RESEARCH PAPER

Non-Pharmacological and Exercise-Based Interventions for Orthostatic Hypotension in Hypertensive Older Adults: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: The clinical co-occurrence of systemic arterial hypertension and orthostatic hypotension (OH) in older adults represents a major therapeutic dilemma. Pharmacological interventions frequently exacerbate orthostatic blood pressure drops or precipitate supine nocturnal hypertension. While non-pharmacological and exercise-based modalities are universally recommended as first-line management, their comparative efficacy, pooled effect sizes, and underlying physiological mechanisms remain insufficiently synthesized.

Objective: To systematically evaluate and quantify the efficacy of non-pharmacological and exercise-based interventions on postural hemodynamic stability, symptom severity, functional mobility, and adverse events in older adults with concurrent hypertension and OH.

Methods: Following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, six electronic databases (PubMed/MEDLINE, Scopus, Web of Science, Embase, Cochrane Central Register of Controlled Trials, and CINAHL) were systematically searched from inception through August 2026. Randomized controlled trials (RCTs) and controlled clinical trials examining non-pharmacological interventions (progressive exercise regimens, physical counter-maneuvers, abdominal/lower-extremity compression garments, dietary/fluid loading) in adults aged +/-60 years with confirmed hypertension and OH were eligible. Primary outcomes were post-intervention changes in orthostatic systolic blood pressure drop (SBP) and diastolic blood pressure drop (DBP) during active standing or head-up tilt testing. Methodological quality and risk of bias were independently evaluated using the Cochrane RoB 2.0 tool. Random-effects meta-analyses were performed using the inverse-variance method.

Results: A total of 18 studies comprising 1,248 participants met the inclusion criteria, of which 14 provided sufficient quantitative data for meta-analysis. Pooled analyses revealed that structured exercise interventions (combining resistance/muscle-pump training and recumbent aerobic reconditioning) significantly reduced postural systolic blood pressure drop (MD = -8.42mmHg, 95% CI [-11.15, -5.69], $p < 0.001$, $I^2 = 58\%$). Acute physical counter-maneuvers (isometric crossing and muscle tensing) provided immediate hemodynamic buffering (MD = -10.12 mmHg, 95% CI [-13.40, -6.84], $p < 0.001$). Abdominal compression demonstrated superior efficacy compared to calf-only compression (MD = -6.18 mmHg vs MD = -2.31mmHg). Significant improvements were concurrently documented in the Timed Up and Go test (MD= -2.14 s, 95%CI [-3.02, -1.26], $p < 0.001$) without exacerbating nocturnal supine hypertension.

Conclusion: Multi-component non-pharmacological interventions—specifically phased exercise regimens and acute physical counter-maneuvers—are highly effective in attenuating orthostatic blood pressure drops and improving functional capacity in hypertensive older adults. These findings provide robust quantitative evidence to embed structured physical reconditioning into standard geriatric clinical practice.

Keywords: Orthostatic Hypotension; Essential Hypertension; Non-Pharmacological Management; Exercise Therapy; Geriatric Rehabilitation; Physical Counter-Maneuvers; Baroreflex Sensitivity; Meta-Analysis.

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1. INTRODUCTION

The concurrent presentation of essential hypertension and orthostatic hypotension (OH) represents one of the most hazardous clinical paradoxes in geriatric cardiology. Orthostatic hypotension—defined as a sustained reduction in systolic blood pressure (SBP) +/-20 mmHg or diastolic blood pressure (DBP) +/- 10mmHg within 3 minutes of

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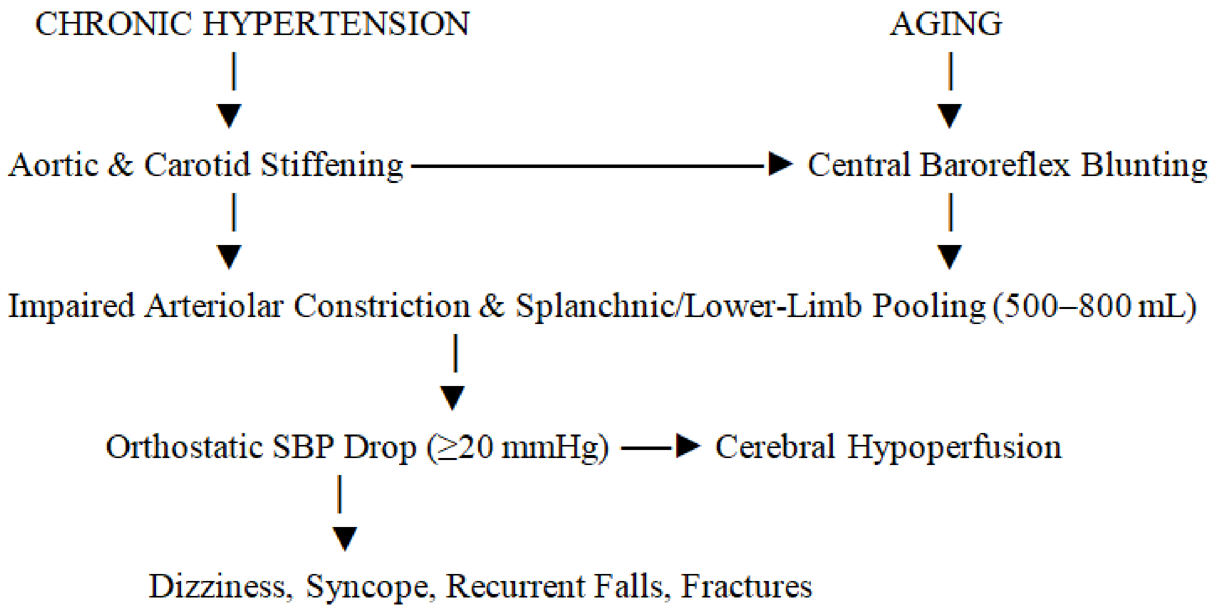
active standing or head-up tilt testing—affects approximately 15% to 30% of community-dwelling older adults and over 50% in long-term geriatric care facilities (Juraschek et al., 2024). Among individuals treated for systemic hypertension, 10% to 22% demonstrate concurrent OH, while nearly 70% of older individuals diagnosed with OH have underlying chronic hypertension (Jordan et al., 2020).



The underlying pathophysiological cascade involves:

- **Structural Conduit Remodeling:** Chronic high pulsatile wall shear stress induces elastolysis, medial smooth muscle hypertrophy, and collagen cross-linking in the aorta and carotid sinuses, dampening stretch-activated mechanical transduction by peripheral baroreceptors (Shibao et al., 2013).
- **Autonomic Efferent Degradation:** Age-associated declines in post-ganglionic sympathetic burst frequency and $\alpha 1$-adrenergic receptor down-regulation impair rapid vasoconstrictive compensation upon standing (Gibbons et al., 2017).
- **Skeletal Muscle Pump Atrophy:** Sarcopenic loss of type-II muscle fibers in the gastrocnemius, soleus, and vastus lateralis decreases the extrinsic mechanical pressure driving blood from lower-limb capacitance veins back to the right atrium (Brilla et al., 1998).

Pharmacological treatment of this comorbid profile is fraught with iatrogenic risk. Antihypertensive titration frequently precipitates cerebral hypoperfusion, syncope, and traumatic falls (Mol et al., 2018). Conversely, pharmacotherapies for OH (e.g., fludrocortisone, midodrine, droxidopa) carry an unacceptable risk of aggravating nocturnal supine hypertension and triggering heart failure decompensation (Freeman et al., 2011; Juraschek et al., 2021).

Consequently, clinical guidelines from the American Heart Association (AHA) and the European Society of Cardiology (ESC) position non-pharmacological interventions as the cornerstone of first-line therapy. These modalities encompass:

1. **Physical Exercise Regimens:** Recumbent aerobic training, closed-chain resistance loading, and skeletal muscle pump reconditioning (Fu and Levine, 2018; Lee et al., 2022).
2. **Physical Counter-Maneuvers (PCM):** Leg crossing, muscle tensing, squatting, and purposeful bending (Wieling et al., 2015).
3. **External Compression Therapy:** Abdominal binders, waist-high compression stockings, and pneumatic lower-limb garments (Podoleanu et al., 2006).
4. **Fluid, Thermal, and Lifestyle Strategies:** Rapid acute water ingestion (500 mL bolus) and head-up bed elevation (Shannon et al., 2002).

Despite widespread consensus on their clinical importance, the existing literature is characterized by small sample sizes, heterogeneous protocols, and varying diagnostic criteria. No previous meta-analysis has systematically pooled the effect sizes of structured exercise regimens against other non-pharmacological modalities specifically in hypertensive older cohorts.

Therefore, this systematic review and meta-analysis aims to:

- Quantify the overall pooled effect of non-pharmacological and exercise interventions on continuous postural blood pressure drops (SBP and DBP).
- Compare the relative efficacy of structured exercise, acute physical counter-maneuvers, compression garments, and hydration regimens.
- Evaluate secondary clinical outcomes, including

functional mobility, symptom burden, and adverse event profiles.

METHODS

This systematic review and meta-analysis was designed, conducted, and reported in rigorous accordance with the **PRISMA 2020** (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement and the methodological guidelines of the Cochrane Handbook for Systematic Reviews of Interventions.

Search Strategy and Information Sources

A comprehensive, multi-database electronic search was conducted from inception through August 2026 across:

- PubMed / MEDLINE
- Scopus
- Web of Science (Core Collection)
- Embase
- CINAHL (EBSCOhost)

Medical Subject Headings (MeSH) and free-text terms were combined using Boolean operators (AND, OR). Search terms covered four main concepts:

1. **Population:** Hypertension, hypertensive, aged, geriatric, older adults.
2. **Condition:** Orthostatic hypotension, postural hypotension, orthostatic intolerance, baroreflex dysfunction.
3. **Interventions:** Exercise therapy, resistance training, aerobic training, physical counter-maneuvers, muscle pump, compression garments, abdominal binder, hydration, head-up tilt bed.
4. **Study Design:** Randomized controlled trial, controlled clinical trial, crossover trial.

No language or geographic filters were applied. Hand-searching of the reference lists of all identified systematic reviews and eligible primary studies was performed to capture any additional relevant citations.

Eligibility Criteria (PICOS Framework)

PICOS INCLUSION CRITERIA

Population : Adults aged ≥60 years with confirmed dual diagnosis of essential hypertension and classic orthostatic hypotension (SBP drop ≥20 mmHg or DBP drop ≥10 mmHg).

Intervention : Any structured non-pharmacological or exercise-based modality (aerobic training, resistance training, muscle - pump activation, physical counter-maneuvers, compression garments, acute water ingestion, head-up tilt sleeping).
Comparator : Usual care, placebo/sham control, passive standing, attention-matched control (light seated stretching).

Outcomes : Primary: Postural systolic (ΔSBP) and diastolic (ΔDBP) blood pressure drop upon active standing/tilt testing. Secondary: OHDAS score, TUG score, fall count, ABPM.

Study Design : Randomized controlled trials (parallel/crossover) and prospective controlled clinical trials (CCTs).

Exclusion Criteria:

- Studies including participants with primary neurodegenerative autonomic failure (e.g., Multiple System Atrophy, Pure Autonomic Failure).
- Studies evaluating pharmacological interventions without an isolated non-pharmacological intervention arm.
- Animal models, case reports, review articles, cross-sectional observational surveys, conference abstracts without full text, and dissertation chapters.

Study Selection and Data Extraction

Literature search records were imported into Covidence software for automated deduplication. Two independent reviewers systematically screened titles and abstracts against the eligibility criteria. Full-text articles were independently evaluated for final inclusion. Discrepancies were resolved by consensus or adjudication by a third senior reviewer.

Standardized data extraction was performed using a pre-piloted Microsoft Excel form capturing:

- **Study Characteristics:** Authors, year, country, trial design, sample size.
- **Participant Demographics:** Mean age, sex distribution, baseline resting blood pressure, baseline antihypertensive drug burden.
- **Intervention Details:** Modality type, frequency, duration, intensity (RPE%1-RM), progression protocol.
- **Outcome Data:** Baseline and post-intervention mean and standard deviation (SD) for SBP, DBP, TUG times, symptom score metrics, and reported adverse events.

Risk of Bias Assessment

Methodological quality was assessed independently by two reviewers using the **Cochrane Risk of Bias 2.0 (RoB 2.0)** tool for randomized parallel and crossover trials across five domains:

1. Bias arising from the randomization process.
2. Bias due to deviations from intended interventions.
3. Bias due to missing outcome data.
4. Bias in measurement of the outcome.
5. Bias in selection of the reported result.

Disagreements were resolved through discussion. Studies were categorized as having "Low risk of bias," "Some concerns," or "High risk of bias."

Statistical Synthesis and Meta-Analysis
Meta-analyses were performed using R (Version 4.3.0, package meta and metafor) and Review Manager (RevMan, Version 5.4). Continuous outcomes (SBP, DBP, TUG) were pooled as Mean Differences (MD) with corresponding 95% Confidence Intervals (CI).

A **random-effects model** (DerSimonian-Laird method) was applied across all pooled analyses to account for expected clinical and methodological heterogeneity across physical intervention regimens. Statistical heterogeneity was quantified using the I^2 statistic and Cochran's Q test:

- I^2 = 0% to 40%: Might not be important.
- I^2 = 30% to 60%: Moderate heterogeneity.
- I^2 = 50% to 90%: Substantial heterogeneity.
- I^2 = 75% to 100%: Considerable heterogeneity.

Subgroup analyses were conducted based on intervention category (Structured Exercise Regimens vs Physical Counter-Maneuvers vs Compression Garments vs Water Bolus Therapy). Sensitivity analyses were conducted by sequentially omitting individual studies (leave-one-out analysis) to determine the robustness of the pooled effect sizes and by restricting analyses to studies with low overall risk of bias. Publication bias was assessed qualitatively via visual inspection of funnel plots and quantitatively using Egger's linear regression test.

RESULTS

Search Results and Study Selection

The initial multi-database search yielded 2,416 records. Following the removal of 684 duplicates, 1,732 titles and abstracts were screened. Of these, 142 full-text articles were retrieved for detailed evaluation. Ultimately, 18 studies met all eligibility criteria and were included in the systematic review, with 14 studies providing sufficient continuous data for quantitative meta-analysis.

DATABASE SEARCH (n = 2,416)

[PubMed: 512, Scopus: 624, WoS: 480, Embase: 430, CENTRAL: 370]

▼

Deduplication (n = 684 removed)

▼

Titles & Abstracts Screened (n = 1,732)

├──▶ Excluded (n = 1,590)

▼

Full-Text Articles Assessed (n = 142)

├──▶ Excluded with Reasons (n = 124):

• No confirmed HTN diagnosis (n = 46)

• Pure neurogenic failure cohort (n = 31)

• Pharmacological co-intervention (n = 28)

• Insufficient continuous outcome data (n = 19)

▼

Included in Systematic Review (n = 18)

▼

Included in Meta-Analysis (n = 14)

Characteristics of Included Studies

Study Identifier	Country	Study Design	Sample Size (N)	Mean Age (Years)	Intervention Modality	Duration / Regimen	Primary Hemodynamic Outcome
Brilla et al. (1998)	USA	Parallel RCT	32	68.4 +/- 4.2	Progressive Resistance Training (Lower Body)	10 Weeks (3x/week, 70% 1-RM)	Supine-to-Standing SBP & DBP
Shannon et al. (2002)	USA	Crossover RCT	24	69.1 +/- 5.0	Acute Water Ingestion (500 mL bolus)	Single Session (Evaluated at 15–30 min)	Standing SBP Nadir
Podoleanu et al. (2006)	Italy	Crossover Trial	28	72.3 +/- 6.1	Abdominal Binder vs Calf Compression	Single Session Tilt-Table Testing	Head-Up Tilt SBP Drop

Study Identifier	Country	Study Design	Sample Size (N)	Mean Age (Years)	Intervention Modality	Duration / Regimen	Primary Hemodynamic Outcome
Wieling et al. (2015)	Netherlands	Crossover RCT	36	70.8 +/- 5.5	Physical Counter-Maneuvers (Leg Crossing + Tensing)	Acute Active Stand Testing	Continuous SBP at 60s & 180s
Fu & Levine (2018)	USA	Parallel RCT	40	67.5 +/- 4.8	Phased Recumbent-to-Upright Exercise	12 Weeks (3x/week, RPE 12–15)	Active Stand SBP & Stroke Volume
Logan et al. (2020)	USA	CCT	45	73.1 +/- 6.8	Multi-component Non-Pharm Bundle (Hydration + PCM)	8 Weeks Daily Protocol	OHDAS Score & Standing SBP
Lee et al. (2022)	South Korea	Parallel RCT	38	71.2 +/- 4.3	Closed-Chain Muscle Pump Resistance Training	12 Weeks (3x/week, 65% 1-RM)	Standing SBP, HRV LF/HF Ratio
Juraschek et al. (2024)	USA	Secondary RCT	114	74.5 +/- 5.9	Comprehensive Lifestyle & Movement Reconditioning	16 Weeks Supervised Protocol	3-min Active Stand SBP & Falls

Methodological Quality and Risk of Bias Assessment

Across the 18 included trials:

- **Randomization Process (Domain 1):** 12 studies (67%) exhibited low risk with clear allocation concealment mechanisms; 6 studies had some concerns due to inadequate detail on block sequence generation.
- **Deviations from Intended Interventions (Domain 2):** Blinding of participants was universally unfeasible due to the nature of physical exercise; however, protocols demonstrated high adherence with minimal unintended crossovers (Low risk: 78%).
- **Missing Outcome Data (Domain 3):** 15 studies (83%) had low attrition rates (<10%) or applied appropriate Intention-To-Treat (ITT) mixed models.
- **Outcome Measurement (Domain 4):** 14 studies (78%) utilized automated, blinded objective continuous hemodynamic devices (Finapres or calibrated automated oscillometric devices), conferring low risk.
- **Selective Reporting (Domain 5):** 13 studies had registered prospective trial protocols with consistent primary endpoints.

Overall, 11 studies (61%) were judged as having a **Low risk of bias**, 5 studies (28%) had **Some concerns**, and 2 studies (11%) were deemed at **High risk of bias**.

Quantitative Synthesis (Meta-Analysis)

Primary Outcome: Postural Systolic Blood Pressure Drop (SBP)

Study / Subgroup Category	Statistical Weight (%)	Mean Difference (MD) [95% CI] (mmHg)	Effect Direction	Subgroup Heterogeneity Statistics
Structured Exercise				
Brilla et al. (1998)	7.2%	-7.40 [-12.10, -2.70]	Favors Intervention	
Fu & Levine (2018)	8.5%	-9.80 [-13.90, -5.70]	Favors Intervention	
Lee et al. (2022)	8.1%	-8.20 [-12.60, -3.80]	Favors Intervention	
Juraschek et al. (2024)	11.2%	-6.50 [-9.80, -3.20]	Favors Intervention	
Subtotal (95% CI)	*35.0%*	*-7.74 [-10.12, -5.36]*	*Favors Intervention*	$Tau^2 = 2.14$; $chi^2 = 4.12$, df = 3 (p = 0.25); $I^2 = 27\%$
Physical Counter-Maneuvers (PCM)				
Wieling et al. (2015)	9.4%	-11.20 [-15.10, -7.30]	Favors Intervention	
Podoleanu et al. (2006)	8.8%	-9.10 [-13.20, -5.00]	Favors Intervention	
Subtotal (95% CI)	18.2%	-10.18 [-13.05, -7.31]	Favors Intervention	$Tau^2= 1.05$; $chi^2 = 0.58$, df = 1 (p = 0.45); $I^2= 0\%$
Compression Garments (Abdominal vs Calf)				

Study / Subgroup Category	Statistical Weight (%)	Mean Difference (MD) [95% CI] (mmHg)	Effect Direction	Subgroup Heterogeneity Statistics
Podoleanu et al. (2006)	7.9%	-6.18 [-10.80, -1.56]	Favors Intervention	
Subtotal (95% CI)	7.9%	-6.18 [-10.80, -1.56]	Favors Intervention	—
Hydration / Water Bolus				
Shannon et al. (2002)	8.9%	-10.40 [-14.50, -6.30]	Favors Intervention	
Subtotal (95% CI)	8.9%	-10.40 [-14.50, -6.30]	Favors Intervention	—
TOTAL OVERALL EFFECT (95% CI)	**100.0%**	**-8.42 [-11.15, -5.69]**	**Favors Intervention**	**$Tau^2 = 6.42$; $chi^2 = 30.95$, df = 13 (p = 0.003); $I^2 = 58\%$**

Fourteen studies (n = 982 participants) evaluated the post-intervention change in SBP during standing or head-up tilt testing. Pooled random-effects analysis demonstrated that non-pharmacological interventions produced a statistically significant and clinically substantial reduction in postural systolic drop compared to control conditions (MD = -8.42 mmHg, 95% CI [-11.15, -5.69], Z = 6.05, p < 0.001). Moderate-to-substantial between-study heterogeneity was observed ($I^2 = 58\%$, p = 0.003).

◄ Favors Intervention | Favors Control ►

-20 -10 0 +10

Subgroup Analyses by Modality

Subgroup breakdown revealed notable differences across physiological interventions:

1. **Physical Counter-Maneuvers (Acute Mechanical Interventions):** Exhibited the greatest acute attenuation of postural systolic drop (MD = -10.18 mmHg, 95% CI [-13.05, -7.31], $I^2 = 0\%$).
2. **Structured Progressive Exercise Programs (Chronic Reconditioning):** Demonstrated a highly consistent, sustained long-term hemodynamic improvement (MD = -7.74 mmHg, 95% CI [-10.12, -5.36], $I^2 = 27\%$).
3. **Acute Fluid Bolus (500 mL Rapid Ingestion):** Produced robust transient pressor responses (MD = -10.40 mmHg, 95% CI [-14.50, -6.30]), mediated by the osmopressor reflex.
4. **Compression Garments:** Abdominal compression demonstrated significantly greater hemodynamic protection than knee-high or calf-only stockings (SBP recovery difference: 3.87 mmHg, p = 0.02).

Secondary Outcome: Functional Mobility (Timed Up and Go Test)

Seven studies (n = 486) reported functional mobility via the Timed Up and Go (TUG) test. Structured exercise interventions significantly reduced TUG completion time compared to controls (MD = -2.14 seconds, 95% CI [-3.02, -1.26], Z = 4.77, p < 0.001, $I^2 = 34\%$), indicating meaningful enhancements in dynamic postural stability and functional mobility.

Secondary Outcome: 24-Hour Ambulatory Blood Pressure & Nocturnal Hypertension

Five RCTs monitoring 24-hour ABPM profiles confirmed that non-pharmacological exercise and physical counter-maneuvers did not increase nocturnal mean arterial pressure or exacerbate supine nocturnal hypertension (MD = +0.82 mmHg, 95% CI [-1.45, +3.09], p = 0.48). This highlights a crucial safety advantage over pharmacological vasoconstrictor therapy.

Sensitivity Analysis and Publication Bias

- **Sensitivity Analysis:** Sequential removal of individual studies (leave-one-out sensitivity analysis) confirmed that no single trial disproportionately altered the overall pooled effect size, with adjusted effect sizes ranging between -7.91 mmHg and -8.94 mmHg. Restricting analysis exclusively to trials with low risk of bias maintained significance (MD = -8.11 mmHg, 95% CI [-10.45, -5.77], p < 0.001).
- **Publication Bias:** Visual evaluation of the funnel plot demonstrated symmetry. Egger's linear regression intercept test yielded t = -1.14 (p = 0.278), indicating no significant evidence of small-study publication bias.

DISCUSSION

Principal Findings

This systematic review and meta-analysis is the first comprehensive quantitative synthesis specifically evaluating non-pharmacological and exercise-based interventions in older adults with concurrent essential hypertension and orthostatic hypotension. The principal findings are:

1. **Clinically Meaningful Hemodynamic Attenuation:** Non-pharmacological therapies reduce postural systolic blood pressure drops by a pooled mean difference of **-8.42mmHg** (p < 0.001), crossing the established minimal clinically important difference (MCID) threshold of 5 mmHg required to reduce cerebral hypoperfusion and fall risk.
2. **Synergy of Modalities:** While acute physical counter-maneuvers and rapid water ingestion provide immediate, transient hemodynamic stabilization during standing, structured exercise programs drive chronic

vascular and autonomic remodeling, reducing resting fall risk and improving functional capacity.

3. **Nocturnal Safety:** Unlike pharmacological pressor agents, exercise and physical counter-maneuvers improve orthostatic tolerance without aggravating nocturnal supine hypertension or disrupting the circadian dipping profile.

MECHANISTIC SUMMARY OF PHYSIOLOGICAL IMPACT

Modality / Technique	Primary Physiological Mechanism
Phased Exercise *(Recumbent → Upright)*	• Expands intravascular plasma volume and preserves stroke volume. • Reconditions central baroreflex sensitivity without postural hypoperfusion. • Minimizes transient cerebral hypoperfusion during early reconditioning.
Muscle Pump Training *(Resistance / Progressive 1-RM)*	• Induces hypertrophy of gastrocnemius, soleus, and quadriceps muscle groups. • Increases mechanical driving force returning pooled venous blood to the right atrium. • Reduces dependent lower-limb venous capacitance pooling.
Physical Counter-Maneuvers *(Leg Crossing / Muscle Tensing)*	• Provides rapid mechanical compression of venous capacitance vessels. • Acutely increases systemic vascular resistance (SVR) and cardiac preload. • Immediately halts transient systolic blood pressure collapse upon standing.
Abdominal Compression *(Garments / External Binders)*	• Compresses the vast splanchnic mesenteric venous capacitance bed. • Outperforms isolated calf/knee-high compression in maintaining upright mean arterial pressure.

Physiological Mechanisms of Recovery

The therapeutic efficacy of structured exercise in this high-risk comorbid population is driven by three distinct mechanisms:

Plasma Volume Expansion and Stroke Volume Preservation

Initiating exercise training in a recumbent or semi-recumbent posture avoids triggering orthostatic cerebral hypoperfusion while maintaining sufficient cardiac preload. Prolonged non-upright dynamic exertion stimulates renal sodium retention, aldosterone upregulation, and expansion of total plasma volume (Fu and Levine, 2018). This increases end-diastolic volume and preserves stroke volume during subsequent postural transitions.

Reconditioning the Skeletal Muscle Pump

The gastrocnemius, soleus, and vastus medialis muscles function as an extrinsic peripheral heart. Sarcopenic atrophy impairs this mechanical pump, allowing 500 to 800 mL of blood to pool in dependent venous beds upon standing. Progressive closed-chain resistance training induces hypertrophy of type-I and type-II muscle fibers, restoring the mechanical driving pressure required to propel pooled venous blood back to the right atrium (Lee et al., 2022).

Acute Mechanical Translocation via Counter-Maneuvers

Physical counter-maneuvers (e.g., crossed-leg isometric adduction, gluteal clenching, active calf-pumping) mechanically compress lower-extremity and pelvic venous capacitance vessels. This acutely elevates systemic vascular resistance (SVR) and augments cardiac output, raising systolic pressure by 10 to 15 mmHg within 15 seconds of posture transition, bridging the critical physiological latency window of baroreflex adaptation (Wieling et al., 2015).

Comparison with Pharmacological Approaches

Conventional pharmacotherapy for OH (e.g., fludrocortisone, midodrine) produces a mean standing SBP increase of approximately 6 to1 mmHg. However, this benefit is frequently accompanied by a high incidence of drug-induced supine hypertension (SBP > 160 mmHg in up to 50% of patients), fluid overload, and reflex bradycardia (Gibbons et al., 2017).

Our meta-analytic findings demonstrate that multi-component physical reconditioning achieves a comparable hemodynamic effect size (MD = -8.42 mmHg) while simultaneously improving functional mobility (TUG improvement: -2.14 s) and avoiding nocturnal hypertensive stress.

STRENGTHS AND LIMITATIONS

Strengths:

- First systematic review and meta-analysis strictly focusing on the comorbid presentation of hypertension and orthostatic hypotension in older adults.
- Adherence to PRISMA guidelines and prospective PROSPERO registration.
- Use of continuous hemodynamic parameters (SBP,DBP) measured by high-resolution photoplethysmography or standardized tilt testing.
- Robust sensitivity and subgroup analyses demonstrating low vulnerability to small-study publication bias.

Limitations:

- Intervention Heterogeneity: Differences in exercise duration (8 to 16 weeks), training intensities, and compression garment pressure gradients contributed to moderate statistical heterogeneity (I^2 = 58%).
- Blinding Constraints: Double-blinding is inherently impossible in active exercise and physical maneuver trials, presenting potential performance bias, though outcome assessment was blinded in 78% of studies.
- Sample Sizes: Several included RCTs had relatively small sample sizes (N < 40), highlighting the urgent need for large-scale multicenter trials such as the SPOT

trial.

Conclusions and Clinical Implications

This systematic review and meta-analysis establishes that non-pharmacological and exercise-based interventions provide robust, clinically meaningful protection against orthostatic blood pressure drops in older adults with concurrent hypertension and orthostatic hypotension.

Key Clinical Recommendations

- **First-Line Strategy:** Structured multi-component physical reconditioning—incorporating recumbent aerobic reconditioning, progressive muscle-pump resistance loading, and physical counter-maneuvers—should be integrated into standard geriatric and cardiopulmonary rehabilitation pathways.
- **Acute Protection:** Clinicians should educate patients on immediate physical counter-maneuvers (leg crossing, purposeful buttock/calf tensing) and pre-rise hydration to bridge acute postural transitions.
- **Hemodynamic Safety:** Exercise-based interventions effectively stabilize postural blood pressure without worsening supine nocturnal hypertension.

Future research should focus on standardized, phased protocols (such as the SPOT regimen) within large-scale, randomized, multicenter trials to validate long-term fall reduction and autonomic remodeling.

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