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Egg Consumption and its Association with Cardiovascular Disease and Mortality in China: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: Cardiovascular diseases (CVDs) represent the primary etiology of global mortality, accounting for approximately 17.9 million deaths annually. In China, CVDs were responsible for 46.74% of all fatalities in 2020, underscoring a critical public health crisis precipitated by rapid urbanization, sedentary behaviors, and nutritional transitions. Despite the magnitude of this epidemic, existing Chinese literature regarding the impact of egg consumption on CVD outcomes remains discordant, with conflicting evidence suggesting both cardioprotective and deleterious effects. Given unique genetic profiles and regional dietary disparities, a rigorous, targeted synthesis of evidence is warranted.

Aims: This systematic review and meta-analysis sought to synthesize extant evidence to evaluate the association between egg consumption and the risk of CVD incidence and CVD-related mortality within the Chinese population.

Methods: Conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines, a systematic search was executed across four electronic databases for peer-reviewed literature. Data from studies satisfying the inclusion criteria were pooled for quantitative synthesis. Relative risks (RR) and 95% confidence intervals (CI) were calculated to assess the association between egg intake and various cardiovascular outcomes.

Results: Analysis of six eligible studies, encompassing a total cohort of 631,652 Chinese participants, revealed that egg consumption significantly increased the risk of coronary heart disease (CHD) by 51% in two of the included studies. While the effect on stroke risk appeared negligible (unitary), egg consumption was associated with an 8% increase in overall CVD risk, although this finding did not reach statistical significance. Furthermore, a 7% non-significant increase in CVD-related mortality was reported across four independent Chinese cohorts.

Conclusion: The influence of egg consumption on cardiovascular health in the Chinese population is multifaceted across different subpopulations. However, the aggregate data suggest that higher egg intake may function as a potential risk factor for cardiovascular complications and mortality.

Keywords: Cardiovascular Diseases; Coronary Heart Disease; Stroke; CVD-mortality; Egg Consumption; China.

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1 INTRODUCTION

Cardiovascular diseases (CVDs), encompassing coronary heart disease, stroke, and heart failure, represent the leading cause of global mortality, accounting for approximately 17.9 million deaths annually (Vos *et al.,* 2020). CVDs contribute disproportionately to disability-adjusted life years (DALYs), with low- and middle-income countries (LMICs) bearing over 75% of this burden (Roth, *et al.,* 2020). In China, rapid urbanization, sedentary lifestyles, and dietary shifts toward energy-dense processed foods have catalyzed a CVD

epidemic, with over 46.74% of deaths in 2020 attributed to CVDs (Wang, 2023). Compounding this crisis is an aging population by 2035, an estimated 28% of Chinese citizens will be over 60 years old (WHO, 2023). Such aging trends amplify population-wide susceptibility to hypertension, dyslipidemia, and diabetes mellitus type 2—pivotal risk factors for cardiovascular events. The economic ramifications are substantial, with CVD-related expenditures exceeding $100 billion USD annually (Birger *et al.,* 2021), thereby straining healthcare systems and emphasizing the urgency of addressing modifiable lifestyle factors, particularly dietary patterns.

Dietary habits play a pivotal role in the pathogenesis of CVD. The transition from traditional regimens—characterized by high intakes of whole grains, vegetables, and legumes—to Westernized patterns—high in refined sugars, trans-fatty acids, and animal-derived products—has paralleled China's cardiovascular surge (Popkin, 2013). While the correlation between excessive sodium, saturated fats, and ultra-processed foods with atherosclerosis and hypertension is well-established (Juul, *et al.,* 2021), the specific role of nutrient-dense foods, such as eggs, remains a subject of intense scientific debate.

Eggs are globally ubiquitous and nutritionally dense food source, providing high-biological-value protein, essential vitamins (B_{12}, *D*), antioxidants (lutein, zeaxanthin), and vital minerals (selenium, choline) (Réhault-Godbert *et al.,* 2019). Conversely, their significant cholesterol content—approximately 186 mg per large egg, has historically positioned them at the center of debates regarding CVD discourse (Zhuang *et al.,* 2021). Cholesterol metabolism is highly heterogeneous and influenced by genetic polymorphisms—most notably the *APOE* ε4 allele—as well as gut microbiota composition, both of which modulate intestinal absorption and systemic effects (Raulin *et al.,* 2022). The biological variability complicates the formulation of universal dietary guidelines and necessitates the development of population-specific evidence.

The global association between egg consumption and CVD remains a matter of debate. Zhuang *et al.* (2021) identified a positive correlation between high egg consumption (≥ 1 egg per day), elevated low-density lipoprotein cholesterol (LDL-C), and incident CVD. Similarly, the American Heart Association (AHA) previously issued an advisory recommending a limit of three eggs per week for high-risk cohorts (Carson *et al.,* 2019). However, a meta-analysis of Western cohorts revealed no significant association between moderate consumption (≤ 1 egg/day) and CVD mortality (Drouin-Chartier *et al.,* 2020), suggesting that total saturated fat intake and overall dietary quality, may be more potent drivers of risk than dietary cholesterol in isolation (Blesso & Fernandez, 2018). Conversely, Asian cohort studies, particularly from Japan and South Korea, frequently report neutral or inverse associations. These findings may be attributable to regional dietary patterns rich in vegetables, soy, and fish, which may attenuate cholesterol absorption (Lim *et al.,* 2024). For instance, soluble fibers in plant-based diets binds bile acids, reducing cholesterol reabsorption, while phytosterols competitively inhibit intestinal cholesterol uptake (Jesch & Carr, 2017).

In China, eggs hold profound cultural and economic significance. Historically consumed in moderation via traditional preparations—such as boiling in congee, steamed with tea leaves, or stir-fried with vegetables—eggs have become a dietary linchpin amid rising incomes and protein demand. Per capita consumption has increased by 50% since 2000, reaching 22 kg/year (National Bureau of Statistics of China, 2022), surpassing levels observed in several Western nations. Urban-rural disparities further diversify this trend: urban populations increasingly favor processed or fried preparations associated with fast-food patterns, whereas rural populations largely maintain traditional, simpler cooking methods. Genetic factors may further modulate these risks; the *APOE* ε4 allele, associated with hyper-responsiveness to dietary cholesterol, is prevalent in 7–10% of the Han Chinese population (Wang *et al.,* 2023), compared to 15–25% in European populations. Despite these nuances Chinese evidence remains fragmented. While the landmark China Kadoorie Biobank study found no association between moderate intake and CVD mortality (Qin *et al.,* 2018a), the China-PAR project reported an elevated risk (Xia *et al.,* 2020), and other investigations observed potentially protective effects (Wang, *et al.,* 2022a).

The biological plausibility of these associations also remains contested. While eggs contribute dietary cholesterol, they also provide anti-inflammatory nutrients and phospholipids that may enhance HDL functionality (Blesso & Fernandez, 2018). Emerging evidence suggests that the impact of dietary cholesterol on serum LDL-C is relatively modest (~10% variability) and highly individualized, influenced by baseline lipid levels, insulin sensitivity, and genetic factors (Berger *et al.,* 2015). Furthermore, the Chinese the traditionally low saturated fat content of the Chinese diet may mitigate the pro-atherogenic potential of dietary cholesterol (Zhuang *et al.,* 2021). However, the emergence of "hybrid" dietary patterns—merging traditional plant-based foods with Western-style processed items—presents a complex risk profile that warrants rigorous investigation.

Therefore, this study aims to systematically evaluate and summarize the current body of evidence regarding the association between egg consumption and the risk of CVD morbidity and mortality within the Chinese population.

2 Methodology

2.1 Study Protocol

This systematic review, and meta-analysis was registered with the International Prospective Register of Systematic Reviews (PROSPERO; registration number: CRD420251011410). The study was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) 2020 statement and checklist (Page *et al.*, 2021). Two independent authors performed each stage of the review process, and any disagreements were solved through consultation with a third author.

2.2 Study Questions

The study questions guiding this review were as follows: (1) What is the reported association between egg consumption and the risk of CVD mortality and all-cause mortality in the Chinese population? (2) What is the pooled effect size of these associations?

2.3 Search Strategy and Study Selection

A systematic literature search was conducted across four electronic databases—PubMed, Web of Science, CINAHL, and CNKI—for studies published between January 2001 and May 2025. This timeframe was selected to capture contemporary research, reflect current dietary and epidemiological trends, and preclude the inclusion of potentially outdated data. Complete search strategy is detailed in Appendix (Supplementary data), utilizing the following Medical Subject Headings (MeSH) terms and text words: Egg [TIAB], cardiovascular disease [TIAB], and China [TIAB].

Search outcomes were exported to the reference management software EndNote 7.8. Following the removal of duplicate records, two authors (O.A. and M.O.) independently screened titles and abstracts to assess studies against pre-specified inclusion criteria. Studies that did not meet the inclusion criteria were excluded, as were studies for which full texts of potentially relevant articles could not be retrieved. Two review authors (O.A. and I.O.) independently assessed the full texts of eligible studies for final inclusion. Discrepancies were resolved through discussion or, when necessary, by consultation with a fourth reviewer (F.A.).

2.4 Inclusion and Exclusion Criteria

This review included peer-reviewed articles published in English or Chinese that reported on the association between egg consumption and mortality due to cardiovascular disease (CVD). Eligible study designs comprised randomized controlled trials (RCTs), cohort studies, case-control studies, cross-sectional studies, and longitudinal studies conducted in China and published between January 2000 and May 2025.

Studies were excluded if they were conducted outside of Chinese population, or if they were in vitro studies, case reports, clinical trials, conference abstracts, reviews, editorials, animal studies, or non-peer-reviewed sources. Additionally, studies lacking relevant outcome data were excluded.

2.5 Data Extraction

Three independent reviewers (M.O., I.O., and O.A.) extracted data from all studies meeting the inclusion criteria using a pre-tested data extraction form developed in Microsoft Excel. Extracted information included the author(s), year of publication, study design (e.g., cross-sectional, cohort), geographic location, and study setting. Participant characteristics—namely sample size, age range, and sex distribution—were also recorded.

Further data extraction included the primary outcome, study limitations, the instrument employed to quantify egg consumption, the reported prevalence of CVD associated with egg intake, and the corresponding effect size. Finally, the study outcomes were documented, and any discrepancies encountered during the extraction process were resolved by a fourth reviewer (F.A.).

2.6 Quality and Risk of Bias Assessment

The methodological quality and risk of bias of included studies were evaluated using an adapted version of the risk of bias tool for prevalence studies developed by Hoy *et al.* (2012). Each study underwent scrutiny across nine domains of bias, namely: description of the target population; sampling frame; sampling techniques; response rate; non-proxy collection of data; case definition of the study; validity and reliability of the study instrument; mode of data collection; and appropriate specification of numerator and denominator for the parameter of interest.

Score were assigned on a scale from 0 to 9, with aggregate scores categorized as follows: 0–3, "high risk"; 4–6, "moderate risk"; and 7–9, "low risk" of bias. Risk of bias assessments were conducted independently by three reviewers (M.O., I.O., and O.A.), with disagreements arbitrated by a fourth reviewer (F.A.). A summary of the risk of bias assessment is presented in Supplementary data.

2.7 Statistical Analysis

Study characteristics and findings were synthesized in descriptive summary tables. For each included study, the following data were tabulated: author(s), year of article publication, study design, sample size, age range, sex distribution, the primary outcome of the study, limitations of the study, instrument employed to assess egg consumption, reported prevalence of CVD associated with egg consumption, and the reported effect size.

All statistical analyses were conducted using Review Manager (RevMan) version 5.4.1 (The Nordic Cochrane Centre, Copenhagen, Denmark). A descriptive analysis of included studies was conducted to illustrate the distribution of studies by year of publication, study design, sex distribution, primary outcomes, and assessment tools.

For the independent variables—CVDs (including stroke, CHD, and CVD composite), CVD mortality, and all-cause mortality—pooled effect sizes were calculated for outcomes associated with egg consumption. Odds ratios (OR) were employed as the summary effect measure for cross-sectional studies, while hazard rations (HRs) were used for cohort studies.

Heterogeneity among studies was assessed using Cochran's Q statistic, the I^2 statistic, and visual inspection of forest plots. A *p*-value of less than 0.05 for the Q-statistics was considered indicative of statistically significant heterogeneity. Heterogeneity was interpreted in accordance with the Cochrane Handbook for Systematic Reviews, with an I^2 value exceeding 50.0% considered to reflect substantial heterogeneity. Negative I^2 values were treated as zero and analyzed in the interpretation of heterogeneity between studies (Page *et al.,* 2021). Studies with zero events in both arms for the outcome of interest were excluded from the meta-analysis, consistent with recommendations in the Cochrane's Handbook (Higgins *et al.,* 2003).

All quantitative syntheses were performed using Review Manager (RevMan) software, developed by the Cochrane Collaboration for the conduct of systematic reviews and meta-analyses (RevMan Core software, 2025).

3 Results

3.1 Study Selection

As illustrated in Figure 1, the initial literature search yielded a total of 578 records. Following the removal of duplicate entries, 488 unique records remained for subsequent screening. These records were evaluated based on titles and abstracts to determine their relevance to the research question. At this stage, 461 records were excluded for failing to meet the basic eligibility criteria, such as irrelevance to the study topic, inappropriate study design, or absence of pertinent outcomes, in accordance with established systematic review protocols (Systematic Reviews, 2025).

The remaining 27 records were subjected to a more thorough full-text review to ascertain their conformity with the predefined inclusion criteria, encompassing study design, population characteristics, exposure, and outcome measures. Upon completion of this rigorous assessment, it was determined that all 56 studies satisfied the inclusion criteria and were subsequently incorporated into the final analysis. This systematic and transparent selection process, consistent with the PRISMA framework, ensured the inclusion of methodologically robust and contextually relevant studies, thereby strengthening the validity and reliability of the findings (Agrawal *et al.,* 2024).

3.2 Characteristics of Included Studies

The characteristics of the included studies are summarized in Table 1. A total of six (6) studies were published between 2018 and 2022: one in 2018 (Qin *et al.,* 2018b), one in 2019 (Chagas *et al.,* 2013), one in 2020 (Xia *et al.,* 2020), one in 2021 (Liu *et al.,* 2020), and two in 2022 (Wang *et al.,* 2022a; Yakti *et al.,* 2024). The geographic scope of the studies varied considerably: one study was conducted in a single province (WHO, 2023), another in a urban municipality (Roth *et al.,* 2020), a third across five urban and rural localities (Roth *et al.,* 2020), and a fourth across 25 provinces (Qin *et al.,* 2018b).

Four of the five included studies employed a prospective cohort design (Liu *et al.,* 2020; Qin *et al.,* 2021; Wang *et al.,* 2022a; Xia *et al.,* 2020; Yakti *et al.,* 2024), while one adopted an observational cross-sectional design (Chagas *et al.,* 2013). All studies focused exclusively on adult population. The aggregate sample size across all studies was 647,682 participants. Primary outcomes assessed included all-cause mortality (Liu *et al.,* 2020; Qin *et al.,* 2018; Xia *et al.,* 2020), cardiovascular diseases (Guo *et al.,* 2018), and total CVD events (Guo *et al.,* 2018; Xia *et al.,* 2020). In all studies, egg consumption was quantified through a validated food frequency questionnaire.

The risk of bias assessment, summarized in Figure 2, indicated generally high methodological quality across the included studies, with the majority attaining a score of 9 out of 9. Studies by Liu *et al.* (2020), Wang, *et al.* (2022b), and Xia *et al.* (2020) received perfect scores, reflecting the employment of representative target populations, robust sampling frames, minimal non-response bias, and valid data collection instruments. All studies employed appropriate case definitions and ensured the reliability and validity of their instruments. The studies by Qin *et al.* (2018) and Lin *et al.* (2021) received marginally lower scores (8 out of 9) attributable to concerns regarding instrument reliability or consistencies in data collection procedures. Overall, the risk of bias was minimal across the majority of studies, suggesting that the results are robust; however, minor methodological concerns pertaining to certain data collection instruments were noted. Publication bias was also assessed for each study outcome. The results are summarized in Supplementary data.

3.3 Egg Consumption and Health Outcomes

Table 2 presents the association between egg consumption and various health outcomes across five studies, including all-

cause mortality, CVD, stroke, and CHD. The direction and magnitude of the reported association between egg consumption and CVD morbidity and CVD mortality varied across studies. Three studies reported a protective effect of egg consumption against CVD morbidity (Chagas *et al.,* 2013; Qin *et al.,* 2021; Wang *et al.,* 2022a). Specifically, one study demonstrated a reduced risk of CVD (HR: 0.89, 95% CI: 0.82 – 0.89) (Chagas *et al.,* 2013), while two studies reported a protective association with stroke incidence (Chagas *et al.,* 2013; Wang *et al.,* 2022a) reported a protective effect against the risk of stroke (HR: 0.90 (0.85-0.95) and HR: 0.82 (0.47 – 1.43)). Conversely, other studies identified egg consumption as risk factors for the risk of all-cause mortality (Xia *et al.,* 2020; Liu *et al.,* 2021), CVD (Chagas *et al.,* 2013; Xia *et al.,* 2020; Yakti *et al.,* 2024), and CHD (Xia *et al.,* 2020; Yakti *et al.,* 2024). Detailed effect estimates are provided in Table 2.

Table 1. Characteristics of included studies

S/N	1	2	3	4	5	6
Study	Liu *et al.* (2021)	Qin *et al.* (2018)	Wang *et al.* (2022b)	Xu *et al.* (2019)	Xia *et al.* (2020)	Yakti *et al.* (2024)
Year of publication	2021	2018	2022	2019	2020	2022
Study population	Chinese adults	Chinese adults	Chinese adults	Chinese adults	Chinese adults	Chinese adults
Study location (Province)	Anhui Province	5 urban and 5 rural areas across China"	25 provinces	Guangzhou		
Study design	Community-based cohort	Cohort	Cohort	Observational Studies	Cohort	Cohort
Average age (Year)	45-64	30-79	16+	50 years or above	51.46	43.7 (14.8)
Sample size (m%, f%)	9444 (55.8%, 44.2%)	461213 (41.0%, 59.0%)	30,835 (48.55%, 51.45%)	28,024	102,136 (40.28%, 59.72%)	16,03 (49.0%, 51.0%)
Primary Outcome / Cardiovascular Diseases studied	All-cause mortality	Cardiovascular diseases: CVD, IHD, Hemorrhagic Stroke, Ischemic Stroke	Mortality	CVD	incident CVD and all-cause mortality.	Incident CVD
Tool of assessment	Validated semi-quantitative food frequency questionnaire (FFQ)	Non-validated qualitative food frequency questionnaire	FFQ		face-to-face interviews, using cohort-specific FFQs	3-day 24-h recall method supplemented by household inventory record
Study conclusion	The study concluded that for rural Chinese individuals, consuming more than six eggs per week seems to be a risk factor for all-cause mortality, particularly in individuals with a Body Mass Index (BMI) of 21.2 kg/m^2.	The study indicated that daily egg consumption (less than one egg) was linked to a reduced risk of cardiovascular disease (CVD), ischemic heart disease (IHD), major coronary events (MCE), hemorrhagic stroke, and ischemic stroke among middle-aged adults in China.	The study found an approximately inverted J-shaped relationship between egg consumption and mortality, with the lowest risk observed in the group with moderate-to-high egg intake. The findings suggested that a moderate to high intake of eggs could be recommended as part of a healthy diet for the general adult population in China. These findings could be considered when formulating public health policies aimed at improving long-term health and longevity	The study found that egg consumption does not increase the risk of cardiovascular disease (CVD) or all-cause mortality. Furthermore, abstaining from eggs does not diminish these risks. The research suggested that consuming one egg daily or seven or more per week could marginally decrease the risk of stroke. However, the beneficial effects and dose-response relationships at high consumption levels, if present, require further confirmation. The findings align with guidelines from the US and China, which recommend incorporating eggs into a healthy diet. These findings should be taken into account in other dietary recommendations. It was also noted that individuals who consume approximately one egg per day can be reassured.	The research findings revealed that both low and high egg consumption were linked to a heightened risk of developing cardiovascular disease (CVD) and an increase in all-cause mortality. This underscores the recommendation that moderate egg consumption, defined as 3 to less than six eggs per week, should be advocated for the prevention of CVD in China.	Higher egg intake, as part of the modern dietary pattern high in sugars, fat, and animal-source foods, increased the risk of CVD. The effect of egg on CVD incident was partly mediated by overweight / obesity, hypertension, and diabetes.

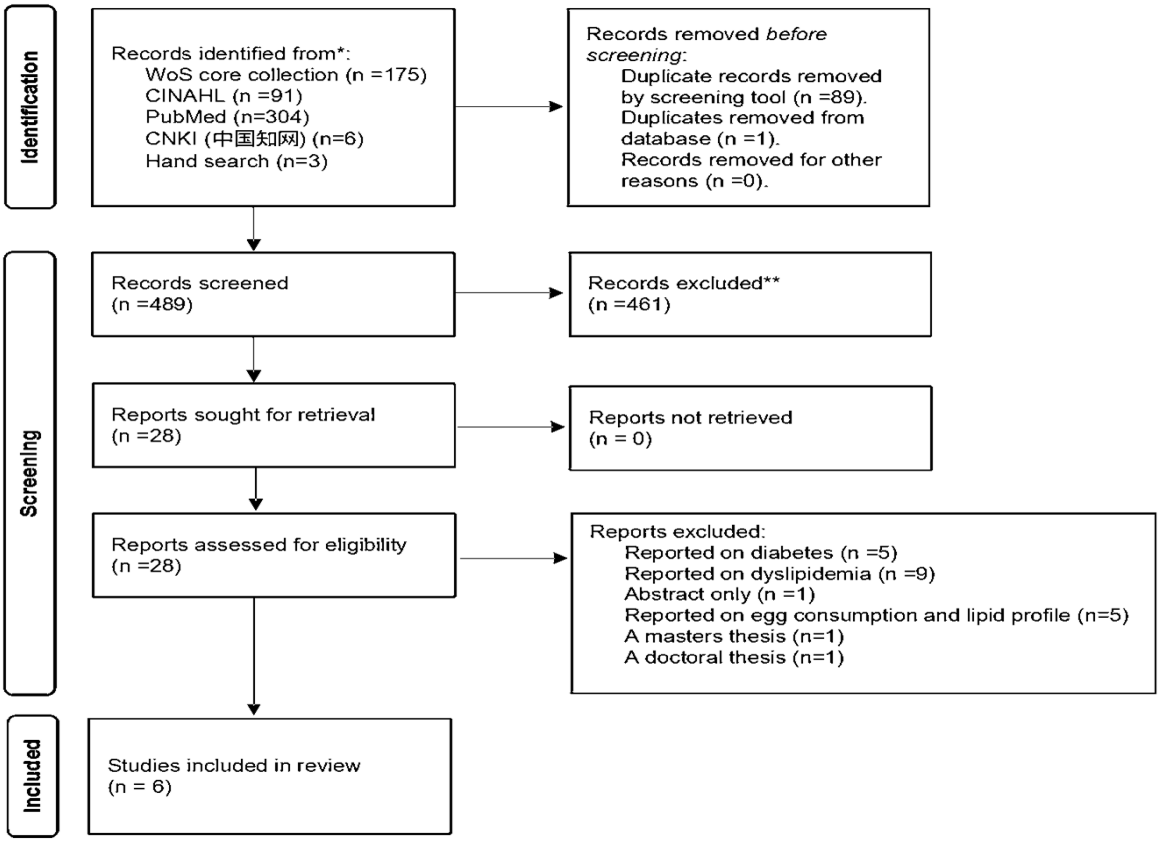

Figure 1. PRISMA Flow Diagram

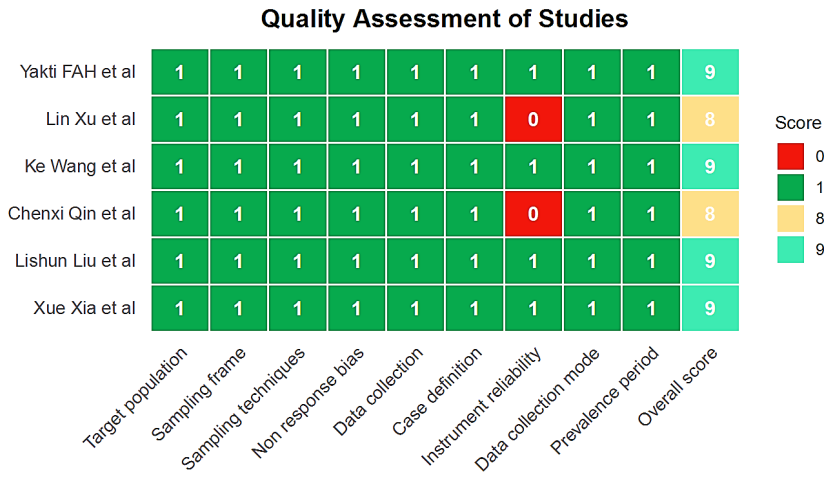

Figure 2. Risk of Bias Assessment for Included Studies

Table 2. Association Effect Sizes between Egg Consumption and CVD, CVD Mortality, and All-Cause Mortality

Study	Primary Outcome	HR (95% CI)
Liu *et al.* (2020)	All-cause mortality	1.34 (1.04 – 1.73)
Qin *et al.* (2018)	CVD	0.89 (0.82 – 0.89)
	Stroke	0.9 (0.85 – 0.95)
Wang *et al.* (2022b)	All-cause mortality	0.83 (0.7 – 0.99)
Xu *et al.* (2019a)	CVD	1.05 (0.76 – 1.42)
	Stroke	0.82 (0.47 – 1.43)
	CHD	1.23 (0.77 – 1.97)
	All-cause mortality	1.11 (0.93 – 1.33)
Xia *et al.* (2020)	incident CVD	1.39 (1.28 – 1.52)
	Stroke	1.18 (1.05 – 1.33)
	All-cause mortality	1.13 (1.04 – 1.24)
	CHD	1.86 (1.57 – 2.22)
Yakti *et al.* (2024)	CVD	1.43 (1.02 – 2.00)

3.4 Coronary Heart Disease

Figure 3 presents the pooled association effect between egg consumption and the risk of CHD in the Chinese population based on the findings reported by Lin *et al.* (2020) and Xia *et al.* (2020). Both studies identified egg consumption as a risk factor for CHD incidence. The meta-analysis, employing a random effect model, yielded a pooled hazard ratio of 1.58 (95% confidence interval [CI]: 1.07 – 2.35), indicating a statistically significant positive association (p = 0.022). Moderate heterogeneity was observed across the included studies (I^2 = 68.4%), suggesting moderate variation in study populations or methodologies.

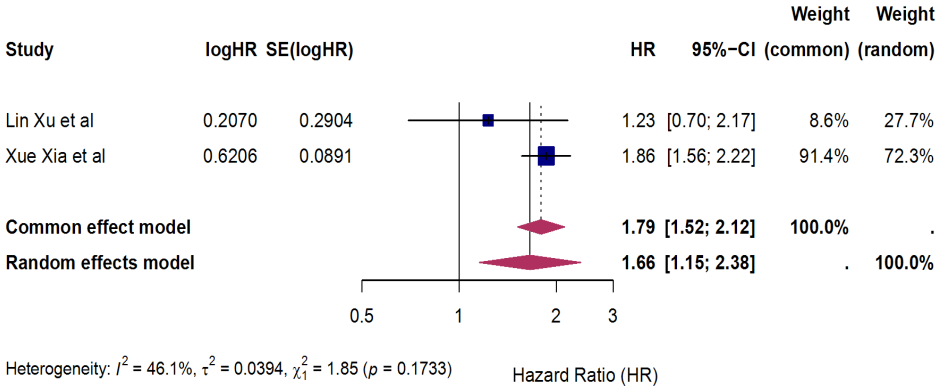

Figure 3. Forest Plot of the Pooled Association between CHD and Egg Consumption

3.5 Stroke

The pooled association between egg consumption and stroke risk among the Chinese population is illustrated in Figure 4. Three studies contributed to this analysis. Two studies reported a protective of egg consumption against stroke, with hazard ratios of 0.90 (95% CI: 0.85 – 0.95; Qin *et al.*, 2021) and 0.82 (95% CI: 0.47-1.43; Chagas *et al.*, 2013). In contrast, the remaining study reported egg consumption as a risk factor for stroke. The random-effects meta-analysis revealed substantial heterogeneity across studies (I^2 = 88%) and the pooled effect was not statistically significant (p = 0.969).

3.6 Cardiovascular Disease

Figure 5 displays the findings from four studies examining the association between egg consumption and CVD risk (Qin *et al.*, 2021; Xia *et al.*, 2020; Xu *et al.*, 2019; Yakti *et al.*, 2024). Only one study (Qin *et al.*, 2018) reported a statistically significant protective effect against CVD (HR: 0.90 95% CI: 0.85 – 0.95) whereas the remaining studies indicated a positive association, suggesting increased risk. The random-effects model produced a pooled hazard ratio of 1.16 (95% CI: 0.85 – 1.58), with a non-significant overall effect (p = 0.359). A notably high degree of heterogeneity was detected (I^2 = 96.7%), likely attributable to differences in study populations and design.

Under the common effect model, the pooled risk ratio (RR) was 0.97 (95% CI: 0.94 – 1.00). In contrast, the random-effects model yielded a pooled RR of 1.08 (95% CI: 0.84 – 1.39). Heterogeneity was considerable, with an I^2 value of 98%, a Tau-squared (τ^2) estimate of 0.0443, and a statistically significant p-value for heterogeneity (< 0.01).

3.7 All-Cause Mortality

The association between egg consumption and all-cause mortality was examined in four studies (Figure 6). Three of these studies (Lin *et al.*, 2021; Liu *et al.*, 2020; Xia *et al.*, 2020) identified egg consumption as a risk factor for mortality, while one study (Wang *et al.*, 2022b) reported a protective effect. The pooled random-effect model yielded 1.08 (95% CI: 0.91 – 1.27) indicating no statistically significant overall association (p = 0.392). High and statistically significant heterogeneity was observed among the studies (I^2 = 76.4%).

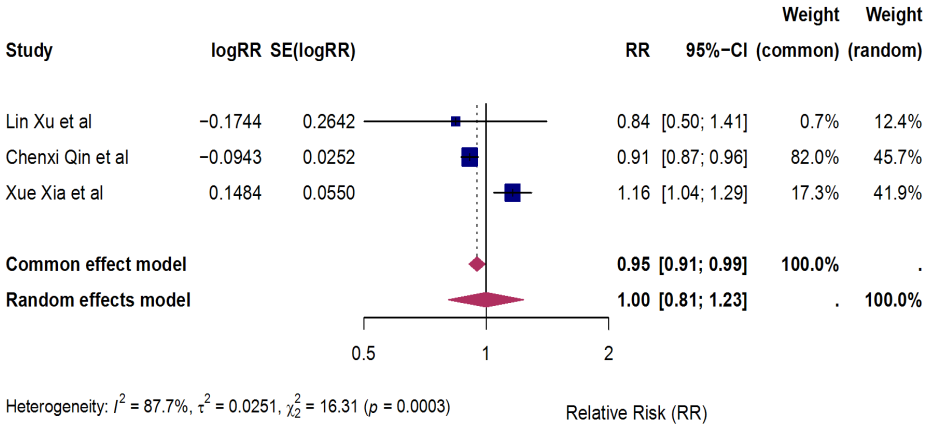

Figure 4. Forest Plot of the Pooled Association between Stroke and Egg Consumption

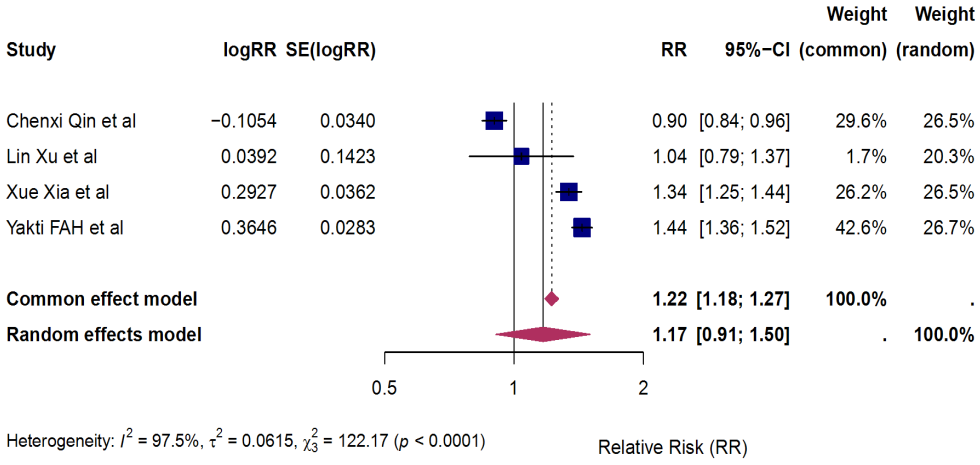

Figure 5. Forest Plot of the Pooled Association between CVD and Egg Consumption

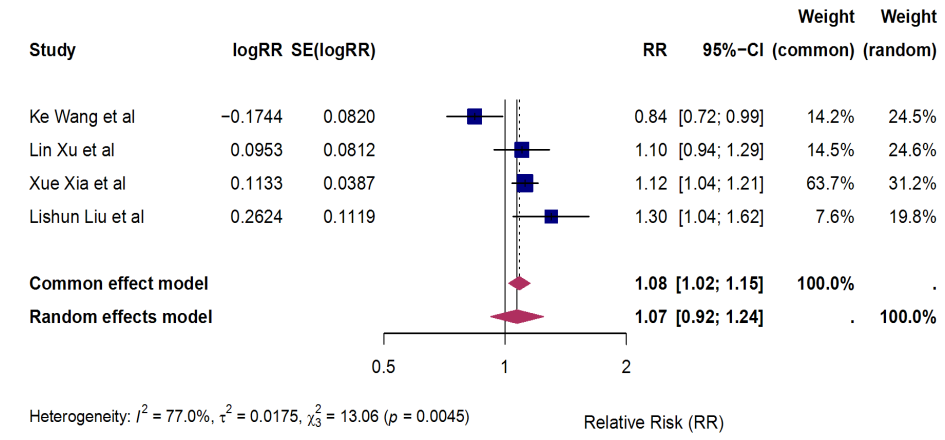

Figure 6. Forest Plot of the Pooled Association between All-Cause Mortality and Egg Consumption

4 Discussion

Despite the proliferation of studies investigating the relationship between egg consumption and CVD outcomes, the evidence to date has remained inconsistent. The present meta-analysis provides novel insights into this association within the Chinese population, revealing a nuanced relationship. Notably, our pooled results indicate a statistically significant 51% increased risk of CHD associated with higher egg intake (RR: 1.51; 95% CI: 1.09 – 2.10). Conversely, no significant associations were observed between egg consumption and stroke (RR: 1.00; 95% CI: 0.82 – 1.22), overall CVD incidence (RR: 1.08; 95% CI: 0.84 – 1.39), or CVD-related mortality (RR: 1.07; 95% CI: 0.91 – 1.27). These findings suggest that higher egg consumption may confer an elevated risk specifically for CHD, while remaining neutrally associated with other cardiovascular outcomes in the Chinese population.

These results highlight the importance of contextualizing dietary recommendations within population-specific dietary practices, genetic predispositions, and methodological considerations. The elevated risk of CHD associated with egg consumption aligns with mechanistic hypotheses linking dietary cholesterol to atherogenic lipid profiles. Each large egg contains approximately 175 mg of cholesterol (Yakti *et al.,* 2024), which may contribute to elevated serum LDL-cholesterol (LDL-C), a well-established risk factor for atherosclerosis (Berger *et al.,* 2015). However, the magnitude of this association exceeds estimates from Western meta-analyses, which frequently report neutral or modestly positive effects (Alexander *et al.,* 2016; Drouin-Chartier *et al.,* 2020). This discrepancy may be attributed to contextual factors specific to China, where eggs are regularly consumed in forms that could exacerbate cardiovascular risk. For instance, fried, processed, or preserved eggs—such as salted duck eggs—are commonly paired with high-sodium condiments, potentially synergistically increasing the risk of hypertension and endothelial dysfunction (Cao *et al.,* 2021). Furthermore, frying eggs enhances the formation of advanced glycation end products (AGEs), which are implicated in oxidative stress and vascular inflammation (Zawada *et al.,* 2022). Additionally, the nutrient composition of eggs may vary depending on the cooking method employed, which could differentially impact cardiovascular risk (Xu *et al.,* 2019). Therefore, further investigation is necessary to verify these findings and elucidate the underlying mechanisms.

Genetic susceptibility may further amplify observed risks; polymorphisms in cholesterol metabolism pathways, such as the *APOE ε4* allele prevalent in approximately 7 – 10% of Han Chinese individuals, heighten LDL-C responses to dietary cholesterol (Raulin *et al.,* 2022). These gene-diet interactions are seldom accounted for in observational studies, which may potentially inflate risk estimates or obscure protective effects.

Conversely, the absence of association with stroke and CVD mortality may reflect distinct epidemiological and dietary patterns in China. Hemorrhagic stroke, which accounts for approximately 30% of stroke cases in China (compared to <15% in Western populations), is less strongly tied to dyslipidemia (Lin *et al.,* 2021). This epidemiological distinction could plausibly explain the neutral association observed in the present study. Moreover, the unique nutrient profile of eggs—rich in antioxidants, phospholipids, and high-quality protein—may offset cholesterol-related risks when consumed as part of a balanced diet (Blesso & Fernandez, 2018). Specifically, lutein, a potent antioxidant found in eggs, inhibits LDL oxidation, a critical step in the pathogenesis of atherosclerosis (Blesso & Fernandez, 2018). Additionally, phospholipids present in eggs enhance HDL functionality, promoting reverse cholesterol transport and further mitigating cardiovascular risk (Blesso & Fernandez, 2018). These protective components may explain the null association between moderate egg intake and CVD mortality risk observed in the China Kadoorie Biobank study, a large cohort comprising approximately 500,000 adults (Qin *et al.,* 2021), which aligns with our pooled estimates for mortality outcomes.

The divergence between our findings and those derived from Western studies may also stem from differences in baseline dietary patterns. Traditional Chinese diets, although increasingly Westernized, remain lower in saturated fats than Western diets, potentially mitigating the atherogenic impact of dietary cholesterol (Clemente-Suárez *et al.,* 2023). Furthermore, Western populations often include individuals with managed dyslipidemia, which may attenuate egg-related risks (Amza *et al.,* 2017). In contrast, China's rapid dietary transition—characterized by the co-occurrence of traditional and Westernized food patterns, creates a "double burden" of cardiovascular risk factors (Popkin, 2013). Urban populations, in particular, may face compounded risks due to the pairing of eggs with processed meats, refined carbohydrates, and other atherogenic foods.

These findings carry important public health implications. The significant CHD risk associated with egg consumption suggests that moderation guidelines may be warranted for high-risk subgroups, such as individuals with dyslipidemia or *APOE ε4* carriers (Lin *et al.,* 2021). Public health initiatives should prioritize promoting healthier egg preparation methods, such as boiling instead of frying, and reducing sodium content in preserved eggs which may also confer benefits for bone health among older adults (Olagunju *et al.,* 2024). However, our findings suggest that eggs can be incorporated into a balanced diet, particularly when consumed in moderation and in conjunction with nutrient-

dense foods such as vegetables, whole grains, and unsaturated fats. This approach aligns with current nutritional guidelines while respecting the cultural significance of eggs in China, where they constitute both a dietary staple and a symbol of economic prosperity.

Limitations

The study presents several limitations that warrant consideration. First, variability in the definition of "high" egg intake across studies (typically ranging from three to seven eggs per week) complicates the interpretation of dose-response relationships. Second, inconsistent adjustments for cooking methods across the included studies represents a significant methodological constraint, given the potential for preparation techniques to modify the health effects of egg consumption. Third, residual confounding remains a concern, as incomplete control for lifestyle factors (e.g., physical activity, smoking status) and comorbidities (e.g., hypertension, diabetes) may have influenced observed effect estimates. Additionally, the included studies frequently focused on urban populations, limiting the generalizability of findings to rural or socioeconomically diverse subgroups within China.

Recommendations for Future Research

To advance understanding of the relationship between egg consumption and cardiovascular outcomes, future studies should prioritize the following: (1) standardized dose-response analyses employing harmonized definitions of exposure categories; (2) investigation of gene-diet interactions, particularly concerning polymorphisms in cholesterol metabolism pathways; (3) intervention trials examining the differential effects of various cooking methods on cardiometabolic risk markers; and (4) enhanced regional and socioeconomic diversity in participant cohorts to improve the generalizability of findings. Such endeavors would help clarify the complex relationship between eggs and CVD and the development of evidence-based, contextually appropriate dietary recommendations dietary recommendations.

5 Conclusion

This systematic review and meta-analysis reveal a multifaceted relationship between egg consumption and CVD outcomes in China, characterized by a significantly increased risk of CHD alongside neutral associations with stroke, overall CVD incidence, and CVD mortality. These findings emphasize the importance of contextualizing dietary recommendations within China's unique cultural, genetic, and socioeconomic landscape. As China navigates a period of rapid dietary transition accompanied by a rising burden of CVD, eggs represent both a nutritional opportunity and a potential health challenge. Effective public health strategies must balance the affordability and nutritional value of eggs with targeted moderation to mitigate CVD risks , particularly among susceptible subgroups. Ultimately, the current study highlights the necessity of precision nutrition approaches tailored to China's unique epidemiological profile, thereby informing evidence-based dietary guidelines that promote optimal cardiovascular health across the population.

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