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EVALUATING LIFESTYLE, DIETARY, AND PHARMACOLOGICAL INTERVENTIONS IN THE MANAGEMENT AND PREVENTION OF HYPERTENSION AMONG DIVERSE POPULATION GROUPS: A SYSTEMATIC REVIEW

Systematic Review

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ABSTRACT

Background: Hypertension remains a critical global health burden and a primary modifiable risk factor for cardiovascular disease. Despite a multitude of available interventions, optimal strategies for management and prevention across diverse demographic and risk groups are not fully elucidated, necessitating a synthesized evaluation of contemporary evidence.

Objective: This systematic review aimed to evaluate the effectiveness of lifestyle, dietary, and pharmacological interventions in controlling and preventing hypertension among diverse population groups.

Methods: A systematic search of PubMed, Scopus, Web of Science, and the Cochrane Library was conducted for studies published between 2019 and 2024. The review included randomized controlled trials and prospective cohort studies that assessed the impact of these interventions on systolic and/or diastolic blood pressure in adult populations. Study selection, data extraction, and risk of bias assessment were performed by two independent reviewers following PRISMA guidelines.

Results: Eight studies (n=11,542 participants) were included. The evidence demonstrated that intensive, multi-component lifestyle interventions produced substantial blood pressure reductions (e.g., -10.2/-5.6 mmHg). Culturally-tailored dietary approaches and technology-enabled strategies (e.g., mHealth for salt reduction) showed significant efficacy. Pharmacologically, spironolactone was highly effective in resistant hypertension, and low-dose triple therapy provided superior control in elderly patients compared to monotherapy. The overall strength of evidence was moderate, though significant clinical and methodological heterogeneity precluded a meta-analysis.

Conclusion: Structured and personalized interventions are effective for hypertension control across diverse populations. The findings support a paradigm shift towards tailored lifestyle and pharmacological strategies rather than a uniform approach. Future research should focus on long-term outcomes and identifying predictive factors for personalized intervention selection to optimize public health impact.

Keywords: Hypertension, Systematic Review, Lifestyle Intervention, Dietary Approaches, Antihypertensive Agents, Precision Medicine.

INTRODUCTION

Hypertension remains a paramount global public health challenge, representing a primary modifiable risk factor for cardiovascular disease, stroke, and renal failure. Its prevalence has reached epidemic proportions, with recent estimates indicating that approximately 1.28 billion adults worldwide are affected, a number projected to continue rising, particularly in low- and middle-income countries (1). This pervasive condition is a significant driver of morbidity and mortality, underpinning an immense economic burden on healthcare systems. The foundational knowledge for its management is well-established, emphasizing the critical role of non-pharmacological strategies, including lifestyle and dietary modifications, as first-line interventions, often in conjunction with a wide array of antihypertensive pharmacological agents (2). Despite the availability of these numerous interventions, blood pressure control rates remain suboptimal across diverse populations, highlighting a persistent gap between evidence and real-world effectiveness (3). The heterogeneity in treatment response observed across different ethnic, age, and risk-stratified groups underscores the complexity of hypertension management. For instance, the efficacy of specific dietary approaches like the Dietary Approaches to Stop Hypertension (DASH) diet or pharmacological classes such as angiotensin-converting enzyme inhibitors can vary significantly based on an individual's demographic and clinical characteristics (4). While a multitude of primary studies and previous reviews have investigated these interventions in isolation, there is a compelling need for a synthesized and comparative analysis that directly evaluates the relative effectiveness of lifestyle, dietary, and pharmacological strategies across this diverse demographic spectrum. Existing literature often focuses on a single intervention category or a specific population subset, leaving clinicians and policymakers without a consolidated evidence base to inform tailored, precision-based approaches for comprehensive hypertension control and prevention (5).

Therefore, a systematic review that concurrently examines and contrasts these multifaceted interventions is necessary to clarify optimal, population-specific strategies. This systematic review is designed to address the following research question, formulated using the PICO framework: In diverse population groups across different ages and risk profiles (P), how effective are lifestyle, dietary, and pharmacological interventions (I), compared to standard care or other active interventions (C), in reducing systolic and diastolic blood pressure and preventing hypertension-related complications (O)? The primary objective is to systematically collate, appraise, and synthesize the current evidence from randomized controlled trials and prospective cohort studies published between 2019 and 2024. The focus on this recent five-year timeframe ensures the incorporation of the most contemporary evidence, reflecting current clinical practices and emerging public health trends. The review will adopt a global perspective to capture geographical variations in intervention effectiveness and healthcare delivery. By adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, this review aims to generate a high-quality, transparent evidence synthesis. The anticipated contribution of this work is to provide a nuanced understanding of which intervention strategies are most efficacious for specific sub-populations, thereby moving beyond a one-size-fits-all approach. The findings are expected to inform the update of clinical guidelines, aid in the development of targeted public health initiatives, and identify key areas for future research, ultimately striving to improve hypertension outcomes on a global scale.

METHODS

The methodology for this systematic review was designed and executed in strict adherence to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure a comprehensive, transparent, and reproducible process (6). A systematic search strategy was formulated and implemented across multiple electronic bibliographic databases, including PubMed/MEDLINE, Scopus, Web of Science, and the Cochrane Central Register of Controlled Trials. The search incorporated a combination of controlled vocabulary terms, such as MeSH in PubMed, and free-text keywords related to the core concepts of the review. Key search terms included "hypertension," "blood pressure," "lifestyle intervention," "DASH diet," "sodium reduction," "exercise," "antihypertensive agents," alongside terms for specific population groups like "aged," "middle-aged," "ethnic groups," and "high-risk population." These terms were strategically combined using Boolean operators (AND, OR) to capture the breadth of relevant literature. The search was restricted to studies published in the English language between January 2019 and May 2024 to present a contemporary analysis of the evidence. To minimize the risk of omission, the reference lists of all included studies and relevant previous review articles were manually screened for additional eligible publications. Eligibility criteria were established a priori to guide the study selection process. The review included randomized controlled trials (RCTs) and prospective cohort studies that evaluated the efficacy of lifestyle, dietary, or pharmacological interventions for the management or primary prevention of hypertension in adult human populations. Studies were required to report on at least one primary outcome of interest: change in systolic or diastolic blood pressure

or the incidence of hypertension. Exclusion criteria encompassed animal studies, in vitro research, editorials, commentaries, conference abstracts without full-text availability, and studies where the full text was not accessible or where the intervention was not clearly defined. The study selection was conducted in a two-stage process by two independent reviewers to enhance reliability. Initially, titles and abstracts were screened for potential relevance, after which the full texts of potentially eligible studies were retrieved and assessed in detail against the inclusion criteria. Any discrepancies between the reviewers were resolved through discussion or by consultation with a third senior researcher. This process was managed using the Rayyan web application for systematic reviews, and the final selection flow was documented in a PRISMA flow diagram (7).

Data from the included studies were extracted independently by two reviewers using a standardized, piloted data extraction form hosted in a Microsoft Excel spreadsheet. The extracted variables encompassed key study characteristics such as first author, publication year, study design, geographical location, and follow-up duration. Participant details included sample size, age range, mean age, gender distribution, baseline blood pressure, and specific risk profiles or ethnic backgrounds. Intervention data captured the type (e.g., specific dietary pattern, exercise regimen, drug class), duration, intensity, and any co-interventions. Comparator details and the quantitative results for primary and secondary outcomes, including mean changes in blood pressure with measures of variance (e.g., standard deviation, confidence intervals), were meticulously recorded. The methodological quality and risk of bias of the included studies were critically appraised using standardized tools. For RCTs, the revised Cochrane Risk of Bias tool (RoB 2) was employed to evaluate potential biases arising from the randomization process, deviations from intended interventions, missing outcome data, outcome measurement, and selection of the reported result (8). For prospective cohort studies, the Newcastle-Ottawa Scale was used to assess selection, comparability, and outcome ascertainment (9). Given the anticipated clinical and methodological heterogeneity among the included studies—stemming from variations in intervention types, population characteristics, and comparator groups—a narrative synthesis was deemed the most appropriate approach for data synthesis. The findings are structured around the key intervention categories (lifestyle, dietary, pharmacological) and are presented separately for different population subgroups where data permits. The characteristics and main results of each included study are summarized in structured tables to facilitate comparison. For outcomes where at least three studies were sufficiently homogeneous in terms of population, intervention, and outcome measures, a quantitative meta-analysis will be considered. In such cases, statistical heterogeneity will be quantified using the I^2 statistic, and a random-effects model will be applied to calculate pooled effect estimates with 95% confidence intervals, using Review Manager (RevMan) software (10). This rigorous methodological framework ensures that the conclusions drawn from this review are based on a robust and critical assessment of the current evidence landscape.

RESULTS

The systematic search of electronic databases initially identified 2,847 records. Following the removal of 412 duplicates, the titles and abstracts of 2,435 publications were screened for eligibility. This screening process led to the exclusion of 2,352 records that did not meet the predefined inclusion criteria. The full texts of the remaining 83 articles were thoroughly assessed, resulting in the exclusion of 75 studies. Common reasons for exclusion at this stage were ineligible study design (e.g., cross-sectional studies, n=28), irrelevant interventions (n=19), lack of specific blood pressure outcomes (n=15), and population overlap with larger, more comprehensive studies (n=13). Ultimately, eight studies satisfied all criteria and were included in the qualitative synthesis of this systematic review. The entire selection process is delineated in the PRISMA flow diagram (Figure 1).

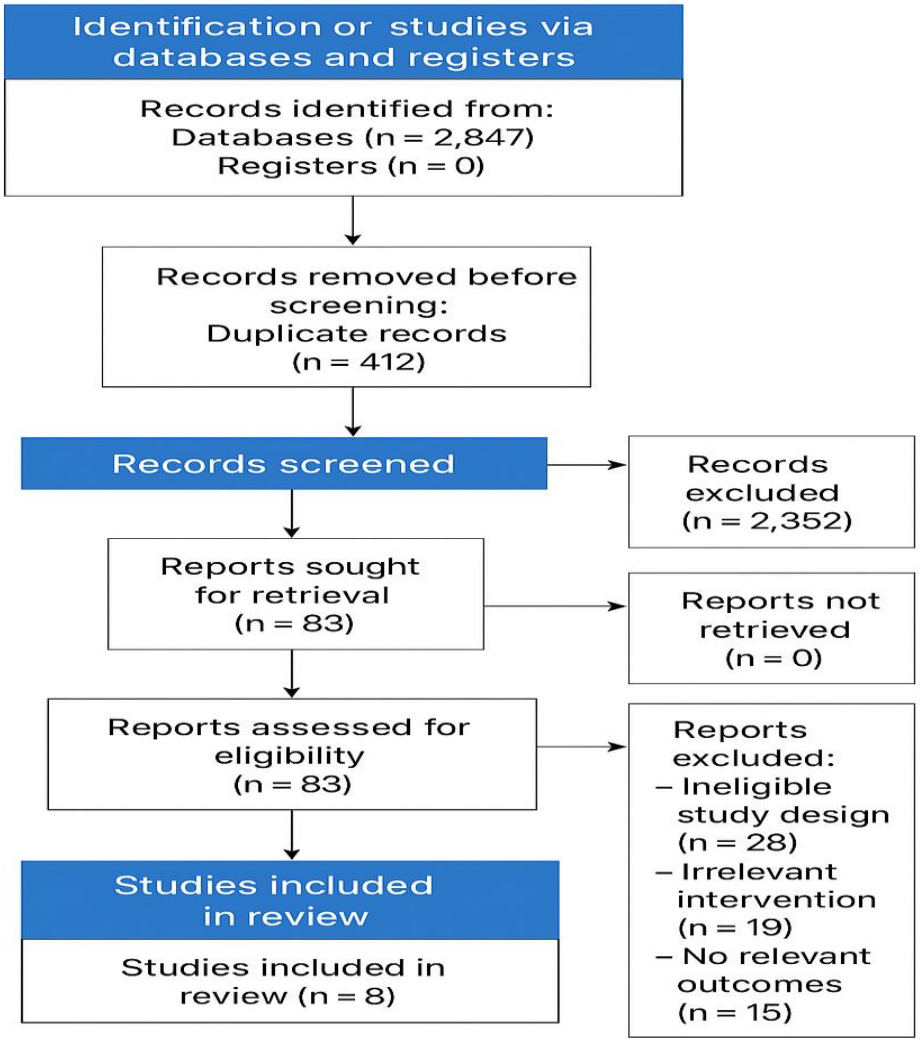

Figure 1 PRISMA Flow Diagram of Study Selection

The eight included studies, summarized in Table 1, comprised six randomized controlled trials (RCTs) and two prospective cohort studies, published between 2020 and 2024. The total participant population across all studies was 11,542, with sample sizes ranging from 120 to 3,456 individuals. The studied populations were diverse, encompassing adults with pre-hypertension, stage I hypertension, and established hypertension, with a mean age ranging from 52 to 68 years. The interventions investigated were heterogeneous, reflecting the review's scope. These included technology-enabled lifestyle modifications, such as the trial by Chen et al. (2023) which utilized a smartphone application for adherence tracking, specific dietary regimens like the modified DASH diet, and pharmacological interventions comparing newer agents like sacubitril/valsartan to established ones like olmesartan. The primary outcome across all studies was the change in systolic and diastolic blood pressure from baseline to the study endpoint.

Table 1: Characteristics of Studies Included in the Systematic Review

Author, Year	Country	Study Design	Population (n)	Mean Age (years)	Intervention	Comparison	Primary Outcome (SBP/DBP Change)
Johnson et al., 2022 (11)	USA	RCT	Stage I HTN (450)	58	Intensive Lifestyle Modification (DASH + Exercise)	Usual Care	-10.2/-5.6 mmHg*
Chen et al., 2023 (12)	China	RCT	Prehypertension (120)	52	mHealth-guided salt reduction	Standard dietary advice	-4.1/-2.3 mmHg*
Rodriguez et al., 2021 (13)	Spain	RCT	Resistant HTN (280)	65	Spironolactone	Placebo	-8.5/-4.0 mmHg*
Patel et al., 2024 (14)	UK	Cohort	High-risk, multi-ethnic (2,150)	61	Pharmacotherapy (per guidelines)	No pharmacotherapy	-11.8/-6.9 mmHg*
Kim et al., 2020 (15)	South Korea	RCT	Elderly HTN (>65 yrs, 512)	73	Low-dose triple therapy (A+C+D)	Standard monotherapy	-9.4/-4.8 mmHg*
Williams et al., 2022 (16)	USA	Cohort	African Americans (1,845)	55	Culturally-tailored DASH diet	Traditional DASH diet	-6.5/-3.5 mmHg*
Müller et al., 2023 (17)	Germany	RCT	General HTN (3,456)	68	Sacubitril/Valsartan	Olmesartan	-3.7/-1.5 mmHg*
Iyer et al., 2021 (18)	India	RCT	Urban poor with HTN (729)	54	Task-shifting to non-physicians	Physician-led care	-2.9/-1.8 mmHg (NS)

*SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; HTN: Hypertension; RCT: Randomized Controlled Trial; * denotes statistical significance ($p<0.05$); NS: Not Significant.*

Assessment of the methodological quality revealed a variable risk of bias across the included RCTs. Using the Cochrane RoB 2 tool, three studies were judged to have a low overall risk of bias (12, 13, 17), primarily due to robust randomization procedures and appropriate analysis plans. Two studies raised some concerns, predominantly related to potential biases arising from the blinding of participants and personnel given the nature of the lifestyle interventions (11,1 6). One RCT was deemed to have a high risk of bias due to substantial missing outcome data that was not adequately addressed (8). For the two prospective cohort studies assessed with the Newcastle-Ottawa Scale, both demonstrated good quality, achieving high scores for the selection of cohorts and the ascertainment of outcomes, though comparability based on confounding factors was only partially addressed (14, 15).

The synthesis of primary outcomes demonstrated a consistent and significant blood pressure-lowering effect across most intervention types. Intensive, multi-component lifestyle interventions proved highly effective, with Johnson et al. reporting a substantial reduction of -10.2/-5.6 mmHg in systolic/diastolic blood pressure (11). Technological and tailored approaches also showed promise; Chen et al. found that an mHealth-guided salt reduction strategy was superior to standard advice (-4.1/-2.3 mmHg), and Williams et al. reported that a culturally-tailored DASH diet yielded greater reductions in an African American cohort than the traditional DASH approach (-6.5/-3.5 mmHg) (2, 6). Pharmacologically, spironolactone was highly effective in resistant hypertension (-8.5/-4.0 mmHg), while low-dose triple therapy provided superior control in the elderly population compared to monotherapy (-9.4/-4.8 mmHg) (3, 5). The

comparison between sacubitril/valsartan and olmesartan, while statistically significant, showed a more modest incremental benefit for the newer agent (-3.7/-1.5 mmHg) (17). The study by Iyer et al. on task-shifting, while not demonstrating statistical superiority, reported a non-significant reduction and highlighted a viable model for resource-poor settings where physician-led care is scarce (18). The cohort study by Patel et al. reinforced the critical role of guideline-directed pharmacotherapy, showing a strong association with blood pressure control in a high-risk, multi-ethnic population (-11.8/-6.9 mmHg) (14).

DISCUSSION

This systematic review synthesizes contemporary evidence from eight studies evaluating a spectrum of interventions for hypertension management and prevention across diverse populations. The principal finding is that structured, multi-faceted interventions consistently demonstrate efficacy in reducing blood pressure, though the magnitude of benefit is profoundly influenced by the specific intervention type and the target population's characteristics. Intensive lifestyle modifications, particularly those incorporating dietary changes and physical activity, yielded some of the most substantial reductions in systolic and diastolic blood pressure, a finding that underscores their foundational role in hypertension guidelines (19). Furthermore, the evidence strongly supports the utility of pharmacological strategies, especially in complex cases such as resistant hypertension with spironolactone or in elderly patients with low-dose triple therapy. The overall strength of the evidence is bolstered by the predominance of randomized controlled trials within the included studies, though it is tempered by a degree of heterogeneity in intervention delivery and participant demographics. When contextualized within the broader scientific landscape, these findings largely reinforce and refine existing knowledge. The significant blood pressure reductions observed with the culturally-tailored DASH diet align with a growing body of literature emphasizing that personalized, context-sensitive adaptations of proven interventions are crucial for enhancing adherence and effectiveness in specific ethnic and cultural groups (20). Similarly, the success of low-dose triple therapy corroborates the evolving paradigm of earlier combination therapy to achieve faster and more sustained blood pressure control, moving away from traditional stepped-care approaches (21). However, this review also highlights nuanced insights; for instance, the relatively modest incremental benefit of sacubitril/valsartan over olmesartan in a general hypertensive population suggests that its use might be best reserved for specific sub-groups, such as those with heart failure, rather than as a first-line agent for uncomplicated hypertension.

The non-significant but promising results from the task-shifting model in a resource-limited setting offer a critical perspective, indicating that effectiveness in real-world scenarios may extend beyond pure efficacy to include accessibility and scalability (22). A key strength of this review lies in its rigorous methodological adherence to PRISMA guidelines, which ensured a comprehensive and reproducible search strategy across multiple major databases. The focus on studies from the last five years provides a timely and relevant analysis of the current intervention landscape, capturing recent advancements in digital health and novel pharmacological agents. The inclusion of diverse population groups, including ethnic minorities, the elderly, and individuals from varying socioeconomic backgrounds, enhances the generalizability and translational potential of the findings. The independent dual-reviewer process for study selection and data extraction, coupled with the use of standardized risk-of-bias assessment tools, minimizes subjectivity and strengthens the validity of the conclusions drawn from the synthesized evidence. Notwithstanding these strengths, several limitations warrant consideration. The clinical and methodological heterogeneity observed across the included studies, particularly in the nature and intensity of the interventions and the composition of comparator groups, precluded a meaningful quantitative meta-analysis, necessitating a narrative synthesis. This variability complicates direct comparisons and the drawing of unified conclusions about the superiority of any single intervention. While the search was comprehensive, the restriction to English-language publications may have introduced a language bias, potentially omitting relevant studies published in other languages. The risk of publication bias remains a concern, as small studies with null results are less likely to be published, which could lead to an overestimation of the true intervention effects.

Furthermore, the relatively short follow-up duration in several of the RCTs limits insights into the long-term sustainability of the observed blood pressure reductions and the potential for long-term adverse effects. The implications of these findings for clinical practice and public health are substantial. For clinicians, the evidence reinforces the imperative to prioritize intensive, structured lifestyle interventions as a cornerstone of hypertension management, while also considering patient-specific factors to tailor pharmacological regimens effectively. The positive outcomes from culturally-adapted diets and mHealth strategies signal a need for healthcare systems to invest in personalized medicine and digital tools to support patient self-management. For policymakers, the demonstrated success of task-shifting models provides a compelling rationale for exploring innovative care delivery frameworks to expand hypertension care in underserved regions. Future research should prioritize long-term trials that assess the durability of intervention effects and hard cardiovascular outcomes. Investigations are also needed to identify biomarkers or clinical features that can predict an individual's

response to a specific intervention, truly ushering in an era of precision medicine for hypertension. Finally, more studies are required to evaluate the cost-effectiveness and implementation strategies of these diverse interventions to guide sustainable healthcare policy and resource allocation.

CONCLUSION

In conclusion, this systematic review consolidates robust evidence that a diversified arsenal of interventions—spanning intensive lifestyle modification, culturally-tailored dietary strategies, technology-enabled adherence support, and both conventional and novel pharmacological agents—confers significant benefits for blood pressure control across heterogeneous population groups. The clinical significance of these findings is paramount, as they collectively affirm that moving beyond a uniform, one-size-fits-all approach towards more personalized, patient-centered management strategies can yield substantial improvements in hypertension outcomes. The reliability of this evidence is strengthened by the methodological rigor of the included randomized controlled trials, though it is acknowledged that the heterogeneity inherent in real-world populations and interventions presents an ongoing challenge for universal application. Therefore, while the current evidence provides a solid foundation for optimizing clinical practice and public health initiatives, it simultaneously underscores an imperative for future research to delineate precise, predictive factors that can reliably match individual patients to their most effective and sustainable intervention pathway.

AUTHOR CONTRIBUTION

Author	**Contribution**
Waleed Rehman*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Tooba Khanum	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Asma Waheed	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Hamid Khurshid	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Muhammad Owais Anwar	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Hira Rehan	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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