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COMPARATIVE EVALUATION OF SPORT-BASED EXERCISE MODALITIES FOR REDUCING ARTERIAL HYPERTENSION: A LITERATURE REVIEW

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ABSTRACT

Background: Hypertension is the principal modifiable risk factor for cardiovascular disease worldwide and the leading preventable cause of mortality. Over the past 30 years prevalence has doubled to ≈1.3 billion people. Each 20-mmHg increase in systolic or 10-mmHg rise in diastolic blood pressure approximately doubles cardiovascular and stroke mortality; even modest BP reductions substantially lower cardiovascular events, reducing premature mortality globally.
Aim: The aim of this study was to provide a comprehensive review of different types of physical exercise and to compare their effectiveness in reducing arterial blood pressure.
Materials and Methods: Between May-July 2025 we searched PubMed, PMC and Google Scholar (MeSH and free-text). Human studies only; included RCTs, non-randomized, cohort, cross-sectional studies, systematic reviews and meta-analyses. Two reviewers screened; heterogeneity precluded meta-analysis; findings narratively synthesized per PRISMA.
Research results: Different exercise modalities-including aerobic, resistance, isometric, interval, and mind-body practices-consistently reduce blood pressure, with magnitude varying by modality, intensity and duration. Evidence suggests a dose-response for aerobic training and robust SBP reductions for isometric protocols, while resistance, interval and mind-body interventions provide moderate benefits. Heterogeneity in study designs, populations and quality limits direct comparisons and highlights the need for standardized, high-quality trials.
Conclusions: Various exercise types-including aerobic, resistance, isometric, interval, and mind-body practices-consistently reduce blood pressure. Isometric training strongly lowers systolic BP, aerobic exercise shows dose-response benefits up to 150 min/week, and other modalities offer moderate effects. Regular physical activity is a safe, effective nonpharmacological strategy, supporting integration into comprehensive hypertension management.

KEYWORDS

Sport, Hypertension, Aerobic Training, Isometric Training, Resistance Training, Blood Pressure Reduction

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Introduction.

Elevated blood pressure is the foremost modifiable determinant of cardiovascular morbidity worldwide, substantially contributing to stroke, peripheral arterial disease, renal impairment and ischemic heart disease.(Yang et al., 2012) The World Health Organization identifies high blood pressure (BP) as the single greatest risk factor for mortality globally.(Lim et al., 2012) American epidemiological data indicate that up to 40.6% of cardiovascular deaths are attributable to hypertension, whereas smoking accounts for 13.2%, poor nutrition for 11.9%, lack of physical activity for 8.8%, and elevated plasma glucose for 8.8%.(Mozaffarian et al., 2016) About 5% of patients with diagnosed hypertension meet criteria for resistant hypertension, while roughly 8% exhibit intolerance to multiple antihypertensive agents - a pattern reported more frequently among female patients. Over the last three decades the global prevalence of hypertension has roughly doubled-from an estimated 650 million to 1.3 billion people-driven primarily by population ageing and the rising prevalence of obesity.(Cegłowska et al., 2024) Epidemiological data indicate that a 20 mm Hg rise in systolic blood pressure or a 10 mm Hg rise in diastolic blood pressure is associated with an approximate doubling of mortality due to cardiovascular disease and stroke linked to hypertension. Pooled analyses by Ettehad and colleagues, which synthesized randomized controlled trials of antihypertensive treatment in mild-to-moderate hypertension, showed that modest mean reductions in diastolic pressure (3-6 mm Hg) were linked to an approximately 40-42% lower stroke incidence and a 16-25% reduction in major cardiovascular events.(Ettehad et al., 2016)

Since 1991 the share of deaths attributable to cardiovascular disease in Poland has shown a sustained downward trend. National mortality statistics indicate that cardiovascular disease was responsible for 47.7% of deaths in Poland in 1991 (42.8% in men and 53.3% in women). By 2014, there were 169,735 CVD deaths (441.1 per 100,000), representing 45.8% of total mortality (40.9% in men and 51.1% in women). Over the past 30 years the number of individuals with hypertension has doubled, from 650 million. The NATPOL 2011 study forecasts that approximately 14 million Poles aged 18-79 will have hypertension by 2035.(Niklas et al., 2018) A meta-analysis by Kearney estimated the global adult prevalence of hypertension at 26.4% (972 million persons) in 2000, projecting an increase to 29.2% (1.65 billion persons) by 2025.(Kearney et al., 2005)

The predominant clinical presentation is essential (primary) hypertension, a diagnosis made when no single causative factor can be identified. Identification of secondary causes is important because many are potentially treatable; if unrecognized or untreated, secondary hypertension may progress to resistant hypertension and lead to cardiac or renal complications.(Puar et al., 2016) Secondary causes account for approximately 10% of hypertensive cases. Although clinicians most commonly consider secondary etiologies such as renal disease or aortic coarctation in children and young adults under 30, it is important to recognize that secondary causes-particularly primary aldosteronism, renal disease, and obstructive sleep apnea (OSA)-also occur frequently in older patients.(Puar et al., 2016)

In the 2024 ESC/ESH Guidelines for the management of elevated blood pressure and hypertension, a new target systolic blood pressure range of 120-129 mmHg has been introduced. Consequently, a systolic blood pressure of 120-139 mmHg and/or a diastolic. blood pressure of 70-89 mmHg measured in a clinical setting are now classified as 'elevated blood pressure' (Table. 1).

Table 1. Previous and new classification of blood pressure (BP) categories. Based on ("Erratum: 2023 ESH Guidelines for the Management of Arterial Hypertension The Task Force for the Management of Arterial Hypertension of the European Society of Hypertension: Endorsed by the International Society of Hypertension (ISH) and the European Renal Association (ERA)(J Hypertens (2023) 41 (1874-2071) DOI: 10.1097/HJH.0000000000003480)," 2024; Mancia et al., 2023)

<table>
<tr><th colspan="2">Systolic and diastolic blood pressure [mmHg]</th><th>Previous Blood Pressure Categories</th><th>New Blood Pressure Categories</th></tr>
<tr><td>< 120 and</td><td><70</td><td rowspan="2">Optimal BP</td><td>Optimal BP</td></tr>
<tr><td>< 120 and/or</td><td>70-79</td><td rowspan="3">Elevated Blood Pressure</td></tr>
<tr><td colspan="2">120–129 and/or 80–84</td><td>Normal BP</td></tr>
<tr><td colspan="2">130–139 and/or 85–89</td><td>High-normal BP</td></tr>
<tr><td colspan="2">≥ 140 and/or ≥ 90</td><td>Hypertension Grade 1</td><td rowspan="3">Hypertension</td></tr>
<tr><td colspan="2">≥ 160 and/or ≥ 100</td><td>Hypertension Grade 2</td></tr>
<tr><td>≥ 180 and/or ≥ 110</td><td></td><td>Hypertension Grade 3</td></tr>
</table>

The definition of hypertension remains unchanged: it is defined as a persistent elevation in office systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg.("Erratum: 2023 ESH Guidelines for the Management of Arterial Hypertension The Task Force for the Management of Arterial Hypertension of the European Society of Hypertension: Endorsed by the International Society of Hypertension (ISH) and the European Renal Association (ERA)(J Hypertens (2023) 41 (1874-2071) DOI: 10.1097/HJH.0000000000003480)," 2024; Mancia et al., 2023)

This study sought to deliver an in-depth synthesis of the various modalities of physical exercise and to evaluate their relative efficacy in lowering arterial blood pressure.

Pharmacological basics of treatment hypertension

The treatment of hypertension employs several pharmacological classes. Thiazide and thiazide-like diuretics (e.g. hydrochlorothiazide, chlorthalidone, indapamide) act at the distal convoluted tubule by inhibiting the Na^+/Cl^- cotransporter, thereby promoting natriuresis and increasing renal potassium loss. Loop diuretics (e.g. furosemide, ethacrynic acid) act in the thick ascending limb of Henle and are typically used, often in combination with thiazide-type agents, in patients with reduced glomerular filtration rate, congestive heart failure, sodium retention, or edema. Potassium-sparing diuretics (spironolactone, amiloride, triamterene) reduce potassium excretion by antagonizing aldosterone receptors (spironolactone) or by blocking epithelial sodium channels in the distal nephron (amiloride, triamterene).

Agents targeting the renin-angiotensin-aldosterone system include angiotensin-converting enzyme inhibitors (ACEIs), angiotensin II receptor blockers (ARBs), and direct renin inhibitors. ACEIs (e.g. captopril, ramipril, lisinopril) reduce angiotensin II and aldosterone synthesis and increase bradykinin, while ARBs (e.g. irbesartan, olmesartan, telmisartan, valsartan, candesartan, losartan) selectively block AT_1 receptors, producing vasodilation and attenuating downstream catecholaminergic effects.

Calcium channel blockers comprise dihydropyridines (nifedipine, amlodipine, nicardipine, nimodipine) and non-dihydropyridines (verapamil, diltiazem); they lower blood pressure by inhibiting calcium influx into vascular, cardiac and renal excitable cells, with variable affinity for L-, T- and N-type channels.

β-Adrenergic blockers lower blood pressure principally by reducing cardiac output through decreased heart rate and contractility; they are particularly useful in patients with tachycardia and may exhibit enhanced antihypertensive efficacy when combined with a diuretic or a dihydropyridine CCB. Postsynaptic selective α_1-

adrenergic blockers (prazosin, doxazosin, terazosin) lower peripheral vascular resistance and can be effective as monotherapy or in combination with other agents.

Centrally acting α_2-agonists (e.g. methyldopa, clonidine) reduce sympathetic outflow; methyldopa is considered safe in pregnancy, and clonidine may have a role in resistant hypertension.

Combining agents with complementary mechanisms enhances blood pressure reduction and may mitigate adverse effects. Guidelines favor combinations such as a RAAS blocker with a dihydropyridine CCB or a thiazide diuretic, and recommend fixed-dose single-pill combinations to improve efficacy, accelerate blood pressure control, and reduce side effects, while recognizing that monotherapy remains appropriate for selected low-risk or frail patients.(Lewis et al., 2001; Mancia et al., 2022; Redon et al., 2012; Redon & Carmena, 2024; Thomopoulos et al., 2020)

Non pharmacological basics of treatment hypertension

The Dietary Approaches to Stop Hypertension (DASH) diet emphasizes increased consumption of fruits and vegetables and reduced intake of dairy products, red meat, saturated fats, and sugar-sweetened beverages. Adherence to the DASH pattern has been associated with mean reductions in systolic blood pressure (SBP) of approximately 5.5 mm Hg and diastolic blood pressure (DBP) of approximately 3 mm Hg. Substantial and consistent evidence demonstrates that reduction of dietary sodium lowers blood pressure. Current recommendations advise adults to consume no more than 2,400 mg of sodium daily (≈5 g or 1 teaspoon of table salt); further reduction to 1,500 mg daily is preferable, as it is linked to even greater BP reductions.

Tobacco use markedly increases cardiovascular risk and remains the leading preventable cause of death. A meta-analysis of 20 prospective cohort studies indicated that smoking cessation after myocardial infarction or cardiac surgery reduces five-year mortality by more than 33%. Numerous cross-sectional epidemiological investigations report a positive association between average alcohol consumption and the prevalence of hypertension. In dependent heavy drinkers, abstinence during the first month of treatment produces an average overall SBP reduction of about 5 mm Hg and DBP reduction of about 3 mm Hg, with the greatest benefit observed in individuals with elevated baseline BP.

Evidence from randomized controlled trials suggests that garlic supplementation may exert modest antihypertensive effects compared with placebo in patients with hypertension. Environmental interventions to reduce exposure to fine particulate matter (PM2.5), including personal air cleaners and high-efficiency indoor filters, have also been evaluated: median use of personal air cleaners for 13.5 days was associated with an approximate 4 mm Hg decrease in SBP in randomized trials, whereas no consistent effect on DBP was observed.

Taken together, dietary modification (DASH and sodium reduction), tobacco cessation, reduction of harmful alcohol intake, selected nutraceuticals, and mitigation of indoor air pollution offer complementary, evidence-based approaches to lowering blood pressure and should be integrated within comprehensive hypertension management strategies.(Bromfield & Muntner, 2013; Chia et al., 2017; Filippou et al., 2020; Hernandez-, 2015; Hinderliter et al., 2014; Verma et al., 2021)

Material and methods

Between May and July 2025 we conducted a comprehensive search of PubMed, PMC and Google Scholar using both MeSH (Medical Subject Headings) and free-text keywords (e.g., "hypertension", "aerobic training", "resistance training", "isometric training", "HIIT", "yoga", "tai chi", "blood pressure reduction"). Searches were restricted to human studies; animal, in vitro and single-case reports without extractable blood-pressure data were excluded. Eligible designs included randomized controlled trial, non-randomized interventions, cohort and cross-sectional studies, systematic reviews, meta-analyses and narrative reviews reporting resting or ambulatory systolic/diastolic BP; both acute (single-session) and chronic interventions were considered. No statistical analyses or quantitative pooling were performed because of heterogeneity; a structured narrative synthesis, guided by PRISMA principles, was presented.

Research results

Aerobic exercise represents a distinct category within physical activity classifications, with consistent implementation conferring significant multisystem health benefits. Substantial evidence confirms its therapeutic efficacy in blood pressure reduction among hypertensive and pre-hypertensive populations. The meta-analysis conducted by Jabbarzadeh Ganjeh B.et al. encompassing 34 randomized controlled trials with 1,787 participants in the intervention group and 1,119 in control groups indicates that performing 30 minutes of aerobic exercise per week is associated with reductions of 1.78 mmHg in systolic blood pressure (SBP), 1.23 mmHg in diastolic blood pressure (DBP), 1.37 mmHg in mean arterial pressure, and 1.08 beats per minute in resting heart rate (HR). The analysis demonstrated a proportional reduction in systolic blood pressure (SBP) levels with increasing duration of aerobic exercise up to 150 minutes per week, beyond which the effect estimate plateaued with only marginal gains. The mean reduction for individuals exercising up to 150 minutes weekly was substantial, with a mean difference of -7.23 mmHg for SBP and -5.58 mmHg for diastolic blood pressure (DBP). This dose-response relationship was consistently observed for both parameters. Notably, while aerobic exercise performed for 30 minutes weekly was associated with a 1.55 mmHg reduction in 24-hour ambulatory SBP, it exhibited no statistically significant effect on daytime or nighttime ambulatory SBP measurements. The analysis additionally reveals that aerobic exercise enhances specific quality of life (QoL) domains in hypertension-notably physical functioning, emotional role limitations, vitality, and bodily pain-while demonstrating no significant effects on other QoL parameters. The neuroendocrinological mechanisms underlying this reductio including decreased circulating noradrenaline, downregulation of its receptors, and reduced angiotensin II enhance nitric oxide bioavailability, augment antioxidant capacity, improve insulin sensitivity, and upregulate cardioprotective factors such as apelin. Furthermore, the authors demonstrate that regular exercise reduces circulating adrenaline levels by 30%, contributing to concomitant reductions in heart rate. Emerging evidence suggests the apelin receptor system modulates blood pressure regulation through β-arrestin-dependent signaling pathways. Additionally, apelin promotes fluid homeostasis by antagonizing arginine vasopressin release, increasing renal blood flow and urine output, and significantly lowering blood pressure. (Jabbarzadeh Ganjeh et al., 2024; Jayedi et al., 2022; Sharman et al., 2015; Swain, 2005; Tsai et al., 2004)

A subsequent meta-analysis of randomized controlled trials by Edwards et al. incorporated 358 effect sizes, including 182 from aerobic exercise training (AET). The analysis demonstrated significant systolic blood pressure (SBP) reductions following resistance training (RT; -4.55 mmHg) and combined training (CT; -6.04 mmHg). While aerobic interval training (AIT) showed non-significant changes, high-intensity interval training (HIIT; -4.08 mmHg) and sprint interval training (SIT; -5.26 mmHg) elicited significant SBP reductions.

Diastolic blood pressure (DBP) decreased significantly across AET modalities: walking (-2.53 mmHg), cycling (-1.44 mmHg), and running (-3.20 mmHg), with an overall AET reduction of -5.67 mmHg. Resistance training (-3.04 mmHg) and combined training (-2.54 mmHg) similarly reduced DBP. High-intensity interval training (-2.50 mmHg) and sprint interval training (-3.29 mmHg) showed significant DBP reductions, unlike AIT. (Blond et al., 2020; Edwards et al., 2023; "Erratum: Department of Error (The Lancet (2021) 398(10304) (957–980), (S0140673621013301), (10.1016/S0140-6736(21)01330-1))," 2022; Richling, 2017; Wang et al., 2017)

Carlson D. et al. conducted a meta-analysis of nine randomized controlled trials comprising 223 participants (127 assigned to exercise training and 96 controls). Although aerobic exercise has well-established antihypertensive effects, recent meta-analytic evidence indicates that isometric training may produce greater reductions in blood pressure than dynamic aerobic or resistance modalities. Isometric exercise-characterized by a sustained static muscular contraction against an immovable resistance without appreciable change in muscle length or joint angle-has shown clinically meaningful hemodynamic benefits in recent trials.(Carlson et al., 2014; Khatri et al., 2007)

Among the nine selected trials, six employed isometric handgrip training (IHT) and three utilized isometric leg exercise (ILE). No adverse events were reported across studies. Participants exhibited significant reductions in SBP (mean difference [MD] = -6.77 mmHg,). Hypertensive individuals receiving antihypertensive pharmacotherapy demonstrated attenuated SBP reductions (MD = -4.31 mmHg) compared to normotensive counterparts. DBP decreased substantially (MD = -3.96 mmHg), with hypertensive participants showing greater reductions than normotensive individuals (MD = -5.48 mmHg). Mean arterial pressure (MAP) declined significantly (MD = -3.94 mmHg), particularly among medicated hypertensive subjects (MD = -6.01 mmHg vs. -3.58 mmHg in normotensives).

The authors concluded these reductions are comparable or superior to other exercise modalities. Consistency was observed across trials for SBP, DBP, and MAP reductions. Effect sizes support the equivalence or superiority of isometric training over dynamic aerobic/resistance or combined training for SBP reduction. While DBP and MAP reductions were less pronounced than SBP, they remain clinically significant and align with other exercise interventions.

The precise hemodynamic mechanisms remain incompletely elucidated. Similar to dynamic aerobic training, reduced systemic vascular resistance (SVR) likely mediates blood pressure reduction. Although vascular functional adaptations - particularly enhanced endothelial-dependent vasodilation during reactive hyperemia - are well-documented, no evidence indicates attenuated sympathetic vascular regulation. Contemporary research confirms isometric training improves resistance vessel endothelial function concurrently increasing arterial diameter, blood velocity, and flow in trained limbs while reducing vascular conductance. (A. Baross et al., 2013; A. W. Baross et al., 2012; Carlson et al., 2014; de Araújo et al., 2011)

Edwards et al. performed a meta-analysis evaluating the antihypertensive effects of isometric exercise training (IET), incorporating 18 IET trials comprising 628 participants. The included interventions comprised three leg-extension IETs, four wall-squat IETs and eleven handgrip IETs. Six study populations were receiving antihypertensive medication, and eight trials enrolled hypertensive cohorts. Intervention duration ranged from 4 to 12 weeks, with all protocols delivered three times weekly. Wall-squat and leg-extension protocols were performed at intensities eliciting peak heart rates of ≈95% and were associated with decreased vascular conductance, whereas most handgrip protocols used 30% of maximal voluntary contraction. Compared with controls, IET produced substantial reductions in SBP, DBP and mean blood pressure (MBP), with weighted mean differences of -9.35 mmHg, -4.30 mmHg and -5.21 mmHg, respectively. These antihypertensive effects were consistent across normotensive, pre-hypertensive and hypertensive subgroups, and did not differ meaningfully between medicated and unmedicated participants. Resting heart rate decreased by 1.55 beats per minute versus control; reductions in heart rate were larger in medicated cohorts than in unmedicated cohorts, although neither IET modality nor baseline hypertension status demonstrably modified the blood-pressure response.(A. Baross et al., 2013; A. W. Baross et al., 2012; Carlson et al., 2014; de Araújo et al., 2011)

Among the exercise modalities previously discussed, resistance training constitutes a particularly noteworthy form of physical activity with significant implications for blood pressure regulation. In a comprehensive meta-analysis conducted by McDonald et al., the effects of resistance training on arterial blood pressure were systematically evaluated. The analysis incorporated 64 controlled trials, encompassing a total of 1,305 participants engaged in resistance training interventions and 1,039 individuals in the control groups. Of those undertaking resistance training, 349 participants were concurrently receiving antihypertensive pharmacotherapy.

Across the included trials, dynamic resistance training was implemented for an average duration of 14.4 ± 7.9 weeks, with training sessions performed 2.8 ± 0.6 days per week. The prescribed training intensity typically ranged from 65% to 70% of the one-repetition maximum (1RM), with a mean intensity of 64.7 ± 13.0% of 1RM. Although 91% of the resistance training protocols targeted the entire body, substantial heterogeneity existed in the acute program variables employed. On average, participants completed 2.8 ± 0.9 sets of 11.0 ± 3.8 repetitions for 7.9 ± 2.9 dynamic resistance exercises per session. Approximately one-quarter of the studies assessed blood pressure as their primary outcome.

When compared to control conditions, dynamic resistance training elicited small-to-moderate mean reductions in systolic blood pressure (SBP; -3.0 mm Hg) and diastolic blood pressure (DBP; -0.30 mm Hg), although the magnitude of these effects varied considerably across studies. Trials involving participants with higher baseline SBP demonstrated a graded, dose-response reduction: no change in individuals with normotension, a decrease of 3.0 mm Hg in those with prehypertension, and a reduction of 5.7 mm Hg in hypertensive cohorts. Notably, greater SBP reductions were observed in studies enrolling predominantly non-white populations compared to white populations, and in samples not receiving antihypertensive medication compared to those who were medicated. Moreover, studies prescribing eight or more resistance training exercises per session, as opposed to fewer than eight, and those prioritizing blood pressure as a primary endpoint, reported more pronounced SBP decreases.

With respect to DBP, larger resting reductions were observed in trials including participants not taking antihypertensive medication compared to medicated participants. Specifically, the reductions were -5.2 mm Hg in hypertensive individuals, -3.3 mm Hg in those with prehypertension, and -1.0 mm Hg in normotensive individuals. Trials recommending resistance training more than three days per week, as opposed to fewer than three days, and those with lower methodological quality, demonstrated greater DBP decreases. Collectively, these study-level moderators accounted for approximately half of the observed variability in blood pressure responses to dynamic resistance training.(Castaneda et al., 2002; Kelley & Kelley, 2000; MacDonald et al., 2016)

Beyond conventional aerobic, resistance, and isometric exercise modalities, exercise taxonomy recognizes hybrid mind-body practices such as yoga and Tai Chi. These disciplines inherently integrate physiological principles from multiple exercise domains through synchronized movement, breath control, and neuromotor engagement. Zhang et al. investigated the antihypertensive efficacy of Tai Chi-a Chinese martial art practiced as moving meditation and mind-body exercise. Characterized by deliberate, fluid movements, diaphragmatic breathing, and mental focus, Tai Chi shares aerobic exercise classification with walking. Subgroup analyses revealed that 60-minute sessions at moderate intensity significantly reduced blood pressure, with homogeneous study outcomes underscoring clinical relevance.

Mechanistically, Tai Chi mimics conventional aerobic exercise: cyclic muscle contraction-relaxation sequences enhance peripheral blood flow, augmenting vascular wall shear stress. This stimulates endothelial surface receptors, triggering nitric oxide (NO) synthesis and subsequent vasodilation via vascular smooth muscle relaxation. Our analysis further demonstrated Tai Chi's superior blood pressure reduction compared to standard aerobic protocols (ΔSBP: -3.1 mmHg,; ΔDBP: -1.7 mmHg).

The practice's unique respiratory component-controlled abdominal breathing-amplifies diaphragmatic excursion and stimulates thoracic baroreceptors. Prolonged baroreceptor compression increases venous return, potentiating parasympathetic activation while reducing vascular tone. Collectively, these findings indicate Tai Chi provides greater reductions in systolic/diastolic blood pressure and greater NO elevation than antihypertensive monotherapy in hypertensive cohorts. (Li et al., 2021; Ma et al., 2023; Yin et al., 2023; Zhang et al., 2024)

Yoga represents a mind-body intervention with demonstrated potential for blood pressure modulation. Although historically rooted in ancient traditions and incorporating postural practices breath regulation, meditation and ethical frameworks), contemporary research operationalizes yoga through diverse protocols lacking standardized definition-a methodological challenge requiring explicit study parameterization.(Cowen & Adams, 2005; Feuerstein, 2002). Hagins et al. conducted a meta-analysis examining yoga's antihypertensive efficacy across 17 randomized controlled trials involving 1,013 participants (yoga: n=473; control: n=540). Yoga demonstrated statistically significant yet modest reductions in both systolic (-4.17 mmHg;) and diastolic blood pressure (-3.26 mmHg;). Intervention efficacy varied significantly by control group comparator and yoga, though not by intervention duration. Substantial interstudy heterogeneity may reflect these methodological variations.

The aggregate blood pressure reduction aligns with guideline-recommended lifestyle modifications, including structured exercise and sodium restriction. However, the evidence base was limited by predominantly high risk of bias across included studies, constraining definitive clinical interpretations. (Hagins et al., 2013; Hegde et al., 2011; Khatri et al., 2007; Mizuno & Monteiro, 2013)

Discussion

The research revealed that several exercise modalities have a great antihypertensive potential, although there are major disparities in their efficacy, mechanisms, and population-specific responses. Aerobic exercise is the most extensively researched group. This sort of exercise significantly lowers both systolic and diastolic blood pressure in clinical settings, notably in hypertensive and prehypertensive populations. The observed dose-response pattern, in which benefits plateau at around 150 minutes per week, is consistent with current physical activity guidelines and provides an upper limit for additional blood pressure-lowering benefits. According to studies, the minimal requirement for this exercise is 30 minutes of aerobic physical activity each week.(Jabbarzadeh Ganjeh et al., 2024; Tsai et al., 2004)

Aerobic training causes a variety of cardiovascular adaptations, including decreased sympathetic nervous system activation, improved endothelial function through increased nitric oxide bioavailability, modulated activity of the renin-angiotensin-aldosterone system, and activation of the apelin-APJ receptor pathway.(Jabbarzadeh Ganjeh et al., 2024; Sharman et al., 2015) Integration of these physiological circuits contributes to the prolonged hemodynamic improvements documented in investigations. However, the lack of substantial effects on daytime and nighttime ambulatory blood pressure at modest training times implies that the dose and distribution of exercise stimuli may influence circadian blood pressure management.

When comparing different types of training, dynamic resistance training (RT) and combination training (CT) provide considerable blood pressure decreases, but to a smaller extent than aerobic training.(Edwards et al., 2023; Kelley & Kelley, 2000; Wang et al., 2017) Importantly, the highest benefits are shown in untreated hypertension patients, implying a possible ceiling impact in conjunction with medication. Resistance training results appear to be responsive to program factors, with more exercise variety and frequency linked with higher decreases in both SBP and DBP.

The impact of ethnicity on blood pressure response emphasizes the importance of culturally and demographically customized therapies.(Castaneda et al., 2002; Kelley & Kelley, 2000; MacDonald et al., 2016)

Isometric exercise training (IET) appears to be a particularly effective and time-efficient option, with equal or superior SBP reductions than aerobic and resistance training.(A. Baross et al., 2013; Carlson et al., 2014) Meta-analysis results show consistent benefits in normotensive, prehypertensive, and hypertensive populations, with no significant differences between treated and untreated patients. Although the precise mechanisms are unknown, lower systemic vascular resistance, enhanced endothelium-dependent vasodilation, and favorable vascular remodeling appear to be crucial to its antihypertensive effects.(A. Baross et al., 2013;

de Araújo et al., 2011) The paucity of documented adverse events supports IET's feasibility and safety, while long-term adherence and durability require further investigation.

Hybrid mind-body interventions, including Tai Chi and yoga, broaden the non-pharmacological treatment options for hypertension. Tai Chi lowers blood pressure more effectively than traditional aerobic regimens, thanks to the synergistic effects of rhythmic muscle exercise, regulated breathing, and parasympathetic activation.(Yin et al., 2023; Zhang et al., 2024) Its capacity to increase nitric oxide-mediated vasodilation distinguishes it as a culturally flexible and physiologically beneficial therapeutic. Yoga also provides moderate but significant blood pressure decreases, which are compatible with lifestyle modification goals.(Cowen & Adams, 2005; Hegde et al., 2011) However, significant heterogeneity and methodological inconsistency in yoga studies, notably in terms of intervention standardization and control group selection, hinder the capacity to make unambiguous clinical recommendations.

These findings demonstrate the need of structured physical exercise in the treatment of hypertension, with the approach chosen based on patient characteristics, comorbidities, and adherence potential. While aerobic training remains the foundation, isometric approaches show promise for performance gains, and mind-body practices give additional psychophysiological advantages. Currently, there are few randomized controlled trials that assess the efficacy of combined therapies or guide long-term adherence methods. Furthermore, studies that combine vascular, neuroendocrine, and autonomic assessments are required to clarify the various pathways by which different types of exercise modulate blood pressure, allowing for a better understanding of the mechanisms of action and, as a result, more effective training options for hypertension prevention and treatment. The cumulative data clearly supports the inclusion of individually tailored exercise recommendations in the routine management of hypertensive patients, both as monotherapy in the early stages of the condition and as an adjuvant to pharmaceutical treatment.

Conclusions

Various types of physical exercise, such as aerobic, resistance, isometric, interval training, and mind-body practices, consistently lower blood pressure, with efficacy varying depending on the kind, intensity, and duration of the intervention. Isometric training is very helpful at lowering systolic blood pressure, while aerobic training has a dose-response relationship up to about 150 minutes per week. Resistance and interval exercise, as well as mind-body therapies like Tai Chi and yoga, offer minor advantages while also promoting better cardiovascular and metabolic function.(Castaneda et al., 2002; Edwards et al., 2023) Despite study variability and methodological limitations, evidence suggests that regular physical activity is a safe and effective nonpharmacological approach to blood pressure regulation. These results support the integration of exercise into complete hypertension management programs that also involve lifestyle adjustments such as salt, alcohol, and smoking cessation.

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