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REVIEW ARTICLE

Egg consumption and breast cancer risk: a meta-analysis

Ruohuang Si · Kunpeng Qu · Zebin Jiang · Xiaojun Yang · Peng Gao

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Abstract The relationship between egg consumption and breast cancer risk has been inconsistent, so it is necessary to conduct a meta-analysis to evaluate the relationship. PubMed, EMBASE and ISI Web of Knowledge were searched to find cohort studies or case control studies that evaluated the relationship between egg consumption and breast cancer risk. A comprehensive meta-analysis software was used to conduct the meta-analysis. 13 studies were included. The meta-analysis results showed that egg consumption was associated with increased breast cancer risk (RR 1.04, 95 % CI 1.01–1.08). Subgroup analyses showed egg consumption was also associated with increased breast cancer risk based on cohort studies (RR 1.04, 95 % CI 1.00–1.08), among European population (RR 1.05, 95 % CI 1.01–1.09), Asian population (RR 1.09, 95 % CI 1.00–1.18), postmenopausal population (RR 1.06, 95 % CI 1.02–1.10), and those who consumed ≥2, ≤5/week (RR 1.10, 95 % CI 1.02–1.17), but not in case–control studies (RR 1.06, 95 % CI 0.97–1.15), among American population (RR 1.04, 95 % CI 0.94–1.16), premenopausal population (RR 1.04, 95 % CI 0.98–1.11) and those who consumed ≥1, <2/week (RR 1.04, 95 % CI 0.97–1.11) or >5 eggs/week (RR 0.97, 95 % CI 0.88–1.06). Egg consumption was associated with increased breast cancer risk among the European, Asian and postmenopausal population and those who consumed ≥2, ≤5/week.

Keywords Breast neoplasms · Egg · Meta-analysis

Introduction

It has been reported that breast cancer was the most frequently diagnosed cancer and the leading cause of cancer death among females, accounting for 23 % (1,383,500) of the total cancer cases and 14 % (458,400) of cancer deaths [1]. Although the incidence rates for female breast cancer in most Asian countries are much lower than those in Western countries, there has been a marked increase in recent years [2]. The incidence and death rates of breast cancer were high in both developed countries and developing countries [3, 4]. The average age-standardized incidence rate of breast cancer among women in the developed countries was 63.22/100,000 [5].

Evidence showed that lifestyle factors were related to breast cancer risk, so it is possible for women to reduce breast cancer risk by changing their lifestyle [6]. For example, coffee consumption could be associated with an increased breast cancer risk [7], so its consumption should be reduced to decrease the risk. However, for egg consumption, the results from available studies have been inconsistent. Some studies indicated that there was no relationship between egg consumption and breast cancer risk [2–4, 8–11], while others revealed that egg consumption might be associated with reduced breast cancer risk [12–14] and some other studies showed that egg consumption might be associated with increased breast cancer risk [5, 6]. So it is necessary to conduct a meta-analysis to evaluate the relationship between egg consumption and

R. Si and K. Qu contributed equally to this article.

R. Si · K. Qu · Z. Jiang · X. Yang · P. Gao (✉)
No. 2 Department of General Surgery, Gansu Provincial Hospital, No. 160, Donggang West Road, Lanzhou 730000, Gansu, China
e-mail: gaopeng1959@163.com

R. Si
e-mail: qkp109@163.com

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breast cancer risk and find the reasons for the difference among studies.

Methods

Search strategy

PubMed, EMBASE and ISI Web of Knowledge were searched to find cohort studies or case control studies that evaluated the relationship between egg consumption and breast cancer risk. The search terms included egg, breast cancer, breast neoplasms, breast tumor and breast adenocarcinoma. Study designs were also considered by using "cohort study" or "case control study" in the process of search. If possible, subject heading terms were added. Reference lists from the meta-analysis, review articles and identified trials were hand searched. The searches were conducted independently by two reviewers (Ruohuang Si and Kunpeng Qu) in February 2013 without language or publication date restrictions; differences were checked by each other and resolved by discussion.

Inclusion criteria and study selection

We identified all published case–control studies or cohort studies that evaluated the relationship between egg consumption and breast cancer risk. When multiple articles for a single study had been published, we used the latest publication. For example, these two studies [12, 15] were all from the same study and the same population, and the results written by Dai [15] were part of the results written by Bao [12]. In this condition, we just included the study reported by Bao [12]. Two reviewers (Ruohuang Si and Xiojun Yang) independently assessed relevant citations for inclusion according to the inclusion criterion and disagreements were resolved by a third reviewer (Peng Gao).

Data abstraction

Two independent authors (Kunpeng Qu and Zebin Jiang) collected the following baseline characteristics for included studies: lead author, publication year, study design, mean age, sample size and outcomes. Any disagreement in the abstracted data was resolved by a third reviewer (Peng Gao).

Data analysis

A systematic review was conducted to qualitatively review all available evidence about the relationship between egg consumption and risk of breast cancer. A meta-analysis was also conducted to quantitatively assess the relationship between egg consumption and risk of breast cancer. In the meta-analysis, the studies in which the egg consumption in the control group was <1/week (<7 g/day) were included. Egg consumption was classified into four groups: <1/week (<7 g/day), ≥1, <2/week (7–13 g/day), ≥2, ≤5/week (14–35 g/day) and >5/week (>35 g/day).

The measure of interest was the risk ratio (RR) (estimated by the odds ratio (OR) in case–control and the hazard ratio (HR) in cohort studies). Only adjusted values were used in the meta-analysis. If there were two or more adjusted values, the values adjusted by more variables were included. If the study only supplied crude data without adjusted data, the study would not be analyzed in the meta-analysis. Subgroup analyses of different egg consumption classifications, study designs (cohort studies vs. case–control studies), geographical locations (Asia vs. Europe vs. America) and menopausal statuses (postmenopausal vs. premenopausal) were conducted. Data were pooled using random-effects model. Heterogeneity was tested using the I^2 statistic, which was deemed significant when I^2 was more than 40 % according to the Cochrane Handbook [16]. Then the sources of heterogeneity were detected. Sensitive analysis was also conducted to test the stability by excluding the studies which resulted in high heterogeneity. Publication bias was assessed by visually inspecting a funnel plot. The small-study effect in terms of publication bias was also estimated using Egger's linear regression test. Data were analyzed using comprehensive meta-analysis software.

Results

Search results

After comprehensive search, we found 94 citations (Pubmed 31 citations, Embase 7 citations, ISI web of knowledge 35 citations, Reference tracking 21 citations). After screening of titles and abstracts, we excluded 7 duplicates and 41 citations that did not obviously meet the inclusion criterion. After reading the full texts, 24 citations that did not relate to egg consumption and 9 citations that had identical data [15, 17–24], finally 13 citations, were included [2–6, 8–14, 25].

Characteristics of included trials

The trials were from China ($n = 3$) [3, 12, 14], USA ($n = 2$) [10, 13], Japan ($n = 2$) [2, 11], Norway ($n = 2$) [4], Uruguay ($n = 1$) [5], Italy ($n = 1$) [8] and Germany ($n = 1$) [9]. Two studies [6, 25] were included: one of them from European countries [6] and the other a pooled

project whose data were from both European and American countries [25]. Four were cohort studies [4, 6, 10, 11], one [25] was a pooled project of eight cohort studies [17–24] and eight were case–control studies [2, 3, 5, 8, 9, 12–14]. The total sample size of cohort studies was 722908 with 15173 breast cancer events; the total sample size in case–control studies for the breast cancer cases was 13949 and the total sample size in case–control studies for the control group cases was 37883. Other information is presented in Table 1.

Table 1 Characteristics of included studies

References	Country	Study design	Sample size	Breast cancer event	Age	Follow-up	Confounders adjusted
Gaard [4]	Norway	Cohort	31209	248	20–54	10.4 years	5-year-interval age groups
Key [11]	Japan	Cohort	20832	427	–	13 years	Attained age, calendar period, city, age at time of bombing and radiation dose
Missmer [25]	Europe and America	Cohort	351041	7379	31–93	15 years	Age at menarche, interaction between parity and age at first birth, oral contraceptive use, history of breast disease, family history of breast cancer, menopausal status at follow-up, BMI, the interaction between BMI and menopausal status at follow-up, postmenopausal HRT, smoking status, education, height, alcohol and total energy
Pala [6]	Europe	Cohort	319826	7119	20–70	8.8 years	Energy, height, weight, years of schooling, alcohol intake and smoking
Holmes [10]	USA	Cohort	88647	4107	46.7	18 years	Age, total energy, alcohol, parity and age at first birth categories, BMI, weight change, height in inches, family history of breast cancer, history of benign breast disease, age at menarche in years, menopausal status, age at menopause and HRT use categories, duration of menopause
Aune [5]	Uruguay	Case–control	3539	2032	23–89		Age, sex, residence, education, income, interviewer, smoking status, age at starting smoking, cigarettes, years since quitting smoking, duration of smoking, alcohol, fruits and vegetables, grains, dairy foods, total meat, other fatty foods, mate drinking status, energy, BMI
Hermann [9]	Germany	Case–control	355	838	24–52		Education, duration of breast-feeding, family history of breast cancer, number of births, BMI, energy, alcohol and non-consumer of each specific food group
Frazier [13]	USA	Case–control	843	8430	40–65		Age at diagnosis, age at menarche, menopausal status, family history, benign breast disease, adult height, parity/age at first birth, postmenopausal HRT, BMI, alcohol and vitamin A
Zhang [3]	China	Case control	438	438	25–70		Age at menarche, live birth and age at first live birth, BMI, history of benign breast disease, family history of breast cancer, physical activity, passive smoking, use of deep-fried cooking method, total energy, vegetable, fruit and soy food
Shannon [14]	China	Case–control	378	1070	>35		Age, total energy and breast-feeding
Bao [12]	China	Case control	3443	3474	25–70		Total energy, age, education level, history of benign breast disease, family history of breast cancer, participation in regular exercise, BMI, study phase, age at menarche, menopausal status, parity, total vegetable and total fruit
Franceschi [8]	Italy	Case–control	2568	2588	20–74		Age, center, education, parity, energy and alcohol
Hirose [2]	Japan	Case–control	2385	19013	–		Age, visit year, family history, age at menarche, parity and age at first full-term pregnancy

HRT hormone replacement therapy, *BMI* body mass index

Systematic review of available evidence from cohort and case control studies

We included 13 citations (11 cohort studies, 8 case–control studies) in this systematic review. Most included studies did not support an association of egg consumption with breast cancer risk [2–4, 8–11, 25].

Three studies [12–14] showed that egg consumption might be associated with reduced breast cancer risk. Among them, one study [13], which was a case control study from the USA, showed that an egg every day could be associated with a low risk of breast cancer (RR 0.82, 95 %CI 0.67–0.99). The other two studies which were also case–control studies showed that the highest level of consumption of eggs was associated with a lower risk of breast cancer than the lowest level (≥43.70 vs. <16.55 g/day in the study conducted by Bao et al. [12] and ≥6.0/week vs. ≤2/week in the study conducted by Shannon et al. [14]). The highest level of egg consumption in both studies [12, 14] was approximately more than six eggs every week. This suggested that eating more than six eggs every week might lower the risk of breast cancer for Chinese women.

Two studies [5, 6] showed that egg consumption might be associated with increased breast cancer risk. The study conducted by Aune et al. [5] which was a case control study showed that both <3.5/week and >3.5/week of egg consumption were associated with increased breast cancer risk. The study conducted by Pala et al. [6] was a cohort

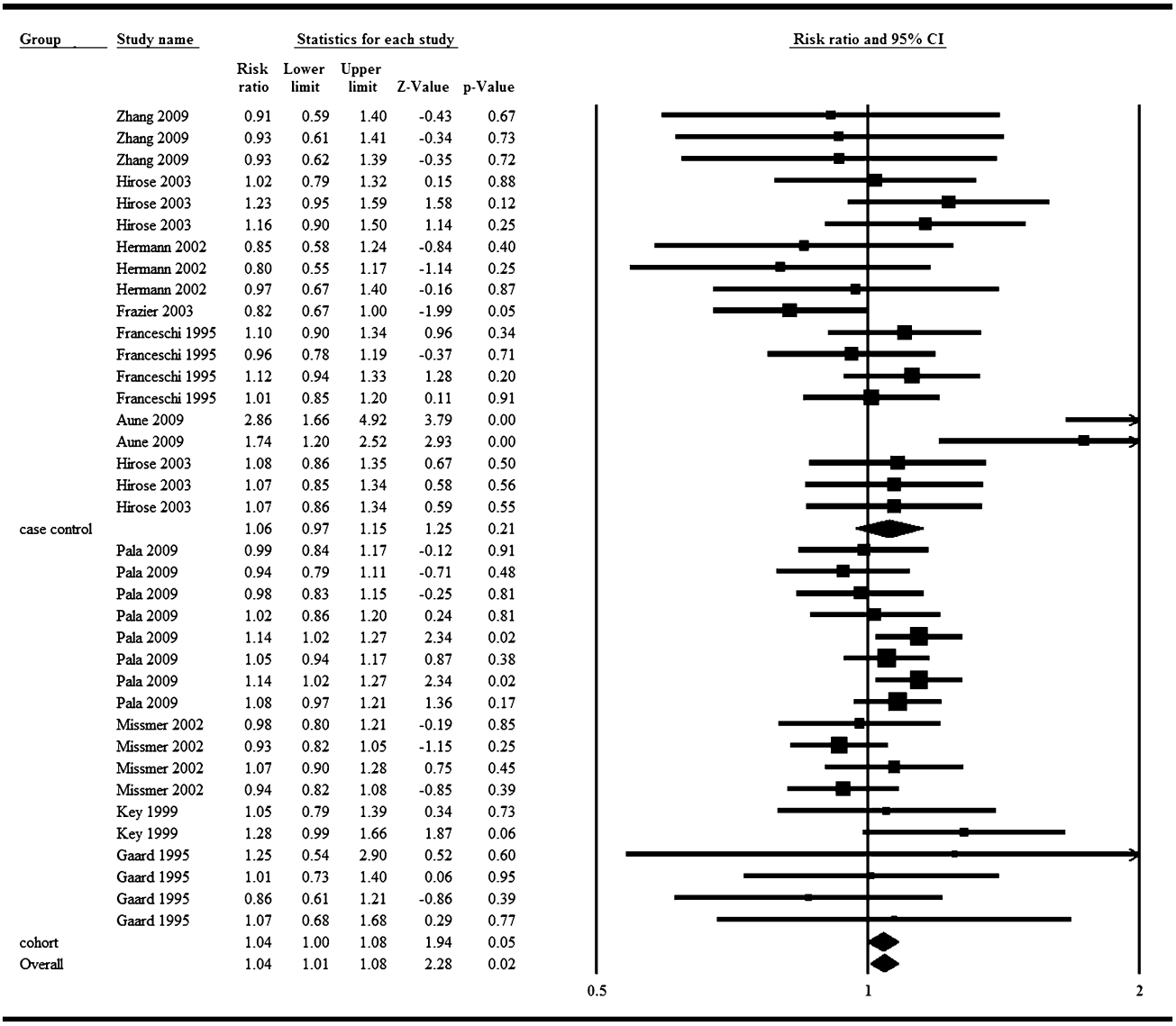


Fig. 1 Subgroup analysis of different study designs

study which showed that breast cancer risk was increased for postmenopausal women who consumed eggs with a median amount of 7.8 or 21.5 g/day.

Results of meta-analysis

A systematic review could only show the study results of the relationship between egg consumption and risk of breast cancer, and the inconsistency among studies could not be explained and investigated. So we conducted a meta-analysis trying to explain and investigate the inconsistency among the studies. The study conducted by Missmer et al. [25] is a pooled analysis of eight prospective studies [17–24], in which Nurses' Health Study [22] was included. The study reported by Holmes et al. [10] was from this same study, but some data were missing in the pooled analysis, so we also included the study reported by Holmes et al. [10] in our meta-analysis. For the two Chinese studies [12, 14], the control group was not <1/week (<7 g/day), so we excluded them in the meta-analysis. After pooling all data from included studies, we found that egg consumption was associated with increased breast cancer risk (RR 1.04, 95 % CI 1.01–1.08, $I^2 = 10$ %) (Fig. 1).

Subgroup analysis of different study designs

Subgroup analysis of different study designs showed that egg consumption was not associated with increased breast

Group	Study name	Risk ratio	Lower limit	Upper limit	Z-Value	p-Value
	Frazier 2003	0.82	0.67	1.00	-1.99	0.05
	Aune 2009	2.86	1.66	4.92	3.79	0.00
	Aune 2009	1.74	1.20	2.52	2.93	0.00
	Holmes 2003	1.03	0.93	1.15	0.55	0.59
	Holmes 2003	1.03	0.93	1.14	0.57	0.57
	Holmes 2003	0.95	0.86	1.05	-1.01	0.31
	Holmes 2003	1.04	0.94	1.16	0.73	0.46
America		1.07	0.94	1.21	1.03	0.30
	Zhang 2009	0.91	0.59	1.40	-0.43	0.67
	Zhang 2009	0.93	0.61	1.41	-0.34	0.73
	Zhang 2009	0.93	0.62	1.39	-0.35	0.72
	Hirose 2003	1.02	0.79	1.32	0.15	0.88
	Hirose 2003	1.23	0.95	1.59	1.58	0.12
	Hirose 2003	1.16	0.90	1.50	1.14	0.25
	Key 1999	1.05	0.79	1.39	0.34	0.73
	Key 1999	1.28	0.99	1.66	1.87	0.06
	Hirose 2003	1.08	0.86	1.35	0.67	0.50
	Hirose 2003	1.07	0.85	1.34	0.58	0.56
	Hirose 2003	1.07	0.86	1.34	0.59	0.55
Asia		1.09	1.00	1.18	2.06	0.04
	Hermann 2002	0.85	0.58	1.24	-0.84	0.40
	Hermann 2002	0.80	0.55	1.17	-1.14	0.25
	Hermann 2002	0.97	0.67	1.40	-0.16	0.87
	Franceschi 1995	1.10	0.90	1.34	0.96	0.34
	Franceschi 1995	0.96	0.78	1.19	-0.37	0.71
	Franceschi 1995	1.12	0.94	1.33	1.28	0.20
	Franceschi 1995	1.01	0.85	1.20	0.11	0.91
	Pala 2009	0.99	0.84	1.17	-0.12	0.91
	Pala 2009	0.94	0.79	1.11	-0.71	0.48
	Pala 2009	0.98	0.83	1.15	-0.25	0.81
	Pala 2009	1.02	0.86	1.20	0.24	0.81
	Pala 2009	1.14	1.02	1.27	2.34	0.02
	Pala 2009	1.05	0.94	1.17	0.87	0.38
	Pala 2009	1.14	1.02	1.27	2.34	0.02
	Pala 2009	1.08	0.97	1.21	1.36	0.17
	Gaard 1995	1.25	0.54	2.90	0.52	0.60
	Gaard 1995	1.01	0.73	1.40	0.06	0.95
	Gaard 1995	0.86	0.61	1.21	-0.86	0.39
	Gaard 1995	1.07	0.68	1.68	0.29	0.77
Europe		1.05	1.01	1.09	2.47	0.01

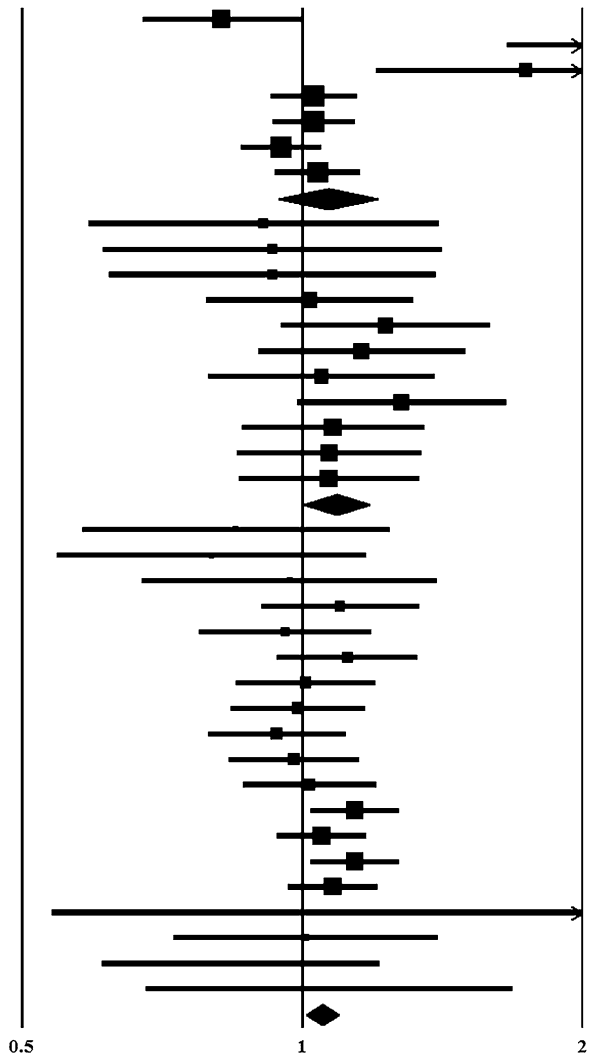


Fig. 2 Subgroup analysis of different geographical locations

cancer risk based on the pooled results of case–control studies (RR 1.06, 95 % CI 0.97–1.15, $I^2 = 22$ %), but the pooled studies of cohort studies showed that egg consumption was associated with increased breast cancer risk (RR 1.04, 95 % CI 1.00–1.08, $I^2 = 0$ %) (Fig. 1).

Subgroup analysis of different geographical locations

Subgroup analysis of different geographical locations showed that egg consumption was associated with increased breast cancer risk among the European population (RR 1.05, 95 % CI 1.01–1.09, $I^2 = 0$ %) and Asian population (RR 1.09, 95 % CI 1.00–1.18, $I^2 = 0$ %), but not among American population (RR 1.04, 95 % CI 0.94–1.16, $I^2 = 67$ %) (Fig. 2) The sources of heterogeneity might be due to the study conducted by Aune et al. [5], and the result of the association of egg consumption with breast cancer risk among American population did not change (RR 0.99, 95 % CI 0.93–1.06) without high heterogeneity ($I^2 = 14$ %) after excluding this study.

The pooled results for Chinese and Japanese studies were different. The meta-analysis showed that egg consumption might not be associated with increased breast cancer risk (RR 0.92, 95 % CI 0.73–1.18, $I^2 = 0$ %) among Chinese people, while it might be associated with increased risk (RR 1.15, 95 % CI 1.02–1.21, $I^2 = 0$ %) among Japanese people (Fig. 3).

Subgroup analysis of different menopausal statuses

Subgroup analysis of different menopausal statuses showed that egg consumption was associated with increased breast cancer risk for the postmenopausal population (RR 1.06, 95 % CI 1.02–1.10, $I^2 = 8$ %), but not for the premenopausal population (RR 1.04, 95 % CI 0.98–1.11, $I^2 = 0$ %) (Fig. 4).

Subgroup analysis of different egg consumption classifications

Subgroup analysis of different egg consumption classifications showed that ≥1, <2/week (RR 1.04, 95 % CI 0.97–1.11, $I^2 = 0$ %) or >5 eggs/week (RR 0.97, 95 % CI 0.88–1.06, $I^2 = 0$ %) was not associated with increased breast cancer risk, but ≥2, ≤5/week was associated with increased breast cancer risk (RR 1.10, 95 % CI 1.02–1.17, $I^2 = 0$ %) (Fig. 5).

Publication bias

There might be publication bias based on funnel plot (Fig. 6). However, Egger's test indicated that there was not a possibility of publication bias for the relationship between egg consumption and breast cancer risk (intercept 0.28, 95 % CI −0.57 to 1.13 $p = 0.52$).

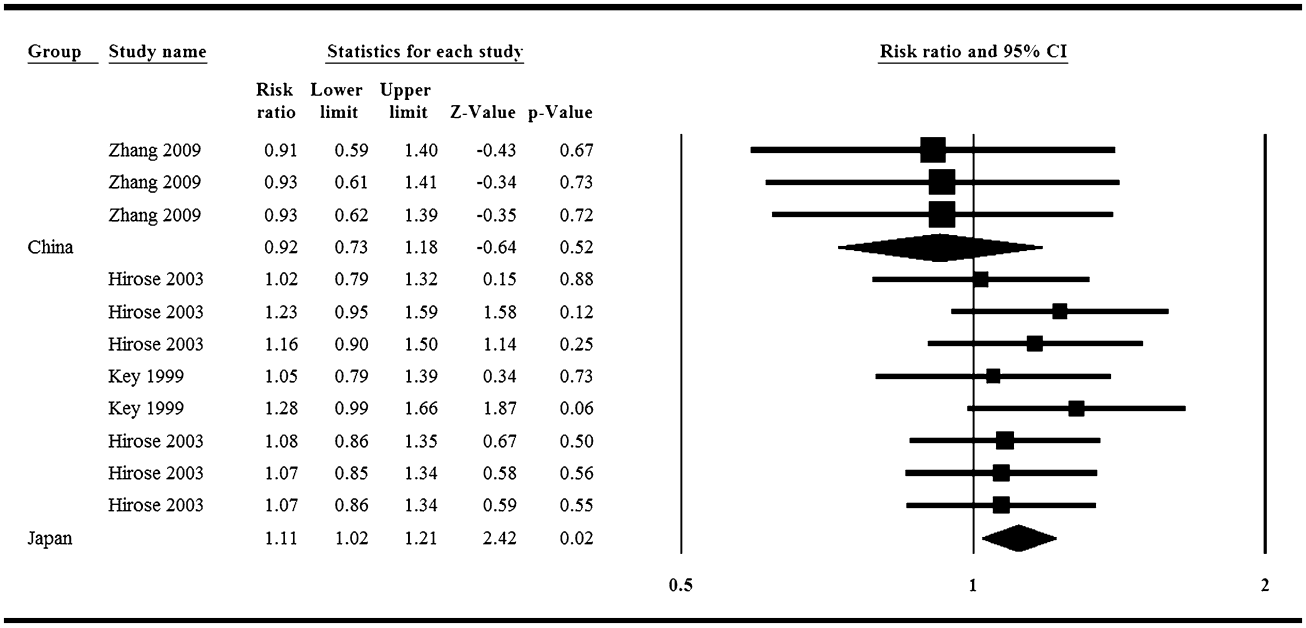


Fig. 3 Subgroup analysis of Chinese and Japanese studies

Discussion

Summary of finding

Eggs are one of nature's most nutritious foods with low levels of saturated fat and high levels of protein [26]. Eggs are also a good dietary sources of choline, vitamin A, vitamin D, iron, conjugated linoleic acid (CLA), lutein and zeaxanthin. Although various health concerns are associated with egg consumption, it remains a popular ingredient in cooking worldwide. Consumers previously were warned about eating eggs due to their high cholesterol content, but it has been found that consumption of up to one egg per day is unlikely to have a substantial overall impact on the risk of coronary heart disease or stroke based on recent systematic reviews [27–29]. A recent meta-analysis showed that there were no associations between egg intake and bladder or prostate cancer [26, 30, 31].

The most plausible mechanism of the possible effect of egg intake upon breast cancer risk might involve the nutrition ingredients of eggs [5, 12]. It was reported that eggs are particularly high in cholesterol (425 mg per 100 g), and the recommended daily allowance is 300 mg [25]. Cholesterol is a precursor of steroid hormones and might affect breast cancer risk through the formation of estrogens [5]. Hu et al. [32] found that high cholesterol intake was linked to increased risk of various cancers. Cholesterol is a precursor of steroid hormones, and accumulation of cholesterol in cells may affect prostate cancer risk through the formation of androgen. Alterations in cholesterol level could also contribute to cellular inflammation, which is a critical component of tumor progression [26, 33]. Cholesterol homeostasis is disrupted in malignant cells, leading to accumulation of cholesterol, which is a precursor of androgen and may alter signaling pathways to promote cancer progression [31]. Experimental studies of cholesterol feeding and mammary tumor development have provided mixed results [5]. Evidence showed that the association of eggs with breast cancer was not necessarily due to cholesterol [5, 9], as adjustment for cholesterol

Group	Study name	Risk ratio	Lower limit	Upper limit	Z-Value	p-Value
	Pala 2009	1.08	0.97	1.21	1.36	0.17
	Pala 2009	1.14	1.02	1.27	2.34	0.02
	Pala 2009	1.14	1.02	1.27	2.34	0.02
	Pala 2009	1.05	0.94	1.17	0.87	0.38
	Holmes 2003	0.97	0.86	1.09	-0.50	0.61
	Holmes 2003	0.97	0.86	1.09	-0.50	0.61
	Holmes 2003	1.02	0.91	1.15	0.33	0.74
	Holmes 2003	1.01	0.89	1.14	0.16	0.87
	Hirose 2003	1.02	0.79	1.32	0.15	0.88
	Hirose 2003	1.23	0.95	1.59	1.58	0.12
	Hirose 2003	1.16	0.90	1.50	1.14	0.25
Postmenopausal		1.06	1.02	1.10	2.72	0.01
	Pala 2009	0.99	0.84	1.17	-0.12	0.91
	Pala 2009	0.94	0.79	1.11	-0.71	0.48
	Pala 2009	0.98	0.83	1.15	-0.25	0.81
	Pala 2009	1.02	0.86	1.20	0.24	0.81
	Holmes 2003	1.00	0.79	1.26	0.00	1.00
	Holmes 2003	1.23	0.97	1.55	1.73	0.08
	Holmes 2003	1.22	0.95	1.57	1.55	0.12
	Holmes 2003	1.15	0.90	1.47	1.12	0.26
	Hirose 2003	1.08	0.86	1.35	0.67	0.50
	Hirose 2003	1.07	0.85	1.34	0.58	0.56
	Hirose 2003	1.07	0.86	1.34	0.59	0.55
Pre-menopausal		1.04	0.98	1.11	1.29	0.20

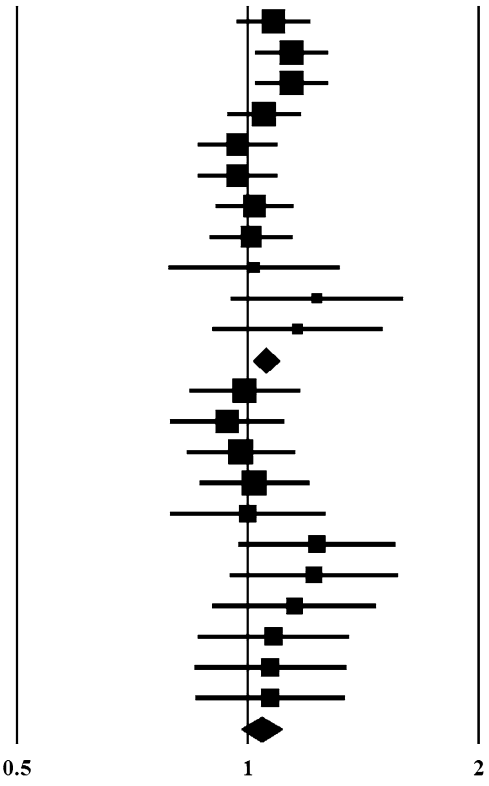


Fig. 4 Subgroup analysis of different menopausal statuses

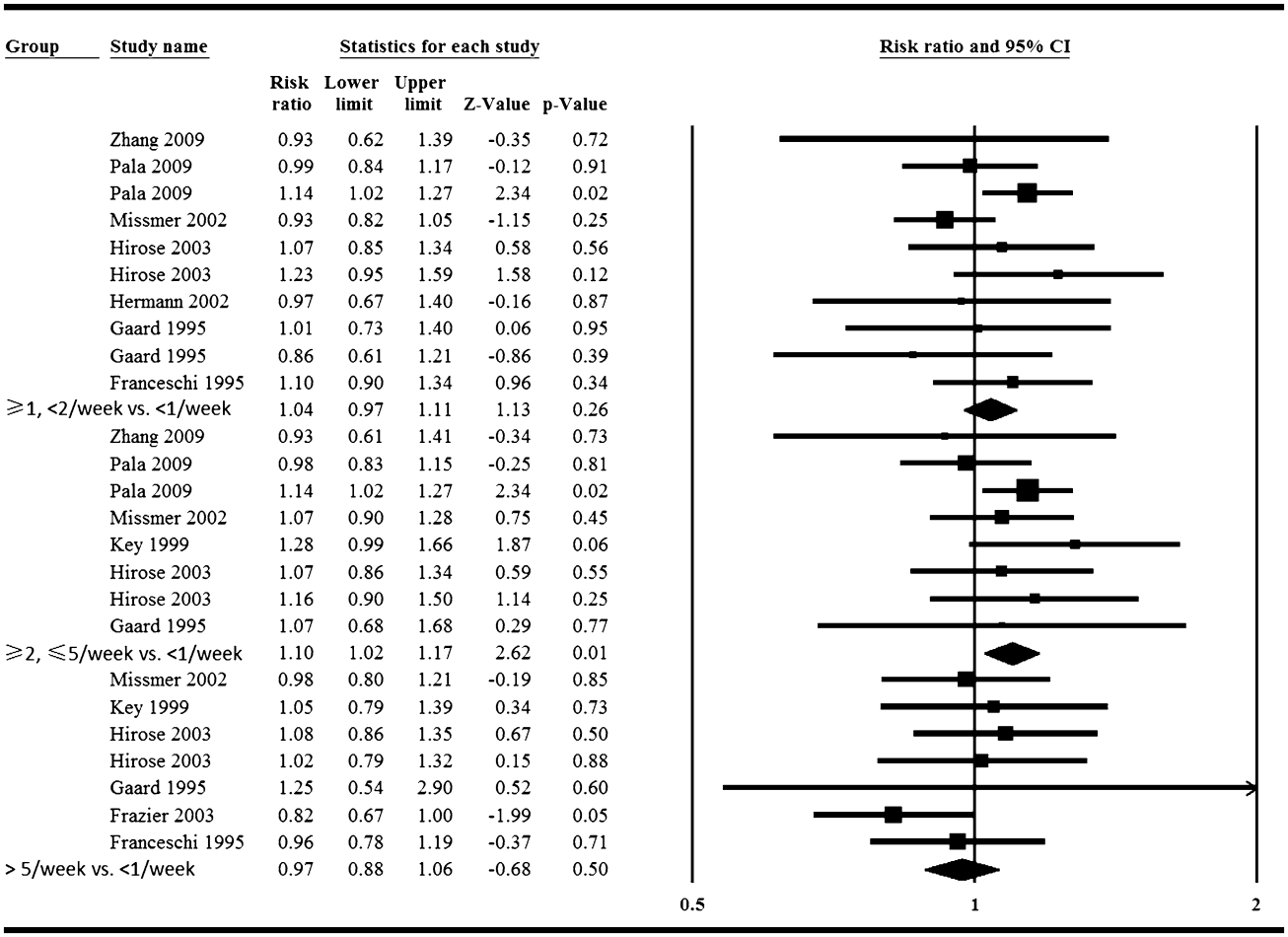


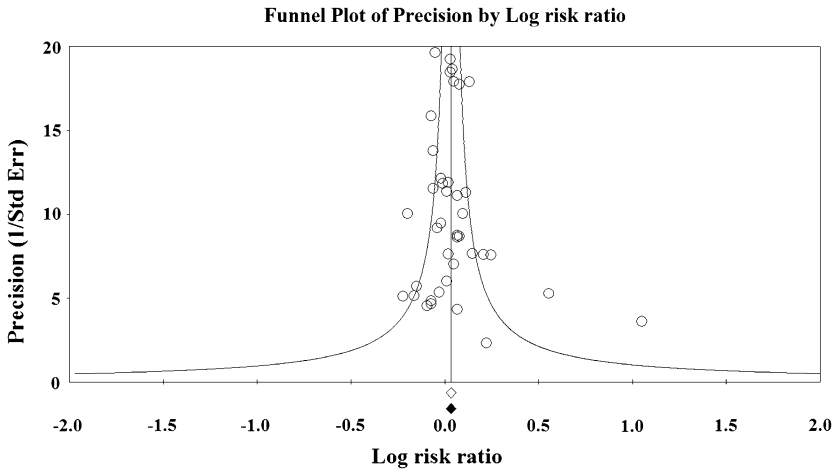
Fig. 5 Subgroup analysis of different doses

intake slightly strengthened the association between egg intake and cancer risk suggesting that other factors than cholesterol may account for the associations we observed [5]. Two meta-analyses also showed that the effect of lowering LDL cholesterol on breast cancer was lacking [34, 35], based on both observational studies and randomized trials. It is also said that eggs can also be a source of heterocyclic amines which are formed during high-temperature cooking [36], which could explain why European women suffer higher breast cancer risks. Several kinds of carcinogenic compounds are produced during the process of frying protein-rich foods, particularly when the cooking temperature is very high and the fats used for frying appear to further increase the mutagenic activity of some of these compounds. This was confirmed by a meta-analysis, which showed that fried egg intake was positively associated with bladder cancer as well (summary relative risk estimates = 2.04, 95 % CI 1.41–2.95) [30].

However, some researchers believe that eggs are helpful for reducing breast cancer risk, as eggs are sources of certain amino acids, lutein, zeaxanthin, omega-3 and omega-6 fatty acids which may be used to prevent cancer [12]. Meanwhile, one egg contains 11.5 % of the recommended daily allowance of folate and 6.5 % of that of vitamin D [37]. Although one ecological study found an inverse association between egg consumption and breast cancer mortality [38], these mechanisms were not tested in experimental studies or with supporting large epidemic data. Egg yolks are also a significant source of choline, the consumption of which has been found to be associated with a lower risk of breast cancer [39, 40]. One egg contains 125.5 mg of choline, or roughly a quarter the recommended daily supply, making eggs an excellent source of this essential nutrient. Choline is a vital nutrient that is critical for the normal functioning of cells, including brain cell and nerve function, metabolism, liver functioning and nutrient transport. Choline is also essential for a variety of cell functions involved in cancer growth and progression [31].

The presence of a variety of bioactive compounds lends biological plausibility to a role of egg consumption in the etiology of cancer [41]. Another reason for this might be

Fig. 6 Publication bias



the ethnic differences in genetic backgrounds which might be taken into account. A recent meta-analysis showed that genetic differences were common in different ethnic groups [42–44]. This might explain why egg consumption was associated with breast cancer risk among the European and Asian populations, but not among American population. We tried to investigate whether there were any differences between the Chinese and Japanese populations, and our meta-analysis showed that egg consumption was associated with increased breast cancer risk among the Japanese population, but not among the Chinese population. The two case–control studies that we did not include in the meta-analysis due to the control group (<2 eggs per week) also showed that the highest level of egg consumption (approximately 6 eggs per week) was associated with reduced breast cancer risk among Chinese population as compared to the lowest level of egg consumption (<2 eggs per week). This also confirmed that besides the ingredient in eggs and cooking methods, the genetic differences in different ethnic groups might play an important role in the relationship of egg consumption with breast cancer risk.

Our meta-analysis showed that the amount of egg consumption could influence the relationship of breast cancer risk, as our meta-analysis found that ≥2, ≤5/week was associated with increased breast cancer risk, but ≥1, <2/week or >5/week was not associated with increased breast cancer risk. This is consistent with the Pooling Project [25]. The Pooling Project reported an unexpected weak positive association of breast cancer risk with egg intake, an RR (95 % CI) of 1.22 (1.03–1.45) for approximately 2 eggs per day [25]. This study also found a J-shaped association for breast risk reduction, but we did not confirm it. Due to limited data, we could not assess the relationship between two eggs daily with breast cancer risk; we used the cutoff point 2 and 5 eggs/week. We also tried to analyze other cutoff points, such as 3.5/week (25 g/day) and 7/week (50 g/day). We did not present the data, but the results were interesting. No associations were found for breast cancer risk when the consumption was more than 3.5/week or 7/week, but an increased risk of breast cancer was found for those who consumed <3.5/week or 7/week. Then another cutoff point (2/week, 24 g/day) was also analyzed. No associations were found for breast cancer risk when the consumption was more or <2/week. All these analyses showed that moderate consumption of eggs might be associated with increased breast cancer. No sensible reasons could be used to explain this.

Our meta-analysis also showed that egg consumption was associated with breast cancer risk among the postmenopausal population. This might be due to some nutrition ingredients of eggs, or therapy such as hormone replacement treatment, which could affect breast cancer risk through the formation of estrogens. However, the accurate content that has such an effect was not clear.

Strength and limitation

Our meta-analysis was the first that evaluated the relationship between egg consumption and breast cancer risk. We applied rigorous systematic searches, study selection, data abstraction and data analytical methods. We used subgroup analysis to test the influences of different potential variables on the relationship. However, our meta-analysis has its own limitations. First, we only included articles written in English, which means that we might have missed studies that were in other languages. A selection bias might exist in our meta-analysis as all included studies were in English, although the publication bias analysis showed that there might be not any missed studies. Second, we did not evaluate the relationship between two eggs daily and breast cancer risk, although we conducted a dose–response relationship analysis. The categorical standards for egg consumption were confused.

Some studies used g/day, g/week, servings/week, servings/day or the number eaten per week. In this condition, it is difficult to compare the differences among studies. In our study, we used the following category: <1/week (<7 g/day), ≥1, <2/week (7–13 g/day), ≥2, ≤5/week (14–35 g/day) and >5/week (>35 g/day). Third, we did not evaluate the influences of different ER or PR statuses on the relationship, although one included study showed that egg consumption might influence the relationship of breast cancer risk [12]. Fourth, it was said that cooking eggs at a high temperature could influence the ingredient, but we did not ascertain cooking methods and are thus unable to determine whether these possible associations represent relationships with foods cooked in such a manner as to form heterocyclic amines. The relationship of breast cancer risk with different cooking methods of eggs was not investigated. Fifth, although we used adjusted risk estimated in our studies, the variables adjusted in included studies for the meta-analysis were not the same. For example, hormone therapy was regarded as one risk factor of breast cancer [45–47]; however, only three included studies [10, 13, 25] adjusted it when analyzing the data. The weight of egg intake might be dependent on others such as meat, fish and milk intake. As described in the study of Holmes [10], the consumption of food will change according to the time period. This might bias the results of our meta-analysis.

Implications to future research and practice

Most available studies were case–control studies with conflicting results, and the cohort studies have the advantage of being less vulnerable to selection and recall bias than case–control studies, so in the future more cohort studies should be well conducted. At the same time, a well-recognized categorical standard for egg consumption should be developed. In addition, future studies should conduct subgroup analyses of different ER, PR or menopausal statuses with the most variables adjusted.

In practice, we could recommend that egg consumption be reduced in the European, Japanese and postmenopausal populations to reduce breast cancer risk. Regarding how many eggs should be eaten, we could not give a suggestion, as it was really hard to explain the results of this meta-analysis. However, based on our meta-analysis, five eggs every week would not increase the risk of breast cancer in the premenopausal population.

Conclusion

Although the pooled results of case–control studies showed that egg consumption might not be associated with breast cancer risk, the pooled results of cohort studies and the combined results showed that egg consumption was associated with increased breast cancer risk, especially for the European and postmenopausal populations, those who consumed ≥2, ≤5/week and the Japanese people. At the same time, more cohort studies should be conducted using a well-recognized categorical standard for egg consumption and appropriate subgroup analyses of different ER, PR or menopausal statuses. Egg consumption should be reduced in the European, Japanese and postmenopausal populations to reduce breast cancer risk.

Conflict of interest None.

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