873 ± 68	3353 ± 32	0.000
Vitamin E (TE)	9.2 ± 0.2	10.5 ± 0.3	8.9 ± 0.2	0.000
Vitamin A (RE)	990 ± 15	1072 ± 30	971 ± 17	0.006
Vitamin C (mg)	105 ± 1	111 ± 3	104 ± 1	0.022
Vitamin B6 (mg)	1.8 ± 0.0	1.8 ± 0.0	1.8 ± 0.0	0.577
Folate (μg)	275 ± 3	293 ± 5	271 ± 3	0.001
Vitamin B12 (μg)	5.1 ± 0.1	6.2 ± 0.3	4.8 ± 0.1	0.000

[1] Data are presented as Weighted Mean ± SE

[2] Subjects were participants of NHANES III

[3] Level of significance of difference between egg consumers and nonconsumers as assessed by *t* test.

RE=retinol equivalents, TE=tocopherol equivalents.

intake of energy and certain nutrients (total, saturated and polyunsaturated fat, cholesterol, dietary fiber, sodium, folate and vitamins E, A, C, B6 and B12). Subjects were divided into those who were EC (subjects who reported consuming at least one egg-group product in the 24-hour recall) and those who did not report consuming any egg-group products in the 24-hour recall (NC). Egg-group products were defined based on the USDA food grouping system and were those food items with a food code that has '3' as the first digit. Individuals also were grouped according to the frequency of reported egg consumption (≥4/week; 2 to 3/week; ≤1/week).

When analyzing the effect of egg consumption on the percentage of subjects whose nutrient intake was inadequate or sufficient, subjects were grouped according to whether their nutrient intake was less than, equal to or greater than the EAR (or 70% RDA) prior to being grouped according to whether or not they consumed egg group products.

The effect of the following sociodemographic characteristics on egg consumption also was assessed in this manner: (1) age (< 17, 17–24, 25–54, 55–64, 65–74, or ≥ 75 years), (2) gender, (3) race/ethnicity (White, non-Hispanic; Black, non-Hispanic; Mexican-American or other) and (4) highest level of education completed beyond kindergarten (≤ 6, 7–12, 13–16, or ≥ 17 years).

Data Analysis

SUDAAN software was used for all data analyses because of its ability to estimate variances from a stratified, multistage probability design [7]. Sample weights were applied to all analyses to account for the unequal probability of selection and noncoverage and nonresponse bias due to oversampling of young children, the elderly, Blacks and Mexican-Americans.

Table 4. Percentage of Nutrient Intake from Eggs in Egg Consumers[1]

Nutrient	Gender[2]	%
Energy (kcal)	All	9
	Male	9
	Female	9
Total fat (g)	All	17
	Male	16
	Female	17
Saturated fat (g)	All	16
	Male	15
	Female	16
Polyunsaturated Fat (g)	All	16
	Male	16
	Female	16
Cholesterol (mg)	All	61
	Male	60
	Female	62
Vitamin E (TE)	All	21
	Male	21
	Female	21
Vitamin A (RE)	All	25
	Male	26
	Female	24
Vitamin B6 (mg)	All	9
	Male	9
	Female	9
Folate (μg)	All	17
	Male	17
	Female	17
Vitamin B12 (μg)	All	25
	Male	24
	Female	27

[1] Egg consumers are those subjects who reported consuming an egg- group product in the 24-hour recall period of NHANES III.

[2] n = 6,551 (all), 3,466 (male), 3,085 (female).

RE=retinol equivalents, TE=tocopherol equivalents.

Table 5. Percentage of People Whose Nutrient Intake Is < or ≥ EAR[1] or 70% RDA[2]

Nutrient		Total [3] n	Egg Consumers[4]		Nonconsumers[4]		
			n	%[5]	n	%[5]	*p* value[6]
Vitamin B6							
	<EAR	5,797	1,401	18.9	4,396	81.1	0.8015
	≥EAR	21,581	5,150	18.7	16,431	81.3	
Folate							
	<EAR	15,068	3,561	18.2	11,507	81.9	0.0917
	≥EAR	12,310	2,990	19.7	9,320	80.3	
Vitamin B12							
	<EAR	4,934	676	10.1	4,258	89.9	<0.00005
	≥EAR	22,444	5,875	20.9	16,569	79.1	
Vitamin A							
	< 70%RDA	11,205	2,483	15.8	8,722	84.2	<0.00005
	≥ 70%RDA	16,173	4,068	20.9	12,105	79.1	
Vitamin E							
	< 70%RDA	10,836	2,091	13.5	8,745	86.5	<0.00005
	≥ 70%RDA	16,542	4,460	22.0	12,082	78.0	
Vitamin C							
	< 70%RDA	4,080	882	14.7	3,198	85.3	0.0001
	≥ 70%RDA	23,298	5,669	19.5	17,629	80.5	

[1] EAR is the Estimated Average Requirements set by the Food and Nutrition Board.

[2] RDA is the Recommended Dietary Allowance set by the Food and Nutrition Board.

[3] Total is number of subjects with intake for particular nutrient being < or ≥ EAR or 70% RDA.

[4] Egg consumers (n=6,551) are those subjects who reported consuming an egg group product in the 24-hour recall period of NHANES III; nonconsumers (n=20,827) did not.

[5] Rows add to 100% weighted percentage based on nutrient intake being < or ≥ EAR or 70% RDA.

[6] Level of significance of difference between those with adequate or inadequate nutrient intake as determined by chi-square analysis.

Percentage and standard error of means were calculated by the linearization (Taylor series) variance estimation method for population parameters by SUDAAN. Distributions of categorical variables were assessed using a chi-square test. Means for interval scale variables were compared using *t* tests (accounting for the population variance). Logistic regression analyses were conducted between serum cholesterol and egg consumption after controlling for race, gender, smoking status, age and exercise by using SAS (Version 6.12) and SUDAAN (Version 7.5).

RESULTS

Characteristics of EC are shown in Table 1. Nearly 20% of the population reported consuming eggs in the 24-hour recall. Egg consumption was significantly influenced by gender, ethnicity, age and education level. Egg ingestion was higher in males than females and in Mexican-Americans compared to other ethnic groups. Older Americans and people with lower education levels were more likely to eat eggs than younger or more educated people. Types of egg products eaten by EC are listed in Table 2. Eggs were consumed most often as omelet/scrambled eggs (52%), followed by whole fried or boiled eggs (38%).

Daily nutrient intake of EC was greater than that of NC for all nutrients studied ($p < 0.05$) except for dietary fiber and vitamin B6 (Table 3). Cholesterol intake averaged 273 mg/day, (127 mg/1000 kcal) for all subjects, 565 mg/day (256 mg/1000 kcal) for EC and 205 mg/day (98 mg/1000 kcal) for NC. Subgroup analyses revealed that some relationships were more pronounced in certain age and gender groups (data not shown). For example, differences between vitamin E and folate in EC *vs*. NC were most pronounced in 25- to 54-year olds.

Among EC, eggs contributed < 10% of energy and vitamin B6, 10% to 20% of total, saturated and polyunsaturated fat and folate; and 20% to 30% of vitamins A, E and B12 [Table 4]. In contrast to NC, a greater percentage of EC had adequate intake (≥ EAR or 70% RDA) of vitamin B12, vitamin A, vitamin E and vitamin C than inadequate intake (< EAR or 70% RDA) [Table 5]. Compared to EC, a greater proportion of NC had inadequate intakes for vitamin B12 (10% *vs*. 20%), vitamin A (16% *vs*. 21%), vitamin E (14% *vs*. 22%) and vitamin C (15% *vs*. 20%).

After controlling for the effect of demographic variables (age, gender and ethnicity) and lifestyle variables (smoking and physical activity), egg consumption (as measured by food frequency questionnaire) did not appear to have any significant bearing on serum cholesterol concentration (Table 6 and Fig. 1). Total serum cholesterol concentration was used as an outcome variable because total cholesterol and non-HDL cholesterol were highly correlated ($r^2 = 0.94$, $p < 0.001$). Contrary to

Table 6. Regression Model for Serum Cholesterol by CVD Risk Factors[1]

Category	Variable	β[2]	±SE	p value[3]
Egg Consumption	≤1 egg/week	0		
	2–3 eggs/week	−2.28	1.84	0.2218
	≥4 eggs/week	−6.45	1.91	0.0014
Race	White	0		
	African-American	−0.35	1.52	0.8191
	Mexican-American	2.41	1.61	0.1407
	Other	0.39	4.29	0.9283
Gender	Male	0		
	Female	−1.88	1.47	0.2053
Smoking Status	No	0		
	Yes	−0.46	1.48	0.7560
Age (years)		0.89	0.06	0.0000
Exercise (Mets)[4]		−0.01	0.01	0.0396

[1] Serum cholesterol data were obtained from participants of NHANES III.

[2] Regression coefficient.

[3] p value is for comparison between group with $\beta = 0$ and other groups within each category (if listed).

[4] Oxygen consumption in metabolic equivalents (Mets).

what might be expected, total serum cholesterol concentration was negatively related to frequency of egg consumption. Subjects who reported eating four or more eggs per week had a significantly lower mean serum cholesterol concentration than those who reported eating one or fewer eggs per week (193 ± 1.2 mg/dL *vs.* 197 ± 0.7 mg/dL, $p < 0.01$).

DISCUSSION

Health professionals have recommended that Americans should decrease their intake of dietary fat and cholesterol to reduce the risk of CVD [8,9]. Since eggs are a source of dietary fat and cholesterol, this suggests that egg consumption should be reduced or avoided. Results of our study refute this hypothesis. The fact that serum cholesterol levels were inversely related to egg consumption supports results of epidemiological studies which show that serum cholesterol levels are not directly related to dietary cholesterol levels [10–13]. This may explain why increased egg consumption has not been linked to increased risk of CVD [3].

It can be argued that our analysis is confounded by inclusion of subjects with high serum cholesterol levels who were on egg-restricted diets. We attempted to remove this bias by excluding all those suspected of having high cholesterol levels (i.e., those on medication for hyperlipidemia or unspecified heart disease, those consuming egg white products and those who reported changing their diets in the past year due to high cholesterol.) The fact that the average serum cholesterol level of subjects was less than that which triggers dietary and/or pharmacological intervention (220 mg/dL) [14,15] indicates that we were largely successful in removing individuals with known high cholesterol levels from our analysis.

If people eliminate or reduce a specific food (e.g., eggs) from their diet, they may replace it with calories from another source [16–19]. It is altogether possible that the food that replaces eggs is higher in calories and/or fat. Since eggs are primarily a breakfast food, people trying to reduce their egg intake may simply skip breakfast altogether. Numerous studies have shown that breakfast skippers have poorer nutritional status than breakfast eaters (even when those breakfasts contain eggs) [20–24]. As our study shows, eggs contain many nutritionally beneficial components that would be ingested in lower amounts (along with the dietary fat and cholesterol) if eggs were reduced or eliminated from the diet. Egg consumers had higher daily intakes of vitamins C, E and B12 as well as folate. Deficiencies in these vitamins have been associated with increased risk of a number of different diseases including cancer, cardiovascular and coronary heart disease and Alzheimer's disease [25–35]. Therefore, by increasing levels of these micronutrients in the diet, egg consumption may actually help guard against development of chronic diseases, rather than promote them.

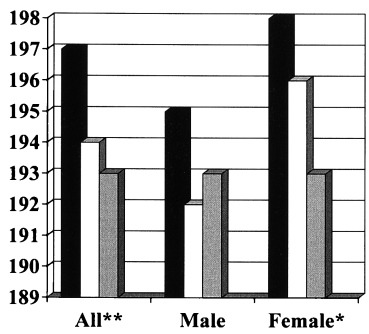

Fig. 1. Effect of frequency of egg consumption on serum cholesterol (mg/dL). ■ ≤ 1 egg/week, □ 2–3 eggs/week, ▨ ≥ 4 eggs/week. * = significant effect at $p < 0.05$; ** = significant effect at $p < 0.01$.

CONCLUSIONS

Results of our study indicate that eggs make important nutritional contributions to the American diet, and frequent egg consumption does not associate adversely with serum cholesterol concentrations. Our work repudiates the hypothesis that increased egg consumption leads to increased serum cholesterol concentrations and also adds to the growing body of literature which supports the nutritional benefits of eggs. Although our results suggest that higher egg consumption is associated with lower serum cholesterol, this study should not be used as a basis for recommending higher egg consumption for regulation of serum cholesterol.

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