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Review

Ghee's health benefits on cardiovascular health and lipid profile: Insights from a systematic review and meta-analysis

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Abstract. *Background:* This study aims to evaluate the clinical evidence on the efficacy and safety of consuming Ghee (clarified butter) for human health. Ghee has been an important part of Indian cuisine for centuries and plays a vital role in Ayurvedic medicine. It is a healthy dietary fat recommended for daily use, but recent studies suggest it might raise the risk of coronary heart disease (CHD). Over the years, studies on this subject have produced inconsistent and conflicting results. *Methods:* Following Prisma 2020 and Moose guidelines, a systematic review analyzed studies on Ghee's health effects from 1994 to 2024. A total of 919 articles were retrieved from various platforms. From these, 33 were further selected, and finally, 18 were included in the meta-analysis. *Results:* A meta-analysis of ghee consumption and CHD included 10 clinical and epidemiological study designs with 19,948 participants, including 4,558 cases-subsjects from the Indian subcontinent. Using a random-effects model, the CHD risk was ORp: 1.15 (95% CI: 0.71–1.59). Another meta-analysis of eight studies on ghee and lipid profiles found that ghee intake had neutral to positive effects on lipid levels. *Conclusion:* This review and meta-analysis aimed to clarify the conflicting information regarding the health effects of Ghee consumption. Our findings indicate that Ghee consumption is associated with a marginally increased risk of coronary heart disease (CHD). However, Ghee consumption does not appear to have a significant impact on the overall lipid profile in humans. These results underscore the need for further research to explore the mechanisms underlying these associations and to provide more definitive guidance on the health implications of Ghee consumption.

Introduction

Ghee (clarified butter) has been a traditional and culturally significant product in the Middle East and, more prominently, in India for centuries (1-3). Not only is Ghee central to Indian cuisine, but it also plays a vital role in Ayurveda, the traditional Indian system of medicine (4,5,6). While modern scientific studies on Ghee's functional benefits are limited (7,8), Ayurveda extensively documents its therapeutic uses (9-11). Despite its cultural significance and commercial value, Ghee remains a controversial lipid. Ghee is an important bioorganic compound classified as a saturated fatty acid (SFA) (2,12). Some studies suggest that consuming Ghee may be beneficial in reducing lipid profiles (13,14). However, recent research suggests that Ghee may also be associated with negative health effects, including an increase in lipoproteins, lipids, and the atherogenic index, which are linked to cardiovascular diseases (15- 17). Ghee has recently gained popularity in Western countries as a healthier and nutritional alternative to traditional butter. This interest is reflected in the increase in registered new trademarks for Ghee, reaching 17 in Italy,41 in Spain, 88 in France, and 212 in the United States (August 21, 2024), according to the OpenFoodFacts database (18). Additionally, the number of publications on Ghee listed in PubMed has significantly increased. In 1994, there were only seven publications on Ghee; from 1994 to the present, 173 articles have been published covering some aspects of clarified butter. This growing interest is linked to new scientific insights into dairy fats. As a result, traditional

negative views on saturated fats, including Ghee, are being re-evaluated, challenging long-standing beliefs (7,8,19,20). This review evaluates conflicting information about the positive and negative health effects of consuming Ghee. We conducted a systematic review and two meta-analyses to summarize the evidence on how dietary ghee intake affected the risk of coronary heart disease and impacted the lipid profiles in humans. This article aims to identify and uncover gaps in current research and suggest future study areas on the therapeutic potential of Ghee.

What is Ghee

Definitions of Ghee in the Codex Alimentarius and Food Safety Standards Authority India (FSSAI) are broad (21). Indian Ghee is a product obtained exclusively from animal milk, cream, or butter through processes that remove almost all water and non-fat solids, resulting in a distinct flavor and texture (cow or buffalo). Ghee predominantly comprises 99.5% fat and less than 0.5% moisture. It is also a source of fat-soluble vitamins, including vitamins A, D, E, K, and phospholipids (12, 20). Food chemists classify the fatty acid composition of Ghee based on its degree of unsaturation: SFA (saturated fatty acids), MUFA (monounsaturated fatty acids), and PUFA (polyunsaturated fatty acids). Ghee is unique among edible fats and oils due to its high SFA content, as well as its conjugated linoleic acids, omega-3 and omega-6 fatty acids, and butyric acid. Buffalo ghee contains 59.91% saturated fatty acids (SFA), slightly surpassing the 55.34% found in cow ghee. (22) The differences in fatty acid profiles between buffalo ghee and cow ghee can significantly influence their health effects. In rural regions, buffalo ghee is more common due to the greater availability and the local tradition of homemade production (17). These fatty acids are valued not only for their role as saturated fats but also for their anti-inflammatory and antioxidant properties. Additionally, they contribute to brain health and support a range of physiological functions. (7, 8, 19, 20). Ghee is prepared using different methods (12). *The traditional method of ghee preparation:* the indigenous milk butter process, as applied in homes in India, involves the souring of raw milk in earthenware vessels that have been used previously as milk containers, and which contain an inoculum of bacteria within pores of the wall. The fermented milk is churned into butter after adding more milk over successive days. The butter is then boiled in an open pan at 110-120 ^{o}C for 10-20 min to allow the evaporation of water without charring the proteins. The Ghee is transferred while hot and stored in earthenware containers. During the heat treatment, protein, fat, and lactose degrade, and their interaction results in the characteristic ghee flavor. *Commercial methods:* industrial centrifugal separators separate the cream from the milk. White butter is used as the raw material in the creamy butter method. The pre-stratification method involves gravity-based separation of moisture and solids-not-fat from white butter, significantly saving thermal energy.

Material and Methods

Inclusion and exclusion criteria of the review

The inclusion criteria for this systematic review encompassed articles published between 1994 and 2024 that investigated the potential health benefits of ghee for humans and provided clinical evidence related to its biological activities. The review specifically focused on ghee derived from animal sources, particularly traditional clarified ghee made from cow and buffalo milk, commonly known as Indian ghee.Special care was taken to distinguish traditional Indian clarified ghee from other varieties, such as Vanaspati ghee (A hydrogenated product rich in trans fats.) and plant-based alternatives like mustard, coconut, or shea butter. Because of their different chemical compositions, these alternative types of ghee were excluded from the scope of this review. On the other hand, the exclusion criteria ruled out experimental studies involving animals, in vitro tests using cultured cells, industrial production processes, and articles focusing on chemical or microbiological analyses and quality control, as these aspects were outside of this review.

Bibliographic review

We conducted a systematic review, including a statistical meta-analysis, following the 2020 Prisma

Guidelines (http://www.prisma-statement.org) [23] and adhering to the Moose (Meta-Analysis of Observational Studies in Epidemiology) checklist(24). We also conducted an extensive search of scientific literature and medical databases in English and Spanish. The databases consulted included PubMed, Web of Science, Scorpus, Embase, Cochrane, LILACS, and ClinicalTrials.gov. A bibliographic search covered the main non-indexed journals from India, Pakistan, Iran, Bangladesh, and Malaysia. The comprehensive review was independently conducted by two authors, an experienced researcher (1*) and a student in training (2*). They established a protocol for selecting and including relevant publications. We standardized computer-based tools to include various sections (title, authors, journal, year, abstract). The research strategy encompassed all studies on developing associations with specific terms or keywords used in the query. To capture a comprehensive range of studies related to Ghee and its health effects, a systematic search was conducted using specific keywords. The MeSH (Medical Subject Headings) descriptors included the terms "Ghee*", "Clarified butter," and "Human" These terms were chosen to focus on studies involving human participants, thereby excluding animal or in vitro research. We recognize that these terms might lack specificity. Therefore, additional keywords such as "Ghee and CHD", "Ghee and lipid profile", "Beneficial effects Ghee on human health", "Harmful effects ghee on human health" , "Ghee and clinical trials","cholesterol and Ghee" and similar combinations were considered to refine the search further. This approach ensured the inclusion of studies that directly examined the relationship between Ghee consumption and health outcomes such as coronary heart disease and lipid profiles. The search strategy was iteratively adjusted to balance sensitivity and specificity, ensuring the inclusion of relevant studies while minimizing irrelevant results. No specific population was targeted in the search. The selected articles use diverse methodologies, including case-control designs, randomized cross-sectional studies, randomized controlled trials, randomized prospective cohort studies, and randomized retrospective epidemiological analyses.The article selection period was unrestricted, covering publications until the paper's submission date (1994–2024). All references were managed using Mendeley reference management software. The two researchers held regular meetings after each platform search (e.g., PubMed, Web of Science, etc.) to provide training feedback and compare findings while assessing the concordance of different options. Several quality control measures were applied during the bibliographic review. Tools were developed to assess the quality of the studies, including calculating the Kappa concordance index between the two authors during the selection of systematic reviews. In addition, the quality of the selected publications was evaluated using the Newcastle-Ottawa Scale (NOS), which examines three main criteria: participant selection, study group comparability, and exposure assessment (25). This scale assigns a maximum score of 9 stars (*), classifying studies as high quality (7-9 stars), moderate quality with potential methodological limitations (4-6 stars), or low quality with a high risk of bias (0-3 stars). To ensure proper internal quality control, both authors reached a consensus on the score assigned to each selected publication. Finally, a Prisma flowchart (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) was used to guarantee the reliability of the results.

Statistical analysis

The statistical analysis used Stata version 18.5 (STATA Corp, College Station, TX, USA). Cohen's Kappa coefficient was used to evaluate the agreement between two authors in selecting articles during the screening process. The Kappa coefficient was interpreted following Bryant's criteria (26). Additionally, bias-adjusted Kappa indices (BAK) and prevalence and bias-adjusted Kappa indices (PARAB) were calculated. In order to estimate the effect of each item, the authors applied multivariate or binary logistic regression analysis. This generated odds ratios (OR) with 95% confidence intervals (CIs). The model was adjusted for variables such as age, hypertension, diabetes, and smoking, with a significance level set at a p-value of less than 0.05. Using Greenland's formula, odds ratios (OR) and 95% CIs were log-transformed to compute the corresponding standard errors for β-coefficients. In cases where logistic regression was not applied, OR and CIs were determined using the exact

mathematical method (27). Lastly, a lipid meta-analysis was performed by calculating Cohen's difference for each parameter before and after the ghee-based diet proposed in each study. Finally, the reported frequency of dietary items consumed per month, week, or day in this article was converted into daily consumption.

Meta-Analysis methodology

A meta-analysis was conducted using STATA version 18.5 and Review Meta-Analysis Manager 9.0 to evaluate the association between dietary saturated fat (Ghee) and CHD risk and lipid profile. The mathematical inverse variance method with the fixed-effects model and the random-effects model with DerSimonian and Laird's formula was employed to estimate weighted pooled odds ratios (ORp) due to the evidence of heterogeneity among studies (28). These models also combine ORp and 95% confidence intervals (CIs). Since the test for homogeneity Q is not very powerful, it is advisable to set the threshold for statistical significance at a p-value of less than 0.10. The I^2 index was used to assess heterogeneity with the H and Cochran's Q statistics, where values greater than 50% indicated substantial heterogeneity. Publication bias was assessed using funnel plots, Egger's test, Begg's test, and, more specifically, Peters's publication bias test (29). Finally, the quality of the studies was assessed using the NOS scale (25).

Results

A comprehensive search was independently conducted by two authors using PubMed, Web of Science, Scopus, Embase, Cochrane, LILACS, and ClinicalTrials.gov, identifying 890 articles. Additionally, 23 articles from non-indexed Indian and Pakistani journals and six from non-indexed Iranian, Bangladeshi, and Malaysian journals were included, totaling 919 publications at the Identification stage. After removing duplicates, irrelevant studies (e.g., animal studies, in vitro test), and unrelated industrial or microbiological analyses articles, 213 articles remained at the screening stage. During the Eligibility phase, two authors independently conducted a detailed review of 33 articles. Finally, in the Included stage, 18 studies were selected: 10 focused on coronary heart disease and 8 explored the relationship between ghee consumption and lipid biochemical parameters. The selected studies included various methodologies such as case-control designs, randomized cross-sectional studies, randomized control trial, randomized prospective cohort studies, and randomized retrospective epidemiology analyses. These 18 studies were ultimately included in the meta-analysis (Figure 1).

Kappa agreement

The Kappa agreement index has been calculated between the two researchers for the 213 articles resulting from the screening stage. The agreement index for the 33-eligibility stage (1*) reports for (2*) is as follows: Kappa =0.394 (95% CI 0.214-0.571). Adjusted kappa for bias (BAK) k =0.386, and Adjusted kappa for prevalence and bias (PARAB) k =0.736, Agreement 86.79%. According to Byrt's scale (26), a kappa index of 0.736 present a good rating that could be improved with experience in subsequent systematic review work.

Ghee &CHD (Cardiovascular Heart disease)

The literature review identified 10 publications from 1994 to 2022 that examine the relationship between ghee consumption and CHD. The characteristics of each publication are presented in Table 1 (30-39). The meta-analysis was conducted on 19,948 individuals with 4,558 case-subjects from the Indian subcontinent with an average daily consumption of Ghee 32 g/day (23-42 g/day), with an average duration of 511 days (7-1060 days). We conducted a meta-analysis of the studies on this topic using multivariate-adjusted risk (multilogistic odds ratio or simple OR) provided by each of the ten studies (29).

The initial calculation of the weighted OR was performed using the inverse variance method (29) with the "fixed effects model," resulting in a weighted ORp of 1.40 (95% CI: 1.25-1.57). The heterogeneity analysis indicated an I^2 of 89.2% and an H of 3.04, with a Cochran's Q value of 83.16 (p=0.0001), suggesting significant heterogeneity, so it was advisable to recalculate the weighted ORp using the "random

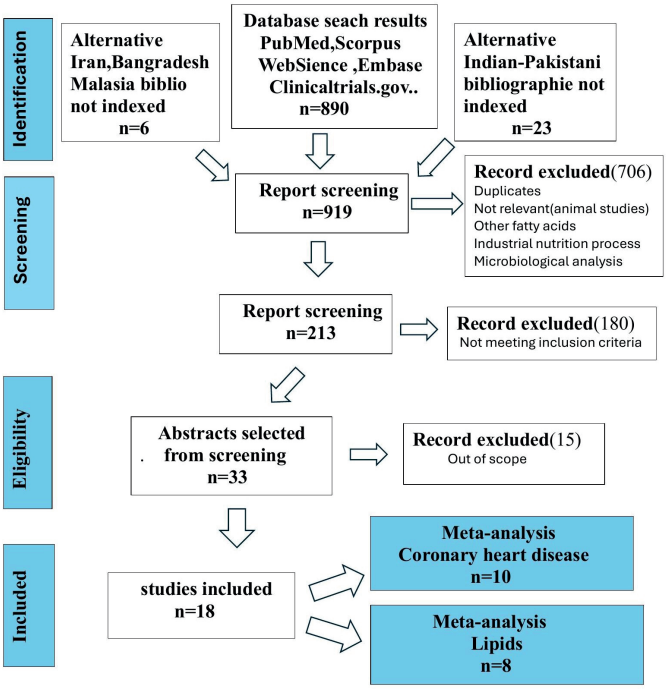

Figure 1. PRISMA Flow diagram showing study selection procedure

effects model," which resulted in a weighted ORp of 1.15 (95% CI: 0.71-1.59) I^2=0 H=0.95 and Q=8.05 (p=0.525). The forest and funnel plots (Figure 2).

In the second stage, it was deemed necessary to stratify the analysis by sex, given that some literature suggests a higher risk in females (32,33). For females (8 studies), a statistical analysis using the random-effects model (due to confirmed heterogeneity) yielded a weighted ORp of 1.35 (95% CI: 0.77–1.93). In contrast, for males (9 studies), the random-effects model indicated a weighted ORp of 1.00 (95% CI: 0.60–1.40) (Figure 3). Although these findings indicate a potentially higher risk in females, the overlapping confidence intervals suggest no statistically significant difference between the sexes. Cochran's Q test for the two groups produced Q = 1.66 (p = 0.20), confirming no significant sex-based difference. Nevertheless, females appear to exhibit a slightly higher risk of CHD (Figure 3).

In the third stage, the results were analyzed based on rural and urban origins, as some studies suggested there might be significant differences between these populations (31,35). The calculation of the weighted ORp using the random effects model in 7 studies of urban populations shows a weighted ORp of 1.20 (95% CI: 0.65-1.76). On the other hand, four studies of rural populations show a weighted ORp of 1.36 (95% CI: 0.51-2.21). These results suggested no significant differences between the rural and urban populations, as confidence intervals for both groups overlap, and Cochan's test shows Q 0.09(p=0.76) confirms no significant differences between dwellings. However, in our study, rural dwellings have a slightly higher risk of CHD. In the next stage, publication bias was studied. First, graphical methods such as funnel plots (Figure 2) were applied, which are difficult to interpret but, in our case, show some symmetry that is hard to explain. Various statistical analyses were subsequently applied to assess publication bias. Begg's test, using Kendall's tau calculation, yielded a correlation coefficient of $\tau = 0.022$ with $p = 1.00$, indicating no evidence of publication bias. Similarly, Egger's test showed a

Table 1. Characteristics of studies included in the meta-analysis CHD (Coronary Heart Disease) risk

Study/reference/Title	Data (year)	Country	Study-design	Patient (Case)	Calidad NOS (1-9*)
Wander GS et al. (30) Epidemiology of Coronary Heart Disease in a Rural Punjab Population-Prevalence and correlation with Varios Risk Factors.	1994	India	Retrospectiv Epidemiology prevalence study	1100(566)	1*
Singh RB et al. (31) Association of trans fatty acid (vegetable ghee) and clarified butter (Indian ghee) intake with higher risk of coronary artery disease in rural and urban population with low fat consumption.	1996	India	Randomy Cross-sectional study	2265(458)	6*
Gupta R et al. (32) Association of Dietary Ghee Intake with Coronary Heart Disease and Risk factor Prevalence in Rural Males.	1997	India	Random Cross-sectional study	1982(782)	1*
Jafar TH (33) Women in Pakistan have a greater burden of clinical cardiovascular risk factors than men.	2006	Pakistan	Cross-sectional study	7622(1335)	2*
Rafique R et al. (34) Dietary predictors of early-onset ischaemic heart disease in a sample drawn from a Pakistani population.	2012	Pakistan	Case-control study	570(190)	2*
Manna S et al. (35) Comparison of Mustard Oil and Ghee consumption on the history of coronary heart disease in Urban Population of India.	2016	India	Random cross-sectional study	137(62)	4*
Vyas S et al. (36) Association of Ghee consumtion with Lowered CHD history:A study in urban North Indian Adults.	2017	India	Random Cross-sectional study	138(63)	4*
Sadeghi M et al. (37) Longitudional association of dietary fat intake with cardiovascular events in a prospective cohort study in Eastern Mediterranean region.	2021	Iran	Random prospective Cohort study	5432(751)	2*
Khatun T et al. (38) Dierary habits of patients with coronary artery disease in a tertiary-care hospital of Bangladesh:A case-controlled study	2021	Bangladesh	Random Case-control study	210(105)	2*
Hanif MK et al. (39) Dietary Habits of patients with coronary artery disease:A Case-Control study from Pakistan.	2022	Pakistan	Case-control study	492(246)	4*

non-significant intercept at the original regression line-1.94 (p = 0.296), confirming the absence of bias (29). Finally, the regression analysis proposed by Peters corroborated these findings, as the slope of -1.015 was also non-significant (p = 0.995). Lastly, the quality of the publications was evaluated using the NOS scale (25), which rates each article with a maximum score of 9 starts based on selection of participants, compatibility

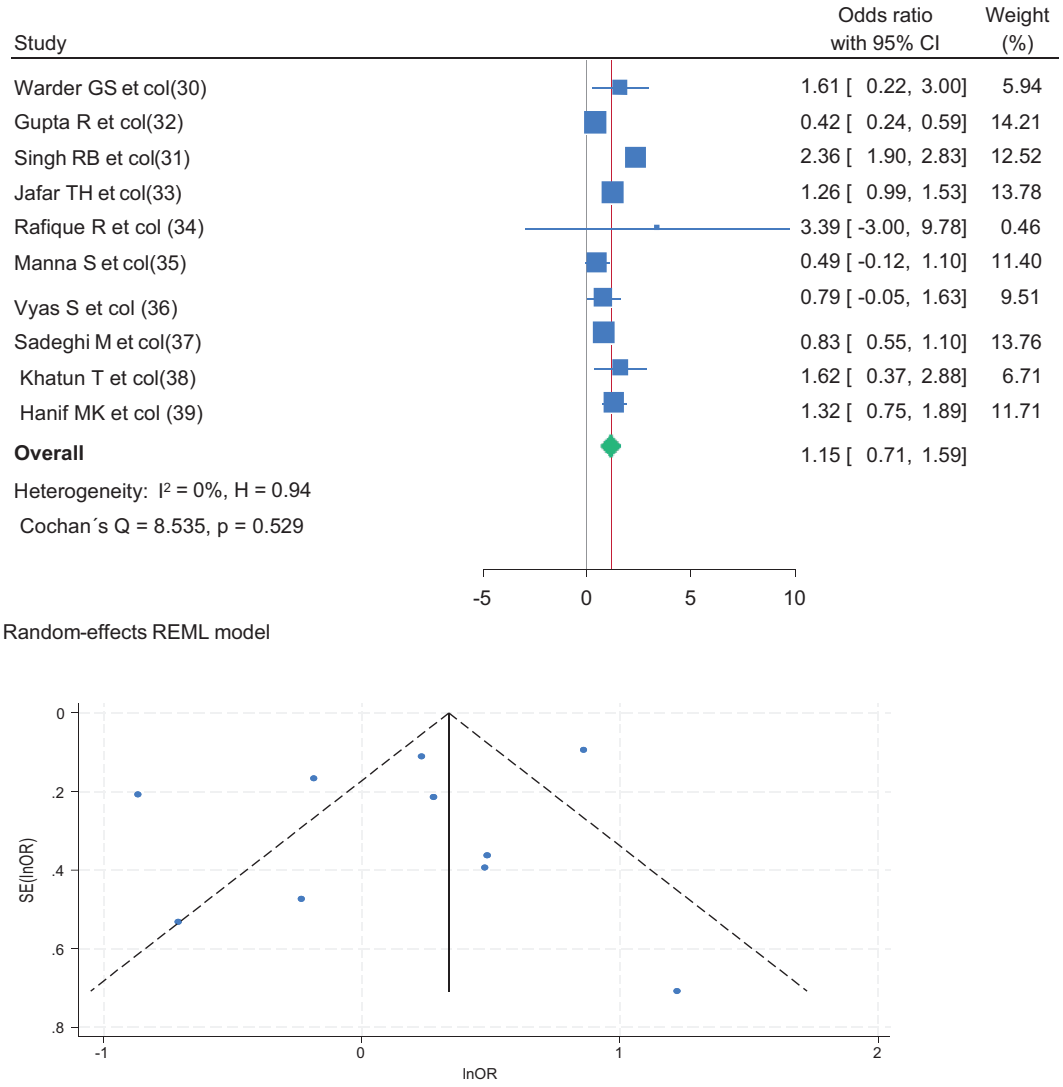

Figure 2. Forest, Funnel Plots. Coronarary Heart Disease (CHD) risk

of the groups, assessment of exposure. Table 1 presents the scoring results, both authors reached a consensus on the score assigned to each publication.

Ghee&Perfils lipids

It is well-established that lipids, lipoproteins, and other lipid mediators play a crucial role in the development of atherosclerosis and significantly contribute to cardiovascular risk (15). These effects are often mediated through changes in blood lipid profiles, increased oxidative stress, pro-inflammatory pathways, and their influence on CHD (16). Given this, conducting a meta-analysis to evaluate the impact of ghee consumption on lipid profile alterations seemed both logical and necessary. The literature review identified eight publications (four randomized control trial, cross sectional study, randomized crossover clinical trial, prospective designee study and single blind randomized control clinical study) from 2002 to 2022 that examine the relationship between Indian ghee consumption and lipid levels (Total cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides). The characteristics of each publication are presented in Table 2 (13,40-46).

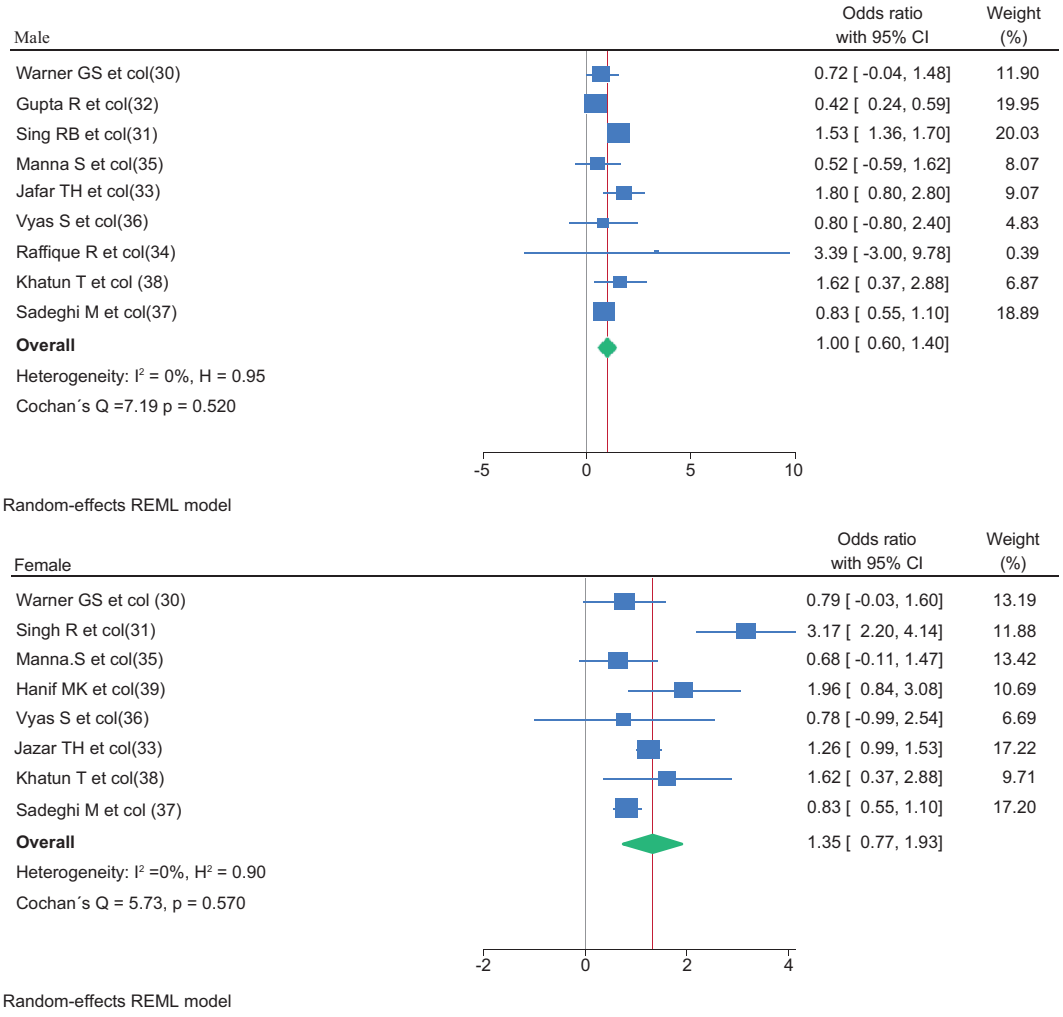

Figure 3. Forest Plot of meta-analysis regarding Sex. Test of group differences: Q=1.66, p=0.20

The meta-analysis was conducted on 649 individuals with 240 case-subjects from the Indian subcontinent, primarily from India, Jordanian, and Iran, with an average daily ghee consumption of 27 g/day (5-42 g/day) over a mean duration of 103 days (14-360 days). We conducted a meta-analysis by calculating the weighted Cohen's d for each lipid parameter before and after the ghee-based diet proposed in the study designs of the eight included studies (29).

The weighted Cohen's difference for Total cholesterol(mg/dl) was calculated using the inverse variance method with the fixed effects model, yielding a weighted Cohen's difference of -0.22 (95% CI: -0.39 to -0.056). The heterogeneity analysis showed I^2 of 89.14% and H 3.03, with a Cochran's Q value of 64.47 (p=0.0001), indicating significant heterogeneity (29). A recalculation using the random effects model resulted in a weighted Cohen's difference of -0.04 (95% CI: -0.52-0.43), Q = 5.58(p=0.589). Cohen's weighted difference was calculated using the random effects model for HDL cholesterol(mg/dl), yielding Cohen's difference of +0.33 (95% CI: 0.001- 0.67), Q =7.40(p=0.038). Using the random effects model for LDL cholesterol(mg/dl), the weighted Cohen's difference was -0.17 (95% CI: -0.59-0.26), Q =6.56 (p=0.476). The initial calculation using the fixed effects model for triglycerides (mg/dl) resulted in a weighted Cohen's difference of -0.36 (95% CI: -0.54

Table 2. Characteristics of studies included in the meta-analysis. Lipid profile

Study/reference/Title	Data (year)	Country	Study-design	Patients (Case)	Calidad NOS (1-9*)
Shankar SR et al. (13) Effect of partial replacement of visible fat by ghee (clarified butter) on serum lipid profile.	2002	India	Randomized control Trial	24(11)	2*
Rawashdeh A (40) Influences of Olive Oil and Ghee (samen balady) on Serum Cholesterol of Jordanians.	2002	Jordania	Randomized controlled trial	24(24)	4*
Shankar SR et al. (41) Serum lipid response to introducing ghee as a partial replacement for mustard oil in the diet of healthy young Indians.	2005	India	Randomized controlled trial	63(30)	2*
Mohammadifard N et al. (42) Comparison of effects of soft margarine, blended, ghee, and unhydrogenated oil with hydrogenated oil on serum lipids: A randomized clinical trial.	2013	Iran	Randomized controlled trial	197(48)	6*
Sharma HB et al. (43) Beneficial effect of ghee consumption over mustard oil on lipid profile: A study in North Indian adult population.	2018	India	Cross-sectional study	200(62)	4*
Hosseinabadi SM et al. (44) Effects of diets rich in ghee or olive oil on cardiometabolic risk factors in healthy adults: a two-period, crossover, randomised trial.	2022	Iran	Randomised crossover clinical trial	30(15)	2*
Munisekhar K et al. (45) Lipid profile in healthy human volunteers before and after consuming ghee.	2022	India	Prospective designed study	51(23)	2*
Vinod P et al. (46) Single Blind Randomized Control Clinical Study to Assess the Effect of Cow-Ghee on Lipid Profile and Blood Glucose in Healthy Volunteers.	2023	India	Single blind randomized Control clinical study	60(27)	6*

to -0.19). The heterogeneity analysis showed and I^2 of 94.9% and a H of 4.42, with a Cochran's Q value of 136.62 (p=0.0001). A recalculation with the random effects model resulted in a weighted Cohen's difference of -0.34 (95% CI: -1.12- 0.44), Q =6.85 (p=0.444). In the next stage, publication bias for cholesterol and triglycerides was assessed. First, the total cholesterol parameter was analyzed. Egger's test for publication bias revealed a non-significant intercept at the origin of the regression line (b = 8.69, p = 0.067), suggesting the absence of bias. For triglycerides, Egger's test also showed a non-significant intercept at the origin of 1.01, p = 0.903, confirming the absence of bias (29). Lastly, the quality of the publications was assessed using the NOS scale (25). The scoring results, reached by consensus between the two authors, are shown in Table 2.

Discussion

The benefit areas associated with Ghee in Ayurveda literature have been largely overlooked in recent research, with limited interest in cognitive health,

gastrointestinal health, wound healing, dermatological applications, and eye health (6-8,10, 19, 20). However, the modern scientific literature on Ghee has largely focused on its cardiovascular health risks, primarily due to its 60% saturated fatty acid composition (15,33, 39, 44, 47). Human clinical trials show mixed results. Ayurvedic texts rarely mention Ghee regarding cardiovascular health, although it is used in nearly 50 Ayurvedic medicinal preparations as a fat carrier (6,9-11). Some research suggests that Ghee may lower its atherogenic potential. For example, consuming Ghee as 25% of total energy intake has been shown to reduce cholesterol, triglycerides, and fatty streaks in arteries (13,14,41). Other studies found no significant link between daily ghee consumption and heart disease risk, although ghee and vegetable oil consumption were associated (19,20). The results of our first meta-analysis explore the relationship between ghee consumption and CHD. This analysis is based on a review of 10 scientific publications dating back to 1994-2024, primarily from India, Pakistan, Bangladesh, and Iran. Given that all publications originate from the Indian subcontinent, a potential bias regarding the race of the participants must be acknowledged. This should be explicitly noted when extrapolating to Western populations. The findings indicate that ghee consumption is associated with an increased risk of coronary heart disease (CHD), with a weighted odds ratio (ORp) of 1.15 (95% CI: 0.71–1.59). Since the confidence interval does not include the value zero, this association warrants attention. The risk appears to be higher among females, with a weighted ORp of 1.35 (95% CI: 0.77–1.93), aligning with recent literature on the topic (31, 33). In rural populations, the weighted ORp is 1.36 (95% CI: 0.51–2.21), a finding that contradicts existing studies (31). This discrepancy may be influenced by dietary habits in these regions, where buffalo ghee is more commonly consumed due to the abundant availability and a long-standing tradition of homemade production. Buffalo ghee contains 59.91% saturated fatty acids (SFA), slightly higher than the 55.34% found in cow ghee, which could have significant health implications (22). These differences in fatty acid composition may partly explain the anomalies observed in our study. Furthermore, in rural área,where education levels tend to be lowe,variations in cooking and ghee preparation methods could also contribute to an increased health risk. However, since these findings are based on only four studies conducted in rural settings, their statistical significance is limited. Therefore, further research is necessary to confirm these results and to better understand their potential health impacts. Publication bias was assessed using a funnel plot (Figure 2), which showed symmetry, and statistical tests such as Begg's, Egger's, and Peters, all indicating no bias (29). Article quality was evaluated using the NOS scale (Table 1). Although some studies had a low NO2 score (25), all articles were included in our research because of their important historical value. Several theories attempt to explain the relationship between ghee consumption and coronary heart disease (47,48), including the possible adulteration of commercially prepared Ghee with trans fatty acids or vanaspati, which is common in India (1,31,49). Another hypothesis, the Cholesterol-PUFA ester (Polyunsaturated unsaturated fatty acids) peroxidation theory (50), suggests that these compounds are incorporated into lipoproteins and transferred by LDL into cells, potentially leading to inflammatory and atherogenic diseases. Additionally, cholesterol oxidation products (COPS) made for the traditional way of preparation might initiate atherosclerosis and have mutagenic effects (51). However, none of these theories are entirely clear. The results of our second meta-analysis, which investigates the relationship between ghee consumption and lipid levels, are based on eight selected studies, primarily from the Indian subcontinent. The findings indicate that ghee consumption reduces total cholesterol by -0.04 (95% CI: -0.52-0.43) and increases HDL cholesterol by +0.33 (95% CI: -0.001–0.67), potentially acting as a cardioprotective factor against CHD. Furthermore, ghee intake reduces LDL cholesterol by -0.17 (95% CI: -0.59 -0.26) and decreases triglyceride levels by -0.34 (95% CI: -1.12-0.44). The results regarding cholesterol and triglycerides publication bias were studied, confirming the absence of any bias. The analysis of these results shows us that, by encompassing zero, the reference intervals indicate that these reductions cannot be considered significant. Several theories have been proposed to explain the neutral or improvement in the lipid profile of ghee consumers, with the most credible being that of

Kumar, M (14). Their research suggests that an increase in the secretion of biliary lipids mediates the hypocholesterolemic effect and improvement in lipid profiles from consuming Ghee. In the final stage, we aimed to determine the recommended doses based on the lipid meta-analysis results. The findings were unclear and sometimes contradictory. Only Vyas.S (36) established a maximum consumption of 20 g/day, linked to a lower risk of coronary heart disease. Other authors, such as Singh. RB (31) and Rafique. R (34) suggested that consuming 0-30 g/day, does not significantly increase CHD risk. In conclusion, a maximum consumption of 20-30 g/day, seems does not significantly affect CHD risk. In summary, the statistical analysis results indicate that the findings cannot be considered statistically very robust, as associations between ghee consumption and CHD with an OR of 1.15 below 1.6 are deemed statistically weak (27). Additionally, some lipid confidence intervals include zero. However, given the limited number of studies on the benefits and drawbacks of ghee consumption, we believe that, despite the statistical limitations, the analysis suggests a trend toward improved lipid levels with ghee consumption. At the same time, it shows that there is a tendency to develop cardiovascular disease, although not to a statistically significant extent. Racial bias should be considered when extrapolating these findings to Western populations, given the complete lack of clinical trials in Western countries on this genuine Indian product, whose consumption is spreading across Europe and the United States.

Conclusions

Ghee consumption is associated with a slight increase in the risk of coronary heart disease, with a weighted odds ratio ORp of 1.15 (0.71–1.59), particularly among women ORp 1.35(0.77–1.93). Therefore, the potential increase in cardiovascular risk warrants caution, especially in populations with additional risk factors such as obesity, diabetes, hypertension, or metabolic syndrome. Moderate ghee consumption (20–30 g/day) may align with traditional Ayurvedic practices, potentially offering health benefits without significantly affecting lipid levels. However, further research is necessary to better understand its therapeutic potential

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