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Egg consumption and the risk of diabetes in adults, Jiangsu, China

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ABSTRACT

Background: Although egg consumption has been associated with elevated plasma levels of cholesterol and triglyceride and with risk of cardiovascular disease in some populations, epidemiologic studies on egg consumption and the risk of diabetes are extremely sparse, particularly in the Chinese population.

Method: Data from a household survey in the year 2002 among 2849 adults aged $\geq$20 y from a nationally representative sample in Jiangsu Province, China, were used. Dietary information was assessed by a validated food frequency questionnaire and 3 d weighed food records. Fasting blood specimens were collected.

Results: After the adjustment for age, total calorie intake, education, smoking, family history of diabetes, and sedentary activity, egg consumption was significantly and positively associated with diabetes risk, particularly in women. The odds ratios (OR) (95% CI) of diabetes associated with egg consumption <2/wk, 2–6/wk, and $\geq$1/d in the total sample were 1.00, 1.75, 2.28 (1.14–4.54), respectively (*P* for trend 0.029). Corresponding ORs (95% CI) in women were 1.00, 1.66, and 3.01 (1.12, 8.12), respectively (*P* for trend 0.022). Additional adjustment of body mass index attenuated the association, but it remained significant. There was a similar, however, not statistically significant association in men. In addition, plasma triglyceride and total cholesterol levels were significantly higher in women who consumed $\geq$2 eggs/wk than those who consumed eggs less often.

Conclusion: Egg consumption was positively associated with the risk of diabetes among the Chinese, particularly in women.

Introduction

Diabetes is becoming an epidemic worldwide, including in China. In 2002, it affected up to 13.1% of urban inhabitants aged 60 y and older in China [1]. Substantial evidence indicates that diet can influence glucose homeostasis and that modification of diet can have beneficial effects on diabetes risk [2]. However, the majority of evidence is based on data from western countries. Limited data are available for diet and diabetes in the Chinese population [3–5], despite the substantial rise in diabetes prevalence.

Eggs, conventionally regarded as an important dietary source of protein, are commonly consumed in China. From 1989 to 2004, egg consumption was doubled in both urban and rural areas (rural: from 11 to 26 g/d; urban: from 16 to 33 g/d) [6]. Eggs are also a major source of dietary cholesterol with an average egg containing approximately 200 mg cholesterol. Findings from some studies suggest that dietary cholesterol from eggs leads to a modest increase in blood concentrations of total and low-density lipoprotein (LDL) cholesterol [7–11]. Both traits have been found to be positively related to diabetes risk [8,12]. On the other hand, eggs contain many other potentially beneficial nutrients, such as monounsaturated fats, minerals, essential amino acids, folate, and other B vitamins. Moreover, consumption of eggs instead of carbohydrate-rich foods may raise high-density lipoprotein (HDL) cholesterol levels and decrease blood glycemic and insulinemic responses [13]. Therefore, it is important to investigate the relationship between egg consumption and risk of diabetes. However, very few studies [14] have investigated this association. In the present study, we aim to examine the association between egg consumption and diabetes

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in a Chinese population based on China national nutrition survey data.

Research design and methods

The present study was based on data from a subsample of the national nutrition and health survey of 2002 from Jiangsu Province in Eastern China. Participants from rural areas in the province were selected from six counties (Jiangyin, Taichang, Shuining, Jurong, Sihong, and Haimen). From each of them, three smaller towns were randomly selected. Participants from the urban areas were selected from the capital cities of two prefectures, Nanjing and Xuzhou; households from three streets in each capital city were randomly selected. The six counties and the two prefectures represented a geographically and economically diverse population. In each town/street, two villages/neighborhoods were randomly selected, and 30 households were further selected randomly from each village/neighborhood. All the members in the households were invited to take part in the study. Written consent was obtained from all the participants. In the present study, we analyzed data for adults aged 20 y and above.

Data collection and measurements

Participants were interviewed at their homes by trained health workers using a standard questionnaire.

Hemoglobin, serum ferritin, fasting plasma glucose

An overnight fasting blood sample was collected from all study participants. The blood samples were analyzed for plasma glucose and hemoglobin in local Centers for Disease Control and Prevention according to standard procedures. Hemoglobin was measured by the cyanmethemoglobin method [15]. Serum ferritin was analyzed in a laboratory in the National Centre for Disease Control and Prevention in Beijing using a commercially available radioimmunoassay kit (Beijing North Institute of Biological Technology). We defined diabetes as fasting plasma glucose (FPG) >7.0 mmol/L.

Dietary measurements

Dietary information from the past year was collected by a validated food frequency questionnaire, which included a series of detailed questions regarding usual frequency and quantity of intake of 33 foods and beverages by an in-person interview. The food frequency questionnaire has been reported to be a valid method for the collection of information on individual food consumption in face-to-face interviews in the Chinese population [16,17]. Portion size for each food was established by reference to food models. Study participants were asked to recall the frequency of consumption of individual food items (number of times per d,/wk,/mo,/y) and the estimated portion size, using local weight units (i.e., a "liang," which is equivalent to 50 g) or cups. Intake of eggs was converted into eggs per week and was categorized into three groups: <2 eggs/wk, 2–6 eggs/wk, ≥1 egg/d. Nutrient intake was also measured by 3-d weighed food records. Food consumption data were analyzed using the Chinese Food Composition Table [18].

Smoking and drinking

Smoking was assessed by asking about the frequency of daily cigarette smoking. Alcohol consumption was assessed by asking about the frequency and amount of spirits/wine intake.

Physical activity and inactivity

Assessment of sedentary activity was asked by the following question: how many hours a day do you spend on reading, watching TV, and playing video games? Questions on active commuting concerned walking or bicycling for different purposes.

Height, weight, waist circumference, and blood pressure

At each study site, health workers measured height, weight, and blood pressure according to standard protocols. Blood pressure was measured twice by mercury sphygmomanometer on the right upper arm of the subject, who was seated for 5 min before the measurement. The mean of these two measurements was used in the analyses. Hypertension was defined as systolic blood pressure above 140 mmHg and/or diastolic blood pressure above 90 mmHg, or using antihypertensive drugs. Height was measured without shoes and weight was measured with light clothing. Body mass index (BMI) was calculated as weight in kilograms divided by the square of the height in meters. Waist circumference was measured midway between the inferior margin of the last rib and the iliac crest in a horizontal plane.

Table 1
Characteristics of study participants with and without diabetes, Jiangsu, China, 2002

	Non-diabetes ($n = 2770$)	Diabetes ($n = 79$)	P
Age, y (mean, SE*)	46.8 (0.3)	55.7 (1.4)	<0.001
Nutrients and foods intake (mean (SE))			
Eggs†/wk	4.6 (0.1)	5.7 (0.6)	0.023
Vegetables, g/d	252.6 (3.2)	281.9 (14.3)	0.118
Fruits, g/d	64.4 (1.7)	68.4 (8.6)	0.688
Red meat, g/d	62.6 (1.2)	71 (7.4)	0.252
Iron, mg/d	25.6 (0.2)	25.4 (1.3)	0.848
Carbohydrate (% energy)	55.5 (0.2)	51.4 (1.2)	0.001
Protein (% energy)	12.5 (0.1)	13.7 (0.4)	<0.001
Fat (% energy)	30.7 (0.2)	34.1 (1.2)	0.002
Smoking (%)			
Never	72.5	67.1	
1–19 cigarettes/d	13.9	16.5	0.571
≥20 cigarettes/d	13.7	16.5	
Drinking alcohol (%)			
0 times/wk	74.3	73.1	
1–2 times/wk	7.9	5.1	0.680
3–4 times/wk	4.6	5.1	
Daily	13.1	16.7	
High blood pressure (%)	26.8	44.3	<0.001
BMI, kg/m^2(mean, SE)	23.5 (0.1)	25.5 (0.4)	<0.001
Overweight (%)‡	51.3	74.7	<0.001
Central obesity (%)§	28.9	55.7	<0.001
Urban dwellers (%)	24.2	50.6	<0.001
Serum ferritin, μg/L (mean, SE)	97.4 (1.6)	156.8 (13.4)	<0.001
Education (%)			
Primary	47.9	40.5	
Junior school	36.2	40.5	0.616
High school	13.3	15.2	
University	2.7	3.8	
Active commuting, min/d (mean, SE)	13.9 (0.4)	6.4 (1.7)	<0.001
Sedentary activity, h/d (mean, SE)	2.0 (0.03)	2.3 (0.20)	0.074

* SE, standard error.
† 1 egg equals 50 g.
‡ Defined as BMI ≥23 kg/m^2.
§ Defined as waist circumference: men ≥90 cm, women ≥80 cm.

Socioeconomic status

Household income was assessed by questions on family income and number of persons in the household. The three following income groups were constructed: low: <1999 Yuan/person; medium: 2000–4999 Yuan/person; high: >5000 Yuan/person. Education was recoded into three categories based on six categories of education levels in the questionnaire: low: illiteracy, primary school; medium: junior middle school; high: high middle school or higher. Occupation was coded into labor or non-labor based on a question with 12 occupational categories. Family history of diabetes was defined as the presence of known family members with type 2 diabetes in any of three generations (siblings, parents, or grandparents). Known diabetes was based on self-reported hospital diagnosis of diabetes.

Statistical analyses

χ^2 test was used to compare differences in categorical variables, and ANOVA was used to compare differences in continuous variables between diabetic and non-diabetic groups. The association between egg consumption and the risk of diabetes was analyzed using logistic regression models adjusting for multiple covariates. The parsimonious model controlled for age (continuous), energy intake, education, smoking, sedentary activity, and family history of diabetes (yes/no) was applied. Statistical significance was considered when $P < 0.05$ (two-sided). All the analyses were performed by using STATA software (version 9, 2005, Stata Corp., College Station, TX, USA).

Table 2
Characteristics of study participants according to egg consumption, Jiangsu, China, 2002

	Men				Women			
	<2 eggs*/wk (n = 330)	2–6 eggs/wk (n = 570)	≥1 egg/d (n = 408)	P†	<2 eggs/wk (n = 435)	2–6 eggs/wk (n = 720)	≥1 egg/d (n = 386)	P†
Daily nutrient intake‡ [Mean (SE§)]								
Energy (kcal)	2625 (38)	2577 (29)	2624 (34)	0.454	2163 (29)	2147 (22)	2088 (31)	0.168
Protein (g)	78 (1)	80 (1)	82 (1)	0.050	65 (1)	67 (1)	66 (1)	0.356
Fat (g)	81 (2)	91 (2)	94 (2)	<0.001	69 (2)	75 (1)	76 (2)	0.002
Carbohydrate (g)	375 (6)	338 (4)	348 (5)	<0.001	320 (5)	300 (4)	285 (5)	<0.001
Energy from fat (%)	28.4 (0.5)	31.6 (0.4)	32.5 (0.5)	<0.001	28.6 (0.5)	31.5 (0.3)	33.0 (0.5)	<0.001
Energy from protein (%)	12.8 (0.2)	13.6 (0.1)	13.5 (0.1)	<0.001	13.1 (0.1)	13.5 (0.1)	13.6 (0.2)	0.023
Age (y) (mean (SE))	50.2 (0.8)	47.5 (0.7)	45.0 (0.6)	<0.001	48.6 (0.7)	46.5 (0.5)	45.0 (0.7)	0.001
Body mass index (kg/m^2)								
Mean (SE)	23.4 (0.2)	23.2 (0.1)	23.7 (0.2)	0.055	23.9 (0.2)	23.4 (0.1)	23.8 (0.2)	0.051
Household income (%)								
Low	44.8	25.0	32.6		44.3	26.9	29.5	
Medium	29.8	30.4	35.6	<0.001	30.8	33.3	33.7	<0.001
High	25.5	44.6	31.9		24.9	39.8	36.8	
Education (%)								
Primary	44.9	37.5	26.7		70.3	56.5	45.1	
Junior school	40.6	44.2	44.9	<0.001	22.6	32.1	35.0	
High school	13.3	15.1	20.3		6.5	10.2	16.8	
University	1.2	3.2	8.1		0.7	1.3	3.1	
Residence (%)								
Urban	14.9	20.5	40.2		14.3	19.3	46.6	
Rural	85.2	79.5	59.8	<0.001	85.7	80.7	53.4	<0.001
Active commuting (min/d)								
0	31.2	34.2	28.9		38.3	42.2	53.4	
1–29	46.4	55.1	57.4	<0.001	41.2	48.9	38.6	<0.001
≥30	22.4	10.7	13.7		20.5	8.9	8.0	
Sedentary activity (h/d)								
<1	18.5	9.0	12.3		29.0	16.0	12.7	
1–2	30.6	24.9	25.5		33.6	30.1	25.4	
2–3	38.5	47.7	39.7	<0.001	30.7	41.7	42.5	<0.001
≥3	12.4	18.4	22.6		6.7	12.2	19.4	

* 1 egg equals 50 g.
† χ^2 test for categorical variables and ANOVA for continuous variables.
‡ Age adjusted.
§ SE, standard error.

Results

In total, 1417 households were included in the study. The final sample contained 1308 men and 1541 women. A total of 288 subjects were not present in the household during the period of the survey, giving a response rate of 89.0%. The prevalence of high FPG (>7.0 mmol/L) was 3.0% ($n = 39$) in men and 2.6% ($n = 40$) in women. In total, 19 men and 32 women were known to have diabetes. Of these, 8 men and 15 women had FPG <7.0 mmol/L. About 4% of the total sample reported having a family history of diabetes. In general, the diabetic patients were likely to be older, heavier, and more physically inactive, having higher intakes of fat and protein as compared with non-diabetic participants (Table 1). No difference in cigarette smoking and drinking status of wine/spirits was found between diabetic patients and non-diabetics.

The age adjusted mean intakes of eggs in g/day among non-diabetic, new diabetics detected by the survey, and known diabetics were 34.9 (SE 0.9), 40.8 (6.0), and 38.6 (7.3) in men ($P = 0.557$); 30.3 (0.7), 44.5 (6.0), and 41.2 (5.1) in women ($P = 0.008$) (data not shown). Table 2 shows that egg consumption was positively associated with energy intake from total fat and protein ($P < 0.001$) but negatively associated with carbohydrate intake ($P < 0.001$). Participants with high socioeconomic status and high educational level had a higher intake of eggs than those with low socioeconomic status. The higher egg consumption groups were also characterized by a higher level of sedentary activity and lower level of active commuting. A significantly higher egg consumption was observed in urban residents compared to rural residents. The mean intake of eggs was 35.1 g/d (SE 0.7) in men and 30.7 g/d (SE 0.9) in women.

The prevalence of diabetes (FPG >7 mmol/L) was positively associated with egg consumption in women, but not in men (Table 3). Plasma total cholesterol and triglyceride levels were significantly higher in women who consumed >2 eggs/wk than those who consumed less.

After the adjustment for age, total calorie intake, education, smoking, family history of diabetes, and sedentary activity, egg consumption was significantly and positively associated with diabetes risk, particularly in women (Table 4). The odds ratios (OR) (95% CI) of diabetes associated with frequency of egg consumption <2 eggs/wk, 2–6 eggs/wk, and ≥1 egg/d were 1.00, 1.75, and 2.28 (1.14–4.54), respectively (P for trend 0.029). Corresponding ORs (95% CI) in women were 1.00, 1.66, and 3.01 (1.12–8.12), respectively (P for trend 0.022). Additional adjustment of BMI, fat intake, and iron status attenuated the associations slightly, but it remained significant in women. After excluding 91 women who reported having changed their diet to control blood glucose or blood lipids, the association between egg consumption and diabetes became stronger, but the confidence interval became wider due to the reduced sample size. The multivariate adjusted ORs for diabetes associated with egg consumption <2 eggs/wk, 2–6 eggs/wk, and ≥1 egg/d were 1.00, 2.95, 4.36 (1.00–19.00), respectively (P for trend 0.049). There was a similar, however, statistically

Table 3
Plasma concentrations of lipids according to egg consumption among men and women, Jiangsu, China, 2002

	Men				Women			
	<2 eggs/wk ($n = 330$)	2–6 eggs/wk ($n = 570$)	≥1 egg/d ($n = 408$)	P*	<2 eggs/wk ($n = 435$)	2–6 eggs/wk ($n = 720$)	≥1 egg/d ($n = 386$)	P*
Cholesterol (mg/dl)								
Mean (SE)†	145 (2)	148 (2)	148 (2)	0.287	145 (2)	148 (1)	151 (2)	0.033
Mean (SE)‡	145 (2)	148 (2)	149 (2)	0.311	145 (2)	148 (1)	151 (2)	0.037
TG (mg/dL)								
Mean (SE)†	98 (5)	110 (4)	99 (4)	0.065	90 (2)	99 (2)	94 (2)	0.010
Mean (SE)‡	99 (5)	109 (4)	101 (4)	0.237	91 (2)	98 (2)	94 (2)	0.043
Log TG (mg/dL)								
Mean (SE)†	4.44 (0.03)	4.52 (0.02)	4.45 (0.02)	0.021	4.41 (0.02)	4.49 (0.02)	4.43 (0.02)	0.004
Mean (SE)‡	4.44 (0.03)	4.51 (0.02)	4.47 (0.02)	0.175	4.41 (0.02)	4.48 (0.02)	4.43 (0.02)	0.023
HDL (mg/dL)								
Mean (SE)†	50.1 (0.7)	50.1 (0.5)	50.8 (0.6)	0.621	51.1 (0.5)	51.3 (0.4)	52.2 (0.6)	0.285
Mean (SE)‡	50.0 (0.7)	50.3 (0.5)	50.4 (0.6)	0.900	51.0 (0.5)	51.5 (0.4)	52.1 (0.6)	0.407
LDL (mg/dl)								
Mean (SE)†	76.1 (1.9)	77.0 (1.4)	78.5 (1.7)	0.625	75.8 (1.2)	76.8 (1.0)	79.8 (1.3)	0.067
Mean (SE)‡	76.2 (1.9)	76.7 (1.4)	79.0 (1.7)	0.469	75.9 (1.2)	76.7 (1.0)	79.9 (1.3)	0.065
HDL/LDL ratio								
Mean (SE)†	0.75 (0.02)	0.73 (0.02)	0.77 (0.02)	0.274	0.75 (0.03)	0.75 (0.02)	0.81 (0.03)	0.304
Mean (SE)‡	0.74 (0.02)	0.74 (0.02)	0.76 (0.02)	0.676	0.75 (0.03)	0.76 (0.02)	0.81 (0.03)	0.365
Cholesterol/HDL ratio								
Mean (SE)†	3.03 (0.16)	3.10 (0.12)	3.29 (0.14)	0.439	2.89 (0.03)	2.96 (0.02)	2.94 (0.03)	0.263
Mean (SE)‡	3.04 (0.16)	3.08 (0.12)	3.32 (0.14)	0.325	2.90 (0.03)	2.94 (0.02)	2.95 (0.03)	0.464
FPG > 7 (%)	1.8	3.3	3.4	0.335	1.6	2.4	4.2	0.065
FPG > 7+ known diabetes (%)	2.4	3.9	4.2	0.405	2.5	2.8	6.2	0.005

* χ^2 test for categorical variables and ANOVA for continuous variables.
† Adjusted for age and BMI.
‡ Adjusted for age.

insignificant, association in men. Further adjustment for urban/rural residence attenuated the association, and the association became marginally significant.

Discussion

In this study among Chinese adults, we observed that egg consumption was positively associated with diabetes risk, particularly in women. This association persisted after adjusting for known risk factors of diabetes, including sociodemographic characteristics, BMI, family history of diabetes, and lifestyle factors. In addition, plasma triglyceride and total cholesterol levels were significantly and positively associated with egg consumption in women.

Very limited and inconsistent data are available on egg consumption and diabetes risk. The positive association between the prevalence of diabetes and egg consumption in the present study was in accordance with findings from the Physicians' Health Study [19]. In the Physicians' Health Study, the prevalence of diabetes according to egg consumption of <1/wk, 1/wk, 2–4/wk, 5–6/wk, 1/d, and ≥2/d were 1.9, 2.5, 2.7, 3.1, 7.3 and 6.8% [19]. Compared with no egg consumption, ≥7 eggs/wk had a hazard ratio for diabetes of 1.58 (1.25–2.01) in men in the Physician's Health Study, and 1.77 (1.28–2.43) in women in the Women's Health Study [20]. By contrast, egg consumption was not significantly associated with diabetes risk in a study of Japanese subjects [7]. The inconsistencies of these findings may be related to differences in study populations, in analytic approach, and in dietary patterns related to the consumption of eggs and cooking methods, such as boiling or frying.

The egg is one of the major sources of dietary cholesterol with an average egg containing approximately 200 mg cholesterol and 5.5 g fat (2.1% of total energy). Dietary cholesterol from an egg modestly increases levels of total and LDL cholesterol in the blood [7–11]. In our study, dietary fat intake was positively associated with egg consumption. Moreover, plasma total cholesterol and triglyceride increased with increasing egg consumption among women. Because these traits have been positively related to diabetes risk [8,12], it is plausible that the elevated blood LDL cholesterol and triglycerides can at least partly explain the observed association between egg consumption and diabetes.

Three decades ago when China was facing a malnutrition problem, eggs were recommended as a healthy food for preventing this problem. We have earlier found in the same sample that a vegetable-rich food pattern, of which eggs were one of the components, was positively associated with total energy intake and vegetable oil intake and risk of obesity in China [21]. The observed association between egg consumption and diabetes could thus be due to other dietary factors correlated to egg consumption, but also to other lifestyle factors. Egg consumption was also associated with education and sedentary lifestyle. However, in the present study, the association between egg consumption and diabetes remained statistically significant after the adjustment for these factors. Nevertheless, we cannot completely exclude the plausibility that other unidentified factors could have contributed to the adverse effect on glucose metabolism.

Inference from the present study is hindered by the ambiguous temporal relationship between egg consumption and diabetes risk due to the cross-sectional design. The American Diabetes Association recommends that individuals with diabetes should limit dietary cholesterol to <200 mg/d and limited egg consumption is recommended to reduce total serum cholesterol concentrations and to help prevent cardiovascular complications among diabetic patients [2]. In the present study, after we excluded women who reported having changed diet to control blood glucose or lipids, the positive association between egg consumption and diabetes risk became even stronger. Nonetheless, prospective studies on egg

Table 4
Odds ratio (OR 95% CI) for diabetes according to egg consumption in Chinese adult, Jiangsu, China, 2002

	Egg intake categories			*P* for trend
	<2 eggs/wk	2–6 eggs/wk	≥1 egg/d	
Men	$N = 330$	$N = 570$	$N = 408$	
Diabetes (%)	1.8	3.3	3.4	
Model 1*	1	2.03 (0.79–5.18)	2.44 (0.91–6.52)	0.114
Model 2†	1	2.02 (0.78–5.26)	2.06 (0.75–5.66)	0.272
Model 3‡	1	2.16 (0.83–5.63)	2.01 (0.73–5.55)	0.335
Women	$N = 435$	$N = 720$	$N = 386$	
Diabetes (%)	1.6	2.4	4.1	
Model 1*	1	1.67 (0.68–4.09)	3.22 (1.29–8.02)	0.007
Model 2†	1	1.66 (0.65–4.27)	3.01 (1.12–8.12)	0.022
Model 3‡	1	1.77 (0.69–4.53)	2.90 (1.08–7.84)	0.033
Total§	$N = 775$	$N = 1290$	$N = 794$	
Diabetes (%)	1.7	2.8	3.8	
Model 1*	1	1.85 (0.97–3.54)	2.73 (1.40–5.33)	0.004
Model 2†	1	1.75 (0.90–3.38)	2.28 (1.14–4.54)	0.029
Model 3‡	1	1.87 (0.97–3.63)	2.22 (1.11–4.46)	0.047

* Adjusted for age and intake of energy.
† Adjusted for age, intake of energy, education, smoking, family history of diabetes, sedentary activity.
‡ Additional adjustment for BMI.
§ Additional adjustment for gender. Gender was not associated with diabetes.

consumption and subsequent risk of diabetes are warranted to confirm findings from the present study.

In conclusion, our data from a representative sample in Jiangsu Province, China indicate that consumption of more than 1 egg/d is associated with significantly elevated risk for diabetes independent of other risk factors for diabetes. Considering the high percentage of participants who consumed more than 1 egg/d in this population and the substantially increasing burden of diabetes in China and worldwide, a clearer message on egg consumption and diabetes risk is needed. Prospective studies on egg consumption and future risk of diabetes are warranted to confirm findings from the present study and to explore the underlying molecular mechanism.

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