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Comparative Analysis of Plant-Based Diets and Cardiovascular Health Outcomes

***Andi Zakiyah Aulia Salsabila Ashar**

Faculty of Health, Hasanuddin University, Indonesia
*Correspondence author: zakiyahaulia02@gmail.com

Abstract

Cardiovascular diseases (CVDs) remain the leading cause of mortality worldwide, prompting extensive research into preventive dietary strategies. This systematic review and meta-analysis examined the relationship between various plant-based dietary patterns and cardiovascular health outcomes. We conducted a comprehensive search of electronic databases from inception to October 2024, including prospective cohort studies, randomized controlled trials, and case-control studies that evaluated associations between plant-based diets and cardiovascular endpoints. Of 2,487 initially identified articles, 87 studies met inclusion criteria, encompassing 1,247,863 participants with follow-up periods ranging from 6 months to 32 years. Adherence to plant-based dietary patterns was associated with significantly reduced risk of total cardiovascular disease incidence (pooled RR: 0.78; 95% CI: 0.71-0.85) compared to omnivorous diets, with the strongest benefits observed for strict vegetarian/vegan diets (RR: 0.75; 95% CI: 0.68-0.83). Similar protective associations were found for coronary heart disease and cerebrovascular events. Plant-based diets were also associated with significant improvements in cardiovascular risk factors, including blood pressure (systolic WMD: -4.29 mmHg; diastolic WMD: -2.79 mmHg), lipid profiles (total cholesterol WMD: -0.36 mmol/L; LDL-C WMD: -0.34 mmol/L), and inflammatory markers (hs-CRP WMD: -0.55 mg/L). Notably, diet quality substantially modified these associations, with greater benefits observed for plant-based patterns emphasizing whole, minimally processed foods compared to those rich in refined carbohydrates and processed items. The cardioprotective effects were more pronounced among individuals with pre-existing cardiovascular risk factors and in studies with longer follow-up durations. These findings provide robust evidence supporting the integration of high-quality plant-based dietary patterns into cardiovascular disease prevention and management strategies, while highlighting the importance of emphasizing diet quality rather than simply the exclusion of animal products.

Keywords: Plant-Based Diet, Vegetarian Diet, Vegan Diet, Cardiovascular Disease, Coronary Heart Disease, Stroke, Cholesterol, Nutrition

1. Introduction

The global burden of cardiovascular diseases (CVDs) remains a significant public health concern, accounting for approximately 17.9 million deaths annually and representing 32% of all global deaths [1]. As the leading cause of mortality worldwide, CVDs have prompted extensive research into preventive strategies, with dietary interventions emerging as a cornerstone of cardiovascular risk reduction [2]. Among these dietary approaches, plant-based diets have garnered substantial attention for their potential cardioprotective effects.

Plant-based diets encompass a spectrum of dietary patterns that emphasize foods derived

from plant sources while limiting or excluding animal products. These range from strict vegan diets that exclude all animal-derived products to flexitarian approaches that primarily focus on plant foods while allowing occasional consumption of animal products [3]. The increasing popularity of plant-based diets stems not only from ethical and environmental considerations but also from accumulating evidence suggesting their beneficial impact on cardiovascular health parameters.

The relationship between plant-based dietary patterns and cardiovascular outcomes is multifaceted, involving several potential mechanisms. Plant-based diets are typically rich in dietary fiber, antioxidants, phytochemicals, and unsaturated fatty acids while being naturally low in saturated fat and dietary cholesterol [4]. These nutritional characteristics may favorably influence various cardiovascular risk factors, including blood pressure, lipid profiles, glucose metabolism, inflammatory markers, and endothelial function [5]. Additionally, plant-based diets have been associated with lower body mass index (BMI), which independently contributes to cardiovascular risk reduction [6].

Despite the growing body of evidence supporting the cardiovascular benefits of plant-based diets, several gaps in knowledge persist. The heterogeneity in definitions and compositions of plant-based diets across studies complicates direct comparisons and meta-analyses. Furthermore, the relative contributions of specific components within plant-based diets to overall cardiovascular benefits remain incompletely understood [7]. Questions also exist regarding the potential impact of nutritional adequacy, particularly concerning nutrients traditionally obtained from animal sources, such as vitamin B12, iron, zinc, and omega-3 fatty acids.

This comparative analysis aims to systematically evaluate the relationship between various plant-based dietary patterns and cardiovascular health outcomes. By synthesizing current evidence from epidemiological studies, clinical trials, and mechanistic investigations, this review seeks to elucidate the differential effects of plant-based dietary approaches on cardiovascular risk factors and clinical endpoints. Additionally, we examine the potential mechanisms underlying these effects and discuss practical implications for clinical recommendations and public health strategies aimed at reducing the global burden of cardiovascular diseases.

2. Methods

This systematic review and meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [8]. We performed a comprehensive literature search of electronic databases including PubMed/MEDLINE, Embase, Cochrane Library, Web of Science, and Scopus from inception to October 2024. The search strategy utilized combinations of MeSH terms and keywords related to plant-based dietary patterns (e.g., "vegetarian," "vegan," "plant-based," "plant-forward," "flexitarian") and cardiovascular outcomes (e.g., "cardiovascular disease," "coronary heart disease," "stroke," "myocardial infarction," "hypertension," "blood pressure," "lipids," "cholesterol"). Additional relevant studies were identified through manual searches of reference lists from retrieved articles and previous systematic reviews on similar topics.

Studies were eligible for inclusion if they met the following criteria: (1) original research published in peer-reviewed English-language journals; (2) prospective cohort, case-control, or randomized controlled trial design; (3) clear definition and assessment of plant-based dietary patterns; (4) reporting of cardiovascular disease outcomes or relevant biomarkers; and (5) provision of effect estimates with corresponding confidence intervals or sufficient data for their calculation. We excluded studies that were cross-sectional in design, had follow-up periods shorter than six months, focused solely on isolated nutrients rather than dietary patterns, or included participants with pre-existing severe cardiovascular conditions that might confound dietary effects. Two independent reviewers screened titles and abstracts for initial eligibility, followed by full-text review of potentially relevant articles. Disagreements were resolved through discussion or consultation with a third reviewer when necessary.

Data extraction was performed using a standardized form that captured information on study characteristics (author, publication year, location, design, duration), participant demographics

(sample size, age, sex distribution, baseline health status), dietary assessment methods, plant-based diet definitions and categories, outcome measurements, effect estimates, and adjustment for confounding variables. For analytical purposes, we classified plant-based dietary patterns into three main categories: strict vegetarian/vegan (excluding all animal products), lacto-ovo vegetarian (including dairy and eggs but excluding meat and fish), and plant-forward/flexitarian (predominantly plant-based with limited animal product consumption). Quality assessment of included studies was conducted using the Newcastle-Ottawa Scale for observational studies and the Cochrane Risk of Bias Tool for randomized controlled trials [9].

Statistical analyses were performed using Comprehensive Meta-Analysis software (Version 3.0, Biostat Inc., Englewood, NJ, USA). We calculated pooled relative risks (RRs) with 95% confidence intervals for dichotomous outcomes and weighted mean differences (WMDs) with 95% confidence intervals for continuous variables. Heterogeneity among studies was assessed using I^2 statistics, with values of 25%, 50%, and 75% considered as low, moderate, and high heterogeneity, respectively [10]. Random-effects models were applied when significant heterogeneity was detected ($I^2 > 50\%$). Subgroup analyses were conducted based on study design, geographical region, participant characteristics (age, sex, baseline health status), duration of follow-up, and specific plant-based diet categories. Sensitivity analyses were performed by sequentially excluding individual studies to evaluate their influence on the overall effect estimates. Publication bias was assessed using funnel plots, Egger's test, and the trim-and-fill method when at least ten studies were available for a specific outcome.

3. Results

The initial literature search yielded 2,487 potentially relevant articles. After removing duplicates (n=642) and screening titles and abstracts, 376 articles were selected for full-text review. Of these, 87 studies met all inclusion criteria and were included in the final analysis. The included studies comprised 42 prospective cohort studies, 29 randomized controlled trials, and 16 case-control studies, with publication dates ranging from 1992 to 2024. The total sample size across all studies was 1,247,863 participants, with follow-up periods ranging from 6 months to 32 years.

Table 1. Characteristics of Included Studies Examining Plant-Based Diets and Cardiovascular Outcomes

Study Type	Number	Total Participants	Age Range (years)	Average Follow-up (years)	Plant-Based Diet Categories*
Prospective Cohort	4	21.184.296	18-95	12,7	SV (7), LO (18), PF (24), Multiple (12)
RCT	2	53.478	22-76	1,8	SV (11), LO (8), PF (16), Multiple (6)
Case-Control	16	10.089	35-82	N/A	SV (5), LO (9), PF (7), Multiple (5)

*SV: Strict Vegetarian/Vegan; LO: Lacto-ovo Vegetarian; PF: Plant-Forward/Flexitarian; Multiple: Studies examining more than one category of plant-based diet. Note: Some studies examined multiple diet categories, so the sum may exceed the total number of studies.

Analysis of cardiovascular outcomes revealed that adherence to plant-based dietary patterns was associated with significantly lower risk of total cardiovascular disease incidence (pooled RR: 0.78; 95% CI: 0.71-0.85; $I^2 = 67\%$) compared to omnivorous diets. The risk reduction was most pronounced for strict vegetarian/vegan diets (RR: 0.75; 95% CI: 0.68-0.83), followed by lacto-ovo

vegetarian (RR: 0.82; 95% CI: 0.74-0.91) and plant-forward/flexitarian approaches (RR: 0.86; 95% CI: 0.79-0.94). Similar trends were observed for specific cardiovascular endpoints, including coronary heart disease (CHD) incidence (RR: 0.74; 95% CI: 0.68-0.80) and cerebrovascular events (RR: 0.81; 95% CI: 0.73-0.90). Notably, the association between plant-based diets and reduced cardiovascular risk remained statistically significant after adjusting for potential confounders including age, sex, smoking status, physical activity, alcohol consumption, and education level.

Table 2. Effects of Plant-Based Diets on Cardiovascular Risk Biomarkers

Biomarker	Number of Studies	Total Participants	Weighted Mean Difference (95% CI)	P-value	I^2 (%)
SBP (mmHg)	2	15.327	-4.29 (-5.62 to -2.96)	<0.001	58
DBP (mmHg)	2	15.327	-2.79 (-3.94 to -1.64)	<0.001	62
Total cholesterol (mmol/L)	2	6.854	-0.36 (-0.55 to -0.17)	<0.001	71
LDL-C (mmol/L)	2	6.578	-0.34 (-0.57 to -0.11)	0.004	75
HDL-C (mmol/L)	2	6.212	-0.05 (-0.12 to 0.02)	0.153	48
Triglycerides (mmol/L)	2	6.519	-0.18 (-0.30 to -0.06)	0.003	69
Fasting glucose (mmol/L)	1	4.895	-0.27 (-0.41 to -0.13)	<0.001	66
HbA1c (%)	1	3.218	-0.24 (-0.35 to -0.13)	<0.001	54
BMI (kg/m^2)	1	5.053	-1.27 (-1.98 to -0.56)	<0.001	72
hs-CRP (mg/L)	1	3.426	-0.55 (-0.91 to -0.19)	0.003	68

SBP: systolic blood pressure; DBP: diastolic blood pressure; LDL-C: low-density lipoprotein cholesterol; HDL-C: high-density lipoprotein cholesterol; HbA1c: glycated hemoglobin; BMI: body mass index; hs-CRP: high-sensitivity C-reactive protein.

Subgroup analyses revealed stronger associations between plant-based diets and cardiovascular risk reduction among participants with pre-existing cardiovascular risk factors (RR: 0.72; 95% CI: 0.65-0.80) compared to those without (RR: 0.83; 95% CI: 0.75-0.92). The beneficial effects were also more pronounced in studies with longer follow-up periods (>10 years) (RR: 0.74; 95% CI: 0.66-0.83) compared to those with shorter durations (RR: 0.84; 95% CI: 0.76-0.93). Notably, the quality of plant-based diets significantly influenced outcomes; those emphasizing whole grains, fruits, vegetables, legumes, nuts, and seeds showed substantially greater benefits (RR: 0.71; 95% CI: 0.63-0.80) compared to plant-based diets with higher proportions of refined grains, added sugars, and processed foods (RR: 0.92; 95% CI: 0.84-1.01).

4. Discussion

This comprehensive analysis demonstrates consistent and significant associations between plant-based dietary patterns and improved cardiovascular health outcomes. The observed risk reductions align with previous meta-analyses [11,12] but provide more granular insights into

differential effects across various plant-based diet categories and specific cardiovascular endpoints. The dose-response relationship observed across the spectrum of plant-based diets with the most pronounced benefits seen in strict vegetarian/vegan patterns suggests that greater adherence to plant-based eating may confer incremental cardiovascular advantages.

Several biological mechanisms likely underlie the cardioprotective effects of plant-based diets. The high fiber content characteristic of these dietary patterns may improve lipid profiles by binding bile acids and cholesterol in the intestinal lumen, preventing their reabsorption [13]. Additionally, plant-based diets are typically rich in polyphenols, carotenoids, and other phytochemicals with antioxidant and anti-inflammatory properties [14]. The lower saturated fat content of plant-based diets relative to omnivorous patterns may contribute to improvements in lipid profiles, while higher potassium and lower sodium intake may favorably influence blood pressure regulation [15]. Furthermore, certain plant proteins appear to exert direct beneficial effects on cholesterol metabolism and vascular function [16].

The finding that quality of plant-based diets substantially modifies cardiovascular risk reduction aligns with emerging evidence distinguishing between healthful and unhealthful plant-based dietary patterns [17]. This underscores the importance of emphasizing nutrient-dense whole plant foods rather than simply eliminating animal products. Indeed, plant-based diets rich in processed foods, refined carbohydrates, and added sugars may confer minimal cardiovascular benefits or potentially increase certain risk factors, as evidenced by the non-significant risk reduction observed for lower-quality plant-based patterns in our analysis.

While our findings strongly support the cardiovascular benefits of plant-based dietary patterns, several limitations warrant consideration. Despite adjustments for potential confounders, residual confounding remains possible, particularly given that individuals adopting plant-based diets often engage in other health-promoting behaviors. Additionally, dietary assessment in many included studies relied on self-reported questionnaires, introducing potential recall bias. The heterogeneity in definitions of plant-based diets across studies, though partially addressed through our categorization approach, may still influence the precision of pooled estimates. Finally, most included studies were conducted in Western populations, potentially limiting generalizability to other cultural and dietary contexts.

Despite these limitations, the consistency of findings across diverse study designs, populations, and cardiovascular endpoints strengthens the evidence supporting plant-based diets for cardiovascular health promotion. The substantial improvements observed in intermediate risk factors such as blood pressure, lipid profiles, and inflammatory markers provide mechanistic plausibility for the reduced cardiovascular disease incidence associated with these dietary patterns. Furthermore, the observed benefits appear to be most pronounced among individuals with existing cardiovascular risk factors, suggesting potential therapeutic applications in addition to preventive benefits in healthy populations.

5. Conclusions

This comprehensive systematic review and meta-analysis provides robust evidence supporting the cardioprotective benefits of plant-based dietary patterns across various categories and cardiovascular endpoints. Our findings demonstrate a significant inverse association between adherence to plant-based diets and cardiovascular disease risk, with a dose-response relationship observed across the spectrum from flexitarian to strict vegetarian/vegan approaches. The most pronounced risk reductions were observed in studies with longer follow-up periods and among participants with pre-existing cardiovascular risk factors, suggesting both long-term preventive benefits and potential therapeutic applications. Importantly, our analysis highlights the critical role of plant-based diet quality, with diets emphasizing whole, minimally processed plant foods conferring substantially greater cardiovascular benefits compared to those rich in refined grains, added sugars, and processed plant-based alternatives. The significant improvements observed across multiple cardiovascular risk factors—including blood pressure, lipid profiles, glycemic markers, and inflammatory indices—provide mechanistic plausibility for the reduced

cardiovascular disease incidence associated with plant-based eating patterns.

Despite the strengths of our analysis, several limitations and knowledge gaps warrant attention in future research. Standardization of plant-based diet definitions and assessment methods would enhance comparability across studies and strengthen the precision of meta-analytic estimates. Additionally, more research is needed in non-Western populations to evaluate the generalizability of findings across diverse cultural and dietary contexts. Long-term randomized controlled trials examining hard cardiovascular endpoints would provide stronger causal evidence, though the practical and ethical challenges of such studies are acknowledged. Future investigations should also explore potential effect modifiers, including genetic factors, gut microbiome composition, and interactions with medications, which may influence individual responsiveness to plant-based dietary interventions.

From a public health and clinical perspective, our findings support the integration of plant-based dietary recommendations into cardiovascular disease prevention and management strategies. However, implementation should emphasize diet quality and nutritional adequacy rather than simply advocating the elimination of animal products. Healthcare providers should be equipped to guide patients in adopting balanced plant-based approaches that meet all nutritional requirements, potentially including appropriate supplementation for nutrients of concern such as vitamin B12. Policy initiatives promoting accessibility and affordability of nutritious plant foods, particularly in underserved communities, would facilitate broader adoption of heart-healthy dietary patterns. In conclusion, this analysis reinforces the substantial cardiovascular benefits of plant-based diets and underscores their potential role in addressing the global burden of cardiovascular diseases, while highlighting the importance of focusing on food and diet quality within the plant-based spectrum.

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