REVIEW ARTICLE

Dairy Consumption and Colorectal Cancer Risk: A Meta-Analysis of Observational Studies

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ABSTRACT

Background: Colorectal cancer (CRC) is the third most common malignancy and a leading cause of cancer-related mortality worldwide. Dietary factors, particularly dairy consumption, have been suggested to play a protective role in CRC prevention. **Aims & Objectives:** This updated systematic review aimed to evaluate the association between dairy product consumption and the risk of CRC based on recent observational studies published between 2020 and 2025. **Methodology:** A systematic search was conducted in PubMed, Embase, Google Scholar, and Web of Science. Cohort and case-control studies assessing dairy intake and CRC risk were included. Study quality was assessed using the ROBINS-I tool. A random-effects meta-analysis was performed to estimate pooled risk estimates. Heterogeneity was evaluated using Cochran's Q test and the I^2 statistic. **Results:** Out of 571 identified studies, 12 met the inclusion criteria, comprising 821,865 participants. Overall, dairy consumption was associated with a significant 25% reduction in CRC risk (OR = 0.75, 95% CI: 0.67–0.83; I^2 = 87.1%). Cohort studies showed an 11% risk reduction (RR = 0.89, 95% CI: 0.85–0.94), while case-control studies demonstrated a 52% reduction (OR = 0.48, 95% CI: 0.35–0.65). Subgroup analysis indicated reduced risk with total dairy products (OR = 0.74) and milk consumption (OR = 0.72). **Conclusion:** Dairy consumption, particularly milk, may have a protective role against CRC. Further randomized controlled trials are required to confirm these findings.

KEYWORDS

Colorectal Neoplasms; Dairy Products; Milk; Cohort Studies; Case-Control Studies; Meta-Analysis; Risk Reduction; Heterogeneity

INTRODUCTION

Colorectal cancer (CRC) is the third most common cancer worldwide and the second leading cause of cancer-related mortality. According to Bray et al. (2018), CRC represents a major global health burden, particularly affecting individuals over 50 years of age. Lifestyle factors such as diet, physical inactivity, obesity, smoking, and alcohol consumption significantly influence CRC risk. Among dietary factors, the potential role of dairy consumption in colorectal cancer prevention has received considerable attention (World Health Organization, 2025).

Several epidemiological studies have reported an inverse relationship between dairy intake and CRC risk. The protective effect is largely attributed to calcium present in dairy products, which can bind carcinogenic compounds in the intestinal lumen and reduce their harmful impact on the colorectal mucosa (Gil et al., 2022; Cohen et al., 2022; Bakken et al., 2018). The World Cancer Research Fund reported that each 400 g/day increase in dairy consumption may reduce CRC risk by approximately 13% (Xu, 2020; Jin et al., 2020).

Additionally, dairy products may exert protective effects through modulation of gut microbiota and the presence of bioactive compounds (Guo et al., 2021). Fermented dairy products such as yoghurt and cheese contain

beneficial bacteria that reduce inflammation and bacterial genotoxin production (Godos et al., 2019; Veettil et al., 2021; Liang et al., 2022; Zhang et al., 2018). Other compounds including vitamin D and lactoferrin may also contribute to CRC prevention (Zhang et al., 2020; Um et al., 2018; Collatuzzo et al., 2022).

However, some studies have reported inconsistent findings regarding specific dairy products and CRC risk (Barnung et al., 2019; Chan et al., 2022), although many studies support a protective association (Dik et al., 2014; Watling et al., 2023; Lanen et al., 2023). Previous meta-analyses have largely included studies published before 2020; therefore, updated evidence from recent studies is needed.

Aims and Objectives

- To evaluate the association between dairy product consumption and colorectal cancer risk.
- To assess the protective effects of different dairy products including milk and fermented dairy.
- To analyse observational studies published between 2020 and 2025.
- To examine variations in CRC risk across populations and dairy intake patterns.

MATERIALS & METHODS

Study Type and Study Design

This study was conducted as a systematic review and meta-analysis, with the protocol pre-registered in PROSPERO (CRD420251057416). The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009). The research question addressed was: *"Is dairy consumption associated with a reduced risk of colorectal cancer?"* The study followed the PICO framework, including observational studies and randomized controlled trials. The population consisted of adults diagnosed with colorectal cancer (CRC), the exposure was dairy product consumption, the comparison group included individuals without CRC, and the primary outcome was CRC incidence.

Study Setting: The review included studies retrieved from international databases including PubMed, Embase, Google Scholar, and Web of Science.

Study Population: The study population comprised adult participants (≥18 years) from cohort and case-control studies that evaluated the relationship between dairy consumption and colorectal cancer risk.

Study Duration: The literature search included studies published between January 2020 and March 2025.

Sample Size Calculation: As this study is a systematic review and meta-analysis, no primary sample size calculation was performed. The pooled sample included 821,865 participants across all eligible studies.

Inclusion Criteria: Studies were included if they:

- Included adults aged ≥18 years.
- Were cohort or case-control observational studies.
- Examined the association between dairy consumption and CRC prevention.
- Diagnosed CRC using established clinical or medical criteria.
- Reported risk estimates such as OR, RR, or HR with 95% CI, or provided sufficient data for calculation.
- Were published between 2020 and 2025.
- Reported results for individual dairy products separately when multiple dairy items were studied.

Exclusion Criteria: Studies were excluded if they:

- Were conducted on animals.
- Focused on pregnant women, children, or adolescents.
- Were reviews, editorials, commentaries, or meta-analyses.
- Did not report adequate data on dairy intake or CRC risk estimates.
- Were duplicate publications or conference abstracts without full text.
- Focused on colorectal adenomas or serrated lesions rather than CRC.

Strategy for Data Collection: A comprehensive search strategy was conducted using keywords such as "dairy," "dairy products," "milk," "yogurt," "cheese," "butter," "buttermilk," "cream," "ice cream," and "low-fat milk product." These were combined with terms related to colorectal cancer, including "colorectal carcinoma" and "colorectal cancer," using Boolean operators. Two independent reviewers screened titles and abstracts to remove irrelevant studies, followed by full-text assessment to identify eligible articles.

Working Definition: Dairy consumption referred to the intake of total dairy products (TDP), including milk, yogurt, cheese, butter, and other dairy-based foods. The outcome of interest was the incidence of colorectal cancer, confirmed using standard medical diagnostic criteria.

Ethical Issues and Informed Consent: As this study was based on previously published data, ethical approval and informed consent were not required.

Data Analysis: Data extracted included the first author's name, publication year, study location, study design, sample size, dairy product type, and risk estimates with 95% CI. Data extraction was performed independently by two reviewers (A and B), and disagreements were resolved by a third reviewer (C).

Quality assessment was performed using the ROBINS-I tool, which identified moderate risk of bias mainly in exposure measurement and confounding variables (Sterne and Hernán, 2016). Statistical analyses were conducted using R Studio software (Balduzzi et al., 2019).

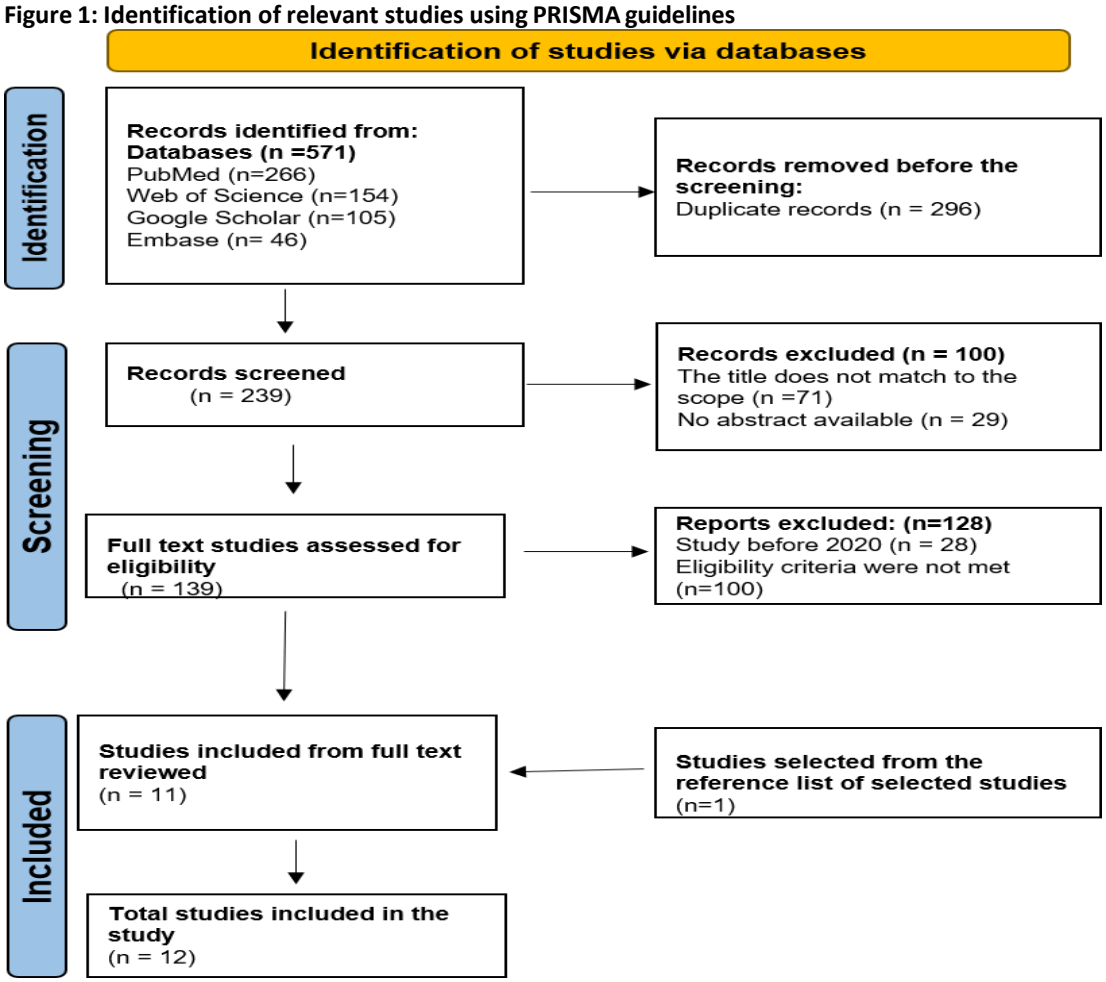
For meta-analysis, odds ratios (OR) from case-control studies and relative risks (RR) or hazard ratios (HR) from cohort studies were pooled using the inverse variance method described by DerSimonian and Laird (1986). Heterogeneity was assessed using Cochran's Q test and the I^2 statistic. Random-effects models were applied when heterogeneity exceeded 50% (Chen and Benedetti, 2017). Publication bias was evaluated using funnel plots, Egger's test, Begg's test, and Trim-and-Fill analysis (Duval and Tweedie, 2017). Sensitivity analysis, including leave-one-out analysis, was performed to assess the robustness of the pooled estimates.

Flow Diagram: The study selection process followed the PRISMA flow diagram, illustrating identification, screening, eligibility assessment, and final inclusion of studies.

RESULTS

Identification of Eligible Studies: The systematic database search identified 571 records. After removal of duplicate records and screening of titles and abstracts, potentially relevant studies underwent full-text assessment. Based on the predefined inclusion and exclusion criteria, 12 studies were finally included in the meta-analysis. The study selection process is presented in the PRISMA flow diagram (Figure 1).

Figure 1: Identification of relevant studies using PRISMA guidelines



Description of Included Studies: The final analysis included 12 observational studies, comprising both cohort and case-control designs. These studies collectively involved a large population sample evaluating the association between dairy consumption and colorectal cancer risk. In cases where individual studies assessed multiple dairy products separately, each exposure category was treated as an independent estimate in the meta-analysis. Detailed study characteristics are presented in **Tables 1 and 2**.

Table 1: Details of Case-control studies

Study details	Cou ntry	Age at baseline	Exposure	Valid ated FFQ	Sample (Control)	size Sample size Case	OD D Ratio	Lower CI	Upper CI	Reduced risk
Zhang et al., 2020	Chin a	35–75 (M & F)	Milk	Validated FFQ	2386	2380	0.52	0.48	0.77	Yes
Kinany et al.,2020	Mor occo	18-75(M &F)	Milk	Valid atedFFQ	1453	1453	0.84	0.74	0.96	Yes
Kinanyet al., 2020	Mor occo	18-76(M &F)	Yougurt	Validated FFQ	1453	1453	0.74	0.64	0.86	Yes
Sneyd and Cox2020	New Zealand	30–74(M &F)	Milk	Valid atedFFQ	174	116	0.65	0.45	0.95	Yes
Zargar et al.,2021	India	19–85(M &F)	Ghee- Healthy	Valid atedFFQ	100	100	0.15	0.08	0.29	Yes
Zargar et al.,2021	India	19–85(M &F)	Total dairy product-Healthy	Valid atedFFQ	100	100	0.61	0.34	1.07	Yes
Zargaret al., 2021	India	19–85(M &F)	Ghee- Hospital	Validated FFQ	100	100	0.27	0.14	0.52	Yes
Zargaret al., 2021	India	19–85(M &F)	Total dairyproduct- Hospital	Validated FFQ	100	100	0.05	0.01	0.17	Yes

Table 2: Details of Cohort studies

Stu dy det ails	Country	Age and Sex	Ex po su re	Dierty assessment	Sa ml e size	Numbe r of positive cases	R R Ra ti o	Lo w e r CI	Up p e r CI	Re duc edrisk
Mic hels et al., 2020	USA	Female 30–55years; Male40-75 years	Yo gu rt	Validated FFQ	1,26,323	2666	0. 84	0.7	0.99	Yes
Ni mpt sch et al., 2021	USA	25–42 (F)	To tal dai ry pr oduct	Validated FFQ and high school food frequencyquestionnaire	27,196	2239	0. 94	0.8	1.11	Yes
Pap adi mitr iouet al., 2022	European countries	35-70 (M & F)	Mi lk	Validated FFQ	3,86,792	5069	0. 95	0.93	0.98	Yes
Pap adi mitr iou et al., 2022	European countries	35-71 (M & F)	Ch ee se	Validated FFQ	3,86,792	5069	0. 96	0.94	0.99	Yes
Ki m et al., 2023	USA	25–42 (F)	To tal dai ry pr oduct	Validated FFQ	94205	349	0. 82	0.6	1.12	Yes
Wat ling et al., 2023	UK	37–73 (M& F)	To tal dai ry prod ucts	Oxford WebQ	1,14,217	1193	0. 8	0.67	0.94	Yes
Wat ling et al., 2023	UK	37–73 (M& F)	Mi lk	Oxford WebQ	1,14,217	1193	0. 79	0.67	0.94	Yes
Pras ath and Nav ane etha n, 2024	USA	59-74 (M & F)	Lo w- fat bu tte r	Diet HistoryQuestionnaire (DHQ)	1,54,892	2359	0. 72	0.37	1.37	Yes
van Lan en et al., 2024	Netherla nds, EuropeanCOunty	59-72 (M & F)	To tal dai ry pr oduct	Validated FFQ	2,283	331	0. 6	0.43	0.83	Yes
Pap ier et al., 2025	UK	45-75 (F)	To tal dai ry pr od ucts	Validated FFQ	542,778	2352	0. 86	0.81	0.92	Yes

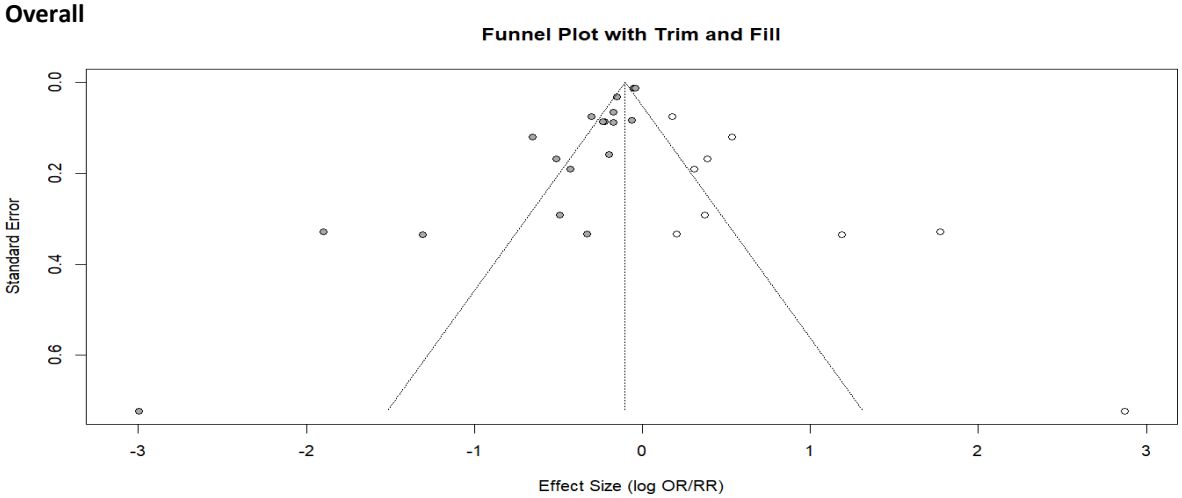
Characteristics of Included Studies

The included studies were conducted across several geographical regions including North America, Europe, Asia, and Africa, reflecting diverse dietary patterns and population characteristics. Some cohort studies focused on specific population groups, such as female participants. Overall, most studies reported an inverse association between dairy intake and colorectal cancer risk. Detailed information regarding study location, population characteristics, and risk estimates is summarized in Tables 1 and 2.

Risk of Bias and Publication Bias Assessment

Quality assessment indicated that the included studies were classified as either low or moderate risk of bias, with no studies categorized as high risk. Assessment of publication bias using a funnel plot suggested possible asymmetry (Figure 2). Statistical testing using Begg and Mazumdar's rank correlation test indicated potential publication bias ($p < 0.05$). Therefore, trim-and-fill analysis was performed to evaluate the influence of missing studies on the pooled estimate.

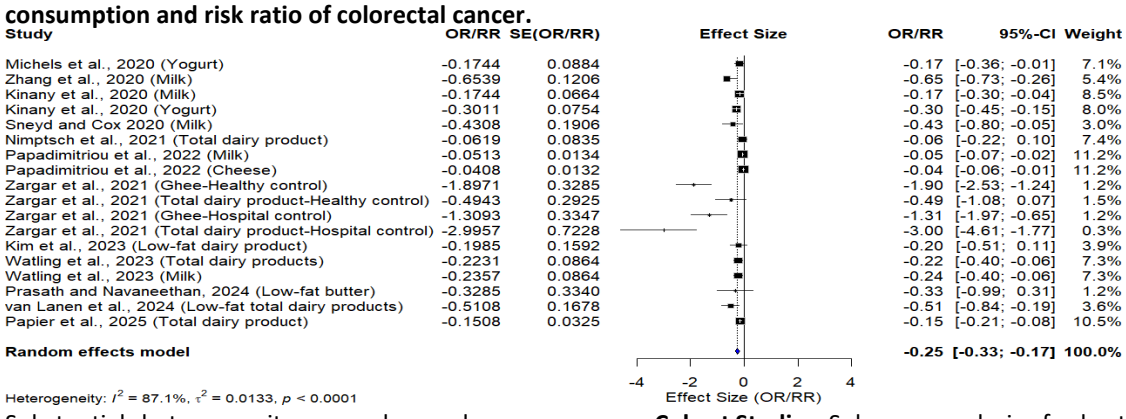
Figure 2: Funnel plot trim and fill symmetry analysis to check the presence or absence of publication bias Overall



Meta-analysis

A meta-analysis was performed to evaluate the association between dairy consumption and colorectal cancer risk. Due to the presence of heterogeneity among studies, a random-effects model was applied for pooling effect estimates. The combined analysis demonstrated a significant protective association between dairy consumption and colorectal cancer risk, indicating a reduced risk among individuals with higher dairy intake. The overall forest plot illustrating the pooled effect estimate is presented in Figure 3.

Figure 3: Random effects meta-analysis of all studies included for metaanalysis that examined dairy consumption and risk ratio of colorectal cancer.



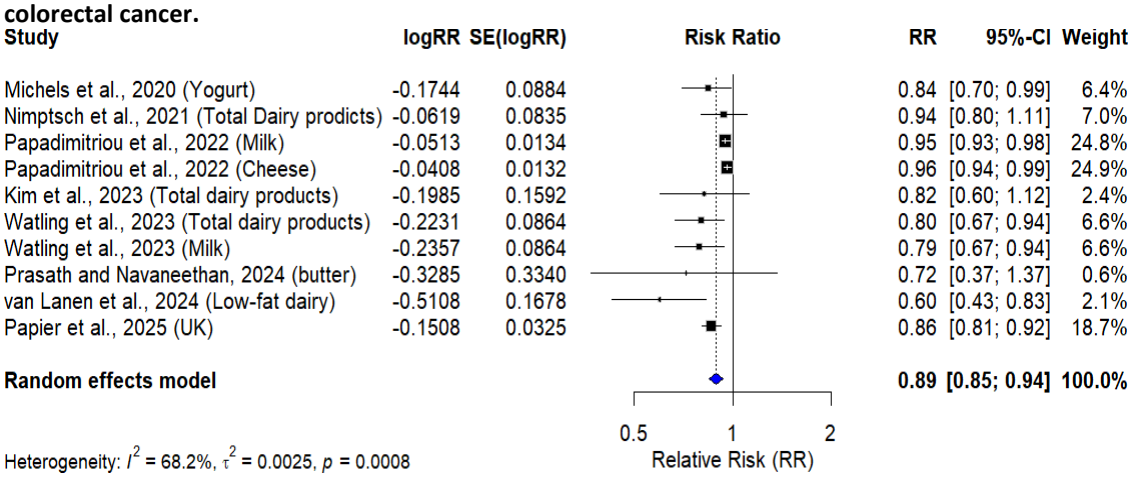
Substantial heterogeneity was observed among studies, which may be attributed to differences in study design, population demographics, dietary assessment methods, and types of dairy products evaluated.

Subgroup Analysis

Cohort Studies: Subgroup analysis of cohort studies showed a protective association between dairy consumption and colorectal cancer risk, although variability across studies was observed. Differences in population characteristics, exposure assessment methods, and dairy product types may explain the

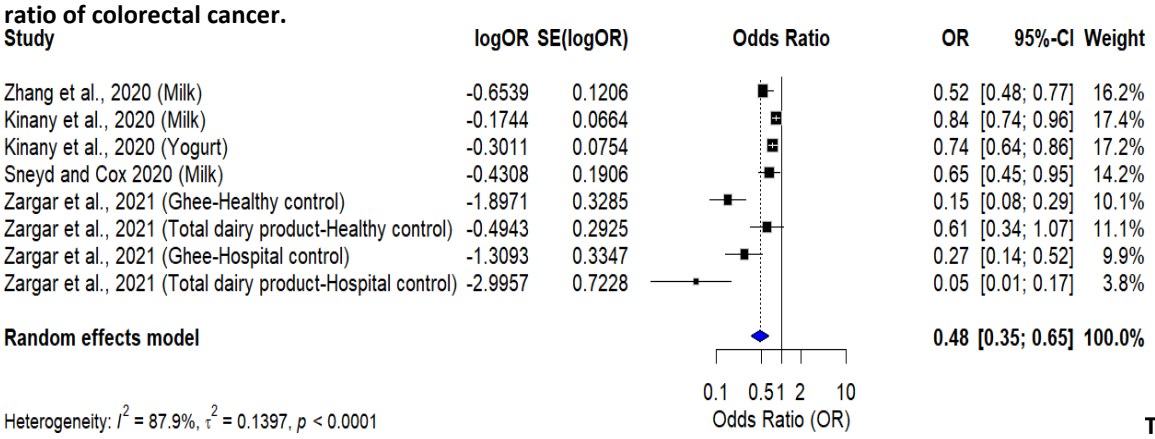
heterogeneity. The pooled results for cohort studies are presented in Figure 4.

Figure 4: Random effects meta-analysis of cohort studies that examined dairy consumption and risk ratio of colorectal cancer.



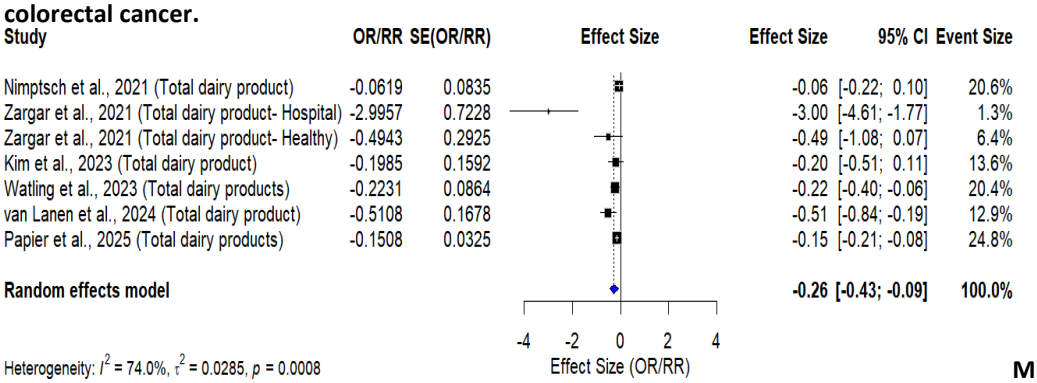
Case-Control Studies: The analysis of case-control studies also demonstrated a protective relationship between dairy intake and colorectal cancer risk, with some studies reporting stronger associations compared with cohort studies. However, heterogeneity among studies remained high. The pooled analysis for case-control studies is shown in Figure 5.

Figure 5: Random effects meta-analysis of case-control studies that examined dairy consumption and risk ratio of colorectal cancer.



Total Dairy Product Intake: Studies evaluating total dairy product consumption indicated a potential protective effect against colorectal cancer. The pooled effect estimates from these studies are presented in Figure 6, demonstrating variability in study results but an overall protective trend.

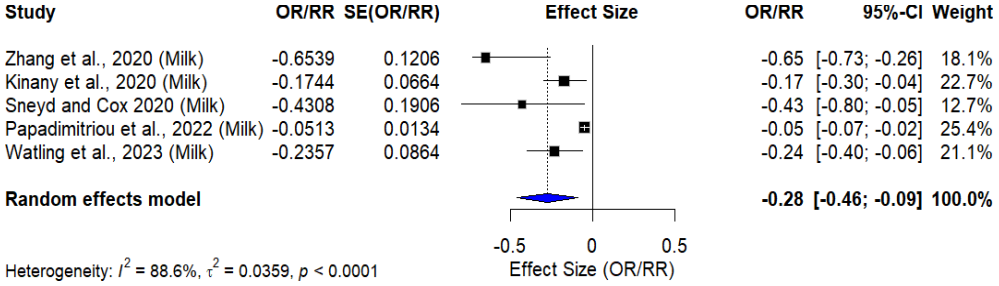
Figure 6: Subgroup meta-analysis of studies that examined total dairy product consumption and risk ratio of colorectal cancer.



Milk Consumption

A separate subgroup analysis of milk intake suggested a protective association between milk consumption and colorectal cancer risk. The pooled results from these studies are illustrated in Figure 7, although heterogeneity remained substantial.

Figure 7: Subgroup meta-analysis of studies that examined milk consumption and risk ratio of colorectal cancer.



DISCUSSION

This meta-analysis provides updated evidence on the association between dairy consumption and colorectal cancer (CRC) risk by synthesizing observational studies published between 2020 and 2025. The pooled findings indicate that higher dairy intake is associated with a protective effect against colorectal cancer, supporting the hypothesis that dietary factors may play an important role in CRC prevention. These findings are consistent with recent epidemiological studies reporting an inverse association between dairy consumption and CRC incidence.

Recent research has suggested that dairy products may reduce CRC risk through several biological mechanisms. Calcium present in dairy products can bind carcinogenic bile acids and fatty acids in the intestinal lumen, thereby reducing mucosal irritation and limiting carcinogenic exposure. In addition, dairy products contain bioactive components such as vitamin D, lactoferrin, and probiotics, which may contribute to anti-inflammatory and anti-tumorigenic effects within the gastrointestinal tract. These mechanisms have been highlighted in recent nutritional epidemiology studies investigating the relationship between dairy intake and cancer prevention (Watling et al., 2023; Liang et al., 2022).

Our findings are broadly consistent with previous systematic reviews and meta-analyses. For example, Jin et al. (2020) reported a significant reduction in CRC incidence and mortality associated with higher dairy consumption, while Guo et al. (2021) demonstrated an inverse relationship between dairy intake and the development of colorectal cancer precursors. Similarly, large prospective cohort analyses have also reported that higher dairy and calcium intake are associated with lower CRC risk across diverse populations (Watling et al., 2023).

Subgroup analyses in the present study further suggest that the protective effect may vary according to the type of dairy product consumed. Milk intake demonstrated a relatively consistent protective association across studies, whereas fermented dairy products showed more variable results. These findings are partially supported by recent meta-analyses indicating that milk consumption may be more strongly associated with reduced CRC risk compared with other dairy products (Zhang et al., 2021). Differences in nutrient composition, fermentation processes, and probiotic content may explain these variations.

Another important observation from this analysis is the variation in study findings across different geographical regions. Differences in dietary habits, dairy consumption patterns, and lifestyle factors may contribute to variations in CRC risk. For example, a large prospective study conducted in China reported no significant association between dairy intake and CRC risk, highlighting the potential influence of regional dietary patterns and genetic factors (Kakkoura et al., 2022). Such variations suggest that the protective effect of dairy consumption may not be uniform across populations.

Despite the overall protective association observed in this meta-analysis, substantial heterogeneity was present among the included studies. This heterogeneity may be explained by differences in study design, dietary assessment methods, and population characteristics. Many studies relied on self-reported dietary questionnaires, which may introduce recall bias and measurement errors. Additionally, the differences observed between cohort and case-control studies may reflect variations in study methodology and follow-up duration.

CONCLUSION

This updated systematic review and meta-analysis indicates that higher dairy consumption is associated with a reduced risk of colorectal cancer. The findings suggest that dairy products, particularly milk and calcium-rich varieties, may contribute to CRC prevention. Although

heterogeneity exists among studies, the overall evidence supports the potential protective role of dairy intake in colorectal cancer risk reduction.

The study adds to current knowledge by synthesizing recent observational evidence (2020–2025) and highlighting variations in the protective effects of different dairy products. However, given the observational nature of the included studies, further large-scale prospective studies and randomized controlled trials are required to confirm these findings and clarify the underlying biological mechanisms.

Recommendation

Moderate consumption of dairy products, particularly milk and low-fat dairy, may help reduce colorectal cancer risk. Public health strategies should promote balanced diets including calcium-rich foods, while further research is needed to confirm these findings.Limitation of the study

Several limitations should be considered when interpreting the findings of this meta-analysis. First, the included studies were observational in nature, which limits the ability to establish a causal relationship between dairy consumption and CRC risk. Second, substantial heterogeneity was observed across studies, likely due to differences in dietary assessment methods, study populations, and exposure definitions. Third, most studies relied on self-reported dietary intake, which may be subject to recall bias or measurement error. Finally, variations in dairy product types and processing methods were not consistently reported across studies, which may influence the observed associations. Relevance of the study

Despite these limitations, the present study provides updated and comprehensive evidence on the association between dairy consumption and colorectal cancer risk by focusing on recent observational studies. By synthesizing the latest research, this meta-analysis contributes to the growing body of evidence supporting the potential protective role of dairy products in colorectal cancer prevention. The findings may help inform dietary recommendations and public health strategies aimed at reducing the global burden of colorectal cancer.

Future research should focus on large-scale prospective studies and randomized controlled trials to better understand the causal relationship between dairy intake and colorectal cancer risk. Further investigations examining the role of different dairy products, processing methods, and population-specific dietary patterns would also provide valuable insights into CRC prevention strategies.Authors Contribution

VKS: Conceptualized and designed the study, SA: Data extraction, quality assessment, SKG: Data analysis and interpretation. SKJ: Methodological guidance and contributed to study design, SS: P Supervised the study and reviewed the manuscript for important intellectual content. All authors read and approved the final manuscript.

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Nil

Conflict of Interest

None

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Declaration of Generative AI and AI Assisted Technologies in the Writing Process

The authors declare that no generative AI or AI-assisted technologies were used in the preparation, writing, or editing of this manuscript.

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