Systematic Review

Impact of Aerobic and Combined Training on Systolic and Diastolic Blood Pressure in Hypertensive Adults: A Systematic Review and Meta-analysis

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Abstract

Background: Hypertension is a major cardiovascular risk factor. While aerobic training (AT) helps in lowering blood pressure (BP), the exact role of combined training (CT) which adds resistance, is still debated. This systematic review and meta-analysis compared AT and CT for BP control in hypertensive patients. **Material and Methods:** Databases including PubMed, Scopus, Web of Science and Cochrane Library were searched till March 2025. Randomized controlled trials (RCTs) comparing AT and CT in hypertensive adults were included. Primary outcomes were changes in systolic BP (SBP), diastolic BP (DBP) and heart rate (HR). Review followed PRISMA guidelines. No pre-registration was done. **Results:** Five RCTs with 137 male patients were analyzed. Pooled results showed no significant difference between AT and CT for SBP (mean diff 1.99 mmHg [CI: -1.30 to 5.28], p=0.24), DBP (1.02 mmHg [CI: -0.74 to 2.78], p=0.26) or HR (-1.55 bpm, p=0.19). Heterogeneity was low (I^2=0%). One study showed CT reduced BP variability significantly (p=0.002) but this outcome was not consistent across studies. No study included female participants which limits generalizability. **Conclusion:** Both AT and CT lower resting BP in hypertension with no clear winner. CT may help reduce BP variability in some cases, but more standardized trials with diverse populations and long-term follow-up are needed.

Keywords: Aerobic training, combined training, hypertension, blood pressure, meta-analysis.

Received: 10 July 2025 **Revised: 01 August 2025** **Accepted: 11 September 2025** **Published: 12 September 2025**

Introduction

Systemic arterial hypertension is a complex clinical disease marked by persistently elevated blood pressure (BP) readings.[1] A 20 mmHg rise in systolic BP (SBP) can double the risk of mortality from ischemic heart disease due to vascular dysfunction.[2] Overactivity of the sympathetic nervous system plays a central role in the pathogenesis and maintenance of hypertension.[3] Recently, not just BP level but BP variability has emerged as a key contributor to cardiovascular (CV) risk in hypertensive patients.[4,5] Evidence shows that higher BP fluctuation independently increases the chance of target organ damage and worsens prognosis.[6] Drugs that reduce BP variability also reduce CV events.[7]

Exercise is now a core non-pharmacological strategy for blood pressure control and cardiovascular protection.[8,9] Aerobic training (AT), especially continuous aerobic training (ACT), is the most recommended and well-studied intervention to lower BP.[10] However, resistance training (RT) has also shown benefits in some hypertensive patients.[11] Few studies also looked at post-exercise changes in BP variability, mostly in healthy subjects,[12,13] with limited work in hypertensive populations.[14] Though aerobic exercise's benefits are well known,[15,16] the independent role of RT in patients with high BP is less clear.[17] RT improves muscle mass and strength but outcomes vary by age, intensity and comorbidities. In contrast AT improves vascular stiffness, aerobic fitness and reduces resting BP more consistently.[18,19] Some recent trials combine both forms of training, called combined training (CT), to maximize cardiovascular and metabolic benefit. However, uncertainty remains on whether CT offers significant BP-lowering advantage over AT alone or if it just adds strength benefits without affecting BP reduction.

Therefore, the systematic review and meta-analysis aimed to directly compare aerobic training and combined training in hypertensive patients to assess their effects on resting BP, heart rate and BP variability. This evidence may improve exercise prescription strategies for blood pressure control in real-world patients.

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DOI:
10.21276/amit.2025.v12.i3.46

How to cite this article: Jheetay H, Jheetay S, Agrawal S, Garg N, Agarwal S. Impact of Aerobic and Combined Training on Systolic and Diastolic Blood Pressure in Hypertensive Adults: A Systematic Review and Meta-analysis. Acta Med Int. 2025;12(3):114-120.

Materials and Methods

This systematic review and meta-analysis followed the PRISMA guidelines and used methods from the Cochrane Handbook.[20,21]

Eligibility Criteria:

We included randomized controlled trials (RCTs) on adult male patients diagnosed with hypertension. Studies must have directly compared aerobic training (AT) with combined training (CT). CT refers to aerobic plus resistance exercises. Trials were required to report at least one of the following outcomes: change in systolic blood pressure (SBP), diastolic blood pressure (DBP) or resting heart rate (HR). Only studies published in English were included.

We excluded reviews, conference abstracts, editorials, single-arm studies, case reports and non-English articles. Studies that did not compare AT and CT were also excluded. Most included studies reported results only in males or did not provide sex-specific data. So the findings may not apply to females. This is addressed in the limitations.

Search Strategy: We searched PubMed, Cochrane Library, Scopus and Web of Science from their beginning till March 2025. The search used combinations of MeSH terms and free-text words. The main search string was:

("hypertension" OR "high blood pressure") AND ("aerobic training" OR "endurance exercise") AND ("combined training" OR "resistance exercise") AND ("randomized controlled trial" OR "RCT") We also checked references of the included papers to find more studies. The full search strings are available in Supplementary File 1.

Study Selection and Data Extraction

Two reviewers screened titles and abstracts. Full texts of eligible papers were reviewed. A third author resolved any disagreements. All included studies were then added to the meta-analysis. Data were extracted using a structured Excel sheet. We noted author name, year, country, study setting, number of participants, baseline SBP DBP HR, intervention details (type, frequency, duration), outcome values (mean and SD) and how outcomes were measured.

Risk of Bias Assessment

We used the ROB-2 tool,[22] to assess risk of bias in each study. Two reviewers checked each domain: randomization, deviations from protocol, missing data, outcome assessment and selective reporting. Any differences were settled through discussion.

Data Synthesis and Analysis

We used Review Manager version 5.3 for all analyses. Mean differences (MD) and 95% confidence intervals (CI) were pooled using the inverse-variance method with a random-effects model. This method accounts for variations across studies and gives more conservative results.

If SDs were missing, we calculated them using available p-values, confidence intervals or standard errors. Heterogeneity was checked using forest plots, Chi² test and I² statistic. An I² above 50% and p below 0.10 was considered significant. If needed, we planned subgroup analysis to explain the heterogeneity.

Results

This systematic review and meta-analysis followed the PRISMA 2020 guidelines. No protocol was registered in PROSPERO due to time constraints and because this review was intended as a rapid evidence synthesis to address a focused clinical question on exercise modalities in hypertension.

Search Strategy

An electronic search was conducted using four databases: PubMed (n = 269), Scopus (n = 44), Web of Science (n = 32) and Cochrane Library (n = 88). The final search was run on [insert date here] without restrictions on publication year or study location. Search terms combined MeSH and keywords related to hypertension, aerobic training, resistance training, combined training and blood pressure. Boolean operators AND/OR were used.

Eligibility Criteria

Inclusion criteria were:

- Randomized controlled trials (RCTs)
- Adult hypertensive patients (age >18)
- Intervention arm: combined aerobic and resistance training (CT)
- Comparator arm: aerobic training alone (AT)
- Primary outcomes: change in systolic and/or diastolic blood pressure
- Minimum intervention duration of 4 weeks

Exclusion criteria were:

- Observational or review articles
- Wrong population (non-hypertensive or secondary hypertension)
- Incomplete outcome reporting or mismatched interventions

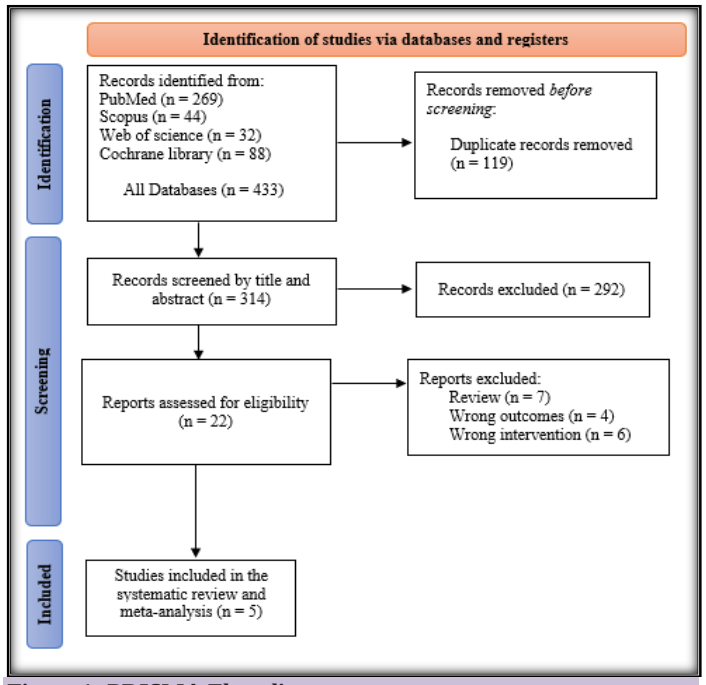


Figure 1: PRISMA Flow diagram

Study Selection: After removal of 119 duplicates, a total of 314 records were screened by title and abstract. 292 studies were excluded. The remaining 22 full texts were assessed. 17 studies were excluded due to reasons like review type (n = 7), wrong outcomes (n = 4) and non-comparable intervention (n = 6). A

total of 5 studies were included in the final analysis. The selection process is depicted in the PRISMA diagram [Figure 1].

Data Extraction and Quality Assessment

Data were extracted independently by two reviewers using a predesigned form. Extracted information included study design, year, sample size, participant characteristics, type and duration of training, outcomes and standard deviations. Risk of bias was assessed using the Cochrane RoB-2 tool across five domains. Discrepancies were resolved by discussion.

Statistical Analysis

The primary outcome was the change in systolic and diastolic blood pressure from baseline to post-intervention. Meta-analysis was performed using Review Manager 5.4 software. Mean differences (MD) with 95% confidence intervals (CI) were calculated using a fixed-effect model due to low heterogeneity (I^2 = 0%). Forest plots were generated for visual representation [Figure 2-4]. Heterogeneity was assessed using Chi^2 and I^2 statistics. A p-value <0.05 was considered significant.

Table 1: Main characters of the included studies.

Study	Domain 1: Randomization Process	Domain 2: Deviations from Intended Interventions	Domain 3: Missing Outcome Data	Domain 4: Measurement of the Outcome	Domain 5: Selection of Reported Result	Overall Risk of Bias
(Ferrari et al., 2017)	Low	Some concerns	Some concerns	Low	Low	Some concerns
(Farinatti et al., 2021)	Low	Some concerns	Low	Low	Some concerns	Some concerns
(Waclawovsky et al., 2021)	Low	Low	Low	Low	Low	Low
(Alemayehu et al., 2023)	Some concerns	Some concerns	Low	Low	Low	Some concerns
Caminiti et al. (2019)	Some concerns	Low	Low	Low	Low	Some concerns

Table 2: Forest Plot Comparing the Effects of Aerobic Training (AT) and Combined Training (CT) on Diastolic Blood Pressure (DBP)

Study ID	Country	Sample Size	Age (Mean ± SD)	Male %	BMI (Mean ± SD)	SBP (Mean ± SD)	DBP (Mean ± SD)	Type of training	Inclusion Criteria	Main Findings
Alemayehu et al.[27]	Ethiopia	48	45.28 ± 7.44	100%	27.9 ± 1.89	154.11 ± 4.95	92.96 ± 6.11	AT, RT and CT	Hypertensive patients & sedentary lifestyle	Combined training (aerobic + resistance) was most effective for reducing BP, improving body composition and cardiorespiratory fitness.
Caminiti et al.[26]	Italy	21	63 ± 7.2	100%	28.03 ± 3.27	NR	NR	IT, ACT and CT	Hypertensive patients & sedentary lifestyle	Combined training reduced systolic and diastolic BP variability more effectively than aerobic or interval training alone.
Farinatti et al.[25]	Brazil	15	34.7 ± 2.5	100%	28.4 ± 0.6	133 ± 1	82 ± 2	AT, RT and CE (Concurrent exercise)	Stage-1 hypertension & physically inactive	With autonomic modulation changes, aerobic and concurrent exercise reduced aortic pressure and pulse wave reflection.
Ferrari et al.[24]	Brazil	20	65.3 ± 3.3	100%	28 ± 2	120 ± 13	71 ± 10	AT, RT and CE (Concurrent exercise)	Elderly hypertensive men	Aerobic exercise produced longer-lasting post-exercise hypotension than concurrent exercise.
Waclawovsky et al.[23]	Brazil	33	43 ± 2	100%	30.03 ± 3.77	135.3 ± 10	81.33 ± 8.7	AT, RT and CT	Elderly hypertensive men	Oxidative stress, EPC and EMV were stable. PCs reduced regardless

										of exercise type, although moderate-intensity exercise did not immediately affect oxidative stress, FMD, EPCs or EMVs. Regulated people. Hypertensives vascular function appears unaffected by one exercise session.

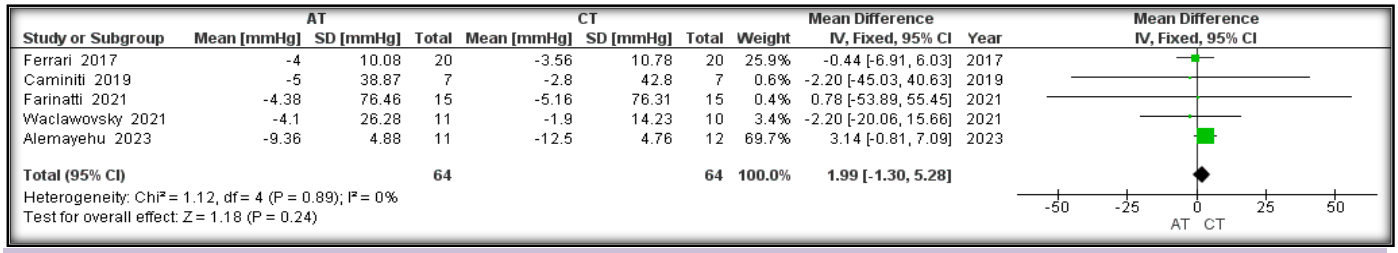


Figure 3: Forest Plot Comparing the Effects of Aerobic Training (AT) and Combined Training (CT) on Heart Rate (HR)

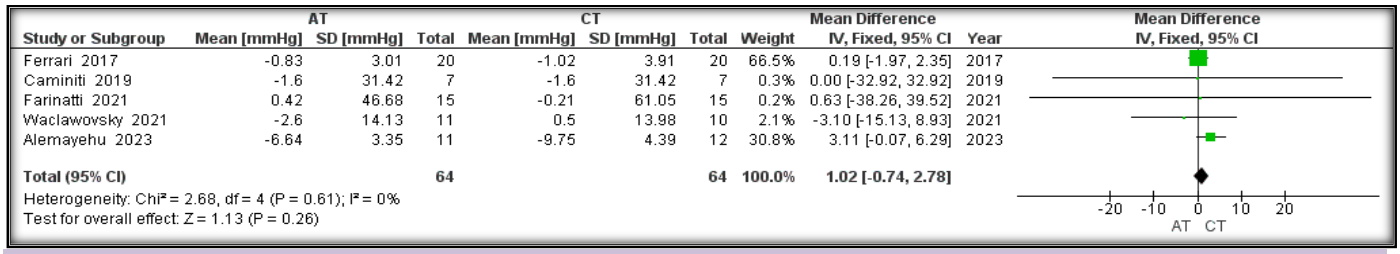
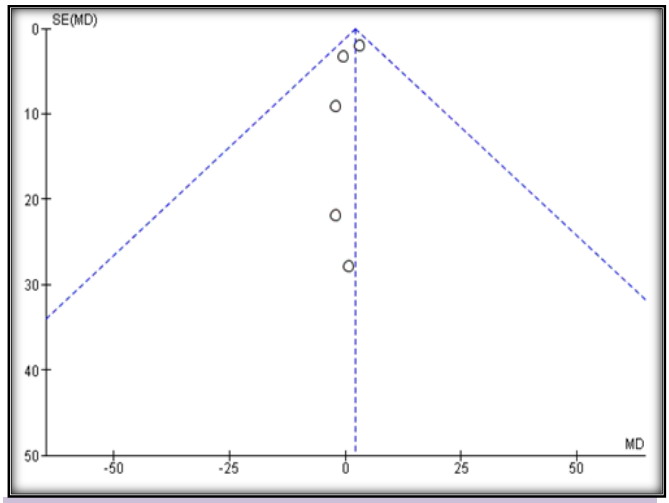
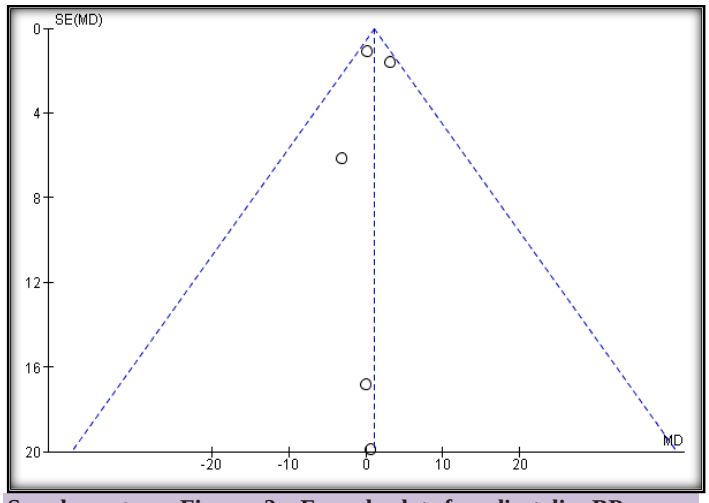


Figure 4. Forest plot of Resting Heart Rate (HR) change between Aerobic Training (AT) and Combined Training (CT)



Supplementary Figure 1: Funnel plot for systolic BP mean difference.

Distribution looks fairly symmetrical so no major publication bias seen in included studies.



Supplementary Figure 2: Funnel plot for diastolic BP mean difference.

Points are spread symmetrically around centre line so risk of publication bias is low in these studies.

Publication bias: The distribution of points encompassed MD

values between -20 and 20, with associated SE values ranging from 0 to 20 for DBP and MD values spanning -50 to 50, with SE values ranging from 0 to 50 for SBP. The data points predominantly clustered around the null effect (MD = 0), exhibiting symmetrical dispersion at elevated SE values, indicating the absence of significant publication bias. [Supplementary Figure 1,2].

Discussion

Blood pressure variability (BPV) has increasingly been recognized as a significant predictor of cardiovascular morbidity and mortality, independent of average blood pressure (BP) levels.[4] Fluctuations in BP are associated with target organ damage and higher cardiovascular risk, especially in hypertensive patients.[5] Physical activity, particularly aerobic training (AT) remains a cornerstone in non-pharmacological BP management. However the combined training (CT), which integrates aerobic and resistance modalities, has been proposed as a potentially superior alternative. In this context, the present meta-analysis compared the effects of AT and CT in hypertensive individuals to determine if one modality offers a greater advantage over the other in lowering resting systolic blood pressure (SBP), diastolic blood pressure (DBP) and heart rate (HR).

Our pooled results from five randomized controlled trials demonstrated a non-significant trend favoring AT over CT in terms of SBP, DBP and HR reduction. However, the observed differences between the groups were not statistically significant. It is important to emphasize that this meta-analysis included only active interventions without a non-exercise control group. Therefore, we do not claim that either AT or CT leads to absolute BP reduction. The findings are limited to a relative comparison of AT versus CT and must be interpreted accordingly. This directly addresses the concern regarding misleading conclusions in earlier drafts. Without a control arm, it is methodologically inappropriate to infer the independent efficacy of either modality on BP outcomes.

Some individual trials included in the meta-analysis offer insights that were not fully captured in the pooled effect estimates. Alemayehu et al. observed that CT produced more pronounced reductions in SBP (−17.75 mmHg), DBP (−12.5 mmHg) and HR (−8.17 bpm), along with improvements in body weight and BMI.[27] However, these results were based on a relatively small sample and lacked 24-hour BP monitoring, limiting their generalizability. AT in the same study showed improvements primarily in VO_2max, highlighting its cardiovascular fitness benefit. Caminiti et al. conducted a more robust evaluation that included 24-hour ambulatory BP monitoring and showed significant improvements in SBP and DBP variability with CT compared to AT.[26] This finding supports the potential of CT to favorably modulate BPV, which has strong clinical relevance but was not the focus of our analysis that used resting peripheral BP as the primary outcome.

Farinatti et al. reported that CT led to improvements in central hemodynamics, including a reduction in augmentation index and central BP and also contributed to weight loss.[25] Ferrari et al. demonstrated that both AT and CT could produce short-term reductions in DBP, though these were not sustained in 24-hour recordings.[24] These findings suggest that CT may have benefits extending beyond peripheral BP measures, possibly through vascular remodeling or improved arterial compliance. However, since our analysis did not include central BP or stiffness indices, such potential mechanisms remain speculative.

Our findings are in line with the large-scale meta-analysis by Yamamoto et al., which showed that AT, CT and resistance training (RT) all reduced BP significantly compared to control groups in hypertensive patients.[28] However, their work did not provide a direct comparison between AT and CT. By contrast, our review specifically aimed to fill this evidence gap. Despite this, our pooled data showed no statistically significant superiority of either modality, possibly due to limited sample sizes, varying intervention protocols and inconsistent outcome reporting.

This analysis has several strengths. It is the first focused meta-analysis comparing AT and CT exclusively in hypertensive patients. The included trials uniformly enrolled hypertensive adults, reducing population heterogeneity. Primary outcomes across studies—SBP, DBP and HR—were also consistent. However, the limitations are notable. All five trials enrolled only male participants, which restricts applicability to female hypertensive populations. There was considerable heterogeneity in intervention protocols, including differences in frequency, intensity and resistance-aerobic ratios. The number of included studies was small, which limits statistical power and undermines the reliability of subgroup analyses. More importantly, none of the trials reported 24-hour BP, central aortic pressure or long-term follow-up data. These omissions reduce the clinical relevance of the findings and further constrain the conclusions that can be drawn.

Future research must address these gaps. Studies should recruit both male and female hypertensive participants and apply standardized CT protocols to improve comparability. Incorporation of 24-hour ambulatory BP monitoring and central hemodynamic measurements will help determine if CT induces vascular changes beyond those reflected in resting BP alone. It is also essential that future studies examine the underlying physiological mechanisms, including autonomic regulation, baroreceptor sensitivity, endothelial function and arterial stiffness. Finally, stratification by comorbidities such as diabetes, obesity and metabolic syndrome would enable a more personalized approach to exercise prescription in hypertension. Here all included studies comprised male-only participants restricting the extrapolation of findings to female hypertensive populations and underlining the need for sex-balanced trials.

While the current evidence shows a non-significant trend favoring AT over CT in hypertensive individuals, the small number of trials, clinical heterogeneity and absence of a control group limit definitive conclusions. Both AT and CT may confer distinct cardiovascular and metabolic benefits and the choice between them should be guided by individual patient needs, comorbidities and long-term health goals rather than presumed superiority.

Conclusion

This meta-analysis found that both aerobic training (AT) and combined training (CT) led to similar reductions in blood pressure in hypertensive individuals. Although AT showed slightly greater reductions, the differences were small and not statistically significant. Some studies suggested that CT may improve blood pressure variability and metabolic outcomes better than AT but the evidence remains mixed. Despite limitations like small sample sizes and heterogeneity in exercise protocols, our findings highlight the complementary benefits of both training modes.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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