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REVIEW

A Critical Review of the Health Benefits Associated with Chia Seeds (*Salvia Hispanica* L.)

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Abstract

Chia seeds (*Salvia hispanica L.*) have attracted interest for their potential health benefits, yet their overall effectiveness remains uncertain due to limited high-quality evidence and heterogeneity across studies. This umbrella review critically synthesizes data from systematic reviews and meta-analyses of randomized controlled trials (RCTs) to evaluate the effects of chia supplementation on key health outcomes. A comprehensive literature search was conducted in PubMed, Scopus, and Web of Science. Eligible studies assessed outcomes including blood pressure, lipid profiles, inflammation, and anthropometric measures. Methodological quality was evaluated using AMSTAR-2, and certainty of evidence was graded using GRADE. Meta-analyses were performed using Comprehensive Meta-Analysis (CMA) software v3.7, with Hedges' *g* and 95% confidence intervals (CI); significance was set at $P<0.05$. Eight meta-analyses involving approximately 2,500 participants were included. Chia supplementation resulted in significant reductions in diastolic blood pressure (g = -0.550; 95% CI: -0.718 to -0.382), systolic blood pressure (g = -0.119; 95% CI: -0.228 to -0.010), total cholesterol (g = -0.300), LDL-C (g = -0.300), triglycerides (g = -0.200), waist circumference (g = -0.289), and C-reactive protein (g = -0.165). However, a small reduction in HDL-C was also observed (g = -0.093). Overall, chia supplementation may offer modest but statistically significant benefits for improving blood pressure, lipid profiles, inflammation, and central obesity. The certainty of evidence, based on GRADE assessments, ranged from moderate to low for most outcomes. .

Keywords Chia · *Salvia hispanica L.* · Health outcomes · Blood pressure

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Introduction

Chia (*Salvia hispanica* L.) is a nutrient-dense seed that has attracted considerable scientific and consumer interest in recent years due to its potential health-promoting properties [1]. Naturally rich in dietary fiber, omega-3 fatty acids (mainly α-linolenic acid), high-quality plant protein, and a variety of bioactive compounds—including polyphenols and antioxidants. Chia seeds are now widely recognized and consumed as a functional food ingredient [2, 3]. These nutritional qualities have led to growing research into the possible role of chia in the prevention and management of chronic conditions such as metabolic syndrome, cardiovascular disease, gastrointestinal disorders, and inflammatory states [4–6].

While chia has garnered substantial attention as a functional food, it is important to situate its potential benefits within the broader landscape of nutritionally comparable interventions. Cinnamon has demonstrated favorable effects on cardiovascular risk factors through anti-inflammatory and insulin-sensitizing mechanisms [7]. Similarly, *Nigella sativa* (black seed) has exhibited lipid-lowering, antihypertensive, and antioxidant properties in various clinical trials [8]. Sesame consumption has also been associated with improvements in blood pressure and lipid profiles, likely owing to its lignan and polyunsaturated fatty acid content [9].

Chia is commercially available in various forms to accommodate different dietary needs and preferences. Whole chia seeds remain the most common form, providing ample fiber, healthy fats, and protein. Ground chia seed powder is increasingly popular, as milling improves digestibility and nutrient bioavailability, particularly for individuals with digestive sensitivities [10]. Chia oil, which is extracted from the seeds, offers a concentrated source of omega-3 fatty acids and is often promoted as a plant-based alternative to fish oil for cardiovascular and inflammatory support [11, 12]. Other products, such as chia-based protein powders, meal replacements, and encapsulated extracts, have also emerged as convenient options for obtaining chia's nutritional benefits without altering food texture or taste [13].

The high soluble and insoluble fiber content in chia contributes to improved glycemic control, weight management, and favorable lipid profiles [14, 15]. Beyond metabolic effects, chia has been linked to enhanced gastrointestinal health, partly due to its mucilage and other bioactive compounds, which may exert prebiotic effects by promoting the growth of beneficial gut microbiota [6, 16–18]. Modulating gut microbiota through Chia consumption could have wider implications for immune regulation, inflammation, and the prevention of chronic diseases.

Furthermore, chia's rich polyphenol content—including flavonoids, quercetin, and chlorogenic acid—confers antioxidant and anti-inflammatory properties that may help mitigate oxidative stress and chronic low-grade inflammation, both key drivers in the development of non-communicable diseases [19–21]. By scavenging free radicals and modulating inflammatory pathways, these compounds may offer cellular protection and support healthy aging [22, 23].

However, despite these promising attributes, some studies have reported no significant health effects from chia consumption, especially when used in low doses or short-term interventions [24–26], as a result, the current body of evidence remains contradictory. Therefore, the aim of this umbrella review was to systematically and critically evaluate the overall effects of chia consumption on various health outcomes by synthesizing findings from existing systematic reviews and meta-analyses of randomized controlled trials (RCTs).

Materials and Methods

Study Design

This umbrella review synthesized evidence from published systematic reviews and meta-analyses to evaluate the effect of chia consumption on various health outcomes. The review followed established guidelines for conducting umbrella reviews, including the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement and guidance for overviews of systematic reviews [27].

Search Strategy

A comprehensive literature search was conducted in PubMed, Scopus, and Web of Science to identify relevant systematic reviews and meta-analyses assessing the effects of chia consumption on health outcomes. The search strategy incorporated keywords including "Chia," "Salvia hispanica," "health outcomes," "health conditions," "systematic review," "meta-analysis," "umbrella review," "cardiovascular diseases," "blood pressure," "diabetes mellitus," "glycemic control," "lipid metabolism," "cholesterol," "triglycerides," "body mass index," "obesity," and "anthropometry" (Supplementary Table 1).

Eligibility Criteria

The eligibility criteria for this umbrella review, include systematic reviews and meta-analyses of RCTs that examine the health effects of chia seed consumption. Studies involving human participants of any age, gender, or health

status were included, provided they assess chia in any form, including whole seeds, ground seeds, chia oil, or chia-based supplements. Eligible studies had to compare chia consumption to a control group, such as a placebo, standard diet, or other dietary interventions. The primary health outcomes of interest include systolic and diastolic blood pressure (SBP and DBP), glycemic control (fasting blood glucose (FBG), fasting blood insulin, and hemoglobin A1c (HbA1c)), lipid metabolism (total cholesterol (TC), low-density lipoprotein (LDL), high-density lipoprotein (HDL), and triglycerides (TG)), anthropometric measures (body weight, body mass index (BMI), waist circumference (WC), hip circumference (HC), and body fat percentage), inflammatory markers (C-reactive protein (CRP), interleukins (IL), and tumor necrosis factor-alpha (TNF-α)), liver function (aspartate transaminase (AST), alanine transaminase (ALT), and alkaline phosphatase (ALP)), etc.

Studies were excluded if they focused on industrial uses rather than health effects, involved non-human research (animal or in vitro studies), were non-English, lacked full-text availability, or were systematic reviews without meta-analysis or clear description of the methodology. Importantly, studies with co-interventions, such as chia combined with other supplements or concurrent dietary modifications, were excluded to isolate the effects of chia consumption alone. To ensure relevant grey literature was not overlooked, we screened the first ten pages of Google Scholar search results; however, no additional eligible studies were identified.

Studies Selection

Two independent reviewers screened the titles and abstracts of the articles according to the predefined eligibility criteria (kappa = 0.68). Subsequently, the selected articles underwent a comprehensive full-text review to verify their compliance with the inclusion criteria for final inclusion. In instances of disagreement between reviewers, discrepancies were resolved through discussion or by consulting a third reviewer. Data extraction was carried out using a standardized form designed to capture study characteristics, types of chia, sample size, number of included studies, effect sizes (mean difference (MD), standardized mean difference (SMD), and weighted mean difference (WMD)) heterogeneity (I^2), confidence interval (CI), and risk of bias assessments.

Quality Assessment

To assess the methodological quality of the included systematic reviews and meta-analyses, the A Measurement Tool to Assess Systematic Reviews (AMSTAR-2) was used, scoring from zero to 16, and the certainty of the evidence was evaluated using the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) approach. Factors such as the risk of bias, inconsistency, indirectness, imprecision, and publication bias were considered in the evaluation [28, 29] (Supplementary Tables 2 and 3). Additionally, data synthesis and analysis involved the creation of summary tables that presented study characteristics, key findings, and quality assessment results. Overlapping studies were analyzed to determine consistency or contradictions across reviews. The level of evidence was categorized based on the direction of effects, statistical significance, and confidence in the findings, and the publication bias was examined.

Meta-Analysis

In the statistical analysis conducted using Comprehensive Meta-Analysis (CMA) software, effect sizes for the various outcomes were calculated using Hedges' g, which corrects for small sample bias, providing an unbiased estimate of the standardized WMD and MD between experimental and control groups. Each effect size was accompanied by a 95% CI to assess precision, with statistical significance determined by a P-value < 0.05. The power analysis was determined by considering the risk ratio, the average sample size per group, the number of effect sizes (studies included), and I^2. Also, corrected covered area (CCA) calculation was perfumed using following formula:

$$CCA = N - r \times (c-1) CCA = r \times (c-1)\, N - r$$
$$\left[\begin{array}{c} NN = Total\ inclusions\ (sum\ of\ all\ 1s\ in\ matrix) \\ = 112; rr = Unique\ original\ studies = 47; cc = Meta - analyses = 8 \end{array}\right]$$

Results

Studies Characteristics and Quality Assessments

In the current study, out of 47 identified studies, eight meta-analyses were included [4, 26, 30–35], covering diverse clinical outcomes such as lipid profiles, glycemic markers, inflammatory biomarkers, body composition, and cardiovascular parameters (Fig. 1). Most trials included adults ranging from healthy individuals to specific subgroups such as overweight, obese, or diabetic participants, with ages generally spanning from 18 to 70 years. The duration of the included randomized controlled trials varied from 4 weeks to 24 weeks with daily doses typically between 5 g and 50 g, reflecting short- to moderate-term interventions. The form of chia varied, including whole chia seeds, oil, and chia-based supplements.

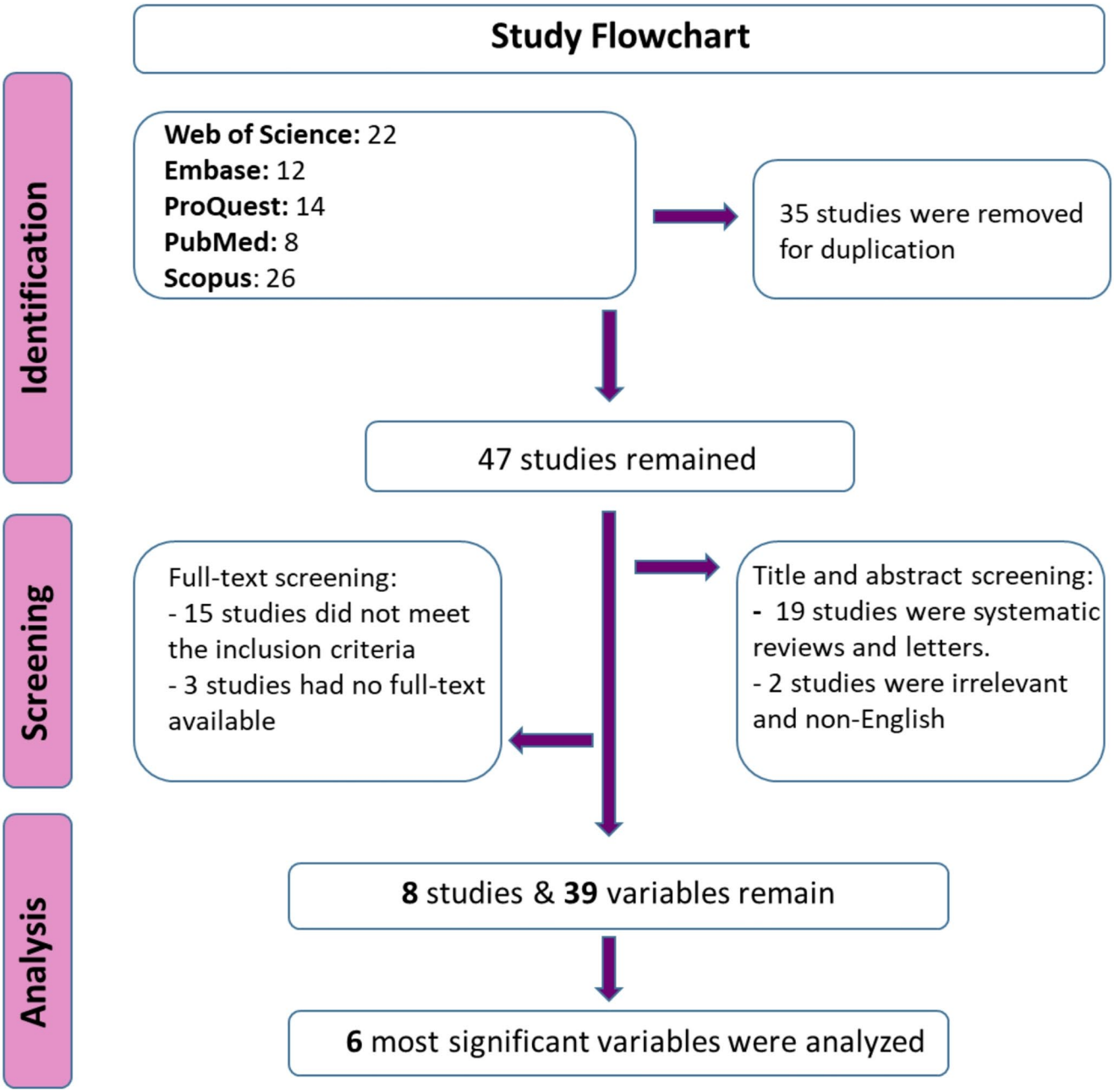

Fig. 1 The flowchart of the studies selection through screening

Sample sizes across the primary studies ranged from 20 to 489 participants. Effect sizes varied from −14.09 to 211.40, with most outcomes showing no statistically significant differences. However, some pooled estimates indicated that chia supplementation significantly reduced DBP, postprandial glucose (PPG), and CRP levels. Heterogeneity was low for DBP (I^2 = 12.2%) and TC (I^2 = 20.2%), but high for CRP (I^2 = 87.9%), indicating substantial inconsistency across CRP studies. Overall, the impact of chia appears modest, with variations depending on dosage, intervention duration, and population characteristics. Heterogeneity was mostly low to moderate, indicating relatively consistent effects across studies.

Quality assessments using AMSTAR 2 and GRADE indicated that most meta-analyses were of moderate to high methodological quality, although some outcomes were graded as low certainty due to imprecision or inconsistency. A detailed overview of the characteristics, outcomes, and quality scores of the included studies is provided in Table 1.

The reported CCA in our study was ≈ 0.20 [$112-4747 \times (8-1) = 65329 \approx 0.20 CCA = 47 \times (8-1) 112-47=32965 \approx 0.20$], which well below the threshold of 5 for moderate

Table 1 Characteristics of seven included studies

Reference	Included studies		Outcomes	Form of Chia	Metric	Effect size	95% CI	I^2%	*P* value	GRADE	AMSTAR 2 score (0–16)
Teoh et al [35]	13	6	TC (mg/dL)	Chia seed	MD	−0.07	−0.30- 0.15	0.0	>0.050	●●○○ (Low)	13 (High)
		5	TG (mg/dL)	Chia seed	MD	−0.08	−0.32- 0.17	4.1	>0.050		
		5	HDL (mg/dL)	Chia seed	MD	−0.10	−0.20- −0.01	11.7	<0.050		
		5	LDL (mg/dL)	Chia seed	MD	−0.01	−0.24- 0.21	0.0	>0.050		
		1	VLDL (mg/dL)	Chia seed	MD	2.00	22.25–18.25	NA	NA		
		5	Weight (kg)	Chia seed	MD	0.07	−0.18- 0.31	0.0	>0.100		
		4	Body fat (%)	Chia seed	MD	−0.07	−1.91- 1.78	0.0	>0.100		
		2	BMI (kg/m^2)	Chia seed	MD	0.04	−1.58- 1.66	0.0	>0.100		
		3	WC (cm)	Chia seed	MD	−1.21	−4.16- 1.74	0.0	>0.100		
		1	HC (cm)	Chia seed	MD	−2.90	−7.36- 1.56	NA	NA		
		1	Android fat (%)	Chia seed	MD	−0.18	−4.82- 1.22	NA	NA		
		1	Gynoid fat (%)	Chia seed	MD	−5.20	−10.24- −0.16	NA	NA		
		2	HbA1c (%)	Chia seed	MD	0.02	−0.37- 0.41	0.0	>0.100		
		6	FBG (mmol/L)	Chia seed	MD	0.02	−0.15- 0.18	0.0	>0.100		
		3	Fasting blood insulin (pmol/L)	Chia seed	MD	4.63	−9.88- 19.13	0.0	>0.100		
		4	PPG (mmol/L)	Chia seed	AUC	−24.10	−53.08- 4.87	67.9	<0.050		
		5	CRP (mg/L)	Chia seed	MD	−0.61	−1.36- 0.14	0.0	>0.100		
		3	IL-6 (pg/mL)	Chia seed	MD	<0.001	−0.01- 0.02	0.0	>0.100		
		2	IL-8 (pg/mL)	Chia seed	MD	−0.73	−2.57- 1.10	0.0	>0.100		
		2	IL-10 (pg/mL)	Chia seed	MD	−0.28	−2.23- 1.66	0.0	>0.100		
		3	TNF-α (pg/mL)	Chia seed	MD	<0.001	<−0.001- 0.01	0.0	>0.100		
		2	VonWillebrand factor (IU/mL)	Chia seed	MD	−0.09	−0.32- 0.14	25.2	>0.100		
		1	Acid glycoprotein1 (mg/dL)	Chia seed	MD	2.00	10.47–14.47	NA	NA		
		1	Factor III (IU/mL)	Chia seed	MD	0.21	0.46−0.04	NA	NA		
		1	Fibrinogen (g/L)	Chia seed	MD	0.26	0.69−0.17	NA	NA		
		1	Leukocyte count (x10^9/L)	Chia seed	MD	0.18	2.40–2.04	NA	NA		
		1	Plasma MCP (pg/mL)	Chia seed	MD	0.04	0.05–0.13	NA	NA		
		4	DBP (mmHg)	Chia seed	MD	−3.37	−7.43- 0.70	64.8	<0.050		
		6	SBP (mmHg)	Chia seed	MD	−2.57	−6.70- 1.55	38.3	>0.050		
		2	AST (U/L)	Chia seed	MD	−0.10	−3.29- 3.08	0.0	>0.050		
		2	ALT (U/L)	Chia seed	MD	3.39	−1.82- 8.60	20.2	>0.050		
		1	ALP (U/L)	Chia seed	MD	0.20	11.17–10.77	−1	NA		
		2	Creatinine (μmol/L)	Chia seed	MD	−1.37	−7.42- 4.69	0.0	>0.050		
		2	BUN (mmol/L)	Chia seed	MD	−0.28	−1.30- 0.74	54.9	>0.050		
		1	Leptin (μg/L)	Chia seed	MD	2.20	9.25–4.85	NA	NA		
		1	Chrelin (pg/mL)	Chia seed	MD	211.40	361.83–60.97	NA	NA		
		1	Peptide tyrosine tyrosine (pg/mL)	Chia seed	MD	5.10	31.56–21.36	NA	NA		

Table 1 (continued)

Reference	Included studies		Outcomes	Form of Chia	Metric	Effect size	95% CI	I^2%	*P* value	GRADE	AMSTAR 2 score (0–16)
Silva et al [33]	10	6	TC (mg/dL)	Chia seed	MD	−2.98	−9.98- 4.02	0.0	>0.050	●●○○ (Low)	11 (Moderate)
		5	LDL (mg/dL)	All forms	MD	2.07	−5.05- 9.19	0.0	>0.050		
		5	HDL (mg/dL)	All forms	MD	−2.92	−5.91- 0.06	58.0	>0.050		
		5	TG (mg/dL)	All forms	MD	−14.09	−33.46- 5.28	42.0	>0.050		
Saadh et al [32]	8	4	DBP (mmHg)	Chia suppl.	WMD	−7.49	−9.64- −5.34	12.2	<0.001	●●●○(Moderate)	12 (Moderate)
		6	SBP (mmHg)	Chia suppl.	WMD	−5.61	−8.77- −2.44	77.8	0.001		
		4	BMI (kg/m^2)	Chia suppl.	WMD	−0.31	−0.96- 0.34	0.0	0.340		
		4	WC (cm)	Chia suppl.	WMD	−1.46	−2.68- −0.25	0.0	0.010		
		6	Weight (kg)	Chia suppl.	WMD	0.09	−0.76- 0.93	0.0	0.840		
Nikpayam et al [4]	14	8	BMI (kg/m^2)	Chia suppl.	SMD	−0.10	−0.33–0.13	8.3	>0.05	●●○○(Moderate)	12 (Moderate)
		12	Weight (kg)	Chia suppl.	SMD	−0.08	−0.27–0.11	0.0	>0.05		
		8	WC (cm)	Chia suppl.	SMD	−0.20	−0.43–0.02	0.0	>0.05		
		8	Body fat	Chia suppl.	SMD	0.02	−0.21–0.24	0.0	>0.05		
		13	SBP (mmHg)	Chia suppl.	SMD	−0.41	−0.59 - −0.22	63.7	<0.05		
		9	DBP (mmHg)	Chia suppl.	SMD	−0.41	−0.05 - −0.17	92.4	<0.05		
		14	FBG (mmol/L)	Chia suppl.	SMD	−0.01	−0.20–0.14	73.2	>0.05		
		5	HbA1c (%)	Chia suppl.	SMD	−0.20	−0.45–0.05	20.8	>0.05		
		5	Insulin (μIU/mL)	Chia suppl.	SMD	0.07	−0.17–0.32	32.4	>0.05		
		6	hs-CRP (mg/L)	Chia suppl.	SMD	−0.09	−0.34 - −13.51	93.6	>0.05		
		4	IL-6 (pg/dL)	Chia suppl.	SMD	0.04	−0.28–0.35	0.0	>0.05		
		4	TNF-α (pg/mL)	Chia suppl.	SMD	−0.02	−0.34–0.30	0.0	>0.05		
		14	TC (mg/dL)	Chia suppl.	SMD	−0.30	−0.48 - −0.13	20.2	<0.05		
		13	TG (mg/dL)	Chia suppl.	SMD	−0.20	−0.38 - −0.02	67.1	<0.05		
		12	HDL (mg/dL)	Chia suppl.	SMD	−0.28	−0.47 - −0.09	77.2	>0.05		
		12	LDL (mg/dL)	Chia suppl.	SMD	−0.30	−0.50 - −0.11	62.7	<0.05		
Pam et al [26]	8	8	FBG (mg/dL)	Chia seed	WMD	0.79	−0.97- 2.55	53.3	0.380	●●●● (High)	14 (High)
		5	HbA1c (%)	Chia seed	WMD	−0.12	−0.27- 0.02	24.6	0.090		
		3	Insulin (μIU/mL)	Chia seed	WMD	1.23	−1.77- 4.22	56.0	0.420		
Pam et al [31]	4	4	CRP (mg/L)	Chia suppl.	WMD	−0.64	−1.24- −0.41	0.0	0.030	●●●● (High)	14 (High)
		2	IL-6 (pg/dL)	Chia suppl.	WMD	0.29	−0.40- 0.98	0.0	0.410		
		2	TNF-α (pg/mL)	Chia suppl.	WMD	0.05	−0.21- 0.30	0.0	0.720		

Table 1 (continued)

Reference	Included studies		Outcomes	Form of Chia	Metric	Effect size	95% CI	I^2%	*P* value	GRADE	AMSTAR 2 score (0–16)
Karimi et al [30]	10	8	TC (mg/dL)	Chia suppl.	MD	−0.29	−8.49- 7.92	18.5	0.950	●●○○ (Low)	12 (Moderate)
		7	TG (mg/dL)	Chia suppl.	MD	−5.80	−21.50- 9.89	0.0	0.470		
		7	HDL (mg/dL)	Chia suppl.	MD	1.53	−4.58- 1.53	32.0	0.330		
		7	LDL (mg/dL)	Chia suppl.	MD	0.63	−7.59- 8.86	10.4	0.880		
		9	FBG (mg/dL)	Chia suppl.	MD	−0.03	−2.82- 2.75	15.9	0.980		
		5	HbA1c (%)	Chia suppl.	MD	−0.13	−0.29- 0.04	0.0	0.130		
		5	Insulin (μIU/mL)	Chia suppl.	MD	0.45	−2.76- 3.66	73.4	0.780		
		5	CRP (mg/L)	Chia suppl.	MD	−1.18	−2.01- −0.36	87.9	<0.0001		
		3	IL-6 (pg/dL)	Chia suppl.	MD	−0.15	−0.88- 0.59	2.1	0.700		
		3	TNF-α (pg/mL)	Chia suppl.	MD	0.03	−0.58- 0.65	9.2	0.910		
		5	BMI (kg/m^2)	Chia suppl.	MD	0.40	−0.36- 0.43	12.5	0.910		
		4	WC (cm)	Chia suppl.	MD	−2.82	−4.32- −1.31	0.0	<0.001		
		7	SBP (mmHg)	Chia suppl.	MD	−3.27	−6.28- −0.27	0.0	0.030		
		5	DBP (mmHg)	Chia suppl.	MD	−2.69	−5.76- 0.38	43.0	0.090		
Taghipour Sheshdeh et al [34]	8	6	SBP (mmHg)	Chia seed suppl.	WMD	−7.19	−10.63- −3.73	42.6	<0.001	●●●○(Moderate)	14 (High)
		3	DBP (mmHg)	Chia seed suppl.	WMD	−6.04	−9.58- −2.49	0.0	0.001		
		5	Weight (kg)	Chia seed suppl.	WMD	−0.90	−4.64- 2.82	0.0	0.634		
		4	Body fat (%)	Chia seed suppl.	WMD	0.09	−1.55- 1.74	4.9	0.908		
		3	WC (cm)	Chia seed suppl.	WMD	−2.10	−5.69- 1.47	0.0	0.250		
		3	BMI (kg/m^2)	Chia seed suppl.	WMD	−0.21	−1.87- 1.45	0.0	0.803		
		6	FBG (mg/dL)	Chia seed suppl.	WMD	0.02	−3.92- 3.98	0.0	0.989		
		4	HbA1c (%)	Chia seed suppl.	WMD	−0.07	−0.30- 0.15	0.0	0.519		

Randomized clinical trials (RCT); mean difference (MD); weighted mean difference (WMD); standardized mean difference (SMD); heterogeneity (I^2); confidence interval (CI); significant (sig); not applicable (NA); area under curve (AUC); supplements (suppl.); standard mean differences (SMD); postprandial blood glucose (PPG); blood urea nitrogen (BUN); fasting blood glucose (FBG); hemoglobin A1c (HbA1c); body mass index (BMI); waist circumference (WC); hip circumference (HC); total cholesterol (TC); triglycerides (TG); high density lipoproteins (HDL); low density lipoprotein (LDL); systolic blood pressure (SBP); diastolic blood pressure (DBP); aspartate transaminase (AST); alanine transaminase (ALT); alkaline phosphatase (ALP); interleukin-6 (IL-6); C-reactive protein (CRP); tumor necrosis factor-alpha (TNF-α); gynoid fat (lower body fat); high sensitive CRP (hs-CRP); android fat (upper body fat); very low density lipoprotein (VLDL)

P value <0.050: Significant

A Measurement Tool to Assess Systematic Reviews (AMSTAR 2) assigns a score ranging from 1 to 16, with higher scores indicating better methodological quality. The quality rating is categorized as follows: 1-4 (Critically Low), 5-8 (Low), 9-12 (Moderate), and 13-16 (High). Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) was reported as very low, low, moderated, and high. ● denotes that a criterion was met, while ○ indicates that it was not. A greater number of ● symbols reflects higher methodological quality and stronger evidence

overlap, indicating minimal and acceptable overlap; therefore, no re-analysis was needed, and a sensitivity analysis excluding duplicate studies showed unchanged results (pooled effect size difference Δ = 0.02).

Total Health Outcomes of Chia Consumption

Considering the quality of the studies, numbers of included RCTs, participants, heterogeneity, and significant level, multiple variables were selected for meta-analysis. Teoh et al [35] reported that chia supplementation significantly reduced PPG levels by −24.10 mmol/L (95% CI: −53.08 to 4.87, I^2 = 67.9%) and had a slight but significant effect on lowering HDL by −0.10 mg/dL (95% CI: −0.20 to −0.01, I^2 = 11.7%). Saadh et al. [32] found a substantial decrease in DBP by −7.49 mmHg (95% CI: −9.64 to −5.34, I^2 = 12.2%). Karimi et al. [30] observed reductions in SBP by −3.27 mmHg (95% CI: −6.28 to −0.27, I^2 = 0.0%), WC by −2.82 cm (95% CI: −4.32 to −1.31, I^2 = 0.0%), and CRP levels by −1.18 mg/L (95% CI: −2.01 to −0.36, I^2 = 87.9%). Nikpayam et al [4] reported that chia consumption significantly decreased TC by −0.30 (95% CI: −0.48 to −0.13, I^2 = 20.2%), LDL by −0.30 (95% CI: −0.50 to −0.11, I^2 = 62.7%), and TG by −0.20 (95% CI: −0.38 to −0.02, I^2 = 67.1%), while no statistically significant effects were observed for BMI, body weight, body fat, HbA1c, insulin, hs-CRP, TNF-α, or IL-6 (Supplementary Table 4).

Meta-analysis demonstrated that chia consumption had a statistically significant effect in reducing DBP (g=−0.550, P<0.001), TC (g = −0.300, P=0.001), LDL (g = −0.300, P=0.003), WC (g=−0.289, P<0.001), and CRP (g=−0.165, P=0.005), SBP (g=−0.119, P=0.033), and TG (g = −0.200, P=0.029), respectively. A significant but negligible reduction in HDL after chia consumption was also observed (g=−0.093, P=0.039). No statistically significant effects were observed on BMI, body weight, body fat, HbA1c, insulin, hs-CRP, TNF-α, or IL-6, indicating a limited impact on these metabolic and inflammatory markers (Table 2; Fig. 2).

Effect of Chia on Blood Pressure

Five studies evaluated the impact of chia on blood pressure, of which Saadh et al. [32], Taghipour Sheshdeh et al [34], and Nikpayam et al. [4] reported a significant impact of chia consumption of controlling both SBP by (WMD: −5.61 mmHg, I^2 = 77.8%, P=0.001), (WMD: −7.19 mmHg, I^2 = 42.6%, P<0.001), and (SMD: −0.41 mmHg, I^2 = 63.7%, P<0.05), respectively, and DBP by (WMD: −7.49 mmHg, I^2 = 12.2%, P<0.001), (WMD mmHg: −6.04, I^2 = 0.0%, P=0.001), and (SMD: −0.41 mmHg, I^2 = 92.4%, P<0.05), respectively. While, Teoh et al. [35] found a significant reduction only for DBP (MD: −3.37 mmHg, I^2 = 64.8%, P<0.050) and Karimi et al. reported [30] a significant reduction in SBP (MD: −3.27 mmHg, I^2 = 0.0%, P=0.030).

Effect of Chia on Lipid Profile

Three meta-analyses assessed the effect of chia consumption on lipid profile, of which, Nikpayam et al [4] found poor but significant impact for TC, TG, and LDL by chia

Table 2 The most significant health outcomes related to chia consumption

Studies	Outcomes	Included studies	Risk ratio	95% CI		*P* value
				Lower	Upper	
Saadh et al [32]	DBP (mmHg)	4	−0.550	−0.718	−0.382	0.000
Karimi et al [30]	WC (cm)	4	−0.289	−0.446	−0.133	0.000
Karimi et al [30]	CRP (mg/L)	5	−0.165	−0.280	−0.049	0.005
Karimi et al [30]	SBP (mmHg)	6	−0.119	−0.228	−0.010	0.033
Teoh et al [35]	PPG (mmol/L)	4	−0.104	−0.228	0.021	0.102
Teoh et al [35]	HDL (mg/dL)	5	−0.093	−0.181	−0.005	0.039
Nikpayam et al [4]	BMI (kg/m^2)	8	−0.100	−0.330	0.130	0.393
Nikpayam et al [4]	Weight (kg)	12	−0.080	−0.270	0.110	0.480
Nikpayam et al [4]	Body fat	8	0.020	−0.205	0.245	0.861
Nikpayam et al [4]	HbA1c	5	−0.200	−0.450	0.050	0.116
Nikpayam et al [4]	Insulin	5	0.070	−0.175	0.315	0.575
Nikpayam et al [4]	TC (mg/dL)	14	−0.300	−0.475	−0.125	0.001
Nikpayam et al [4]	LDL-C (mg/dL)	13	−0.300	−0.495	−0.105	0.003
Nikpayam et al [4]	TG (mg/dL)	13	−0.200	−0.380	−0.020	0.029
Nikpayam et al [4]	hs-CRP	6	−0.090	−0.340	0.160	0.480
Nikpayam et al [4]	TNF-α	4	−0.020	−0.339	0.299	0.902
Nikpayam et al [4]	IL-6	4	0.040	−0.354	0.274	0.803

Confidence interval (CI); postprandial blood glucose (PPG); body mass index (BMI); hemoglobin A1c (HbA1c); body mass index (BMI); waist circumference (WC); total cholesterol (TC); triglycerides (TG); high density lipoproteins (HDL); low density lipoprotein (LDL); systolic blood pressure (SBP); diastolic blood pressure (DBP); interleukin-6 (IL-6); C-reactive protein (CRP); tumor necrosis factor-alpha (TNF-α); high sensitive CRP (hs-CRP).Significant level < 0.05

Study name	Outcome	Hedges's g	Lower limit	Upper limit	p-Value
Saadh et al., 2023	DBP	-0.550	-0.718	-0.382	0.000
Nikpayam et al., 2023 f	TC	-0.300	-0.475	-0.125	0.001
Nikpayam et al., 2023 g	LDL-C	-0.300	-0.495	-0.105	0.003
Karimi et al., 2024 c	WC	-0.289	-0.446	-0.133	0.000
Nikpayam et al., 2023 d	HbA1c	-0.200	-0.450	0.050	0.116
Nikpayam et al., 2023 h	TG	-0.200	-0.380	-0.020	0.029
Karimi et al., 2024 a	CRP	-0.165	-0.280	-0.049	0.005
Karimi et al., 2024 b	SBP	-0.119	-0.228	-0.010	0.033
Li Teoh et al., 2018 b	PPG	-0.104	-0.228	0.021	0.102
Nikpayam et al., 2023 a	BMI	-0.100	-0.330	0.130	0.393
Li Teoh et al., 2018 a	HDL	-0.093	-0.181	-0.005	0.039
Nikpayam et al., 2023 j	hs-CRP	-0.090	-0.340	0.160	0.480
Nikpayam et al., 2023 b	Body weight	-0.080	-0.270	0.110	0.408
Nikpayam et al., 2023 l	IL-6	-0.040	-0.354	0.274	0.803
Nikpayam et al., 2023 k	TNF-a	-0.020	-0.339	0.299	0.902
Nikpayam et al., 2023 c	Body fat	0.020	-0.205	0.245	0.861
Nikpayam et al., 2023 e	Insulin	0.070	-0.175	0.315	0.575

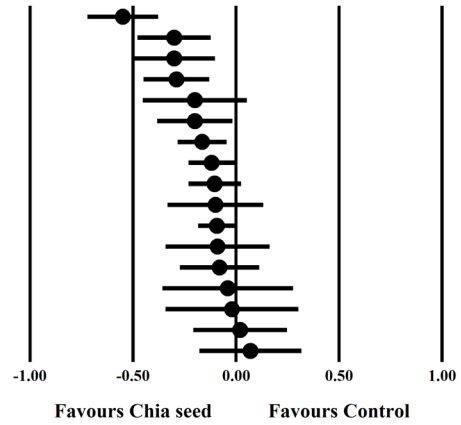

Fig. 2 Hedges's g analysis of the impact of chia consumption on health outcomes using Comprehensive Meta-Analysis (CMA) software (v3.7)/Hedges's g results are interpreted as follows: a small effect size is around g ≈ 0.2, a medium effect size is g ≈ 0.5, a large effect size is g ≈ 0.8, and a very large effect size is greater than 1.0. Significant level: $P<0.05$. Postprandial blood glucose (PPG); body mass index (BMI); hemoglobin A1c (HbA1c); body mass index (BMI); waist circumference (WC); total cholesterol (TC); triglycerides (TG); high density lipoproteins (HDL); low density lipoprotein (LDL); systolic blood pressure (SBP); diastolic blood pressure (DBP); interleukin-6 (IL-6); C-reactive protein (CRP); tumor necrosis factor-alpha (TNF-α); high sensitive CRP (hs-CRP)

intake as (SMD: −0.30 mg/dL, $I^2 = 20.2\%$, $P<0.05$), (SMD: −0.20 mg/dL, $I^2 = 67.1\%$, $P<0.05$), and (SMD: −0.30 mg/dL, $I^2 = 62.7\%$, $P<0.05$), respectively. Only one study by Teoh et al. [35] highlighted that individuals who consumed chia seed represented a significant reduction in HDL (MD: −0.10 mg/dL, $I^2 = 11.7\%$, $P<0.050$).

Effect of Chia on Glycemic Indices

Glycemic parameter changes after chia intake were evaluated in five studies, demonstrating no significant changes in levels of FBG and HbA1c [4, 26, 30, 34, 35], and fasting blood insulin [4, 26, 30] ($P>0.050$). Teoh et al. [35] found that only PPG demonstrated a significant reduction by chia consumption (MD: −24.10 mmol/L, $I^2 = 67.9\%$, $P<0.050$).

Effect of Chia on Inflammatory Responses

Chia consumption effect on inflammatory markers was assessed in four meta-analyses, of which none of them found significant changes in the level of IL-6, IL-8, IL-10, and TNF-α ($P>0.050$) [4, 26, 30, 35]. While, the serum level of CRP was reported to significantly decrease in studies by Pam et al. [31] (WMD: −0.64 mg/L, $I^2 = 0.0\%$, $P=0.030$) and Karimi et al [30] (MD: −1.18 mg/L, $I^2 = 87.9\%$, $P<0.001$) [30]. Although Teoh et al. [35], and Nikpayam et al. [4] found a reduction in CRP and hs-CRP levels, of which this reduction was not statistically significant ($P>0.050$).

Effect of Chia on Anthropometric Parameters

Studies by Teoh et al [35], Saadh et al [32], Karimi et al [30], Nikpayam et al [4], and Taghipour Sheshdeh et al [34] analyzed and evaluated the impact of chia on anthropometric parameters and demonstrated that chia had no significant effect on body weight, BMI, and body fat ($P>0.050$). Only in two studies by Saadh et al. [32] and Karimi et al [30], a significant reduction in WC was reported (WMD: −1.46 mg/L, $I^2 = 0.0\%$, $P=0.010$) and (MD: −2.82 mg/L, $I^2 = 0.0\%$, $P<0.001$), respectively.

Effect of Chia on Liver Enzymes

Teoh et al. [35] reported no statistically significant changes in liver function markers, including ALT, AST, and ALT, indicating that chia supplementation did not adversely affect hepatic enzymes in the included trials.

Power Analysis

The results of the statistical power of the meta-analysis illustrated that the variables with larger effect sizes and lower heterogeneity, such as DBP, TC, LDL, and WC exhibited higher statistical power. In contrast, outcomes such as CRP and PPG demonstrated lower statistical power due to smaller effect sizes and/or higher heterogeneity (CRP $I^2 = 87.9\%$, PPG $I^2 = 67.9\%$). This lower power suggests a

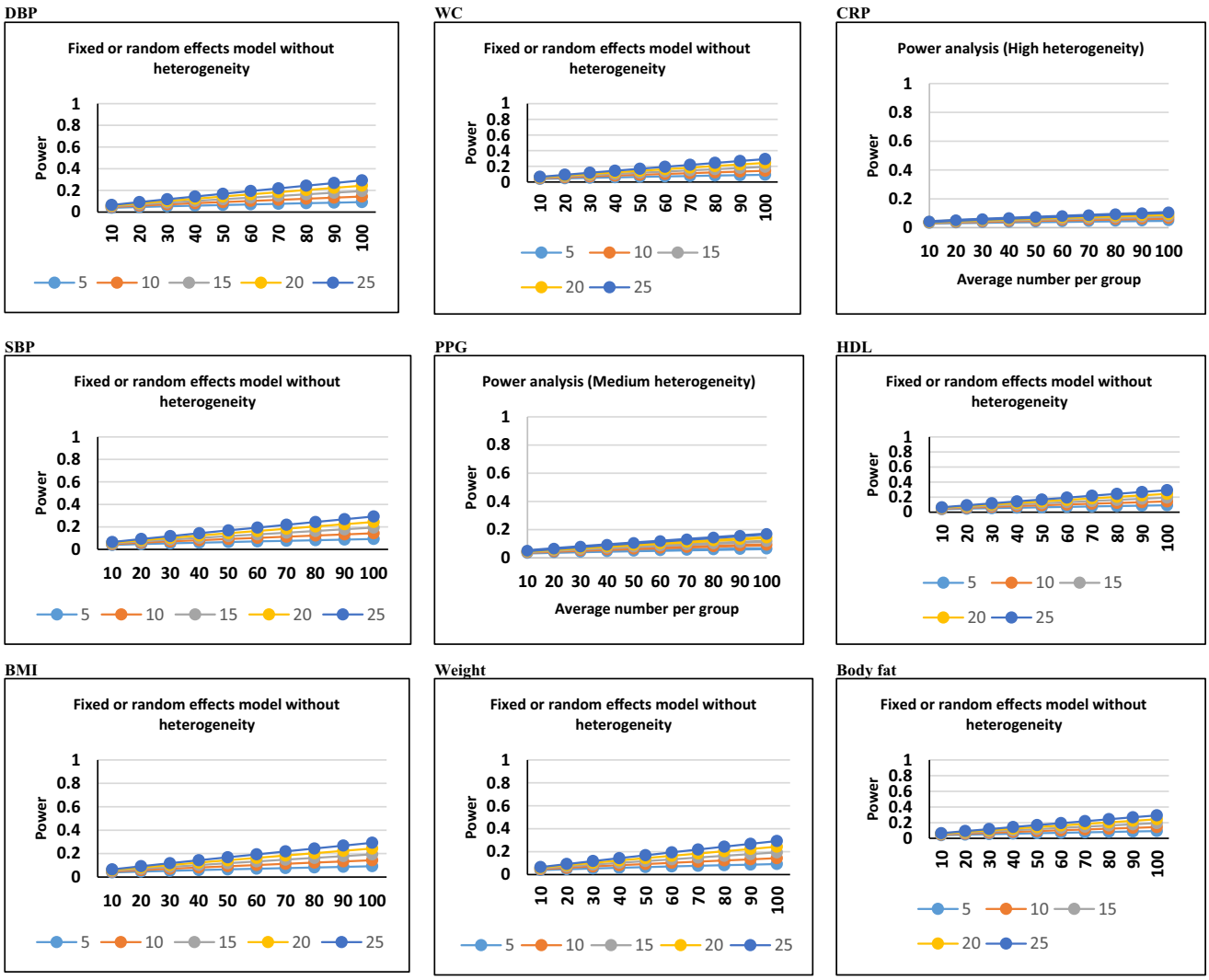

Fig. 3 Power analysis of meta-analysis outcomes based on effect size, sample size, and heterogeneity. The statistical power was calculated based on the risk ratio, the average sample size per group, the number of effect sizes (included studies), and the heterogeneity index (I^2). Outcomes with larger effect sizes and lower heterogeneity demonstrate higher statistical power, while outcomes with smaller effect sizes and higher heterogeneity may have lower power. Postprandial blood glucose (PPG); body mass index (BMI); hemoglobin A1c (HbA1c); body mass index (BMI); waist circumference (WC); total cholesterol (TC); triglycerides (TG); high density lipoproteins (HDL); low density lipoprotein (LDL); systolic blood pressure (SBP); diastolic blood pressure (DBP); interleukin-6 (IL-6); C-reactive protein (CRP); tumor necrosis factor-alpha (TNF-α); high sensitive CRP (hs-CRP)

greater likelihood of Type II error in these outcomes, and thus, findings related to CRP and PPG should be interpreted cautiously, as true effects may be underestimated or missed (Fig. 3).

Discussion

The present umbrella review analyzed the reported data on the effects of chia consumption on health status, encompassing cardiovascular parameters, glycemic control, lipid metabolism, inflammatory responses, and anthropometric measures, suggesting that while chia supplementation exerts modest benefits on specific health parameters such as blood pressure, WC, and CRP levels, its overall impact remains limited. Our findings from multiple meta-analyses indicated that chia consumption has a significant impact on both SBP and DBP, while some others only found a reduction in SBP or DBP with a greater portion in DBP compared to SBP [30, 32, 34, 35].

While these reductions are modest, they may still be clinically meaningful, particularly at the population level. However, the magnitude of BP lowering observed with chia is smaller than that achieved with standard antihypertensive medications, depending on drug class and baseline levels. The modest BP-lowering effect of chia may be attributed to

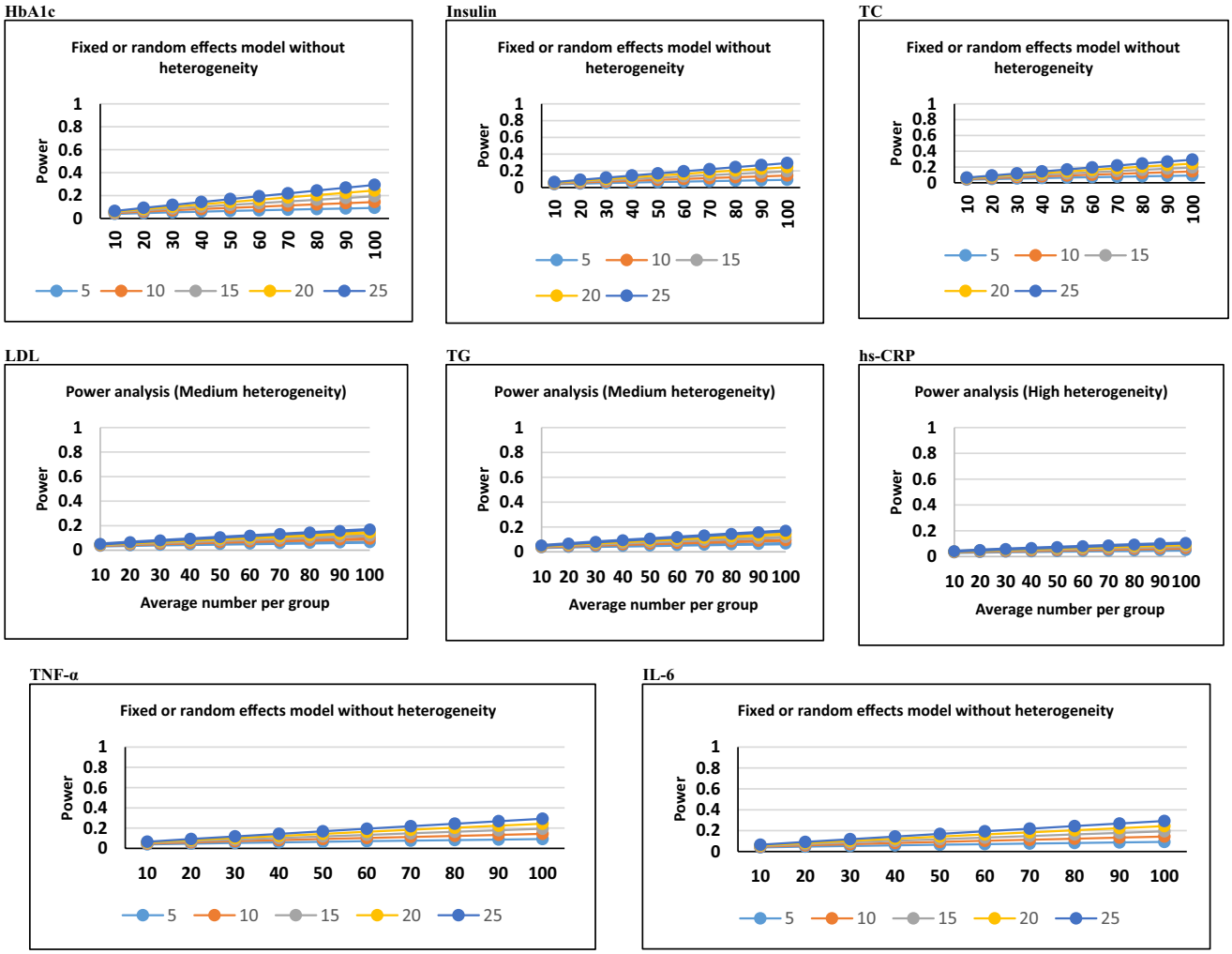

Fig. 3 (continued)

its high fiber, omega-3 fatty acid, and antioxidant content, which can influence endothelial function and inflammation. Fateh et al [36] reported that chia seeds may lower SBP dose-dependently by increasing linoleic acid (LA) levels [36]. Although the BP reductions seen with chia alone are unlikely to replace pharmacotherapy, they may provide a supportive dietary strategy, especially for individuals seeking additional non-pharmacological interventions to manage blood pressure. In comparison, other functional foods such as cinnamon, Nigella sativa, and sesame have demonstrated more pronounced cardiovascular and metabolic benefits. Recent high-impact meta-analyses have reported significant reductions in glycemic indices and lipid profiles with these foods [7–9]. These effects often exceed those observed with chia, suggesting that while chia's benefits are modest, it may serve best as a complementary dietary element rather than a primary intervention.

Chia seeds are rich in ALA, which has been linked to anti-inflammatory effects and improved lipid metabolism. LA and ALA produce bioactive lipids that regulate inflammation and homeostasis. While arachidonic acid (ARA) promotes inflammation, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) have anti-inflammatory effects, reducing cardiovascular disease risk [33, 37, 38]. Despite chia's purported cardiovascular benefits, its impact on lipid metabolism remains inconclusive. Across the reviewed meta-analyses, we found no significant reductions in TC, TG, or LDL levels. Interestingly, only Teoh et al. [35] reported a minor yet significant reduction in HDL levels, which is an unexpected finding that warrants further investigation. The lack of significant changes in lipid parameters may be due to variations in participant baseline lipid levels, dietary intake, or the bioavailability of chia-derived lipids. This unexpected outcome may be explained by variations in baseline health status among participants, as several included trials enrolled healthy individuals or athletes with already normal or high HDL levels, leaving less room for beneficial increases. Other analyses did not find this effect,

so this result should be interpreted with caution and verified in future studies [30, 39].

However, Silva et al. found that chia oil consumption significantly reduced LDL levels in comparison with other types of chia supplements [33]; and Nikpayam et al [4] found significant impact chia supplements consumption on TC, TG, and LDL [4]. Chia seeds contain lignans and phytosterols, which help lower cholesterol by reducing absorption in the gastrointestinal tract and promoting bile acid excretion, leading to decreased TC and LDL levels [23, 40]. Additionally, chia seeds may regulate lipid metabolism by suppressing lipid synthesis genes and enhancing fatty acid oxidation, potentially reducing liver lipid production and promoting fat breakdown [40]. One animal study by Sierra et al. demonstrated that dietary supplementation with chia oil improved vascular function in hypercholesterolemic rabbits by increasing ALA levels, reducing TG rise, and restoring nitric oxide release. Chia oil partially normalized acetylcholine-induced relaxation, intima/media ratio, and blunted vasoconstriction responses, suggesting its potential as a functional food for cardiovascular health [41].

The current study illustrated that chia supplementation showed a mixed impact on glycemic control. While FBG, fasting blood insulin, and HbA1c remained unaffected across multiple studies, Teoh et al. demonstrated a notable reduction in PPG levels, suggesting a potential benefit for postprandial glucose management [35]. This effect could be attributed to the high soluble fiber content in chia, which may slow glucose absorption and improve glycemic response. However, given the moderate heterogeneity observed, further research is needed to establish chia's role in glycemic regulation, particularly in populations with impaired glucose tolerance or diabetes. Studies have shown that the fiber content in chia helps slow down carbohydrate digestion and absorption, leading to a more gradual release of glucose into the bloodstream [5, 42]. This could inform dietary recommendations for individuals with prediabetes or type 2 diabetes seeking to improve postprandial glucose control through functional foods.

Inflammation plays a critical role in metabolic and cardiovascular health, yet the effect of chia on inflammatory markers remains uncertain. While no significant changes were observed in hs-CRP, ILs, or TNF-α in the current study, reductions in CRP levels were noted [4, 30, 31]. However, the high heterogeneity reported by Karimi et al. [30], of which can suggest that the anti-inflammatory effects of chia may be influenced by differences in chia dosage, study duration, baseline CRP levels, and the health status of participants. Variations in the form of chia (whole seeds vs. supplements) may also contribute to these inconsistencies. Although CRP is a non-specific marker, its modest reduction suggests that chia intake may offer additional anti-inflammatory benefits when combined with other lifestyle modifications, but current evidence is insufficient to justify clinical use for inflammation control alone [31, 43].

Furthermore, chia seeds contain about 20% protein, with digested proteins exhibiting anti-inflammatory effects by inhibiting PPARγ and reducing nuclear factor-kappa B (NF-κB) activation. During adipogenesis, albumin and glutelin suppress sterol regulatory element-binding protein 1 (SREBP), further lowering inflammation [44–46]. A study by Joubert et al. on the impact of chia on liver inflammation and metabolic syndrome demonstrated that three months of chia seed administration reversed dyslipidemia, hyperglycemia, inflammation, and endothelial dysfunction in rats, normalizing liver markers, while reducing nitric oxide, nitric oxide synthase, and NF-κB - p65 expression [47].

The impact of chia consumption on body composition remains negligible. Across the analyzed studies, no significant effects were observed on most of the anthropometric parameters. However, we observed that two studies reported a significant reduction in WC, which may indicate a modest role in central adiposity management [30, 32]. The observed reduction in WC could be due to chia's high fiber content, which promotes gut motility, enhances stool bulk, and potentially prevents constipation. A high portion of fiber, protein, and healthy fats in chia, can contribute to a reduction in visceral fat or changes in body fat distribution. Furthermore, chia seeds can absorb several times their weight in water, forming a gel-like consistency that aids digestion and provides a prolonged feeling of satiety [5, 48, 49]. Waruguru et al. reported that chia seed consumption in combination with a hypocaloric diet, can lead to significant weight loss [48].

The overall quality assessment indicated that most included meta-analyses were of moderate to high methodological quality. In the current study, the power analysis indicates that outcomes like DBP and WC showed robust statistical power due to larger effect sizes and low heterogeneity, supporting confident conclusions. In contrast, outcomes such as CRP and PPG demonstrated low power, mainly because of small effect sizes and high heterogeneity, which increases the risk of errors and limits the reliability of effect estimates [50, 51]. Therefore, findings for CRP and PPG should be interpreted with caution and cannot yet guide clinical decisions. To strengthen future evidence, larger and well-designed trials with at least 120–200 participants per group for low-power outcomes are needed, along with standardized methodologies and subgroup analyses to reduce heterogeneity [52, 53]. This would ensure more definitive conclusions and better inform clinical practice regarding the modest effects of chia consumption on inflammation and glycemic control.

In the current study, CCA (0.20) confirmed minimal study overlap, aligning with best practices for umbrella

reviews [54]. However, several limitations should be acknowledged. First, the included studies exhibited varying degrees of heterogeneity, which may have influenced the pooled effect estimates and complicated interpretation. Second, although some studies reported statistically significant effects, the clinical significance remains uncertain due to small effect sizes and the potential influence of publication bias and small-study effects. Third, variations in the form of chia used (whole seeds vs. supplements), dosage regimens, and study durations likely contributed to inconsistencies across findings. Finally, the relatively limited number of RCTs evaluating some health outcomes restricts the generalizability of our conclusions and highlights the need for more robust and standardized future trials. To address these gaps, future research should focus on well-designed, adequately powered randomized controlled trials with standardized chia interventions, clearly defined dosages, and sufficient follow-up periods. Researchers should also explore dose–response relationships, compare different chia formulations, and investigate potential mechanisms of action, including gut microbiota modulation and bioactive compound bioavailability. In addition, future studies should report outcomes using consistent and clinically meaningful measures to improve comparability and allow more robust evidence synthesis.

Conclusion

This umbrella review and meta-analysis indicate that chia supplementation may provide modest but meaningful benefits for cardiovascular and metabolic health, including reductions in blood pressure, WC, inflammatory markers, and improvements in lipid profile. However, its overall effects remain limited and inconsistent due to variations in study quality, intervention methods, and small sample sizes. While chia shows promise as a functional food, its effects appear more modest when compared to other nutritionally similar foods, which have demonstrated more pronounced cardiovascular and metabolic benefits. This comparative perspective reinforces chia's potential role as a complementary component within holistic dietary strategies. Well-designed, large-scale trials are needed to clarify chia's true therapeutic potential and guide evidence-based dietary recommendations.

Abbreviations

RCTs	Randomized controlled trials
ALA	α-linolenic acid
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
AMSTAR-2	A Measurement Tool to Assess Systematic Reviews
GRADE	Grading of Recommendations, Assessment, Development, and Evaluations
CMA	Comprehensive Meta-Analysis
CCA	corrected covered area
SREBP	sterol regulatory element-binding protein 1
ARA	arachidonic acid
EPA	eicosapentaenoic acid
DHA	docosahexaenoic acid
NF-κB	nuclear factor-kappa B
MD	mean difference
WMD	weighted mean difference
SMD	standardized mean difference
I^2	heterogeneity
CI	confidence interval
sig	significant
NA	not applicable
AUC	area under curve
suppl.	supplements
PPG	postprandial blood glucose
BUN	blood urea nitrogen
FBG	fasting blood glucose
HbA1c	hemoglobin A1c
BMI	body mass index
WC	waist circumference
HC	hip circumference
TC	total cholesterol
TG	triglycerides
HDL	high density lipoproteins
LDL	low density lipoprotein
SBP	systolic blood pressure
DBP	diastolic blood pressure
AST	aspartate transaminase
ALT	alanine transaminase
ALP	alkaline phosphatase
IL-6	interleukin-6
CRP	C-reactive protein
TNF-α	tumor necrosis factor-alpha
lower body fat	gynoid fat
hs-CRP	high sensitive CRP
upper body fat	android fat
VLDL	very low density lipoprotein

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Data Availability All data and materials as well as software application information are available in the manuscript.

Declarations

Ethics Approval and Consent to Participate Not Applicable.

Consent for Publication Not Applicable.

Competing interests The authors declare no competing interests.

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