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Review Article

Effects of yogic practices on physiological and biochemical parameters of hypertensive patients: A systematic review of clinical trials

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ABSTRACT

Background: Hypertension affects around 1.28 billion adults worldwide. If not managed properly, it can lead to life threatening conditions. While various pharmacological treatments are available, they are associated with various short- and long-term side effects. Hence it is crucial to explore alternative approaches to complement the standard medical interventions. **Objective:** This systematic review aims to explore the impacts of yogic practices on various physiological and biochemical parameters in hypertensive patients.
Methods: Various electronic databases including PubMed, Cochrane library, Directory of Open Access Journals and Google scholar were systematically searched until October 31, 2023 to collect relevant data.
Results: A total of 15 articles comprising 5 RCTs and 10 clinical trials were identified. The number of participants ranged between 33 and 300, with Yoga intervention lasting from two months to a year. The analyses revealed that Yogic practices, such as loosening practices, *Surya Namaskar*, *Tadasana, Trikonasana*, *Paschimottanasana*, *Shavasana. Anulom-Vilom Pranayama*, *Bhramari Pranayama*, meditation and Yoga Nidra, positively influenced physiological and biochemical markers linked to Hypertension such as autonomic nervous system activity, angiotensin II expression, oxidative stress, lipid metabolism, immune system function and inflammatory gene expression.
Conclusion: The findings of this systematic review indicate that the Yoga practices have a positive impact on physiological and biochemical markers associated with hypertension which may help in its proper management and treatment. Future studies need to assess additional markers associated with hypertension, such as vasopressin, adrenocorticotropic hormone, gamma-aminobutyric acid and others to enhance the understanding of the mechanism of the effects of Yoga on hypertension.
Study registration: PROSPERO ID: CRD42024497060.

1. Introduction

Hypertension, commonly known as high blood pressure, is a prevalent chronic condition affecting a significant proportion of the global population [1]. It is a major risk factor for various cardiovascular diseases, including heart disease, stroke, and renal dysfunction [2]. Despite the availability of pharmacological treatments, achieving optimal blood pressure control remains a challenge. There are various pharmacological treatments which are used to manage hypertension, such as angiotensin-converting enzyme (ACE) inhibitors like Lisinopril which prevents the conversion of angiotensin I to angiotensin II, thereby promoting vasodilation and reducing blood pressure. Along with this, thiazide diuretics like hydrochlorothiazide, are commonly prescribed due to their efficacy in decreasing blood volume and systemic vascular resistance by promoting the excretion of sodium and water. Beta - blockers are another significant class of antihypertensive drugs which reduce cardiac contractility and heart rate, leading to decrease in cardiac output and subsequently lowering blood pressure. These agents are particularly beneficial in patients with concurrent conditions such as angina or arrhythmias, as they help in reducing myocardial oxygen demand and improving cardiac efficiency. Calcium channel blockers (CCBs) are also integral to hypertension management. These drugs inhibit the influx of calcium ions into vascular smooth muscle and cardiac cells, resulting in vasodilation and a reduction in blood pressure. However, these medications are associated with potential side effects, including dizziness, fatigue, dry cough, and electrolyte imbalances

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[3–5]. Also there are various long term complications of using antihypertensive drugs. In particular, thiazide diuretics may lead to electrolyte imbalances like hypokalaemia, affecting muscle function and potentially leading to arrhythmias [6]. Beta-blockers, another class of antihypertensive, might cause metabolic changes, such as an increase in blood glucose levels and impairment of insulin sensitivity [7]. Calcium channel blockers, although effective in lowering blood pressure, might contribute to peripheral oedema and cardiovascular complications [8]. Due to these potential side effects there is a growing interest in exploring complementary and alternative approaches to complement standard medical interventions.

In India, the burden of hypertension is substantial, with an estimated 20%–40% of the adult population affected [9]. This prevalence is concerning due to the significant health risks associated with hypertension and its implications for public health. Integrating complementary and alternative approaches, such as Yoga, into routine healthcare practices could potentially offer a cost-effective and accessible adjunctive therapy for hypertension management in India's diverse population.

Yoga, an ancient mind-body practice originating from India, has gained popularity worldwide for its potential health benefits. It combines Asanas (physical postures), Pranayama (breath regulation), and Dhyana (meditation), aiming to harmonize the body, mind, and spirit [10].

Several studies have examined the potential therapeutic effects of Yoga on hypertensive patients, exploring its impact on physiological and biochemical parameters associated with blood pressure regulation [11, 12]. However, a comprehensive and systematic evaluation of the existing evidence is necessary to draw robust conclusions and inform clinical practice.

Therefore, the aim of this systematic review is to summarize and critically evaluate the effects of yogic practices on physiological and biochemical parameters of hypertensive patients. By synthesizing the available literature, we aim to assess the potential benefits of Yoga as an adjunct therapy for hypertension management and shed light on its mechanisms of action.

2. Methods

2.1. Literature search

This systematic review was built by adopting PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines for systematic reviews [13]. PubMed, Cochrane Library, Directory of Open Access Journals (DOAJ) and Google Scholar were systematically searched for relevant articles using keywords, "Yoga hypertension serum", "Yoga Hypertension Lipid", "Yoga Hypertension Biochemical", "Yoga Hypertension Gene", "Yoga Hypertension Renin", and "Yoga Hypertension Protein".

2.2. Inclusion criteria

Experimental studies available in English language from inception till October 31, 2023 that assessed the impacts of Yogic practices on hypertensive patients on one or more physiological or biochemical parameters were included in the review.

2.3. Exclusion criteria

Review papers, case reports, and survey studies were excluded.

2.4. Data extraction

This review includes summarized data on the attributes of participants (sample size, mean age, dropouts and dropouts' percentage), interventions used (type of practice, delivery method and duration), outcome measures (time taken for recovery, inflammatory markers and questionnaires), key findings (the difference between Yoga group vs. control group), adverse events (safety), and limitations.

2.5. Quality assessment

The risk of bias and adequate statistical reporting of randomized controlled trials included in this review was assessed by Physiotherapy Evidence Database (PEDro) scale. The PEDro scale is based on the Delphi list developed by Verhagen and colleagues at the Department of Epidemiology, University of Maastricht. The scale uses the following 11 criterion to assess the quality of studies – (1) eligibility criteria (2) random allocation of participants, (3) allocation concealment, (4) comparable groups in the beginning, (5) blinding of subjects, (6) blinding of therapists, (7) blinding of assessors, (8) measures of at least one key outcome being measured from more than 85% of the subjects initially allocated to groups, (9) either all the participants received the intervention or control condition as assigned or when this was not the case, data for at least one key outcome was analysed by "intention to treat", (10) between-group statistical comparison being performed and results for at least one key outcome being reported, (11) point measures and measures of variability being provided for at least one key outcome. Each criterion is rated as either "Yes" or "No" and the total PEDro score is the number of criterion met excluding criterion-1 which evaluates the external validity.

3. Results

3.1. Records identified through database search

Fig. 1 shows the flow diagram of the results obtained from various database search. A total of 199 articles were identified through database searching, out of which 80 articles were found duplicate and were removed. 100 records were removed through the initial screening based on title/abstract. 19 records were then assessed for eligibility in which 2 articles were case reports, one article was not in English language and one study exhibited discrepancy in its sample size representation. Specifically, the study initially reported a certain sample size but upon further examination, inconsistencies emerged when comparing it to information presented in other table, hence it was removed. Finally, 15 articles, 5 Randomized Controlled Trials (RCTs) and 10 clinical trials, that assessed the impact of yogic intervention on any kind of hypertension were included in this review [14–28].

3.2. Study characteristics

The general characteristics and key outcomes of the included RCTs and clinical trials have been shown in Tables 1 and 2, respectively. Among the 5 RCTs, three studies were conducted in India [15–17], one study was conducted in Korea [14] and one in USA [18]. Among the 10 clinical trials, nine were conducted in India [20–28] and one was conducted in Brazil [19]. All the studies included either hypertensive or essential hypertensive and the sample size was ranging between 33 and 300 (total participants = 1306). The age of the participants included in the studies was ranging between 20 and 87 years while the mean age was ranging between 43.9 and 69.17. Among the RCTs two studies included hypertensive patients [14,15], two studies included grade 1 hypertensive patients [16–18] and one study included pregnant women with gestational hypertension risk factors [17]. Among the clinical trials six studies included hypertensive patients [19,23,25–28], three studies included essential hypertensive patients [20–22], and one study included diabetic and hypertensive patients [24].

3.3. Quality of studies

Table 3 shows the PEDro score for each study included in this review. As per the instructions of PEDro scale, each item is rated as "Yes" if the

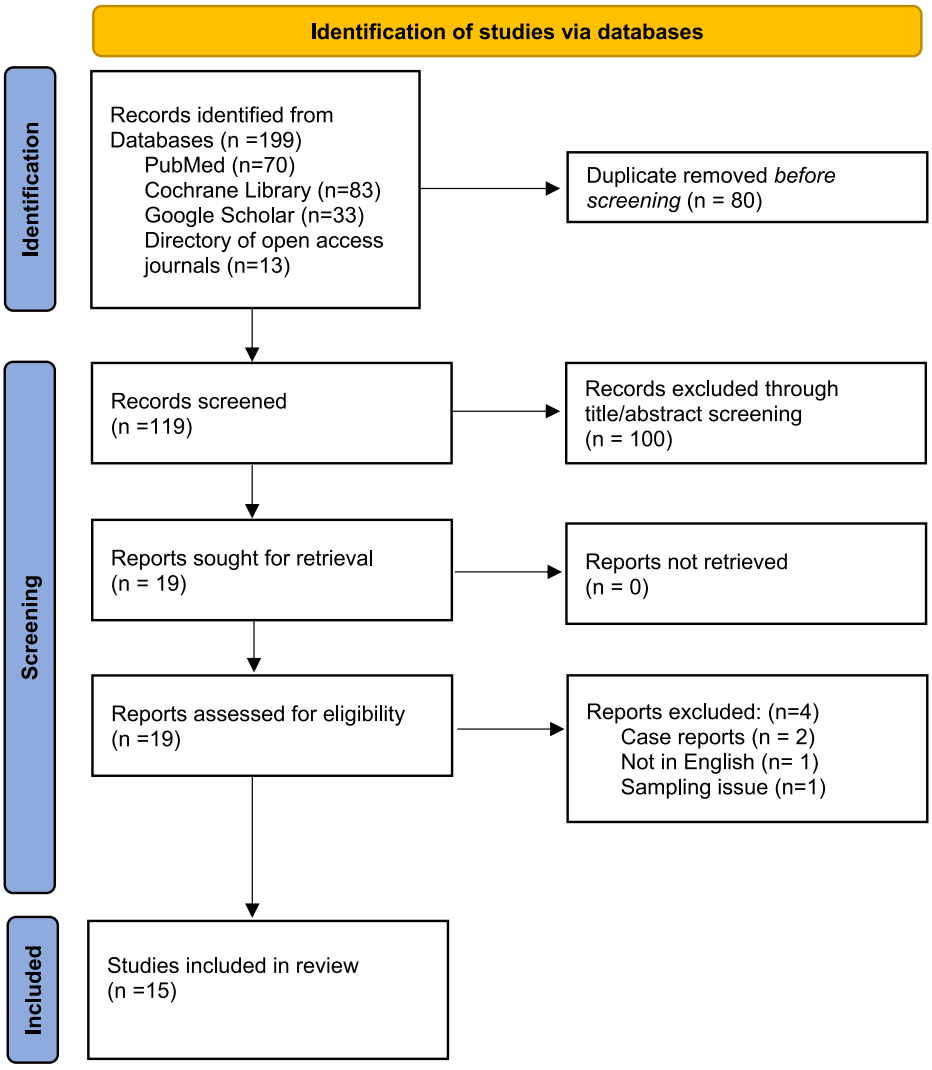

Fig. 1. PRISMA flow chart of the literature search and study selection process.

criterion is met by the study or "No" if the study does not satisfy the criterion. We analysed only those studies which scored 4 or above on PEDro scale in this review. The scores of the studies ranged between 1 and 7. The scores obtained by the studies are 7/10 [14,17], 6/10 [15, 26], 5/10 [16,19], 4/10 [18,21,23,28], 3/10 [22,27], 2/10 [20,25] and 1/10 [24]. Only those studies which had a PEDro score of ≥4 were included in the final assessment.

3.4. Details of intervention

Table 4 represents the details of yogic interventions used in the studies examined in this review. The overall length of the interventions varied from two months to one year. Six studies included Asanas and Pranayama [16–19,21,28], two studies incorporated Yoga Nidra [15, 23], one study integrated Sudarshan Kriya [26], and one study included Brain Education-based Meditation [14]. Table 5 briefly states the percentage of each yogic practice followed by all the studies.

3.5. Effects of Yoga on hypertension

Tables 1 and 2 show the results of Yogic intervention on hypertensive patients (physiological and biochemical parameters along with questionnaire scores). Four RCTs included in the study showed significant reduction in blood pressure, lipid profile and biochemical markers [14–16,18]. On the contrary, one study showed significant increase in systolic and diastolic blood pressure among pregnant women at risk of gestational hypertension, but very low density lipoprotein, low density lipoprotein and total cholesterol were still significantly reduced [17]. All the clinical trials included in the study also showed significant reduction in blood pressure, lipid profile and related biochemical markers [19–27] except one study which did not show any significant change in the parameters [28]. No changes were observed in psychological parameters. Regular practice of Yoga significantly reduced systolic blood pressure, diastolic blood pressure, low density lipoprotein, very low density lipoprotein, total cholesterol, high sensitivity c-reactive protein, interleukin-6, and significantly increased high density lipoprotein, and nitric oxide among hypertensive patient.

4. Discussion

A systematic review was conducted to summarize and evaluate the effects of yogic practices on physiological and biochemical parameters of hypertensive patients. We identified 15 studies from the thorough database search where all the studies have shown a significant beneficial improvement in one or the other physiological or biochemical parameter of hypertensive patients. All 15 studies assessed in this review reported positive outcomes, showing significant improvements in parameters such as low density lipoprotein (LDL), high density lipoprotein (HDL), very low density lipoprotein (VLDL), total cholesterol, basal heart rate, systolic blood pressure (SBP), and diastolic blood

Table 1
General characteristics and key outcomes of Randomized control trials included in the study.

Author, Year, Country	Participants	Intervention		Outcome measures	Results		Adverse events	Limitations
		Experimental Group	Control Group		Experimental Group	Control Group		
	Population Sample size: n (EG, CG) Age range Mean Age: EG, CG Drop out: n (EG, CG) Drop out: %	Interventions Duration		Primary Outcomes Secondary outcomes	Primary outcome Secondary outcome			
Lee et al., 2019, Korea [14]	Hypertensive and/or diabetic participants on medication 48 (24, 24) 57–87 68.48, 68.29 13 (3,10) 27	BEM 8 weeks	HEC	Biochemical parameters Self-report questionnaire	LDL↓[a] SGOT↑ SGPT↓ GGT (NC) Creatine ↓ HDL (NC) MHSR↑ PHSR↑ NF-kB2↓[a] RELA↓[a] IL1B↓[a] RELB↓	LDL↑ SGOT (NC) SGPT ↓ GGT↑ Creatine ↑ HDL↑ MHSR↑ PHSR↓	None	Small sample size, mix participants of diabetes and hypertension
Anjana et al., 2022, India [15]	Hypertensive patients 80 (40,40) 25–60 43.9, 49.13 15 (6,9) 18.75	Om chanting and Yoga Nidra 2 months	Regular medications	BP parameters and lipid profile markers	SBP↓[a] DBP↓[a] PP↓[a] MAP↓[a] RPP↓[a] TG↓[a] HDL↑[a] LDL↓[a] VLDL↓[a] TC↓[a]	SBP↓ DBP (NC) PP↓ MAP (NC) RPP↑ TG (NC) HDL↓[a] LDL (NC) VLDL (NC) TC (NC)	None	Two interventions making it difficult to determine which intervention was beneficial.
Patil et al., 2014, India [16]	Male grade-1 hypertensive patients 60 (30,30) 60–80 68.38, 69.17 3 (2,1) 5	Yoga 3 months	Flexibility and stretching practices	BP parameters and biochemical parameters	SBP↓[a] DBP↓[a] PP↓[a] MAP↓[a] MDA↓[a] SOD↑[a] GSH↑[a] SVit.C↑[a]	SBP↑ DBP↓ PP↑ MAP (NC) MDA ↑[a] SOD ↓ GSH ↓ SVit.C↓[a]	NR	NR
Karthiga et al., 2022, India [17]	Pregnant women with GH risk factors 234 (121,113) NR NR 22 (17,5) 8.59	Yoga therapy with Standard medications and antenatal counselling 20weeks	Standard medications and antenatal counselling	incidence of new-onset hypertension biochemical parameters	Reduced risk of developing GH[a] BHR↓[a] SBP↑[a] DBP↑[a] MAP↑[a] RPP↑ SV↑ LVET↓[a] CO↓[a] TPR ↓[a] BRS ↑[a] HbA1c ↓ Insulin ↓[a] HOMA-IR ↓[a] TC↓[a] TG↓[a] HDL↑[a] LDL↓[a] VLDL ↓[a] hsCRP ↓[a] IL-6 ↓[a] NO ↑[a]	BHR↑ SBP↑[a] DBP↑[a] MAP↑[a] RPP↑[a] SV↑[a] LVET↑ CO↑ TPR↑ BRS↓[a] HbA1c↑[a] Insulin ↑[a] HOMA-IR↑[a] TC↑[a] TG ↑[a] HDL↓[a] LDL↑[a] VLDL ↑[a] hsCRP ↑[a] IL-6 ↑[a] NO↓[a]	None	Did not recruit the subjects in their early prenatal visits.
Cohen et al., 2011, USA [18]	Patients with pre hypertension to stage 1 hypertension 78 (46,32) 22–69 48.2, 48.3 20 (19,1) 43.4	Iyenger Yoga 12 weeks	EUC	Physiological, Urinary and blood biomarkers Psychometric evaluation	SBP ↓[a] DBP ↓[a] MAP ↓[a] HR ↓ ALD (NS) Renin (NS) POMS (NS) PSS (NS) SF-36 (NS)	SBP ↓ DBP↓ MAP↓ HR↓ ALD (NS) Renin (NS) POMS (NS)	NR	Lack of blinding with self-selected study population.

(*continued on next page*)

Table 1 (*continued*)

Author, Year, Country	Participants	Intervention		Outcome measures	Results		Adverse events	Limitations
		Experimental Group	Control Group		Experimental Group	Control Group		
	Population Sample size: n (EG, CG) Age range Mean Age: EG, CG Drop out: n (EG, CG) Drop out: %	Interventions Duration		Primary Outcomes Secondary outcomes	Primary outcome Secondary outcome			
						PSS (NS) SF-36 (NS)		

[a] Significant; ↓, Decreased; ↑, Increased; 6MD, Distance in meters walked in 6 min; ALD, Aldosterone; BEM, Brain Education based Meditation; BG, Blood Glucose; BP, Blood Pressure; BW, Body Weight; DBP, Diastolic Blood Pressure; EUC, Enhanced Usual Care; FBS, Fasting Blood Sugar; GGT, G-Glutamyl Transferase; GH, Gestational Hypertension; GSH, Glutathione total; HbA1c, Hemoglobin A1c; HDL, High Density Lipoprotein; HEC, Health Education based Class; HOMA-IR, Homeostatic Model Assessment of Insulin Resistance; HR, Heart rate; hsCRP, High Sensitivity C-reactive protein; IL1B, Interleukin 1 Beta; LDL, Low Density Lipoprotein; MAP, Mean Arterial Pressure; MDA, Malondialdehyde; NC, No Change; NS, Not Significant; NO, Nitric Oxide; MHSR, Mental Health Self-Report; NA, Not applicable; NF-kB2, Nuclear Factor kappa B subunit 2; NR, Not reported; PHSR, Physical Health Self Report; POMS, Profile of Mood States; PP, Pulse Pressure; PR, Pulse Rate; PRA, Plasma Renin Activity; PSS, Perceived Stress Survey; RELA, REL-Associated Protein; RPP, Rate Pressure Product; SB, Systolic Blood Pressure; SF-36, Short-form Health; SGOT, Serum Glutamic-Oxaloacetic Transaminase; SGPT, Serum Glutamic Pyruvic Transaminase; SKY, Sudarshan Kriya Yoga; SOD, Superoxide Dismutase; TG, Triglyceride; SVitC, Serum Vitamin C; TC, Total Cholesterol; VLDL, Very Low Density Lipoprotein; hs-CRP, high sensitivity C-Reactive Protein; BHR, Basal Heart Rate; EG, Experimental Group; CG, Control Group.

pressure (DBP). The uniformity of these results suggests a strong potential for Yoga to positively impact hypertensive patients.

Several mechanisms have been proposed to explain the beneficial effects of Yoga on hypertension (Fig. 2). Patil et al. suggested that engaging in Yoga practice decreases oxygen consumption in the body, resulting in a reduction of excessive generation of reactive oxygen species (ROS). This, in turn, leads to decreased levels of serum malondialdehyde (MDA), an indicator of decreased oxidative stress. Ultimately, these factors culminate in the reduction of blood pressure [16,29]. Lee et al. highlighted the potential of brain education-based meditation (BEM) to improve stress management and activate the parasympathetic nervous system while deactivating the sympathetic nervous system. This modulation of the autonomic nervous system could influence lipid metabolism, immune system function, and the expression of inflammatory genes [14,30]. Anjana et al. suggested that Yoga Nidra induces a calm state of mind by decreasing sympathetic nervous system activity and increasing parasympathetic activity, possibly through the activation of the hypothalamic-pituitary-adrenal (HPA) axis [15,31,32]. Pa and Verne proposed that Yoga exercises reduce angiotensin II expression, leading to increased vagal tone and cardiac parasympathetic activity [25,33,34]. Dhameja et al. emphasized the role of Yoga in reducing sympathetic activity, increasing parasympathetic tone, and stimulating antioxidant enzyme expression, which collectively contribute to reducing free radical generation and inflammation [28,35]. These explanations suggest a range of mechanisms by which Yoga aids in lowering blood pressure among hypertensive patients.

The consistent evidence of the beneficial effects of Yoga on hypertensive patients has significant clinical implications, particularly in the Indian context where the burden of hypertension is substantial. Integrating Yoga interventions into routine healthcare practices could offer a cost-effective and accessible adjunctive therapy for hypertension management. The non-pharmacological nature of Yoga makes it particularly attractive, as it can be utilized in combination with conventional treatments to optimize patient outcomes. The findings of this review provide evidence-based insights to guide healthcare providers, policymakers, and individuals in decision-making processes related to hypertension management programs in India.

Based on the methodological quality assessment using the PEDro scale, it was found that 5 out of the 15 studies assessed in this review scored less than 4. Therefore, only 10 studies were considered for the final assessment. The limitations observed in these studies included small sample sizes, lack of blinding, absence of true randomization, uncontrolled dietary factors, lack of reporting effect size, statistical power and follow-up.

The presence of these limitations should be taken into consideration when interpreting the results of this review. Small sample sizes may limit the generalizability of the findings, and the lack of blinding and true randomization may introduce potential biases. The absence of control over dietary factors could confound the observed effects of Yoga interventions on physiological and biochemical parameters. Effect sizes provide valuable information about the magnitude of the observed effects, allowing for a more comprehensive understanding of the practical significance of the findings. Statistical power is critical for assessing the reliability of study outcomes and the likelihood of detecting true effects. The absence of these key metrics across the included studies poses challenges in drawing robust conclusions and making broad implications. The variability in sample sizes, study designs, and reporting practices across the studies further complicates our ability to estimate the true effect of Yoga interventions on hypertension. Consequently, the generalizability of the findings to broader populations and contexts is limited by the lack of standardized reporting of effect sizes and statistical power.

Long-term follow-up data are essential for understanding the sustained effects of Yoga interventions on hypertension. Hypertension management requires not only short-term reductions in blood pressure but also the ability to maintain these improvements over time. The absence of extended follow-up assessments hinders our ability to ascertain the durability of the observed effects and whether the benefits of Yoga practice persist beyond the intervention period. The incorporation of follow-up evaluations in future studies is vital for capturing the long-term impact of Yoga on blood pressure regulation and for guiding clinical recommendations.

The studies encompassed in this review have not adhered to an optimal Yoga protocol or a standardized duration. This absence of uniformity in methodology hinders the establishment of a clear correlation between specific Yoga practices and their efficacy in effectively managing hypertension.

To address these limitations and strengthen the quality of future studies, several suggestions can be made. Firstly, efforts should be made to incorporate blinding, at least at the assessor level, in order to minimize potential biases and improve the objectivity of outcome assessments. Although blinding for practical interventions like Yoga may not

Table 2
General characteristics and key outcomes of clinical trials included in the study.

Author, Year, Country	Participants	Intervention		Outcome measures	Results		Adverse events	Limitations
		Experimental Group	Control Group		Experimental Group	Control Group		
	Population Sample size: n (EG, CG) Age range Mean Age: EG, CG Drop out: n (EG, CG) Drop out: %	Interventions Duration		Primary Outcomes Secondary outcomes	Primary outcome Secondary outcome			
Mizuno and Monteiro, 2013, Brazil [19]	Hypertensive patients 33 (17,16) 40 67,62 0 NA	Yoga Four months	Normal routine	Biochemical parameters	TG↓[a] SBP↓[a] BG↓[a]	TG (NS) BG (NS)	NR	No true randomization, Diet was not controlled.
Bhatnagar et all. 2016, India [20]	Essential hypertensive patients 89 (89, NA) 60–80 NR 6 (6, NA) 5.34	Lifestyle modifications (Nadi Shodhana Pranayama) 3 months	NA	BP and Biochemical parameters	SBP↓[a] DBP↓[a] HR↓[a] PP↓[a] MAP↓[a] TC↓[a] TG↓[a] HDL↑[a] LDL↓[a]	NA	NR	NR
Biswas, 2020, India [21]	Essential hypertensive patients 40 (20,20) 20–60 45.75, 45.75 NR NA	Yoga 3 months	routine antihypertensive treatment only	Difference in BP difference in change in lipid values	SBP↓[a] DBP↓[a] TC↓ TG↓ HDL↑[a] LDL↑ VLDL↓	TC↓ TG↓ HDL↑ LDL↑ VLDL↑	NR	NR
Verma et al., 1996, India [22]	Essential hypertensive and normotensive individuals 60 (30,30) NR 48.5, 47.1 NR NR NA	Yoga 30 days	Yoga	Physiological and biochemical parameters	BMI↓ SBP↓[a] DBP↓[a] HR↓ 6MD↑[a] TG↓[a] TC↓[a] HDL↑[a] LPO↓[a] Na + K + ATPase activity↑[a]	BMI↓ SBP↓ DBP↓ HR↓ 6MD↑ TG↓[a] TC↓[a] HDL↓ LPO↓[a] Na + K + ATPase activity (NC)	NR	NR
Devraj et al., 2021, India [23]	Hypertensive patients 74 (31, 43) 35–70 54.61, 49.64 NR NA	Yoga Nidra 12 weeks	Standard treatment	Physiological and biochemical parameters	BMI↓[a] SBP↓[a] DBP↓[a] PR↓ MAP↓[a] Hs-CRP↓[a] TG↑ TC↑ HDL↑ LDL↓ VLDL (NC)	BMI (NC) SBP↓ DBP↓ PR↓ MAP↓ Hs-CRP↑[a] TG↓ TC↑ HDL↓ LDL↓ VLDL (NC)	NR	Small sample size,
Gowtham et al., 2018, India [24]	Diabetic and Hypertensive patients 30 (30, NA) 40–60 NR 6 (6, NA) 20	Yoga 45 days	NA	Alteration in RBC morphology and oxidative stress markers	Improved RBC morphology MDA↓[a] FBS↓[a] SBP↓[a] DBP↓ BMI↓[a]	NA	NR	NR
Pa and Verne, 2017, India [25]	Hypertensive Patients 45 (45, NA) 40–55 NR 4 (4, NA) 8.8	Yoga 6 months	NA	Physiological and biochemical parameters	BW↓[a] SBP↓[a] DBP↓[a] PRA↓ hs-CRP↓[a]	NA	NR	NR

(continued on next page)

Table 2 (*continued*)

Author, Year, Country	Participants	Intervention		Outcome measures	Results		Adverse events	Limitations
		Experimental Group	Control Group		Experimental Group	Control Group		
	Population Sample size: n (EG, CG) Age range Mean Age: EG, CG Drop out: n (EG, CG) Drop out: %	Interventions Duration		Primary Outcomes Secondary outcomes	Primary outcome Secondary outcome			
Mahesh et al., 2018, India [26]	hypertensive and pre-hypertensive patients 300 (18,22) (82,78) (7,5) (43,45) 25–65 43.8 0 NA	Yoga 1 year	Prescribed drugs and lifestyle modifications	Physiological and biochemical parameters	TC↓[a] LDL↓[a] HDL↑[a] VLDL↓[a]		NR	NR
Agte et al., 2011, India [27]	Hypertensive and healthy adults 49 (26, 23) 30–60 48,51.6 NR NR	SKY 2 months		Physiological and biochemical parameters	DBP↓[a] SBP↓ MDA↓[a] TG↓[a] Urea↓[a]	DBP↓ SBP↑[a] MDA↓[a] TG↑ Urea↓	NR	Small sample size.
Dhameja et al., 2013, India [28]	Hypertensive individuals 86 (39,47) 30–60 48.07, 50.33 14 (9,5) 12.04	Yoga with conventional therapy 42 days	Only conventional therapy	Physical and Oxidative Stress Parameters	Weight (NC) BMI ↓[a] BSA ↓[a] SBP ↓ DBP ↓ GST ↑ MDA ↓[a] FRAP ↑[a]	Weight (NC) BMI (NC) BSA (NC) SBP ↓ DBP↓ GST↑ MDA↓ FRAP↑	NR	Small sample size, No randomization,

[a] Significant; ↓, Decreased; ↑, Increased; 6MD, Baroreflex Sensitivity Survey; BSA, Basal Heart Rate; RP, Blood Glucose; BP, Blood Pressure; BW, Body Surface Area; GST, Body Weight; DBP, Brain Education based Meditation; BG, Diastolic Blood Pressure; EUC, Distance in meters walked in 6 min; BEM, Enhanced Usual Care; FBS, Fasting Blood Sugar; GGT,Ferric-reducing ability of plasma,G-Glutamyl Transferase; GH, Gestational Hypertension; HDL, Glutathione S-transferase; MDA, Health Education based Class; HR, Heart rate; IL1B,High-Density Lipoprotein; HEC, Interleukin 1 Beta; LDL, Left Ventricular Ejection Time; TPR, Low Density Lipoprotein; MAP,Malondialdehyde; FRAP, Malondialdehyde; NC, Mean Arterial Pressure; MDA, Mental Health Self-Report; NA, Nitric Oxide; MHSR, No Change; NO, Not applicable; NF-kB2, Not reported; PHSR, Nuclear Factor kappa B subunit 2; NR, Physical Health Self Report; PP, Plasma Renin Activity; RELA, Pulse Pressure; PR, Pulse Rate; PRA,REL-Associated Protein; RPP, Rate Pressure Product; SBP,Rate-pressure product; SV, Serum Glutamic Pyruvic Transaminase; SKY, Serum Glutamic-Oxaloacetic Transaminase; SGPT, Serum Vitamin C; TC, Stroke Volume; LVET, Sudarshan Kriya Yoga; SOD, Superoxide Dismutase; TG, Systolic Blood Pressure; SGOT, Total Cholesterol; VLDL, Total Peripheral Resistance; BRS,Triglyceride; SVitC, Very Low Density Lipoprotein; hs-CRP, high sensitivity C-Reactive Protein; EG, Experimental Group; CG, Control Group

Table 3
PEDro score of included studies.

Study	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	Total score
Lee et al., 2019, Korea [14]	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7
Anjana et al., 2022, India	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes	6
Patil et al., 2014, India [16]	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Karthiga et al., 2022, India [17]	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes	7
Cohen et al., 2011, USA [18]	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4
Mizuno and Monteiro, 2013, Brazil [19]	Yes	No	No	Yes	No	No	No	Yes	Yes	Yes	Yes	5
Bhatnagar et all. 2016, India [20]	Yes	No	No	No	No	No	No	Yes	No	No	Yes	2
Biswas, 2020, India [21]	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4
Verma et al., 1996, India [22]	No	No	No	Yes	No	No	No	Yes	No	No	Yes	3
Devraj et al., 2021, India [23]	Yes	No	No	Yes	No	No	No	Yes	No	Yes	Yes	4
Gowtham et al., 2018, India [24]	Yes	No	No	No	No	No	No	No	No	No	Yes	1
Pa and Verne, 2017, India [25]	Yes	No	No	No	No	No	No	Yes	No	No	Yes	2
Mahesh et al., 2018, India [26]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6
Agte et al., 2011, India [27]	Yes	No	No	No	No	No	No	Yes	No	Yes	Yes	3
Dhameja et al., 2013, India [28]	No	No	No	Yes	No	No	No	Yes	No	Yes	Yes	4

be feasible, blinding of assessors can help reduce performance bias. Secondly, concealed randomization should be implemented to ensure proper allocation concealment and minimize selection bias. This can be achieved through the use of centralized randomization methods or sealed envelopes. Future studies should incorporate the reporting of effect sizes, statistical power, and follow-up records to enhance the robustness of their findings and facilitate a more comprehensive understanding of the long-term impact of Yoga interventions on

Table 4
Interventions used in the included studies.

Author	Intervention
Lee et al., 2019, Korea [14]	Brain Education-based Meditation (BEM).
Anjana et al., 2022, India [15]	Om chanting for 5 min followed by Yoga Nidra developed by Swami Satyananda Saraswati, Bihar School of Yoga, India.
Patil et al., 2014, India [16]	Opening prayer (1min) - Sukshma Vyayama or loosening practices (5 min); Breathing practices like Hands in and out breathing, Ankle stretch breathing, Straight leg raising breathing, Lumbar stretch breathing (5 min); Asanas - Padhastasana, Ardhachakrasana, Shashankasana, Ardha Ustrasana, Bhujangasana, Ardha Salabasana and Trikonasana (15 min); Pranayama - Anuloma Viloma Pranayama and Brahmari Pranayama (5 min); Cyclic meditation, a yoga based guided relaxation technique; Devotional session (5min); and Closing prayer (1 min).
Karthiga et al., 2022, India [17]	Sukshma Vyayama - warm up shoulder exercises (1 min); Asana – Tadasana (30 s), Utkatasana (30 s), Virbhadrasana (30 s), Trikonasana (30 s), Titliasana (30 s), Vakrasana (30 s), Marjariasana (30 s), Uthit Padasana (30 s), Sukhasana (30 s); Slow Pranayama – Anuloma Viloma (5 min), Chandranadi Pranayama (5 min), Bhramari Pranayama (5 min), Sheetali Pranayama (5 min); Shavasana (5 min)
Cohen et al., 2011, USA [18]	Asanas – Savasana (5min), cross bolsters (5min), Supta Baddha Konasana (5min), Supta Swastikasana (5min), Bharadwajasana (1.5 min), Pavanmuktasana (5min), Adho Mukha Virasana (5min), Adho Mukha Swastiaksana (1 min), Adho mukha svanasana (1 min), Uttanasana (1 min), Janu Sirsasana (1 min), Upavisthakonasana (3 min), Paschimottanasana (1 min), Savasana (5 min); Pranayama – Ujjayi (5 min).
Mizuno and Monteiro, 2013, Brazil [19]	Warm-up and general stretching; Asana- Uttanasana, Parsvakonasana, Virabhadrasana I and II, Prasarita Padottanasana, Parsvotanasana, Trikonasana, Dandasana, Janu Sirshasana, Marichyasana, Paschimottanasana, Navasana, Setu Bandhasana, Supta Padangushasana, Shavasana; Breathing meditation.
Biswas, 2020, India [21]	Asana - Tadasana, Ardhakatichakraasana, Pawanmukthasana, Shavasana, Vakrasana, Bhujangasana; Pranayama – Anulom Vilom, Bhramari.
Devraj et al., 2021, India [23]	Warm up, Yoganidra
Mahesh et al., 2018, India [26]	Sudarshan Kriya
Dhameja et al., 2013, India [28]	Pranayama – Bhastrika (2 min), Kapalbhati (10 min), Anulom Vilom (10 min), Bhramari (11–15 times), Udgit Omkar uchcharan (11–15 times), Asana – Tadasana (3 times), Paschimottanasana (3 times), Mandukasana (3 times), Padmasana (1–2 min), Surya Namaskar (once), Shavasana (10 min).

Table 5
Observed percentage of yogic practices included in the review.

Yogic practices	RCTs and clinical trials, n (%)
Loosening practices/warm up	4 (40)[16,17,19,23]
Surya Namaskar	1 (10)[28]
Asana	
Shavasana	5 (50)[17,18,19,21,28]
Tadasana	3 (30)[17,21,28]
Trikonasana	3 (30)[16,17,19]
Paschimottanasana	3 (30)[18,19,28]
Virbhadrasana	2 (20)[17,19]
Pavanmuktasana	2 (20)[18,21]
Uttanasana	2 (20)[18,19]
Janu Sirsasana	2 (20)[18,19]
Padhastasana	1 (10)[16]
Ardha Chakrasana	1 (10)[16]
Shashankasana	1 (10)[16]
Ardha Ushtrasana	1 (10)[16]
Bhujangasana	1 (10)[16]
Ardha Salbhasana	1 (10)[16]
Utkatasana	1 (10)[17]
Marjariasana	1 (10)[17]
Uthit Padasana	1 (10)[17]
Sukhasana	1 (10)[17]
Supta Baddha Konasana	1 (10)[18]
Bharadwajasana	1 (10)[18]
Adho Mukha Virasana	1 (10)[18]
Adho Mukha Swastikasana	1 (10)[18]
Adho Mukha Svanasana	1 (10)[18]
Upvisthakonasana	1 (10)[18]
Parsvakonsana	1 (10)[19]
Prasarit Padottanasana	1 (10)[19]
Parsvottanasana	1 (10)[19]
Dandasana	1 (10)[19]
Marichyasana	1 (10)[19]
Navasana	1 (10)[19]
Setu Bandhasana	1 (10)[19]
Supta Padangushthasana	1 (10)[19]
Ardha Katichakrasana	1 (10)[21]
Vakrasana	1 (10)[21]
Bhujangasana	1 (10)[21]
Mandukasana	1 (10)[28]
Padmasana	1 (10)[28]
Pranayama	
Anulom-Vilom	3 (30)[17,21,28]
Bhramari	3 (30)[16,17,21]
Chandranadi	1 (10)[17]
Sheetali	1 (10)[17]
Ujjayi	1 (10)[18]
Meditation	
Yoga Nidra	2 (20)[15,23]
Om Chanting	2 (20)[15,28]
BEM	1 (10)[14]
Cyclic meditation	1 (10)[16]

References to respective Yoga practices are cited as superscript numbers.

hypertension management. Along with this a consensus-based approach, where experts in the field collaboratively define an ideal Yoga protocol encompassing Asana, Pranayama, and relaxation techniques, should be followed.

Although this review primarily examined the effects of Yoga on physiological and biochemical parameters of hypertensive patients, it's worth noting that there are currently no available studies that have explored crucial biomarkers associated with hypertension. Consequently, there arises a pertinent requirement for future studies to explore the impact of Yoga on specific hormones, neurotransmitters, and molecular markers related to hypertension. For instance, investigating the influence of Yoga on hormones such as renin, vasopressin, adrenocorticotropic hormone (ACTH), insulin, aldosterone, cortisol and Atrial Natriuretic Peptide (ANP) can uncover the influence of yogic intervention in the intricate balance between vasoconstriction and vasodilation, as well as fluid and electrolyte regulation. Along with this exploring the effects of Yoga on neurotransmitters like norepinephrine, dopamine, serotonin, glutamate and gamma-aminobutyric acid (GABA) can help to shed light on its potential to influence sympathetic and parasympathetic activities, which in turn influence heart rate, vessel constriction, and relaxation. This understanding can establish a direct link between Yoga practice and the modulation of neural pathways that govern blood pressure. Studying molecular markers such as Nitric Oxide (NO), endothelin-1, oxidative stress markers (SOD, GPx, MDA), Vascular Endothelial Growth Factor (VEGF) bradykinin, microRNAs, gene expression, epigenetic modifications, and inflammatory cytokines, hormone receptor sensitivity, autonomic nervous activity, and DNA methylation patterns can provide insights into the physiological responses to stress, inflammation, and cellular signalling. Exploring Yoga's impact on these markers can unravel how the practice affects endothelial function, oxidative stress, immune response, and genetic expression, thereby influencing blood pressure regulation at a fundamental level. By assessing these subtle biochemical and genetic changes, future studies can contribute to a more comprehensive understanding of the mechanisms underlying the effects of Yoga on hypertension.

This systematic review identified 15 research articles that assessed the effects of Yoga on various physiological and biochemical parameters

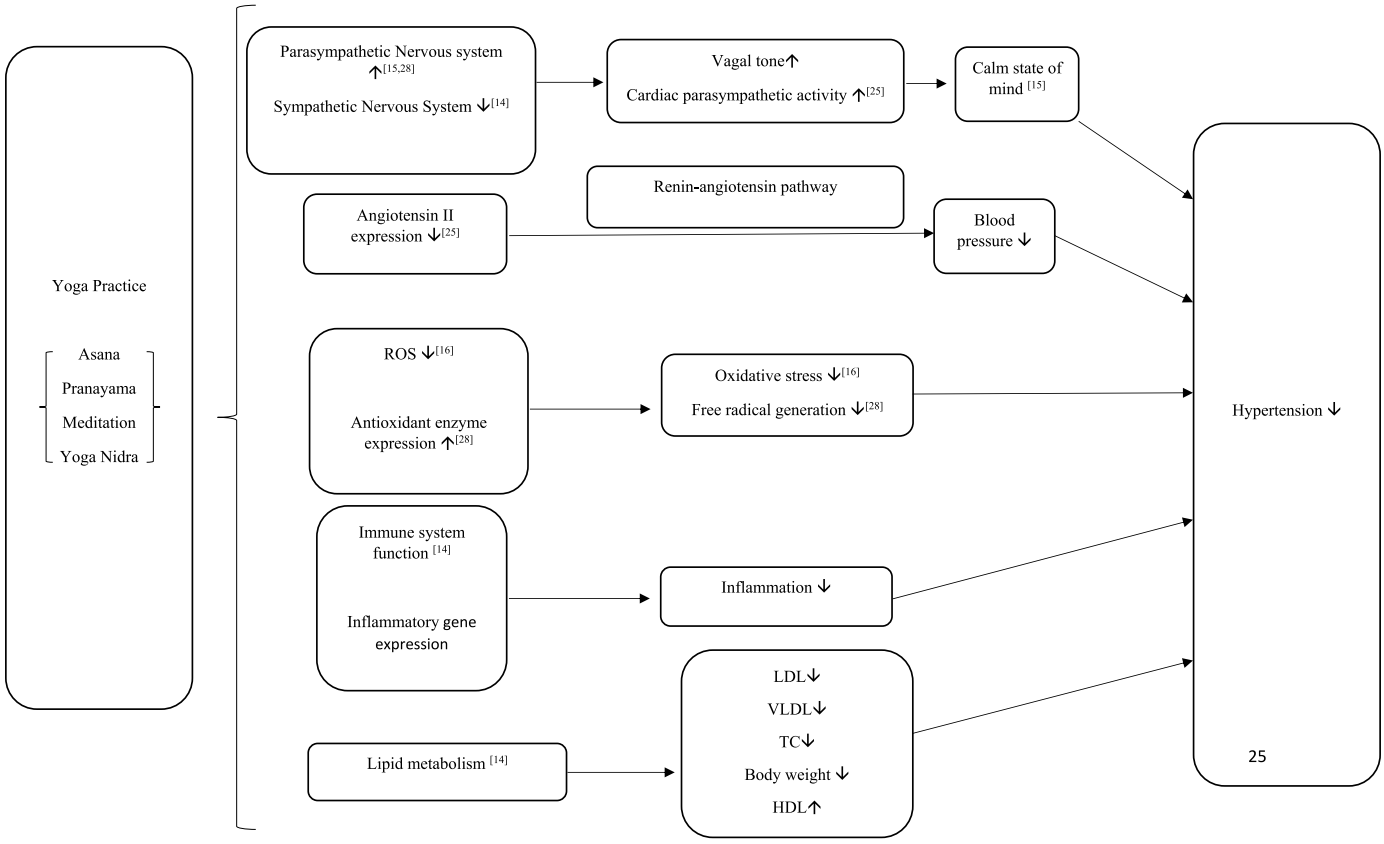

Fig. 2. Mechanism of action of Yogic practices on Hypertension.

of hypertensive patients. The findings of the review indicate that regular practice of Yoga including *Sukshma Vyayama*, *Asana* like *Shavasana*, *Shashakasana*, *Janu Shirshasana*, *Trikonasana*, *Bhujangasana*, *Vakrasana, Pranayama* like *Anulom-Vilom Pranayama, Bhramari Pranayama*, *Yoga Nidr*a, Om Chanting and meditation leads to significant improvement in lipid profiles, reduction in inflammatory markers and blood pressure in hypertensive patients. There is a need to conduct studies with higher methodological quality that assess specific hormones, neurotransmitters and molecular markers related to hypertension to further improve our understanding of the potential benefits and mechanisms of the effects of Yoga on hypertension.

Author contributions

PT: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft. **KJ:** Formal analysis, Resources, Writing – review & editing, Supervision, Project administration.

Data availability

The data utilized for this review can be made available by the authors upon reasonable request.

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None

Conflict of interest

The authors declare no competing interest.

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