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# Yoga for hypertension: A systematic review of randomized clinical trials

Paul Posadzki[a,b,c,d,*], Holger Cramer[e], Adrian Kuzdzal[c], Myeong Soo Lee[d,f], Edzard Ernst[f]

[a] University of Plymouth, Plymouth, UK
[b] Liverpool John Moores University, UK
[c] Rzeszow University, Rzeszow, Poland
[d] Korea Institute of Oriental Medicine, Daejeon, South Korea
[e] University of Duisburg-Essen, Essen, Germany
[f] University of Exeter, Exeter, UK

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**KEYWORDS**
Hypertension;
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Yoga;
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Effectiveness

**Summary**
*Objectives:* To critically evaluate the effectiveness of yoga as a treatment of hypertension.
*Methods:* Seventeen databases were searched from their inceptions to January 2014. Randomized clinical trials (RCTs) were included, if they evaluated yoga against any type of control in patients with any form of arterial hypertension. Risk of bias was estimated using the Cochrane criteria. Three independent reviewers performed the selection of studies, data extraction, and quality assessments.
*Results:* Seventeen trials met the inclusion criteria. Only two RCTs were of acceptable methodological quality. Eleven RCTs suggested that yoga leads to a significantly greater reduction in systolic blood pressure (SBP) compared to various forms of pharmacotherapy, breath awareness or reading, health education, no treatment (NT), or usual care (UC). Eight RCTs suggested that yoga leads to a significantly greater reduction in diastolic blood pressure (DBP) or night-time DBP compared to pharmacotherapy, NT, or UC. Five RCTs indicated that yoga had no effect on SBP compared to dietary modification (DIM), enhanced UC, passive relaxation (PR), or physical exercises (PE). Eight RCTs indicated that yoga had no effect on DBP compared to DIM, enhanced UC, pharmacotherapy, NT, PE, PR, or breath awareness or reading. One RCT did not report between-group comparisons.
*Conclusion:* The evidence for the effectiveness of yoga as a treatment of hypertension is encouraging but inconclusive. Further, more rigorous trials seem warranted.


* Corresponding author at: Honorary University Fellow, University of Plymouth, UK. Tel.: +44 07 950 441367.
*E-mail addresses:* paul.posadzki@plymouth.ac.uk, pawel.posadzki@hotmail.com (P. Posadzki).

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## Contents



## Introduction

High blood pressure (BP) is responsible for 7.6 million deaths per annum worldwide.[1] The WHO has identified high BP as one of the most important causes of premature morbidity and mortality in both developed and developing countries.[2] It is a major risk factor for myocardial infarction (MI), stroke, chronic heart failure (CHF), peripheral arterial disease or chronic kidney disease.[3] In addition, the AHA has estimated the direct and indirect annual costs of high BP in 2010 to amount to $76.6 billion in the US.[4] Treatment of high BP most commonly involve the use of alpha-blockers, angiotensin converting enzyme inhibitors, angiotensin II receptor blockers, beta-blockers, calcium channel blockers or diuretics.[5]

Some patients object to drug treatments or experience adverse effects (AEs). Consequently, they might try non-pharmacological treatments such as yoga.[6–8] Yoga can be defined as ''a practice of gentle stretching, exercises for breath control and meditation as a mind-body intervention''.[9] In Western societies, yoga is regarded as a form of mind-body medicine and often considered to be part of Complementary and Alternative Medicine (CAM).[10] An estimated 6.6% of US adults practice yoga, and these numbers continue to rise.[11]

Several reviews regarding the potential benefits of yoga for reducing BP have recently been published.[12–17] These reviews reached overtly positive conclusions which, in our view, are not fully justified.

The objective of this systematic review (SR) is to systematically and critically evaluate the effectiveness of yoga as a treatment option for hypertension, using data from all randomized clinical trials (RCTs) currently available.

## Methods

We adhered to the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) guidelines while reporting the results of this SR.

### Data sources

First reviewer (PP) searched the following electronic databases (from their inceptions to January 2014): AMED (EBSCO), CINAHL (EBSCO), EMBASE (OVID), MEDLINE (OVID), PsycINFO, The Cochrane Library, ISI Web of Knowledge, two Indian databases (Indian Council of Medical Research and INDMED), one Chinese database (China National Knowledge Infrastructure), three Japanese databases (J stage, Journal archive, and Science Links Japan), and four Korean databases (DBpia, Korea National Assembly Library, Research Information Sharing Service and Oriental Medicine Advanced Searching Integrated System). Details of the MEDLINE search strategy are presented in Appendix 1. Additionally, the reference lists of the located articles and key SRs of yoga and hypertension were manually searched for further relevant literature. Hard copies of all retrieved articles were read in full.

### Study selection

Titles and abstracts of papers identified in the electronic database search were screened for relevance. Potentially relevant articles were retrieved in full for further evaluation and validation according to predefined criteria. The data screening and selection process was conducted independently by three reviewers (PP, HC and MSL) and subsequently validated by the fourth reviewer (EE) and the fifth (AK). Disagreements about whether a study should be included or excluded were resolved through discussions.

### Eligibility criteria

The present SR included all RCTs investigating the effect of yoga on adult patients [≥18 of age] with pre-hypertension [120—139/80—89 mm Hg] or hypertension [≥140/90 mm Hg] (as defined by AHA) with or without existing co-morbidities. In line with our previous review,[18] a practice that was based on traditional yoga philosophy or yoga practice and

that ''can consist of one or more of the following: specific postures, breathing exercises, body cleansing, mindfulness meditation, and lifestyle modifications'' was considered as yoga and therefore eligible for inclusion. Both published and unpublished RCTs with any types of control groups were considered admissible. No gender, time or language restrictions were imposed. Studies involving the use of yoga in combination with other treatments were included. For conceptual clarity, we excluded trials on mindfulness meditation and mindfulness based stress reduction (MBSR) as both can be separate modalities per se, and this is in line with previous SRs on the effectiveness of yoga.[19] Non-randomized or uncontrolled trials were excluded. Prevention trials, studies of healthy subjects or normotensives and articles which were available only as abstracts were excluded.

### Data extraction

Data extraction was conducted by three reviewers independently (PP, HC and MSL) using a predefined form and subsequently validated by another two reviewers (EE and AK). The following information was extracted from the included trials: first author and year of publication, study design, number and characteristics of participants, stage of their hypertension (if available), baseline BP and method of BP measurements, details of experimental and control interventions, concomitant pharmacotherapy, between-group differences in BP, effects size, details of follow-up, author's conclusions, AEs, summary of quality score and RCT's main limitations. We did not extract outcome measures other than BP.

### Quality assessment

The Cochrane tool was utilized to assess the risk of bias (ROB) of the RCTs.[20] This validated tool consists of 7 domains: adequate sequence generation, allocation concealment, patient blinding, assessor blinding, addressing of incomplete data, selective outcome reporting and other sources of other bias. Each domain can be scored as follows: H, high ROB; L, low ROB; and U, unclear ROB. Quality assessment process was performed by three reviewers (PP, HC and MSL) independently. Disagreements about whether a study was of low or high quality were settled through discussions.

### Qualitative data synthesis

The post-treatment differences in SBP and DBP between the intervention and control groups were assessed descriptively using measures of treatment effects (where available). The protocol stipulated that the data would be meta-analyzed if methodological, clinical and statistical heterogeneity permitted. Effect sizes were calculated for the effect of yoga on SBP and DBP. Differences scores between experimental and control group were calculated using the Cohen's d formulas.[21] Subgroup analyses were conducted by existence of complications: (a) hypertension without co-morbidities vs. hypertension with co-morbidities; and by BP levels: (b) pre-hypertension vs. stage I or II hypertension.

## Results

Our electronic searches generated a total of 8489 hits and 17 RCTs met the inclusion criteria (Fig. 1). The key data from the included RCTs are summarized in Table 1. Table 2 illustrates details of the yoga regimens used in these studies. A total of 1310 patients were included in the RCTs which originated from India,[22–29] the Netherlands,[30] Thailand,[31] UAE,[32] the UK,[33] and the US.[6,34–37] Patients were treated with yoga combined with concomitant medication in 8 trials.[22,24,32–34] Fifteen trials used parallel design; and two employed crossover design.[26,33]

### Study description

Cade et al. (2010)[6] aimed to determine whether 60 min sessions 2—3 weekly for 20 weeks of Ashtanga Vinyasa Yoga (VY) and pranayama (PY) improves CVD risk factors, including resting BP in 60 HIV-infected men and women (of those 26% had a history of hypertension and 42% had pre-hypertension) more than usual care (UC) controls. The authors reported significant reductions in both SBP and DBP ($p = 0.04$, no CIs) in the yoga group compared with the controls and concluded that yoga can lower BP in pre-hypertensive HIV-infected adults with mild-moderate CVD risk factors.

Cohen et al. (2008)[34] aimed to evaluate the feasibility and acceptability of 90 min sessions for 10 weeks of yoga (a total of 15 sessions) in 26 overweight, underactive adults with metabolic syndrome. The authors reported significant reductions in SBP ($p = 0.07$, no CIs) and insignificant reductions in DBP ($p = 0.10$, no CIs) in the yoga group compared with no treatment (NT) controls and concluded that yoga was a feasible and acceptable intervention.

Cohen (2011)[35] aimed to evaluate the cardiovascular and physiologic effects of 18 sessions a 70 min for 12 weeks of Iyengar yoga (IY) compared with 4 h of enhanced UC intervention emphasizing dietary approaches on reducing average SBP as measured by 24-h ambulatory BP monitoring (ABPM) in 78 adults with untreated pre-hypertension to stage I hypertension. At 12-weeks follow-up, the authors reported no significant between-group differences in 24 h SBP ($p > 0.05$, no CIs) and DBP ($p > 0.05$, no CIs) and concluded that 12 weeks of IY produced clinically meaningful improvements in 24 h SBP and DBP.

Hagins (2014)[37] aimed to compare the effects of 55 min sessions of Ashtanga yoga, twice a week for 12 weeks to a non-aerobic exercise class, designed for equivalence regarding time, attention, homework requirements, and metabolic output, in 84 prehypertensive or hypertensive adults. Significant between-group differences at 12 weeks were reported for ambulatory diastolic night-time BP ($p = 0.03$, no CIs) and the authors concluded that yoga can reduce BP in patients with mild hypertension.

Latha and Kaliappan (1991)[22] aimed to investigate the effectiveness of 17 twice weekly sessions for 6 months of yoga relaxation, PY and thermal biofeedback (BF) techniques in 14 patients with essential hypertension. The authors reported significant reductions in SBP (MD = 2.86, $p < 0.01$, no CIs) in the yoga group compared with NT controls; and insignificant changes in DBP (MD = 0.44, $p > 0.05$,

**Table 1** RCTs of yoga for hypertension.

| First author (year) (country) [ref] | Study design | Number and characteristics of patients/hypertension stage/baseline BP/BP measured with | Experimental interven-tion/concomitant drug therapy | Control intervention | BP result (between group differences) | Effect size (Cohen's *d*) 1.SDB 2.DBP | Follow-up(s) | Author's conclusions | AEs | Risk of bias[d] | Other limitations |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cade (2010) (US)[6] | RCT with 2 parallel groups | 60 HIV-infected adults/pre-hypertension and hypertension/ 120—139/ 80—89 mmHg/n.r. | Ashtanga VY, 60 min sessions 2—3 × a week for 20 weeks/no | UC including monthly nutrition counseling | 1. Sig. for SBP ($p = 0.04$) 2. Sig. for DBP ($p = 0.04$) | 1. −0.779 2. −0.769 | None | ''Among traditional lifestyle modifications, yoga is a low cost, simple to administer, non-pharmacological, popular behavioral intervention that can lower BP in pre-hypertensive HIV-infected adults with mild-moderate CVD risk factors'' | n.r. | L,U,H,H,L,L,U | Small sample, lack of power and SS calculations, no CIs |
| Cohen (2008) (US)[34] | RCT with 2 parallel groups | 26 adults with metabolic syndrome/≥130/ 85 mmHg/ sphygmomanometer | Yoga, 15 sessions of 90 min for 10 weeks/yes | NT | 1. Sig. for SBP ($p = 0.07$) 2. Sig. for DBP ($p = 0.10$) | 1. −0.793 2.−0.692 | None | ''Restorative yoga was a feasible and acceptable intervention in overweight adults with metabolic syndrome'' | None reported | L,U,H,H,L,L,U | Very small sample, lacked power, blinding and active control group |
| Cohen (2011) (US)[35] | RCT with 2 parallel groups | 78/pre-hypertension and stage I hypertension/ ≥130—<160/ <100 mmHg/ ambulatory BP | IY, 18 sessions of 70 min for 12 weeks/no | Enhanced UC, 4 h classes + 60 min individual phone contact | 1. N.s. for SBP 2. N.s. for DBP | 1. −0.508 2. −0.264 | None | ''Twelve weeks of IY produces clinically meaningful improvements in 24 h SBP and DBP'' | Reported ($n = 3$) | L,U,H,H,L,L,U | Lack of blinding, high drop-out rate |
| Hagins (2014)[37] | RCT with 2 parallel groups | 84 adults with prehypertension or stage I hypertension/ 120—159/ 80—99 mmHG/ ambulatory BP | Ashtanga yoga, 55 min sessions 2 × a week for 12 weeks/yes | Non-aerobic exercise, 55 min sessions 2 × a week for 12 weeks | 1. N.s. for SBP 2. Sig. for night time DBP ($p = 0.038$), n.s. for 24 h DBP | Insufficient data | None | ''This study demonstrates that a yoga intervention in patients with mild hypertension can significantly reduce BP'' | None reported | L,L,H,L,L,L,U | Not adequately powered |
| Latha (1991) (IN)[22] | RCT with 2 parallel groups | 14/essential hypertension/>150/ 100 mmHg/ sphygmomanometer | HY + PY + thermal BF, 17 sessions twice/week for 6 months/yes | NT | 1. Sig. for SBP ($p < 0.01$) 2. N.s. for DBP | Insufficient data | None | ''Yoga relaxation, PY and thermal BF techniques are beneficial in the management of high BP'' | n.r. | L,U,H,U,L,U,U | Very small sample, lack of active control group; no CIs |
| McCaffrey (2005) (TH)[31] | RCT with 2 parallel groups | 54/hypertensive adults/>140/ 90 mmHg/n.r. | HY + PY + relaxation, 63 min sessions 3 × a week for 8 weeks/no | UC | 1. Sig. for SBP ($p < 0.01$) 2. Sig. for DBP ($p < 0.01$) | 1. −1.703 2. −1.952 | None | ''(. . .) data analysis indicates that practicing asana and PY for 8 weeks reduces stress, BP, BMI, and HR among persons in Thailand with mild to moderate hypertension'' | n.r. | L,U,H,H,L,L,U | Lack of power calculations, unknown compliance rates |
| Mourya (2009) (IN)[24] | RCT with 3 parallel groups | 60/stage I essential hypertension/>145/ 90 mmHg/ sphygmomanometer | 1. PY slow breathing PY fast breathing (for both groups: 15 min twice/day for 3 months)[e] /yes | NT | 1. Sig. for SBP ($p = 0.004$) 2. Sig. for DBP ($p = 0.003$) | Insufficient data | None | ''Both types of breathing exercises benefit patients with hypertension'' | n.r. | U,U,H,L,L,L,U | Poor reporting, lack of SDs, CIs, lack of active control group |

Table 1 (*Continued*)

| First author (year) (country) [ref] | Study design | Number and characteristics of patients/hypertension stage/baseline BP/BP measured with | Experimental interven-tion/concomitant drug therapy | Control intervention | BP result (between group differences) | Effect size (Cohen's *d*) 1.SDB 2.DBP | Follow-up(s) | Author's conclusions | AEs | Risk of bias[d] | Other limitations |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Murugesan (2000) (IN)[23] | RCT with 3 parallel groups | 33/hypertensive adults/>150/ 100 mmHg/ sphygmomanometer | HY + meditation, 60 min sessions, twice/day, 6 days/week, for 11 weeks/no | 1. Antihypertensives 2. NT | 1. Sig. for SBP ($p < 0.01$)[b] 2. N.s for DBP[b] | 1. −1.034 2. −1.627 | None | ''The result revealed that both Yoga intervention and drugs treatment helped hypertensives but yoga intervention was more effective'' | n.r. | U,U,H,H,U,U,U | Small sample, lack of power calculation, CIs, and blinding |
| Pal (2013)[29] | RCT with 2 parallel groups | 258 patients with coronary artery disease/>120/ 80 mmHg/ sphygmomanometer | Yoga, 35—40 min sessions 5 × a week for 18 months/yes | UC for 18 months | 1. Sig. for SBP ($p = 0.002$) 2. Sig. for DBP ($p = 0.0002$) | 1. −0.642 2. −0.610 | None | ''This study may provide a base for clinicians and policy-makers indicating that yogic intervention could be prescribed as an adjunct to medical treatment'' | 2 deaths in yoga group, 3 deaths in control group | L,U,U,U,H,U,U | SS calculation unclear |
| Patel (1975) (UK)[33] | Crossover RCT with 2 parallel groups | 34 hypertensive adults/>160/ 110 mmHg/ sphygmomanometer | Yogic relax-ation + breathing + meditation + BF, 60 min sessions, twice/week for 6 weeks/yes | NT | 1. Sig. for SBP ($p < 0.005$) 2. Sig. for DBP ($p < 0.001$) | 1. 1.110 2. 1.571 | 12 months | ''In view of the possible importance of this type of therapy and the absence of undesirable side-effects, it seems desirable that further trials should be carried out in otherwise untreated patients under single-blind conditions, perhaps in hypertension clinics'' | None reported | L,U,U,L,L,L,U | Implausible to isolate the effects of yoga, lack of active control group |
| Saptharishi (2009) (IN)[25] | RCT with 4 parallel groups | 113 young adults with pre-hypertension/ 130—139/ 85—89 mmHg/ sphygmomanometer | HY, 30—45 min/day, 5 days/week for 8 weeks/no | 1. PE-brisk walking for 50—60 min 4 days/week 2. DIM 3. NT | 1. N.s.[c] for SBP 2. N.s.[c] for DBP | 1. 0.40 2. −0.40 | 8 weeks | ''Physical exercise, salt intake reduction, and yoga are effective non-pharmacological interventions in significantly reducing BP among young hypertensives and pre-hypertensives'' | n.r. | L,U,H,H,L,L,U | Unequal distribution between the groups |
| Shantakumari (2012) (UAE)[32] | RCT with 2 parallel groups | 100 hypertensive type II diabetics/≥130/ 80 mmHg/sphygmomanometer | HY + PY + meditation, 60 min daily for 3 months/yes | NT[a] | 1. Sig. for SBP ($p < 0.01$) 2. Sig. for DBP ($p < 0.01$) | 1. −0.969 2. −0.670 | None | ''It can be concluded from this study that the chosen yogic practices are very effective in correcting the hypertension seen in a diabetic patient'' | n.r. | U,U,H,H,L,L,U | Lack of blinding, control for placebo effects, no CIs |
| Subramanian (2011) (IN)[26] | Crossover RCT with 4 parallel groups | 98 young adults with pre-hypertension /130—139/ 85—89 mmHg/n.r. | HY, 30—45 min/day, 5 days/week for 8 weeks/no | 1. PE-brisk walking for 50—60 min 4 days/week 2. DIM 3. NT | 1. N.s.[c] for SBP 2. N.s.[c] for DBP | 1. −0.018 2. 0.025 | None | ''This study reconfirmed that physical exercise was more effective than Salt Reduction or Yoga'' | n.r. | L,U,H,H,L,L,U | Small effect size, lack of power calculations |

Table 1 (*Continued*)

| First author (year) (country) [ref] | Study design | Number and characteristics of patients/hypertension stage/baseline BP/BP measured with | Experimental interven-tion/concomitant drug therapy | Control intervention | BP result (between group differences) | Effect size (Cohen's *d*) 1.SDB 2.DBP | Follow-up(s) | Author's conclusions | AEs | Risk of bias[d] | Other limitations |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Telles (2013)[28] | RCT with 3 parallel groups | 90 adults with essential hypertension/ / ≥140/≥90 mmHG/ sphygmomanometer | Anuloma–viloma pranayama (alternate nostril breathing), single 10 min session/yes | 1. Breath awareness, single 10 min session 2. Reading, single 10 min session | 1. Sig. for SBP ($p < 0.05$) 2. N.s. for DBP | 1. −0.347 2. 0.205 | None | ''The results suggest that the immediate effect of alternate nostril breathing is to reduce the BP (. . .)'' | n.r. | L,U,U,U,U,L,L,U | Lack of appropriate SS calculation |
| Tundwala (2012) (IN)[27] | RCT with 2 parallel groups | 150 obese patients with hypertension and dyslipidemia/> 130/80 mmHg/n.r. | Unspecified asanas + PY + DIM, daily for 3 months/n.r. | DIM | N.r. | 1. −0.50 2. −0.37 | None | ''It is concluded that the yoga and certain asanas have positive and useful effect on certain cardiovascular risk factors viz., obesity, hypertension and dyslipidemia'' | n.r. | U,U,H,H,H,H,H | Poor reporting, lack of details of yoga intervention, impossible to replicate |
| Van Montfrans (1990) (NL)[30] | RCT with 2 parallel groups | 35 hypertensive adults/160–200/ 95–110 mmHg/ sphygmomanometer | HY + breathing + relaxation + AT, 15 min twice daily for 12 months/no | Passive relaxation twice/day for 15 min | 1. N.s. 2. N.s. | 1. 0.041 2. 0.146 | 12 months | ''Relaxation therapy was an ineffective method of lowering 24 h BP, being no more beneficial than non-specific advice, support, and reassurance-themselves ineffective as a treatment for hypertension'' | n.r. | L,L,H,H,L,L,U | Small sample, high drop-out rate |
| Yang (2011) (US)[36] | RCT with 2 parallel groups | 23 adults at high risk of type II diabetes (7 prehypertensive)/ 120–139/ 80–89 mmHg/n.r. | VY, 60 min session, twice/week for 3 months/no | Health education every 2 weeks | 1. Sig. for SBP ($p < 0.05$) 2. Sig. for DBP ($p < 0.05$) | 1. −0.62 2. −0.35 | None | ''(. . .) yoga holds promise as an approach to reducing cardiometabolic risk factors and increasing exercise self-efficacy (. . .)'' | None reported | U,U,H,L,L,L,U | Underpowered, small sample, questionable effect sizes, limited generalisability |

AE, adverse effect, AT, autogenic training; BP, blood pressure; BF, bio-feedback; DBP, dystolic blood pressure; DIM, dietary modifications; HY, Hatha yoga; IY, Iyengar yoga; N.s., not significant; N.r., not reported; NT, no treatment; PE, physical exercise; PY, pranayama; SBP, systolic blood pressure; SS, sample size; UC, usual care; VY, Vinyasa yoga.

[a] Patients received hypoglycemics.

[b] For experimental group vs. drugs and not 'no intervention' group.

[c] For HY vs. PE and/or reduced salt intake groups and not 'no intervention' group.

[d] Domains of quality assessment based on the Cochrane tools for assessing risk of bias [adequate sequence generation, allocation concealment, patient blinding, assessor blinding, incomplete data addressed, selective outcome reporting, other sources of bias]. H — means high risk of bias, L — means low risk of bias, U — means unclear risk of bias.

[e] Once the breathing technique was learned.

**Table 2** Details of yoga regimen.

| First author (year) [ref] | Details of treatment (quote where appropriate) |
|---|---|
| Cade (2010)[6] | ''Each session included: 1. Alignment of muscle locks (bandhas) and controlled breathing (Ujjayi). 2. Warm-up (5 min). 3. Sun Salute A ×3, Salute B ×1 (Surya Namaskara) (7 min). 4. Standing Asanas (25 min). 5. Seated Asanas (10 min). 6. Lying Supine Asanas (5 min). 7. Cool-down (Restorative breathing techniques) (7 min)'' |
| Cohen (2008)[34] | ''Each group yoga class consisted of a brief series of warm-up stretches and breathing exercises followed by 10 poses that were held for 5—10 min each. Poses included Half-Dog at the Wall, Wall Hang, Seated Bound Angle Pose, Seated Wide Angle Pose, Reclining Twist, Supported Bridge, Supported Legs Up the Wall, Child's Pose, Supported Lying Down Bound Angle, and Deep Relaxation Pose'' |
| Cohen (2011)[35] | Savasana 5 min, Cross bolsters 5 min, Supta baddha konasana 5 min, Supta swastikasana 5 min/side, Bharadvajasana 3 × 30 s/side, Pavannamuktasana 5 min, Adho mukha virasana 5 min, Adho mukha swastikasana 1 min/side, Adho mukha 1 min, Uttanasana 1 min, Janu sirsasana 1 min/side, Upavisthakonasana 3 min, Paschimottanasana 1 min, Savasana 5 min, Ujjayi pranayama 5 min |
| Hagins (2014)[37] | Primary series of Ashtanga yoga. Class structure: 1. Meditation 5—7 min; 2. Physical postures (asana) 35 min; 3. Regulated breathing 10 min; 4. Relaxation (Shavasana) 5 min |
| Latha (1991)[22] | ''The experimental group subjects practiced selected breathing techniques and asanas as taught by the first investigator, some of the postures were: breathing with arm movement, Apanasana, Ekapada apanasana, extended exhalation, Shavasana, Shitali, Omkara and Nadishodhana pranayam were also taught. Thermal feedback was added in the 2nd phase of the treatment to aid yoga relaxation'' |
| McCaffrey (2005)[31] | The cassette tape ''(...) contained practice guidance for pranayama, deep relaxation, and 14 yoga asana postures (bow, cobra, corpse, crocodile, fish, head-to-knee, joint exercise, lotus, mountain, thunderbolt, twisting, wheel, yoga mudra, and yoni mudra)'' |
| Mourya (2009)[24] | 1. For SBE: ''The patient was first asked to close one nostril with a thumb and slowly breathe in completely through the other for 6 s. This nostril was then closed and the patient exhaled through the other nostril over a period of 6 s. These steps completed one breathing cycle. An attempt was made to keep the breathing rate about 5—6 breaths per minute. Such alternate nostril breathing cycles were repeated continuously for a period of about 15 min in one sitting.'' 2. For FBE: ''Patients were instructed to breathe quickly and deeply, with an inhalation and exhalation time of 1 s each for 1 min, following which they were given 3 min of rest. The procedure was repeated 4—5 times over a period of 15 min'' |
| Murugesan (2000)[23] | The practice session of yogic practices (sliauasana, pavanamuktasana, ardhahalasana, viparitakarani, ardhamatsyasana makarasana, bhujangasana, ardhashalabhasana,vakrasana, vajrasana, yoga mudra, chakrasana, tadasana, nadi-sodhana, Om recitation and meditation)'' |
| Pal (2013)[29] | ''The yogic practiced were Jal Neti (nasal cleansing) once in a week (...). Shavashana (body awareness, 10—15 min) (...). Bhujangasana (5 times in 3 min) (...). Shashankasana (5 times in 3 min) (...). Ushtrasana (5 times in 3 min) (...). Hasthutthanasana (5 times in 3 min) (...). Shiddhasana (5 min) (...). Nadi Shodhan Pranayama (5 times in 6—7 min) with om chanting (3 times in 2 min) (...)'' |
| Patel (1975)[33] | Active treatment consisted of films and slides of about relaxation, bio-feedback, self-control. Next relaxation (10—12 min) and breathing were performed. ''Once the patient had mastered the method of relaxation, a type of transcendental meditation was introduced. Throughout the session the patient was connected to one of two biofeedback instruments (...)'' fell as the patient relaxed |
| Saptharishi (2009)[25] | ''This included relaxation techniques like pranayama (breathing exercises); and asanas like savasana, ardha matsyendrasana, naadishudhi asana, single leg, and double leg raise'' |
| Shantakumari (2012)[32] | Asanas, 30—35 min: Suryanamaskaram, 5 min, Yoga Mudrasana, 2 min Vajrasana, 2 min Vakrasana, 2 min Paschimottasana, 2 min Pavanamuktasana, 2 min Sashankasana, 2 min Ushtrasana, 2 min Bhujangasan, 2 min Dhanurasana, 2 min Arthakatichakrasana, 2 min Parivatha trilokasanaan, 2 min Shavasana, 5 min Pranayama (Breathing Exercises), 5 min: Ujjayi pranayama, 5 repeats, Anuloma viloma, 10—15 repeats, Alternate Kapalapathi pranayama, 5 repeats Suryabhedha pranayama, 5 repeats Meditations, 15 min: one—one meditation, 5 min, Breath counting meditation, 10 min |
| Subramanian (2011)[26] | ''Subjects of the New Yoga Group were taught yoga exercises effective in reducing BP, by a qualified yoga instructor, and pamphlets containing the yoga lessons were distributed. They performed for 30—45 min/day, at least five days/week'' |

Table 2 (*Continued*)

| First author (year) [ref] | Details of treatment (quote where appropriate) |
|---|---|
| Telles (2014)[28] | ''ANYB involves breathing through left and right nostrils alternately. In this practice the thumb and the ring finger of the right hand were used to manipulate or occlude the nostrils. Throughout this practice the awareness is directed to the breath and breathing'' |
| Tundwala (2012)[27] | ''(...) Pranayama and certain yogic asanas (...)'' |
| Van Montfrans (1990)[30] | ''We used the approach for relaxation described by Patel et al. Briefly, a relaxation therapist trained patients for 1 h a week for 8 weeks in hatha yoga breathing and posture exercises, Jacobson's method of progressive relaxation (straining and subsequent relaxation of the major muscle groups), and exercises derived from the autogenic training method by Schultz and Luthe. Subjects were also taught how to elicit the relaxation response by using the simple meditative technique proposed by Benson'' |
| Yang (2011) [36] | ''This Vinyasa style yoga program included various physical postures (*Asanas*) such as sun-salutations, standing poses, seated/kneeling poses and counterposes. Each movement was combined with various breathing patterns of inhalation and exhalation (*Pranayamas*). (...) Each 1-h session of the yoga program began with a warm-up (5—7 min) and ended with a relaxation period (10 min)'' |

ANYB, alternate yoga nostril breathing; BP, blood pressure; FBE, fast breathing exercises; SBE, slow breathing exercises.

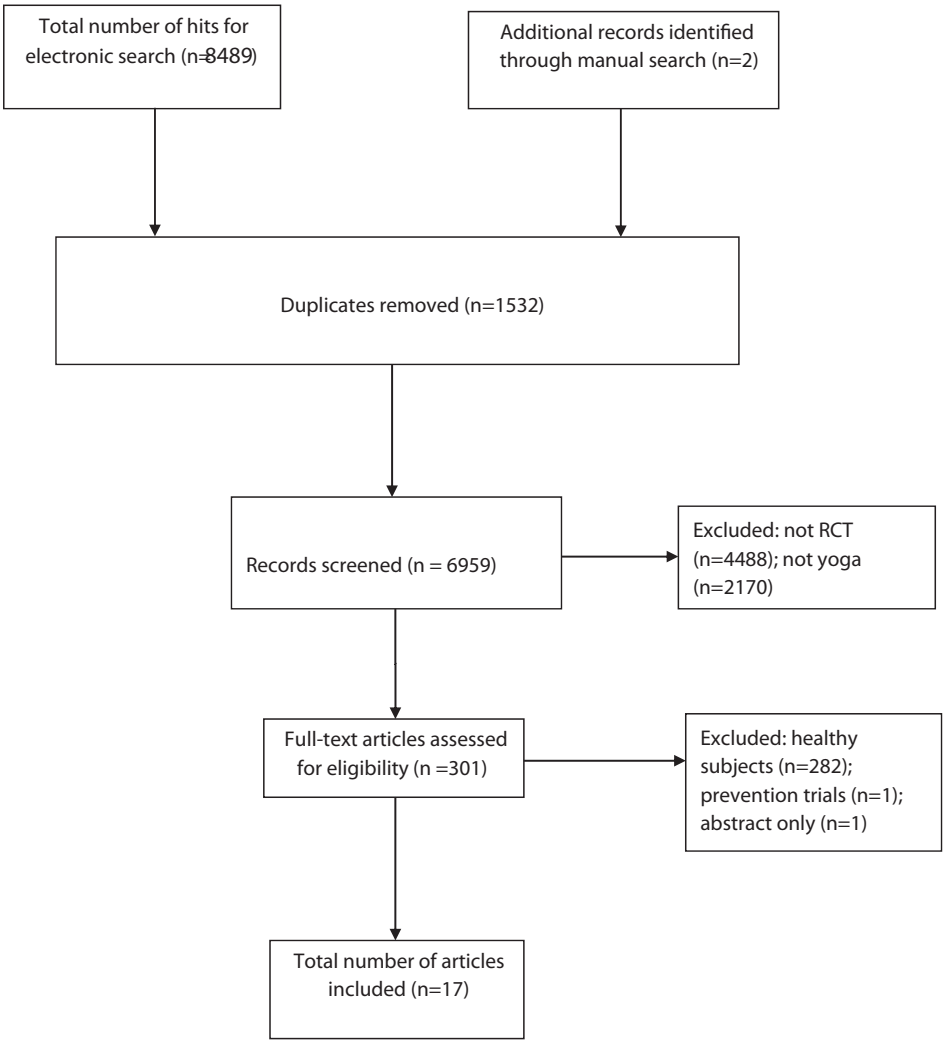


**Figure 1** PRISMA diagram for included studies.

no CIs) and concluded that yoga relaxation, PY and thermal BF techniques are beneficial in the management of high BP.

McCaffrey et al. (2005)[31] aimed to determine the effect of 24 1 h long sessions during 8 weeks of Hatha yoga (HY), PY and relaxation (a total of 24 sessions) on BP in 54 hypertensive adults. The authors reported significant reductions in SBP ($p < 0.01$, no CIs) and DBP ($p < 0.01$, no CIs) in the yoga group compared with UC and concluded that practicing HY and PY for 8 weeks reduces BP among individuals with mild to moderate hypertension.

Mourya et al. (2009)[24] aimed to evaluate 15 min twice daily for 3 months of PY slow and/or fast breathing exercises in 60 patients with stage 1 essential hypertension. The authors reported significant reductions in SBP ($p = 0.004$, no CIs) and DBP ($p = 0.003$, no CIs) in the yoga group compared with NT controls and concluded that both types of breathing exercises benefit patients with hypertension.

Murugesan et al. (2000)[23] aimed to compare the effectives of 60 min sessions, twice daily, 6 days a week, during 11 weeks of HY plus meditation compared to anti-hypertensive medication and NT in 33 patients with hypertension. The authors reported significant reductions in SBP ($p < 0.01$, no CIs) in the yoga group compared with pharmacotherapy; and no significant reductions in DBP ($p > 0.05$, no CIs) and concluded that both yoga and drugs helped hypertensive patients but felt that yoga was more effective.

Pal (2013)[29] aimed to assess the effects of 5 weekly 35—40 min sessions of yoga combined with medication over 18 months to medication alone in 258 patients with coronary artery disease. The authors reported significantly larger reduction of both SBP ($p = 0.002$, no CIs) and DBP ($p = 0.0002$, no CIs) after yoga plus medication than after medication alone and concluded that yoga could be prescribed as an adjunct to medical treatment.

Patel (1975)[33] aimed to investigate the effectiveness of 60 min sessions, twice a week for 6 weeks of yogic relaxation, breathing, meditation and BF in 34 hypertensive adults (of those, 94% were on anti-hypertensive medication). At 12 months follow up, the author reported significant reductions in SBP ($p < 0.01$, no CIs) and DBP ($p < 0.01$, no CIs) in the yoga group compared with NT controls and concluded that further trials should be carried out in otherwise untreated patients.

Saptharishi et al. (2009)[25] aimed to compare the effectiveness of 30—45 min sessions 5 days a week for 8 weeks of HY with physical exercise (PE) 50—60 min 4 days a week for 8 weeks; reduction in salt intake dietary modification (DIM); and NT in lowering BP among 113 young pre-hypertensives and hypertensives. At 8-weeks follow-up, the authors reported no significant between-group differences in SBP and DBP in the yoga group compared with DIM (for SBP:MD = −0.536, $p = 0.766$, 95% CI −2.39 to 1.31; for DBP: MD = −0.861, $p = 0.391$, 95% CI −2.43 to 0.71); and significant between-group differences in SBP and DBP in the PE group compared with yoga (for SBP: MD = 3.479, $p = 0.002$, 95% CI 1.16—5.79; for DBP: MD = 3.747, $p = 0.000$, 95% CI 2.01—5.48). They concluded that PE, DIM, and yoga are effective non-pharmacological interventions in significantly reducing BP among young hypertensives and pre-hypertensives.

Shantakumari et al. (2012)[32] aimed to assess the effectiveness of 60 min daily for 3 months of HY, PY and meditation in 100 hypertensive patients with type II diabetes mellitus. The authors reported significant reductions in SBP ($p < 0.01$, no CIs) and DBP ($p < 0.01$, no CIs) in the yoga group compared with NT controls and concluded that the chosen yogic practices are very effective in correcting the hypertension in diabetic patients.

The RCT by Subramanian et al. (2011)[26] was a follow-up of the RCT by Saptharishi et al. (2009). The authors of the former reported highly significant reduction in SBP and DBP in PE group compared with yoga (for SBP: MD = −2.52, $p = 0.006$, 95% CI −4.36 to −0.68; for DBP: MD = −2.96, $p = 0.003$, 95% CI −4.97 to −0.95); and no significant between-group differences in SBP and DBP in the yoga group compared with DIM (for SBP: MD = −0.24, $p = 0.8$, 95% CI −1.28 to 0.80; for DBP: MD = −0.68, $p = 0.3$, 95% CI −1.80 to 0.45) and concluded that PE, DIM, and yoga are effective non-pharmacological methods for reducing BP in young pre-hypertensive and hypertensive adults.

Telles (2014)[28] aimed to compare the immediate effects of a single 10 min session of anuloma—viloma pranayama (alternate nostril breathing) to breath awareness and reading on BP during the Purdue pegboard task in 90 patients with essential hypertension who were familiar with yoga breathing practices. The authors reported significant within-group reductions of SBP after pranayama and breath awareness, significant within-group reduction of DBP after pranayama, and a significant between-group difference for SBP (all $p < 0.05$, no CIs). The authors concluded that pranayama can reduce BP during focused tasks in patients with hypertension.

Tundwala (2012)[27] aimed to study the effect of unspecified Asanas, PY and DIM, daily for 3 months in 150 patients with obesity, hypertension and dyslipidemia. The authors reported significant (within group) reductions in SBP ($p = 0.001$, no CIs) and DBP ($p = 0.001$, no CIs) in the yoga group (and not in DIM controls) and concluded that the yoga and certain Asanas have positive and useful effect on hypertension.

Van Montfrans (1990)[30] aimed to determine the long term effects of 15 twice daily for 12 months of HY, breathing, relaxation and autogenic training (AT) on 24 h ambulatory intra-arterial BP in 35 patients with mild untreated and uncomplicated hypertension. The authors reported no significant between-group differences in the mean diastolic ambulatory intra-arterial pressure during the daytime in the relaxation group (MD = −1.0, $p > 0.05$, 95% CI −6 to 3—9) and for the passive relaxation control group (MD = −0.4, $p > 0.05$, 95% CI −5.3 to 4—6) and concluded that yoga relaxation therapy was an ineffective method of lowering 24 h BP, being no more beneficial than non-specific advice, support, and reassurance.

Yang (2011)[36] aimed to assess the feasibility of implementing a 60 min session twice a week for 3 months of VY in 23 adults at high risk for type II diabetes (of those 7 were prehypertensive). The authors reported significant reductions in SBP ($p < 0.05$, no CIs) and DBP ($p < 0.05$, no CIs) in the yoga group compared with health education controls and concluded that yoga holds promise as an approach to reducing cardiometabolic risk factors and increasing exercise self-efficacy.

### Effect size of yoga interventions

In three of the 13 RCTs, statistics needed for effect size calculations were not reported.[22,24] Effect sizes (Cohen's *d*) in the remainder of the trials ranged from −0.018 (small) to −1.952 (large); $x' = 0.58$ (medium) (Table 1).

### Subgroup analyses

Subgroup analyses by the existence of complications revealed that in all RCTs investigating patients with co-morbidities; yoga was effective in reducing SBP and DBP.[6,29,32,34,36] In 9 RCTs investigating patients without co-morbidities; 6 favored yoga in reducing SBP[22,31,33] and 5 in reducing DBP.[23,24,31,33] Subgroup analyses by BP levels revealed that 6 (out of 8) RCTs investigating pre-hypertensives favored yoga in reducing SBP or DBP,[6,29,32,34,36,37] whereas in patients with stages I or II hypertension, 6 (out of 8) RCTs favored yoga in reducing SBP[22,31,33] and 3 RCTs (out of 8) favored yoga in reducing DBP.[24,31,33]

### Risk of bias (ROB)

Five of the RCTs had an unclear ROB with regard to adequate sequence generation. Fifteen trials had an unclear ROB with regard to allocation concealment. Fourteen RCTs had high ROB with regard to patient blinding. Ten RCTs had high ROB with regard to assessor blinding. Two RCTs had high and two had an unclear ROB with regard to addressing of incomplete data. Three RCTs had an unclear and one had high ROB with regard to selective outcome reporting. Fifteen RCTs had an unclear and one had high ROB from other sources. The overall quality of the RCTs was therefore poor, and all RCTs had methodological limitations.

## Discussion

Two SRs were recently published[16,17] and they concluded that yoga interventions are effective in reducing BP. In their meta-analysis, Hagins et al.,[16] pooled both randomized and non-randomized trials which is generally discouraged and difficult to interpret.[38] The SR by Wang et al.,[17] included only a fraction of studies we managed to locate.

The aim of this SR was to summarize and critically evaluate the evidence for or against the effectiveness of yoga in lowering high BP. Seventeen trials were found; 11 of them favored yoga in reducing SBP, 8 favored yoga in reducing DBP, while the remaining 5 showed no effect in lowering SBP and 8 showed no effect in lowering DBP, and one did not report between-group comparisons. In general, the methodological quality of the included RCTs was poor. Studies of the highest quality and of the largest sample size both showed significant reductions in SBP[28] and DBP.[29,33] The evidence from RCTs of yoga for treating high BP is thus encouraging but any definitive judgements should be avoided for several reasons.

This SR reveals a lack of methodological rigor and poor reporting in almost all of the RCTs. For instance, only 5 (29.4%) RCTs had reasonably large sample sizes.[25,29,32] Four trials (21.4%) used blinded assessors.[24,33,36,37] None of the trials made an attempt to control for placebo effects by employing sham procedures, e.g., Ref. 39. Other sources of bias included lack of power and sample size calculations,[28,32,35] equal distribution between study arms,[25] or patient compliance with yoga regimen.[31] Only three (5.8%) RCTs provided CIs.[25,26,30] Two RCTs had follow-ups of sufficient length.[30,33] Five RCTs did not use active control group.[22,24,32–34] All of them favored yoga. Equivalence or superiority trials showed inferiority of yoga compared with equally effective therapies such as PE[25,26,37] in reducing SBP. Eight (47%) RCTs focused on one geo-ethnical region, where yoga is strongly ingrained in the Indian culture. Of those, 4 favored yoga[22,29] and one did not report between-group differences.[27] Two trials used yoga in combination with BF; and both of them were positive.[22,33] Such results create difficulties and impracticalities in identifying the active component of the treatment package. Trials of behavioral, multifactorial interventions based on whole system's philosophy such as yoga are particularly difficult to design and execute. Nevertheless, in order to make a progress in this area, researchers need to employ sham techniques such as stretching; facilitate allocation concealment (e.g. by providing sealed envelopes), or assessor blinding; and enhance patients' compliance by offering financial incentives.

In the majority of the included RCTs, the populations of patients were homogeneous.[23,30,31,33,35] In 5 RCTs however, they were heterogeneous including coronary artery disease,[29] HIV-infected adults,[6] individuals with metabolic syndrome,[27] type II diabetes,[32] and those being at high risk of type II diabetes.[36] Blood pressure at baseline ranged from ≥120–139/80–89 mmHg[6,29,36] to 200/95–110 mm.[30] The control interventions were heterogeneous, including the use of DIM,[25–27] enhanced UC,[35] health education,[36] NT,[22,24–26,32–34] pharmacotherapy (anti-hypertensives),[23] passive relaxation,[30] PE[25,26,37] breath awareness or reading[28] or UC.[6,29,31] In 10 RCTs sphygmomanometer was used to measure BP at baseline,[22,28–30,32–34] two used ambulatory BP,[35,37] and 5 did not specify the method used.[6,26,27,31,36] The yoga interventions themselves varied significantly from Ashtanga VY,[6,37] HY,[25,26] IY,[35] PY,[24,28] VY,[36] unspecified Asanas,[27,29] to a combination of HY, PY and thermal BF,[22] HY, PY and relaxation,[31] HY and meditation,[23] yogic relaxation, breathing, meditation and BF[33] or HY, PY and meditation.[32] The duration of yoga intervention ranged from single 10 min session[28] to 18 months[29] (Table 1). Therefore, the clinical and methodological heterogeneity of the data precluded a formal meta-analysis.

Eleven RCTs did not report the incidence rates of AEs.[6,22–28,30–32] Four RCTs mentioned that no AEs had occurred.[33,34,36,37] Cohen et al. (2011) reported that three patients had experienced AEs following IY; with no further details provided.[35] Pal et al. reported two deaths in the yoga group and three deaths in the control group with no further details provided.[29] This again highlights the poor reporting in yoga trials and the need for more rigorous standards in researching this area.[10] Authors of prospect trials of yoga should improve this situation and follow commonly accepted standards of trial design and reporting (e.g., CONSORT).[40]

Although, the clinical relevance of a treatment effect cannot be deduced from the Cohen's formula,[41] on average, the effect size of yoga interventions in reducing BP was medium (Cohen's $d = 0.58$). This might suggest that, if confirmed by more rigorous trials, yoga could become

part of the non-pharmacological management of hypertension. Results from the subgroup analyses also revealed that yoga might be more effective in patients with complicated hypertension; and for those with pre-hypertension (120—139/80—89 mm Hg). Our analyses also reveal that yoga might be more effective in reducing SBD than DBP.

The mechanisms of action are purely hypothetical and may involve neurohumoral, vascular, and structural adaptations such as decreases in catecholamines and cortisol concentrations, HR, RR, total peripheral resistance, renin activity and circulating angiotensin II or endothelin levels; and improvements in endothelial vasodilator function, left ventricular diastolic function, arterial stiffness, systemic inflammation, heart rate variability, baroreflex sensitivity or enhancement of cardiovagal function.[42—45]

The present review has several limitations that should be taken into account when interpreting its results. Firstly, even though our searches were sophisticated, we cannot guarantee that all relevant trials were located. Secondly, due to the clinical, methodological and statistical heterogeneity of the included studies, statistical pooling was deemed implausible. Thirdly, publication and location biases could have distorted the overall picture. Our review has its strengths, including a comprehensive search strategy without language restrictions and a critical appraisal of the included studies.

In conclusion, the evidence for the effectiveness of yoga as a treatment for hypertension is encouraging but inconclusive. Further, more robust trials seem warranted.

## Recommendations for practice

Following the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system,[46] a weak recommendation for the use of yoga in high BP might be given, as there were no serious AEs.

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## Appendix 1. Detailed search strategy for MEDLINE

Concept 1

Yoga.ti,ab. OR yogic.ti,ab. OR yoga.sh OR yoga.tw OR yogic.tw OR yoga.kw OR yogic.kw OR exp alternative medicine/OR exp Complementary Therapies/

Concept 2hypertens.ti.ab. OR hypertens*.tw. OR ((high or elevat* or rais*) adj2 blood pressure).tw OR exp cardiovascular diseases OR exp cardiovascular system OR cardiovascular.mp. OR exp hypertension OR hypertens*.mp. OR exp blood pressure OR blood*.mp

Concept 3

(randomized controlled trial).pt. OR (clin* adj5 trial*).ti,ab. OR ((singl* or doubl* or tripl* or trebl*) adj5 (blind* or mask* or sham)).ti,ab OR random*.ti,ab OR control*.ti,ab. OR prospectiv*.ti,ab. OR exp clinical trial/OR follow-up studies/or prospective studies/OR double-blind method/or random allocation/or single-blind method/OR exp Research Design/

**1 AND 2 AND 3**

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