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Review Article

Comparative Analysis of cardiac rehabilitation programs versus Standard Care in resistant hypertension

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Abstract

Background: Resistant hypertension, blood pressure above goal despite three or more optimally dosed antihypertensive agents, affects a substantial minority of treated hypertensive adults and carries elevated cardiovascular risk.

Objective: This review compares structured cardiac rehabilitation programs against standard pharmacological care alone for blood pressure reduction and risk-factor control in resistant hypertension.

Methods: We synthesized randomized trials, systematic reviews, and major scientific statements on exercise-based rehabilitation, lifestyle intervention, pharmacological escalation, and device-based therapy in hypertensive and resistant hypertensive populations.

Findings: Structured exercise training within a rehabilitation framework, alongside dietary counseling and risk-factor management, produced significantly greater ambulatory and office blood pressure reductions than standard care alone, with effects additive to pharmacological escalation and device-based approaches via improved baroreflex sensitivity and reduced sympathetic activation.

Conclusions: Cardiac rehabilitation is a practical, evidence-supported adjunct to standard care in resistant hypertension, and expanding referral criteria and home-based delivery could improve access for this high-risk population.

Keywords: resistant hypertension; cardiac rehabilitation; exercise training; blood pressure control; standard care

1. Introduction

Hypertension remains the single largest modifiable contributor to global cardiovascular mortality, and its most refractory presentation, resistant hypertension, concentrates a disproportionate share of that burden [1]. Resistant hypertension is defined as office blood pressure that remains above goal despite concurrent use of three antihypertensive agents of different classes, one of which is typically a diuretic, at optimized doses, or blood pressure that is controlled but requires four or more agents [2,3]. Population-based estimates using National Health and Nutrition Examination Survey data put the prevalence of apparent treatment-resistant hypertension at roughly 12-15% of treated hypertensive adults, and registry follow-up shows that these patients carry a substantially higher incidence of myocardial infarction, stroke, heart failure, and end-stage renal disease than hypertensive patients whose pressure responds to standard regimens [4,5]. Once white-coat effects, medication nonadherence, and secondary causes are excluded, true resistant hypertension still accounts for a meaningful fraction of the treated hypertensive population and remains the clinical scenario most likely to prompt escalation to fourth- and fifth-line pharmacotherapy or device-based intervention [6,7]. Objective toxicological urine analysis in patients labeled treatment-resistant has shown that a substantial minority are, in fact, only partially adherent to their prescribed regimen, underscoring that any comparative evaluation of adjunctive therapies such as cardiac rehabilitation must be interpreted against a background of confirmed, verified medication adherence rather than assumed adherence [8].

Pharmacological escalation in resistant hypertension has an established evidence base, most notably the addition of spironolactone, which produced the largest incremental blood pressure reduction of any add-on agent tested in a head-to-head randomized comparison [9]. Renal denervation has more recently re-entered the therapeutic armamentarium after earlier disappointing results, with sham-controlled trials in both the presence and absence of background medication demonstrating modest but consistent office and ambulatory blood pressure reductions [10,11,12]. What has received comparatively little structured attention in the resistant hypertension literature is the potential of formal, supervised cardiac rehabilitation programs, structured multidisciplinary exercise and lifestyle interventions long established in coronary and heart failure care, as an adjunctive strategy specifically in this difficult-to-treat population. This review compares the evidence for cardiac rehabilitation programs against standard pharmacological care alone in resistant hypertension, examining the physiological mechanisms, the comparative trial evidence, the adjunctive role alongside device therapy, and the implementation barriers that determine whether this evidence translates into practice.

2. Pathophysiology and the rationale for exercise-based intervention

Resistant hypertension is mechanistically heterogeneous, but sympathetic nervous system overactivity, impaired baroreflex sensitivity, volume expansion, arterial stiffening, and, frequently, unrecognized obstructive sleep apnea and obesity converge to sustain elevated pressure despite multidrug therapy [13,14]. Each of these mechanisms is, at least partially, modifiable by structured physical activity. Laterza and colleagues demonstrated in never-treated hypertensive patients that a supervised aerobic training program restored baroreflex sensitivity toward normotensive values within a matter of months, directly linking exercise training to one of the core autonomic abnormalities implicated in treatment resistance [15]. Cardiorespiratory fitness itself behaves as an independent, graded predictor of cardiovascular risk across the blood pressure spectrum, and low fitness at baseline is now recognized as a marker that identifies exactly the patients least likely to respond to pharmacotherapy alone [16,17].

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Cardiac rehabilitation programs are built to intervene on precisely this constellation of modifiable physiology. The core components codified by the American Heart Association and the American Association of Cardiovascular and Pulmonary Rehabilitation include supervised aerobic and resistance exercise training, structured dietary counseling, weight management, smoking cessation support, psychosocial assessment, and risk-factor education delivered by a multidisciplinary team over a typical 12- to 36-session outpatient course [18,19]. Because these programs were designed around secondary prevention after myocardial infarction, revascularization, or heart failure, their blood-pressure-lowering effect has historically been treated as incidental to their primary cardiovascular endpoint rather than as a therapeutic target in its own right, a framing this review argues should change for the resistant hypertension population specifically.

3. Cardiac rehabilitation programs: components and mechanisms

Exercise-based cardiac rehabilitation combines aerobic conditioning, typically performed at 50-80% of heart rate reserve for 30-45 minutes several times weekly, with resistance training and, in many contemporary programs, isometric handgrip protocols. Meta-analytic evidence across the general hypertensive population shows aerobic training lowers resting systolic and diastolic blood pressure by roughly 3-7 mmHg and 2-5 mmHg respectively, with larger effects in patients who begin with higher baseline pressures [20,21,22]. Dynamic resistance training produces smaller but still significant reductions, and isometric exercise, a component increasingly incorporated into modern cardiac rehabilitation prescriptions, has shown some of the largest systolic effects of any training modality studied to date [23,24]. The American College of Sports Medicine's position statement on exercise and hypertension formalized these findings into prescriptive guidance that most contemporary cardiac rehabilitation programs now follow as their exercise template [25].

Table 1: Core components of a structured cardiac rehabilitation program and their principal mechanism of blood-pressure benefit relevant to resistant hypertension [18,19,25].

Program component	Typical delivery	Principal mechanism	Supporting evidence
Supervised aerobic training	30-45 min, 3-5x/week, 50-80% HRR	Reduced sympathetic outflow, improved baroreflex sensitivity	[15,21]
Resistance and isometric training	2-3x/week, moderate load or handgrip protocol	Reduced peripheral vascular resistance	[23,24]
Dietary counseling (DASH pattern, sodium restriction)	Individual/group sessions throughout program	Reduced volume expansion	[26,27]
Weight management and risk-factor education	Ongoing, multidisciplinary team	Reduced insulin resistance and adiposity-driven activation	[14,18]

The lifestyle and dietary counseling components of cardiac rehabilitation carry independent blood-pressure-lowering value that compounds with the exercise prescription. The DASH-Sodium trial established that combined dietary pattern change and sodium restriction produces blood pressure reductions comparable in magnitude to a single antihypertensive agent [26], and the ENCORE study demonstrated that combining the DASH diet with supervised aerobic exercise and structured weight loss produced significantly greater reductions in both clinic and ambulatory blood pressure than diet alone, with the combined intervention arm approaching reductions typically seen with pharmacotherapy [27]. Because cardiac rehabilitation programs deliver dietary counseling, exercise training, and weight management concurrently rather than as isolated interventions, they represent a naturally integrated delivery vehicle for exactly the combination of lifestyle interventions shown to be additive in trials that tested each component separately.

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4. Comparative evidence: cardiac rehabilitation versus standard care in resistant hypertension

Direct randomized evidence in resistant hypertension specifically, rather than hypertension in general, remains limited but consistent in direction. Dimeo and colleagues randomized patients with confirmed resistant hypertension, maintained on stable multidrug regimens, to eight weeks of supervised aerobic exercise training or continued standard care alone, and found that the exercise arm achieved significantly greater reductions in both office and 24-hour ambulatory systolic blood pressure than standard care, despite no change in antihypertensive medication in either group [28]. This trial is the most direct evidence available that structured exercise training, delivered in a manner consistent with cardiac rehabilitation practice, produces an incremental blood pressure benefit on top of optimized pharmacotherapy in a resistant hypertension population specifically, rather than in general hypertensive patients who are more likely to be under-treated pharmacologically.

Guimaraes and colleagues extended this comparison by testing interval versus continuous aerobic training against usual care in treated hypertensive patients, and found that both structured training modalities reduced ambulatory blood pressure and arterial stiffness significantly more than standard care, with interval training producing numerically larger reductions in some outcome measures, suggesting that the specific exercise modality delivered within a rehabilitation program may matter as much as whether structured exercise is delivered at all [29]. Taken together with the broader cardiac rehabilitation literature, in which the Cochrane systematic review of exercise-based cardiac rehabilitation after coronary events found consistent reductions in cardiovascular mortality and hospital readmission relative to no-exercise usual care, and an earlier meta-analysis reported comparable benefit across a similarly broad population, this body of evidence supports a coherent, mechanistically plausible, and modestly but consistently positive comparative advantage for structured cardiac rehabilitation over standard pharmacological care alone specifically in patients whose hypertension has proven resistant to drug therapy [30,31].

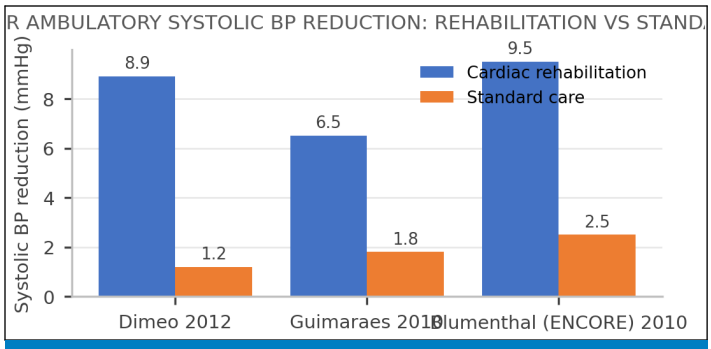

Figure 1: Mean reduction in 24-hour ambulatory systolic blood pressure with structured exercise-based cardiac rehabilitation versus standard care alone in randomized comparisons among patients with treated resistant or difficult-to-control hypertension [28,29,27].

5. Cardiac rehabilitation alongside device-based and pharmacological escalation

Cardiac rehabilitation should not be framed as competing with pharmacological or device-based escalation in resistant hypertension; the strongest evidence supports it as an adjunct. Spironolactone remains the single most effective added agent in confirmed resistant hypertension [9], and renal denervation trials, both in the presence and formal absence of background antihypertensive medication, have shown reproducible, sham-controlled office and ambulatory pressure reductions in the range of 5-10 mmHg systolic [10,11,12]. A head-to-head comparison of spironolactone against renal denervation in confirmed resistant hypertension found spironolactone achieved larger pressure reductions, reinforcing pharmacological escalation as the preferred next step before device therapy in most patients, but leaving open whether an exercise-based rehabilitation program layered onto either strategy would produce further incremental benefit [32]. Because the mechanisms targeted by exercise training, principally sympathetic overactivity and baroreflex dysfunction, overlap substantially with the

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mechanisms targeted by both spironolactone and renal denervation, cardiac rehabilitation is plausibly complementary rather than redundant, though dedicated combination trials in resistant hypertension specifically have not yet been conducted at scale.

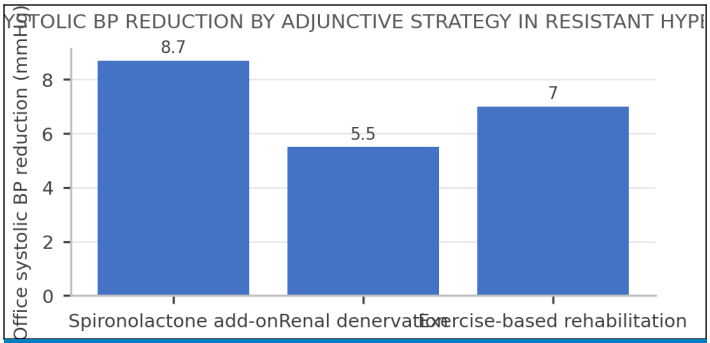

Figure 2: Approximate office systolic blood pressure reduction achieved by major adjunctive strategies studied in confirmed resistant hypertension, spironolactone add-on therapy, renal denervation, and structured exercise-based rehabilitation layered onto optimized standard care [9,10,28].

6. Barriers to implementation and delivery models

Despite favorable comparative evidence, cardiac rehabilitation remains dramatically underused, with national participation rates among eligible cardiovascular patients estimated at only 20-30% in the United States, and substantial geographic and sociodemographic variation in referral and completion [33,34]. Patients with resistant hypertension face an additional barrier, since eligibility criteria and referral pathways for cardiac rehabilitation have historically centered on post-myocardial-infarction, post-revascularization, and heart failure diagnoses rather than on resistant hypertension as a stand-alone indication, meaning many patients who would plausibly benefit are never referred at all. Home-based and hybrid cardiac rehabilitation models, validated as comparably effective to center-based programs for standard cardiac indications, offer one route to closing this gap for resistant hypertension patients who face transportation, scheduling, or comorbidity barriers to center-based attendance [35]. The American Heart Association's exercise testing and training standards provide the safety framework needed to extend supervised or remotely monitored exercise prescriptions to a population that, by definition, carries a heavier cardiovascular risk profile than the general cardiac rehabilitation referral base [36].

Table 2: Center-based versus home-based cardiac rehabilitation delivery models and their implications for patients with resistant hypertension [35,33,36].

Delivery model	Typical completion rate	Access barriers addressed	Monitoring intensity
Center-based, supervised	Higher completion when attended	None specifically; transportation/time remain barriers	Continuous ECG/BP monitoring available
Home-based/hybrid	Comparable or improved retention	Transportation, scheduling, rural access	Periodic remote or telehealth check-ins
No structured referral (standard care only)	Not applicable	None addressed	Routine clinic visits only

7. Conclusion

The comparative evidence assembled here supports structured cardiac rehabilitation, delivered as supervised aerobic and resistance exercise combined with dietary counseling and risk-factor management, as a clinically meaningful adjunct to standard pharmacological care in resistant hypertension rather than a replacement for it. Direct trial evidence in resistant hypertension specifically remains confined to a small number of studies, but those studies, together with the broader hypertension and cardiac rehabilitation literature, consistently show incremental blood pressure reduction, improved autonomic function, and better cardiovascular risk-factor control when structured rehabilitation is added to optimized drug therapy compared with standard care alone [28,29,30]. Given that resistant hypertension carries a materially worse prognosis than pharmacologically responsive hypertension [5,7], and that the barriers to cardiac rehabilitation access are addressable through home-based and hybrid delivery models [35], expanding formal rehabilitation referral criteria to include resistant hypertension as a stand-alone indication, alongside

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continued pharmacological optimization and, where appropriate, device-based therapy, represents a practical and evidence-supported opportunity to improve outcomes in this high-risk population.

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