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Jing-Xian Fang

Shidong Hospital, Yangpu District, Shanghai, China

Fang Huang

Shidong Hospital, Yangpu District, Shanghai, China

Qing Gu

Shidong Hospital, Yangpu District, Shanghai, China

Jian Meng

Shidong Hospital, Yangpu District, Shanghai, China

Hui-Ming Zou

Shidong Hospital, Yangpu District, Shanghai, China

Yu Han

Shidong Hospital, Yangpu District, Shanghai, China

Yue-Xia Han

Shidong Hospital, Yangpu District, Shanghai, China

Hui-Zhen Liu

Shidong Hospital, Yangpu District, Shanghai, China

Xue Hu

Shidong Hospital, Yangpu District, Shanghai, China

Qian-Wen Ma

Shidong Hospital, Yangpu District, Shanghai, China

Xi-Shuang Chen

Shidong Hospital, Yangpu District, Shanghai, China

Sui-Jun Wang

drwangsui.jun@163.com

Shidong Hospital, Yangpu District, Shanghai, China

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Effects of different beverages on glycemic control in patients with type 2 diabetes: a systematic review and meta-analysis of randomized controlled trials

Jing-Xian Fang^{†1}, **Fang Huang**^{†1}, **Qing Gu**¹, **Jian Meng**¹, **Hui-Ming Zou**¹, **Yu Han**¹, **Yue-Xia Han**¹, **Hui-Zhen Liu**¹, **Xue Hu**¹, **Qian-Wen Ma**¹, **Xi-Shuang Chen**^{*1}, **Sui-Jun Wang**^{*1}

¹ Yangpu District Shidong Hospital of Shanghai, Endocrinology and Metabolism

address: No.999, Shiguang Road, Yangpu District, Shanghai, China

ZIP code: 200438

***CORRESPONDENCE**

Sui-Jun Wang; Yangpu District Shidong Hospital of Shanghai, Endocrinology and Metabolism

e-mail address: drwangsuijun@163.com

Xi-Shuang Chen; Yangpu District Shidong Hospital of Shanghai, Endocrinology and Metabolism

e-mail address: drchenxishuang@126.com

Contributing authors

Jing-Xian Fang; Yangpu District Shidong Hospital of Shanghai, Endocrinology and Metabolism

e-mail address: fjx2012bbt@163.com

Fang Huang; Yangpu District Shidong Hospital of Shanghai, Endocrinology and Metabolism

e-mail address: drhuangfangsd@sina.com

Qing Gu; Yangpu District Shidong Hospital of Shanghai, Endocrinology and Metabolism

e-mail address: drquingsd@163.com

Jian Meng; Yangpu District Shidong Hospital of Shanghai, Endocrinology and Metabolism

e-mail address: drmengjian@163.com

Hui-Ming Zou; Yangpu District Shidong Hospital of Shanghai, Endocrinology and Metabolism

e-mail address: drzouhuiming@163.com

Yu Han; Yangpu District Shidong Hospital of Shanghai, Endocrinology and Metabolism

e-mail address: drhanyusd@sina.com

Yue-Xia Han; Yangpu District Shidong Hospital of Shanghai, Endocrinology and Metabolism

e-mail address: drhanyuexia@126.com

Hui-Zhen Liu; Yangpu District Shidong Hospital of Shanghai, Endocrinology and Metabolism

e-mail address: drliuhuizhen@163.com

Xue Hu; Yangpu District Shidong Hospital of Shanghai, Endocrinology and Metabolism

e-mail address: drhuxue@163.com

Qian-Wen Ma; Yangpu District Shidong Hospital of Shanghai, Endocrinology and Metabolism

e-mail address: drmaqianwen@163.com

†These authors share first authorship

Abstract

Background

The role of specific beverages as adjunctive strategies for glycemic control in type 2 diabetes mellitus (T2DM) remains unclear. This systematic review and meta-analysis aimed to evaluate the effects of different beverage interventions—including tea, wine, water, and other beverages—on glycemic control in patients with T2DM.

Methods

A systematic search of PubMed and Web of Science was conducted up to April 27, 2026. Randomized controlled trials (RCTs) assessing beverage-based interventions in patients with T2DM were included. The primary outcome was the change in glycated hemoglobin (HbA1c). Hedges' g with 95% confidence intervals (CIs) were calculated using random-effects models. Heterogeneity was assessed using the I^2 statistic. Risk of bias was evaluated using the Cochrane RoB 2.0 tool.

Results

Twenty-three RCTs comprising 1,368 participants were included. Pooled analysis demonstrated that beverage interventions significantly reduced HbA1c compared with controls (Hedges' $g = -0.37$; 95% CI: -0.58 to -0.16 ; $P < 0.001$), with substantial heterogeneity ($I^2 = 71.6\%$). Subgroup analyses revealed that tea interventions (12 studies) significantly reduced HbA1c (Hedges' $g = -0.34$; 95% CI: -0.55 to -0.13 ; $P = 0.001$; $I^2 = 40.2\%$). Wine interventions (5 studies) showed no significant effect (Hedges' $g = -0.15$; 95% CI: -0.86 to 0.56 ; $P = 0.68$; $I^2 = 84.2\%$), and water interventions (3 studies) demonstrated a non-significant trend (Hedges' $g = -0.36$; 95% CI: -0.94 to 0.22 ; $P = 0.22$; $I^2 = 80.5\%$). Other interventions (beetroot juice, omega-3, high-fiber diet with coffee) showed a significant reduction (Hedges' $g = -0.54$; 95% CI: -1.06 to -0.02 ; $P = 0.04$; $I^2 = 0.0\%$). Only one study (4.3%) was rated as low risk of bias overall; the majority (82.6%) had some concerns.

Conclusion

Tea consumption is associated with a modest but statistically significant improvement in glycemic control in patients with T2DM. Wine and water interventions did not demonstrate consistent benefits. The overall evidence quality is limited by methodological concerns and substantial heterogeneity. Tea may be considered as an adjunctive dietary strategy, but should not replace established diabetes treatments. High-quality, long-term RCTs are needed to confirm these

findings.

Keywords

Type 2 diabetes; glycemic control; tea; wine; water; beverage; HbA1c; meta-analysis; systematic review; randomized controlled trial

Registration: PROSPERO CRD420261392072

Introduction

Type 2 diabetes (T2DM) is a chronic metabolic disease characterized by hyperglycemia resulting from insulin resistance and the progressive decline of pancreatic beta-cell function. Globally, the prevalence of type 2 diabetes has reached epidemic proportions; it is estimated that in 2021, 537 million adults aged 20 to 79, and it is projected to rise to 783 million by 2045 [1]. This disease is associated with significant morbidity and mortality due to microvascular and macrovascular complications. Achieving and maintaining optimal glycemic control is the cornerstone of diabetes management, with the aim of preventing or delaying the onset of these complications [2].

Lifestyle modifications remain an integral part of type 2 diabetes management, just as much as pharmacological treatment [3]. Current clinical guidelines recommend personalized medical nutrition therapy, with a focus on weight management, the quality and quantity of carbohydrates, and dietary patterns such as the Mediterranean diet [4]. In recent years, there has been growing interest in the potential role of specific beverages, including tea, wine, and water, as adjunctive strategies to improve glycemic control [5].

Tea, derived from plants of the *Camellia* genus, is one of the most widely consumed beverages worldwide. Epidemiological studies consistently indicate that regular tea consumption is inversely associated with the risk of developing type 2 diabetes (T2DM). Green tea is rich in catechins, particularly epigallocatechin gallate (EGCG), which preclinical studies have shown to possess antioxidant, anti-inflammatory, and insulin-sensitizing properties [6]. Black tea is produced through fermentation and contains theaflavins and thearubigins, which may also exert beneficial effects on metabolism [7]. Herbal teas such as chamomile, hibiscus, and rooibos have been traditionally used for their medicinal properties, and emerging evidence suggests they may possess antidiabetic effects [8].

Moderate alcohol consumption, particularly red wine, has been shown to be associated with a reduced risk of cardiovascular disease in the general population; this effect is typically attributed to polyphenolic compounds such as resveratrol [9]. However, the impact of alcohol on glycemic control in patients with diagnosed type 2 diabetes (T2DM) remains controversial [10] [11]. While some studies suggest that moderate wine consumption may improve insulin sensitivity and reduce postprandial hyperglycemia [12], other studies have found no benefit and have even reported potential harm, including an increased risk of hypoglycemia, particularly in patients receiving insulin therapy [13].

Other beverages, including beetroot juice, coffee, and various herbal teas, have also been studied for their potential metabolic effects on type 2 diabetes (T2DM) [14] [15] [16]. However, the current evidence remains incomplete, and there is a lack of direct comparisons among beverage types.

Several meta-analyses have examined the effects of various beverage types on glycemic control in patients with type 2 diabetes (T2DM). However, to date, no comprehensive systematic review has compared the effects of multiple beverage categories—including tea, alcohol, water, and other beverages—on glycemic control within a single analytical framework. The aims of this systematic review and meta-analysis were to evaluate the effects of different beverage interventions (tea, wine, water, and other beverages) on glycemic control in patients with T2DM.

Methods

Protocol and Guidance

This systematic review and meta-analysis were conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline. The study protocol has been registered in the PROSPERO database (registration number: CRD420261392072).

Study Selection: Inclusion and Exclusion Criteria

Studies were included if they met the following criteria based on the PICOS framework:

Participants (P)

Patients with a confirmed diagnosis of type 2 diabetes mellitus (T2DM) based on standard diagnostic criteria (e.g., American Diabetes Association or World Health Organization criteria). No restrictions on disease duration, glycemic control status, or concomitant medications (except where explicitly specified in exclusion criteria).

Interventions (I)

Beverage-based interventions, including but not limited to: Tea (green tea, black tea,

chamomile tea, herbal tea, oolong tea, white tea, or other tea-based beverages), Wine (red wine, white wine, or dealcoholized wine), Water (plain water, pre-meal water, post-meal water, or water as substitute for other beverages), Other beverages (beetroot juice, coffee, artificially sweetened beverages, vegetable juices, or fruit juices). No restrictions on dosage, frequency, duration, or mode of administration.

Comparators (C)

Control interventions included placebo, no intervention, usual diet, alternative beverages (e.g., water, non-alcoholic beer), or standard care. Co-interventions were balanced between groups when applicable.

The primary outcome was the change in glycated hemoglobin (HbA1c) from baseline to the end of intervention. Secondary outcomes included glycemic measures (fasting plasma glucose, 2-hour postprandial glucose, fasting insulin, C-peptide, HOMA-IR, HOMA- β , fructosamine, and Green Fluorescent Protein (GSP)), lipid profile, anthropometric measures, blood pressure, inflammatory markers, oxidative stress markers, as well as endothelial function, heart rate variability, bone turnover markers, and continuous glucose monitor metrics.

Study Designs (S)

Eligible study designs included randomized controlled trials (RCTs) with either parallel-group or crossover designs. Only studies published in peer-reviewed journals were considered for inclusion. No restrictions were applied regarding publication date or language to minimize the risk of publication bias and to ensure a comprehensive synthesis of the available evidence.

Information Sources and Search Strategy

A comprehensive systematic literature search was conducted on April 27, 2026, using PubMed and Web of Science electronic databases. The search strategy was developed by an experienced medical librarian and peer-reviewed using the Peer Review of Electronic Search Strategies (PRESS) checklist. It combined terms related to "type 2 diabetes," "beverages," "tea," "wine," "water," and "randomized controlled trials," with no language or date restrictions applied. The complete search strategy is provided in Supplementary Table S1.

Two researchers independently conducted the literature screening. Initially, duplicate records were eliminated using EndNote. Subsequently, a preliminary screening was conducted by examining titles and abstracts to exclude studies clearly irrelevant to the inclusion criteria. Following that, a full-text review was performed to confirm the final inclusion of studies. Any disagreements that arose between the two researchers during the screening were settled through discussion and consensus; when an agreement could not be reached, a third researcher made the final ruling. The entire screening process, along with the reasons for exclusion, is illustrated in the PRISMA flowchart (Figure 1).

Risk of Bias Assessment

The Cochrane RoB 2.0 tool was employed to assess bias risk across five domains: randomization, intervention deviations, missing outcome data, outcome measurement, and selective reporting. Each domain and the overall bias were rated as low-, moderate-, or high-risk. Two researchers independently rated the studies, resolving discrepancies through discussion or third-party involvement. A risk-of-bias summary plot was used to visualize the findings, and a sensitivity analysis was performed by excluding studies with a high risk of bias.

Statistical Analysis

All statistical analyses were performed using R version 4.1.0 with the meta and metafor packages.

For studies reporting change-from-baseline data, the change score method was used. For studies reporting only baseline and endpoint values, post-intervention means were used with adjustment for baseline values where possible.

Effect sizes with 95% confidence intervals (CIs) were calculated for each study. A negative Hedges' g favored the intervention (beverage) over the control, indicating improved glycemic control (lower HbA1c).

When available, intention-to-treat (ITT) data were preferentially extracted. In cases where ITT data were not reported, per-protocol or completer analysis data were used instead. For binary outcomes, the denominator was defined as the total number of randomized participants, strictly following the ITT principle.

Heterogeneity was evaluated using Cochran's Q test and the I^2 statistic. An I^2 value below 50% accompanied by a Q test P -value greater than 0.10 indicated acceptable heterogeneity, prompting the use of a fixed-effects model. In contrast, substantial heterogeneity—defined as $I^2 \geq 50\%$ or Q test $P \leq 0.10$ —led to the application of a random-effects model using the Der Simonian-Laird method. All statistical tests were two-tailed, with statistical significance set at $P < 0.05$.

Publication bias was assessed through a three-pronged approach: (1) visual examination of funnel plot symmetry; (2) Egger's regression test for continuous outcomes and Harbord's test for binary outcomes; and (3) trim-and-fill analysis to adjust for any detected asymmetry.

To test the robustness of the results, several sensitivity analyses were carried out: (1) a leave-one-out analysis, in which each study was sequentially removed and the pooled effect recalculated; (2) a quality-based sensitivity analysis that excluded studies judged to have a high risk of bias; and (3) a small-study sensitivity analysis that excluded studies with small sample sizes (e.g., total sample size below 20).

Result

Study Characteristics

Literature Search and Study Selection

A systematic search of electronic databases (PubMed and Web of Science) from inception to April 27, 2026, identified 399 potentially relevant records. After removing duplicates ($n = 201$), 198 records were screened by title and abstract. Of these, 115 records were excluded as they did not meet the inclusion criteria. The remaining 83 full-text articles were assessed for eligibility, of which 60 were excluded for the following reasons: non-randomized design ($n = 18$), no relevant outcome data ($n = 14$), duplicate publication ($n = 10$), intervention not beverage-based ($n = 9$), abstract only without full data ($n = 5$), and ongoing trials without results ($n = 4$). Finally, 23 randomized controlled trials (RCTs) met the inclusion criteria and were included in the systematic review and meta-analysis [12] [13] [17] [18] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30] [31] [32] [33] [34] [35] [36] [37] (Figure 1).

Characteristics of Included Studies

The 23 included studies were published between 1989 and 2026, with the majority ($n = 17$, 73.9%) published after 2010. A total of 1368 participants with type 2 diabetes mellitus (T2DM) were enrolled across all studies, with sample sizes ranging from 12 to 179 participants per study.

Participant Characteristics

The mean age of participants ranged from 35 to 70 years, with most studies including participants aged 45–65 years. The mean baseline HbA1c ranged from 5.8% to 11.3%. The mean baseline body mass index (BMI) ranged from 25.0 to 35.0 kg/m².

Outcome Measures

The primary outcome was HbA1c. Secondary outcomes included glycemic measures, lipid profile, anthropometric measures, blood pressure, inflammatory markers, oxidative stress markers, endothelial function, HRV, bone turnover markers, and CGM metrics.

Meta-Analysis Results

Overall Effect of Beverage Interventions on HbA1c

A total of 23 studies with 1368 participants were included in the meta-analysis of the effect of beverage interventions on HbA1c. Using a random-effects model to account for anticipated heterogeneity, the pooled analysis demonstrated that beverage interventions significantly reduced HbA1c compared with control interventions (Hedges' $g = -0.37$; 95% CI: -0.58 to -0.16 ; $P < 0.001$) (Figure 2).

Subgroup Analysis by Intervention Type

Subgroup analyses were conducted by beverage intervention type: wine (alcoholic) [12] [13] [17] [18] [30], tea (herbal/green/black) [19] [20] [21] [22] [24] [25] [26] [28] [32] [33] [34] [36], water (pre-meal/post-lunch/ASB substitution) [23] [27] [35], and other interventions (beetroot juice, omega-3, dietary patterns) [29] [31] [37].

Wine Interventions (5 studies)

The pooled analysis of five wine intervention studies showed no significant effect on HbA1c compared with control (Hedges' $g = -0.15$; 95% CI: -0.86 to 0.56 ; $P = 0.68$). Substantial heterogeneity was observed ($I^2 = 84.2\%$, $P < 0.001$), likely due to variations in wine type (red vs. mixed), alcohol dose (11-36 g/day), intervention duration (2 weeks to 12 months), and control conditions (prohibition, non-alcoholic beer, no intervention). When the non-randomized study (Napoli 2005) was excluded, the pooled effect remained non-significant (Hedges' $g = -0.05$; 95% CI: -0.58 to 0.48).

Tea Interventions (12 studies)

Tea interventions demonstrated a statistically significant reduction in HbA1c compared with control (Hedges' $g = -0.34$; 95% CI: -0.55 to -0.13 ; $P = 0.001$). Heterogeneity was moderate ($I^2 = 40.2\%$, $P = 0.07$).

Water Interventions (3 studies)

Water interventions showed a non-significant trend toward HbA1c reduction (Hedges' $g = -0.36$; 95% CI: -0.94 to 0.22 ; $P = 0.22$). However, substantial heterogeneity was observed ($I^2 = 80.5\%$, $P = 0.006$). Notably, the largest and highest-quality study (Odegaard 2026 [SODAS]) [35] found that substituting water for artificially sweetened beverages resulted in a higher HbA1c compared with continuing ASBs (Hedges' $g = 0.26$; 95% CI: 0.03 to 0.49), suggesting that water substitution may not be beneficial in this context.

Other Interventions (3 studies)

Other interventions (beetroot juice, omega-3, high fiber + coffee diet) showed a significant reduction in HbA1c (Hedges' $g = -0.54$; 95% CI: -1.06 to -0.02 ; $P = 0.04$), with no evidence of heterogeneity ($I^2 = 0.0\%$). However, the small number of studies and participants limits the reliability of this finding.

Sensitivity Analysis (Leave-One-Out Meta-Analysis)

A leave-one-out sensitivity analysis was performed to assess the influence of individual studies on the pooled effect estimate (Figure 4). The pooled Hedges' g remained statistically significant across all iterations, ranging from -0.41 (95% CI: -0.62 to -0.20) when omitting Odegaard (2026)

[35] to -0.31 (95% CI: -0.52 to -0.11) when omitting Madjd (2016) [27]. These results indicate that no single study disproportionately influenced the overall effect estimate, supporting the robustness of the findings (Figure 4).

Overall Risk of Bias

The distribution of risk of bias across the 23 studies is summarized in Table 2 and Figure 5. Overall, the methodological quality of the included studies was suboptimal, with only one study (4.3%) rated as low risk of bias across all domains, 19 studies (82.6%) rated as having some concerns, and 3 studies (13.0%) rated as high risk of bias (Figure 6).

Seven studies were rated as low risk of bias in at least four of five domains and classified as having some concerns overall [13] [21] [23] [27] [28] [32] [33]. These studies generally had adequate randomization, low dropout rates, and pre-registered protocols, but were downgraded due to open-label designs (preventing blinding of participants to beverage interventions) or a lack of ITT analysis.

Notably, more recent studies (published after 2015) demonstrated improved methodological quality, with higher rates of pre-registration, ITT analysis, and blinding of outcome assessors. The single highest-quality study (Odegaard 2026 [SODAS]) [35] was published in 2026 and met all RoB 2 criteria for low risk of bias.

Discussion

This systematic review and meta-analysis of 23 randomized controlled trials involving 1,368 participants with type 2 diabetes mellitus (T2DM) evaluated the effects of different beverage interventions on glycemic control, with HbA1c as the primary outcome. The pooled analysis demonstrated that beverage interventions significantly reduced HbA1c compared with control interventions (Hedges' $g = -0.37$; 95% CI: -0.58 to -0.16; $P < 0.001$), with substantial heterogeneity across studies ($I^2 = 71.6\%$). Subgroup analyses revealed that tea interventions were associated with a modest but statistically significant reduction in HbA1c (Hedges' $g = -0.34$; 95% CI: -0.55 to -0.13; $P = 0.001$), whereas wine and water interventions showed no significant effects. The overall evidence quality was limited by methodological concerns, as only one study (4.3%) was rated as low risk of bias, while the majority (82.6%) had some concerns, and three studies (13.0%) were rated as high risk of bias.

The finding that tea consumption significantly improved glycemic control is consistent with previous systematic reviews and meta-analyses [38]. Several biological mechanisms may explain the antidiabetic effects of tea, particularly green and black tea, which are rich in polyphenolic compounds such as catechins, epigallocatechin gallate (EGCG), theaflavins, and thearubicins. These compounds have been shown to inhibit intestinal glucose absorption by suppressing sodium-

dependent glucose transporter 1 (SGLT1) and facilitate glucose uptake in peripheral tissues via activation of AMP-activated protein kinase (AMPK) [39]. Additionally, tea polyphenols may preserve pancreatic β -cell function by reducing oxidative stress and inflammation, improve insulin sensitivity, and modulate the gut microbiota [40]. The moderate heterogeneity ($I^2 = 40.2\%$) observed in the tea subgroup suggests that the effects are relatively consistent across different types of tea (green, black, chamomile, herbal) and study populations, although the included studies varied considerably in tea dosage, preparation methods, and intervention duration.

The absence of significant benefit from wine interventions on HbA1c is noteworthy. While moderate alcohol consumption has been associated with reduced cardiovascular risk in observational studies, the effects on glycemic control in T2DM remain controversial [41] [42]. The substantial heterogeneity ($I^2 = 84.2\%$) among wine studies reflects important differences in study design, intervention protocols, and participant characteristics. Notably, the non-randomized study (Napoli, 2005) [18], which reported a strong favorable effect (Hedges' $g = -1.15$), likely introduced bias due to lack of randomization and allocation concealment. After excluding this study, the pooled effect became negligible (Hedges' $g = -0.05$). Furthermore, the potential risks associated with alcohol consumption, including hypoglycemia, weight gain, and drug interactions, must be considered when interpreting these findings. Current clinical guidelines generally advise caution regarding alcohol intake in patients with T2DM, and the present results do not support recommending wine consumption specifically for glycemic control.

The finding that water interventions did not significantly improve HbA1c, with a trend toward a small effect (Hedges' $g = -0.36$) that was not statistically significant, requires careful interpretation. The high heterogeneity ($I^2 = 80.5\%$) across the three water studies is striking. Notably, the largest and most methodologically rigorous study (Odegaard 2026 [SODAS]) [35] found that substituting water for artificially sweetened beverages resulted in a slightly higher HbA1c compared with continuing ASB consumption (Hedges' $g = 0.26$; 95% CI: 0.03 to 0.49). This counterintuitive finding suggests that the relationship between beverage choices and glycemic control is complex and may be influenced by compensatory dietary behaviors, participant preferences, and the specific context of the intervention. The other two water studies, which reported favorable effects (Madjd 2016: Hedges' $g = -1.21$; Sedaghat 2021: Hedges' $g = -0.33$) [23] [27], were conducted in the context of structured weight loss programs, suggesting that the benefits of water consumption may be realized primarily when it replaces calorie-containing beverages as part of a comprehensive dietary intervention. In the absence of such a program, as in the SODAS trial, simply substituting water for ASBs may not confer additional glycemic benefits.

The overall effect size observed in this meta-analysis (Hedges' $g = -0.37$) is comparable to or slightly smaller than previous meta-analyses of specific beverage types. A meta-analysis of green tea consumption in T2DM reported a weighted mean difference in HbA1c of -0.30% (95% CI: -0.43 to -0.17), consistent with our findings [43]. Similarly, a meta-analysis of coffee consumption

reported a reduction in T2DM risk but limited effects on glycemic control in patients with established diabetes [44]. Our subgroup analysis for wine interventions aligns with previous systematic reviews that have found no consistent benefit of moderate alcohol consumption on HbA1c in T2DM [45]. The present study extends the existing literature by providing a comprehensive comparison across multiple beverage types within a single analytical framework, enabling direct comparisons of effect sizes and the identification of differential effects.

Implications for Clinical Practice and Public Health

Based on the available evidence, tea consumption may offer a modest benefit for glycemic control in patients with T2DM. Drinking 2–4 cups of unsweetened green, black, or herbal tea per day could be considered as part of a healthy dietary pattern, particularly for patients who enjoy tea and can incorporate it without adding sugar or calories. However, the effect size is small (Hedges' $g = -0.34$), which corresponds to an absolute reduction in HbA1c of approximately 0.2–0.3%, and may not be clinically meaningful on its own. Tea should be viewed as an adjunct to, not a replacement for, established diabetes management strategies, including pharmacotherapy, medical nutrition therapy, and physical activity.

For wine and other alcoholic beverages, the present findings do not support recommending their consumption specifically for glycemic control. Patients who already consume alcohol should be counseled to do so in moderation (up to one drink per day for women and up to two drinks per day for men) and only with meals to reduce the risk of hypoglycemia.

For water, the evidence suggests that increasing water intake may be beneficial when it replaces sugar-sweetened beverages as part of a weight loss program. However, substituting water for artificially sweetened beverages without other dietary changes does not appear to improve glycemic control and may even be counterproductive in some contexts.

Limitations

Several limitations of this meta-analysis should be acknowledged. First, substantial heterogeneity was present in the overall analysis ($I^2 = 71.6\%$) and across several subgroups, which was not fully explained by the prespecified subgroup analyses. Possible sources of heterogeneity include variations in intervention duration, dosage, beverage preparation methods, baseline participant characteristics (e.g., disease duration, baseline HbA1c, medication use), and control conditions. Second, the overall methodological quality of the included studies was modest, with only one study rated as low risk of bias. Third, publication bias cannot be ruled out, as suggested by the funnel plot asymmetry. Fourth, the small number of studies in water and other interventions subgroups limits the precision and generalizability of these findings. Fifth, the included studies varied considerably in follow-up duration, ranging from 2 weeks to 12 months, and the sustainability of the observed effects beyond the intervention period remains unknown. Sixth, most studies

excluded patients with poorly controlled diabetes (HbA1c > 9–10%), limiting the generalizability of the findings to patients with more advanced disease. Seventh, the possibility of residual confounding cannot be excluded, particularly for the wine interventions where blinding is challenging.

Conclusions

In conclusion, this systematic review and meta-analysis of 23 randomized controlled trials demonstrates that tea consumption is associated with a modest but statistically significant improvement in glycemic control among patients with type 2 diabetes mellitus. Wine and water interventions did not show consistent benefits. The overall quality of the evidence is limited by methodological concerns, including lack of blinding, high dropout rates, and substantial heterogeneity. Tea may be considered as an adjunctive dietary strategy for glycemic management, but should not replace established diabetes treatments. High-quality, long-term randomized controlled trials are needed to confirm these findings and to identify the optimal type, dose, and duration of tea consumption for patients with T2DM.

Declarations

Consent to Participate

Consent to Participate declaration: Not applicable. This study is a systematic review and network meta-analysis of previously published randomized controlled trials and did not involve direct recruitment, interaction, or data collection from human participants.

Funding Declaration

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Human Ethics and Consent to Participate

Human Ethics and Consent to Participate declarations: Not applicable. As this manuscript is based on published aggregated data from randomized controlled trials, no ethical approval or participant consent was required. All original trials included in this review had obtained appropriate ethical approvals and informed consents from their participants.

Consent to Publish

Consent to Publish declaration: Not applicable. This manuscript does not contain any individual person's data (e.g., images, videos, case reports) that would require consent to publish.

CONFLICT OF INTEREST

No conflict of interest has been declared by the author(s).

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Effects of different beverages on glycemic control in patients with type 2 diabetes: a systematic review and meta-analysis of randomized controlled trials

Figure 1. Flow diagram of the search process.

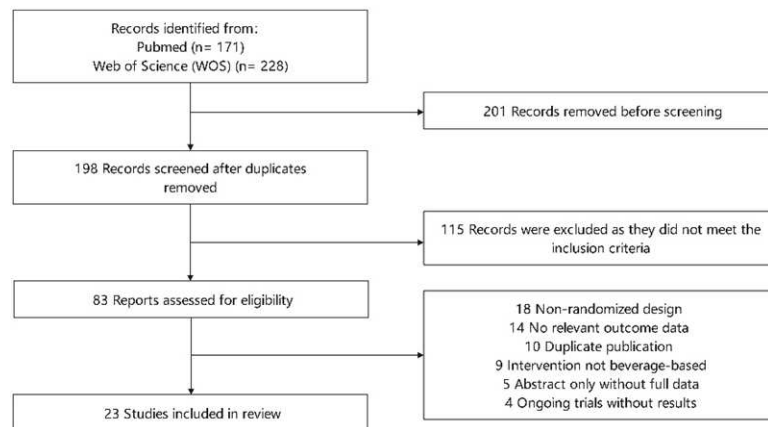
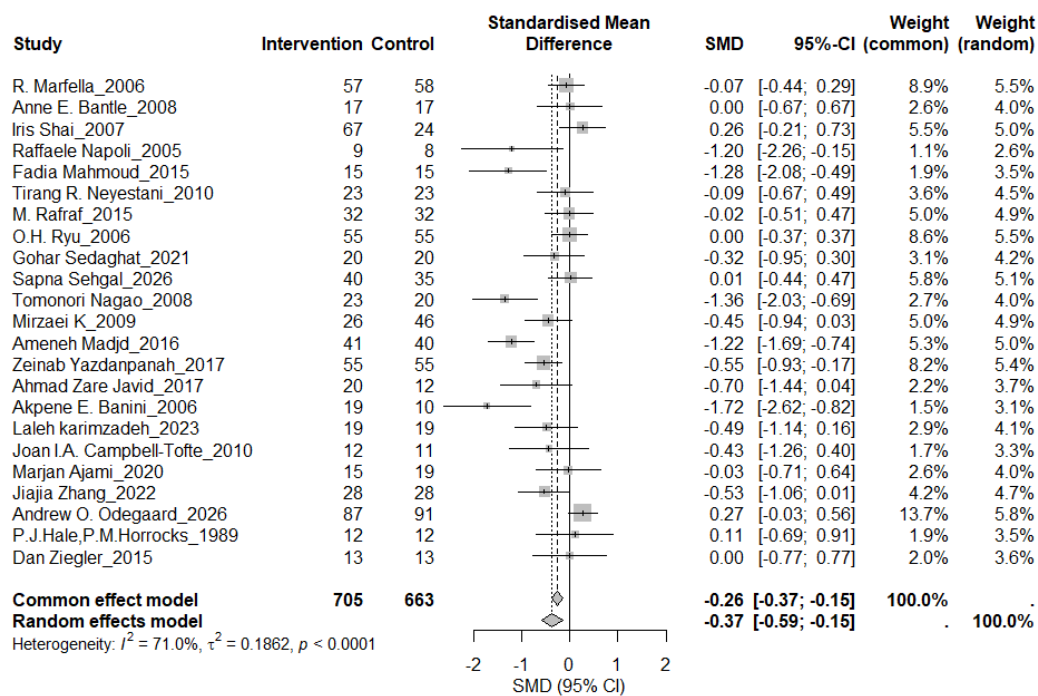


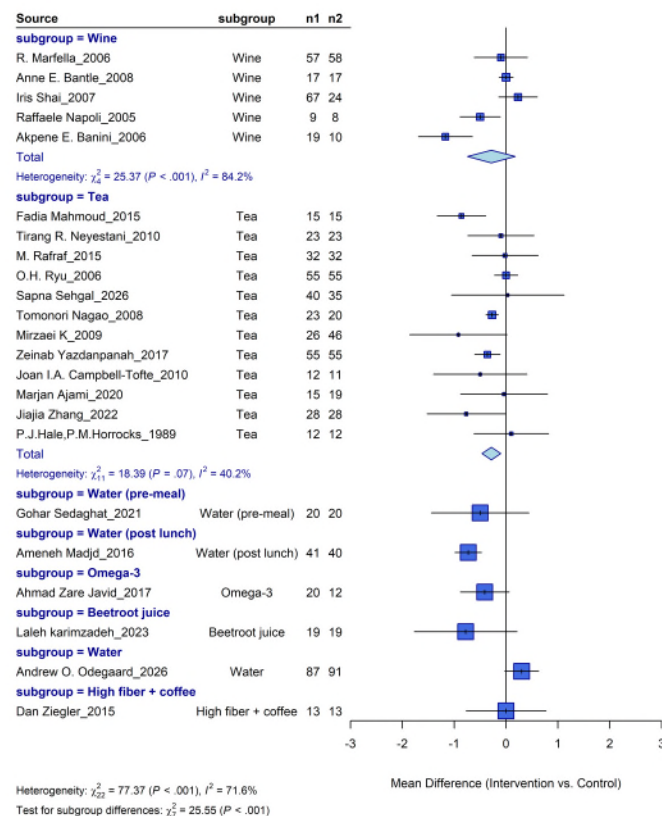
Figure 2. Forest plot of the effect of beverage interventions on HbA1c in patients with type 2 diabetes mellitus.



Data are presented as Hedges' g with 95% confidence intervals (CIs). A random-effects model was used to pool the effect sizes due to anticipated heterogeneity. The diamonds represent the pooled effect sizes for each subgroup and overall. The vertical line at Hedges' g = 0 indicates no effect.

Abbreviations: CI, confidence interval; HbA1c, glycated hemoglobin.

Figure 3. Forest plot of subgroup analysis for the effect of beverage interventions on HbA1c in patients with type 2 diabetes mellitus.

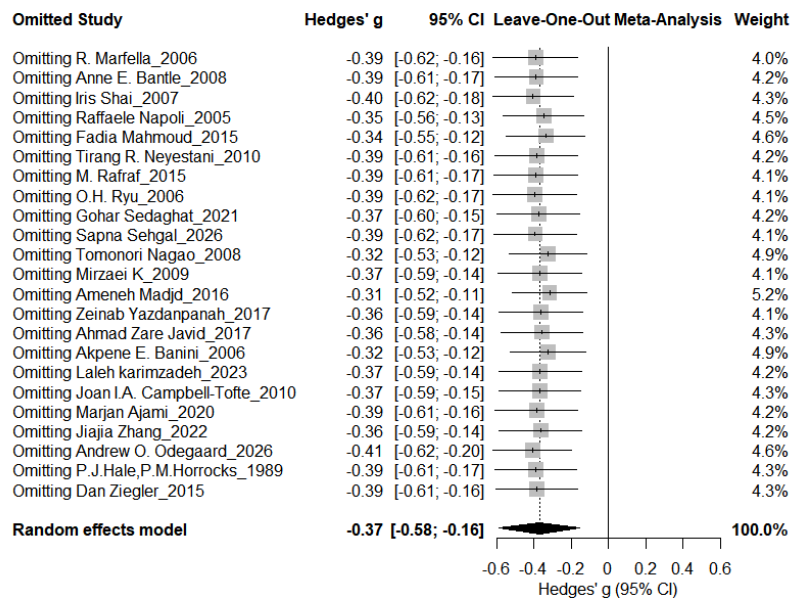


Data are presented as Hedges' g with 95% confidence intervals (CIs). A random-effects model was used to pool effect sizes across studies due to anticipated heterogeneity. Studies were stratified by intervention type: wine (5 studies), tea (12 studies), water (3 studies), beetroot juice (1 study), omega-3 (1 study), and high-fiber + coffee diet (1 study). The size of each square is proportional to the study's weight in the meta-analysis, and horizontal lines represent the 95% CI.

Diamonds indicate the pooled effect size for each subgroup and overall. The vertical line at Hedges' $g = 0$ indicates no effect.

Abbreviations: HbA1c, glycated hemoglobin; CI, confidence interval; n1, number of participants in the intervention group; n2, number of participants in the control group.

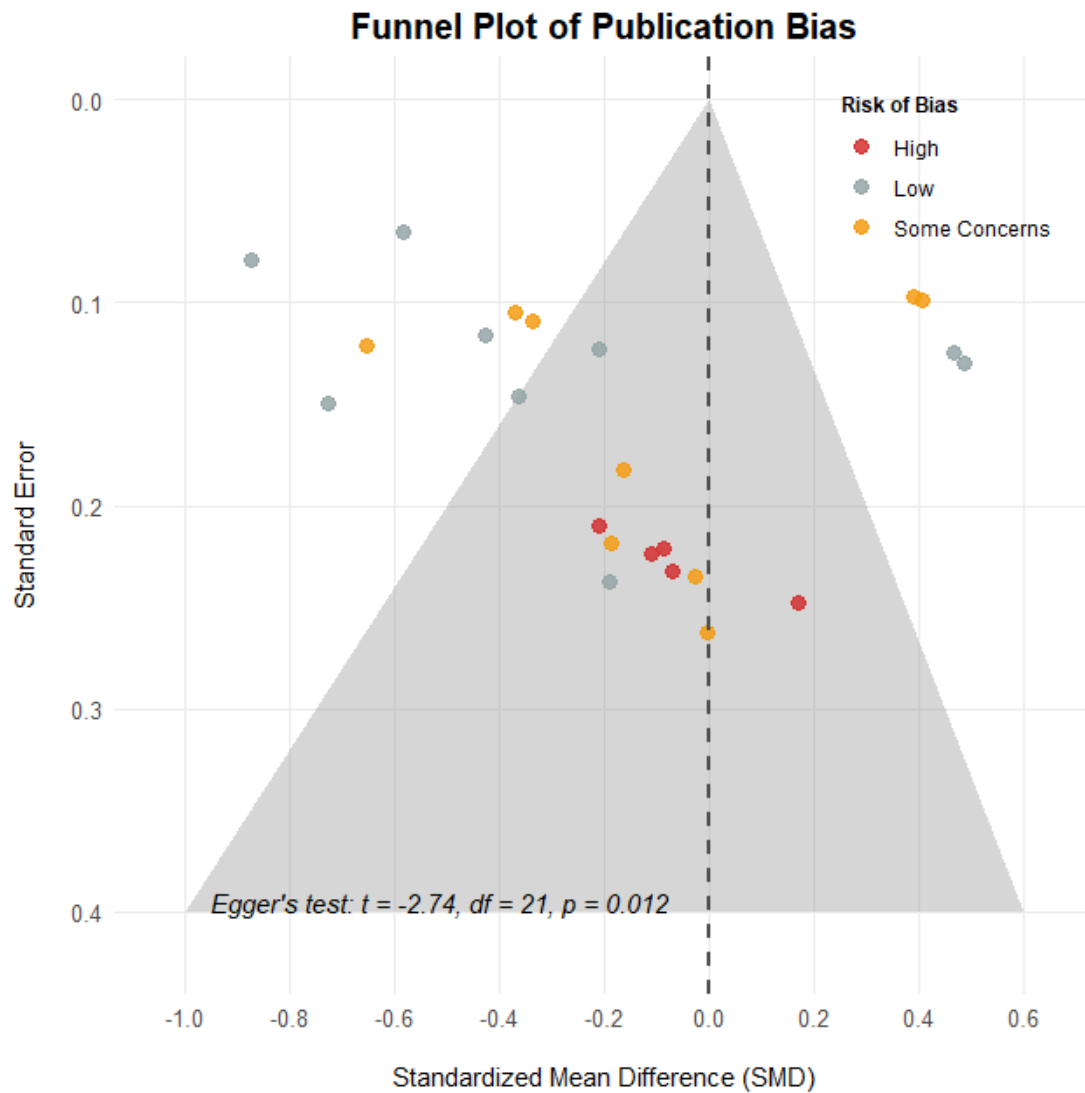
Figure 4. Leave-one-out sensitivity analysis for the pooled effect of beverage interventions on HbA1c in patients with type 2 diabetes mellitus.



Data are presented as pooled Hedges' g with 95% confidence intervals (CIs) after sequentially omitting each individual study. Each point on the forest plot represents the pooled effect estimate calculated after removing the corresponding study, with the horizontal line indicating the 95% CI. The size of each square is proportional to the weight of the omitted study in the meta-analysis. The dashed vertical line represents the overall pooled effect estimate (Hedges' g = -0.37 ; 95% CI: -0.58 to -0.16) from the full random-effects model including all 23 studies.

Abbreviations: CI, confidence interval; HbA1c, glycated hemoglobin;
ASB, artificially sweetened beverage.

Figure 5. Funnel plot for assessment of publication bias.

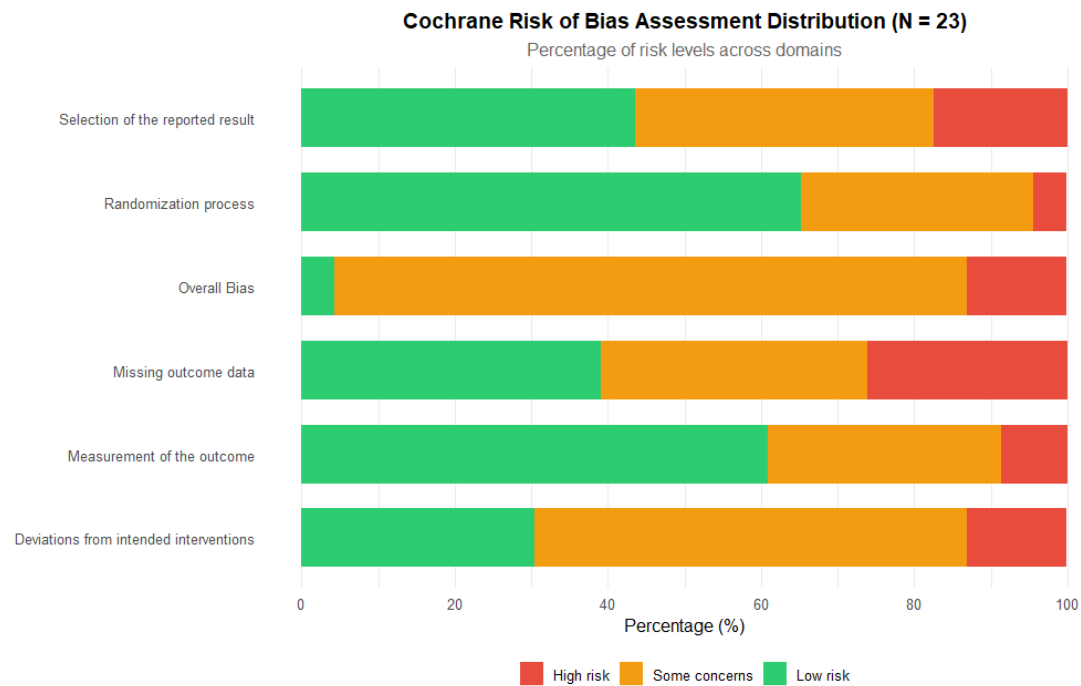


Each point represents an individual study included in the meta-analysis ($n = 23$). The vertical dashed line indicates the pooled effect estimate (Hedges' $g = -0.37$), and the diagonal lines represent the pseudo 95% confidence intervals around the pooled effect. Studies are

color-coded according to their overall risk of bias as assessed by the Cochrane RoB 2 tool: green for low risk of bias, yellow for some concerns, and red for high risk of bias. The horizontal axis shows the standardized mean difference (Hedges' g), and the vertical axis shows the standard error (inverted scale, so smaller studies with larger standard errors appear toward the bottom).

Abbreviation: SMD, standardized mean difference.

Figure 6. Risk-of-bias distribution across 23 included studies (Cochrane RoB 2 tool).



Green: low risk; orange: some concerns; red: high risk. The y-axis lists each assessed domain, and the x-axis represents the percentage of studies. Overall, 1 study (4.3%) was rated as low risk, 19 (82.6%) as some concerns, and 3 (13.0%) as high risk of bias.

Supplementary Files

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