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Original Article

Upper Extremity Aerobic Versus Resistance Training in Hypertensive Patients

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ABSTRACT

Background: Hypertension is a major cardiovascular risk factor, and structured exercise is a core non-pharmacological intervention for improving functional capacity and cardiopulmonary health. Although both aerobic and resistance training are beneficial, comparative evidence regarding upper-extremity exercise modalities in hypertensive patients remains limited. Objective: To compare the effects of upper-extremity aerobic training and upper-extremity resistance training on cardiorespiratory fitness in adults with hypertension. Methods: This randomized clinical trial included 40 hypertensive participants aged 35-65 years recruited from the Multan Institute of Cardiology, Multan. Participants were allocated to upper-extremity aerobic training or upper-extremity resistance training, with 20 individuals in each group. Both interventions were delivered three times weekly for four weeks. Outcome measures included 6-minute walk distance, rating of perceived exertion, and estimated VO2max, assessed at baseline and after completion of treatment. Within-group analysis used paired-samples t tests, and between-group comparisons used independent-samples t tests. Results: Both groups showed significant pre- to post-intervention improvement in all outcome measures. The aerobic group improved from 203.20±45.35 m to 543.50±44.51 m in 6-minute walk distance, from 6.55±0.94 to 1.90±0.64 in RPE, and from 26.50±1.96 to 47.70±5.08 mL/kg/min in VO2max (all $p<0.001$). The resistance group also improved significantly, but to a lesser extent. Between-group analysis favored aerobic training for post-treatment 6-minute walk distance, RPE, and VO2max (all $p<0.001$). Conclusion: Both upper-extremity exercise programs improved cardiorespiratory fitness-related outcomes in hypertensive patients, but upper-extremity aerobic training produced greater short-term benefit. Keywords: Hypertension, aerobic exercise, resistance training, upper extremity, cardiorespiratory fitness, VO2max, 6-minute walk test.

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INTRODUCTION

Hypertension remains one of the most prevalent and consequential non-communicable disorders worldwide and is a major contributor to cardiovascular morbidity, premature mortality, stroke, kidney disease, and functional decline (1–3). Beyond pharmacological treatment, contemporary management of hypertension emphasizes lifestyle modification as a central therapeutic strategy, particularly structured physical activity, because elevated blood pressure is closely intertwined with sedentary behavior, excess adiposity, impaired vascular function, and reduced exercise capacity (3,4). In hypertensive populations, low cardiorespiratory fitness is clinically important because it is associated with diminished functional independence, greater cardiovascular risk, and poorer long-term prognosis, whereas improvement in fitness is linked to better blood pressure control, enhanced physical performance, and superior health-related quality of life (5,6).

Exercise training is therefore recommended as a cornerstone non-pharmacological intervention for the prevention and treatment of hypertension. Aerobic exercise has consistently been shown to improve cardiovascular efficiency, reduce resting and ambulatory blood pressure, enhance oxygen utilization, and increase functional capacity through repeated rhythmic activity involving large muscle groups at low-to-moderate intensity (5,7). Resistance training, although historically prescribed more cautiously in cardiovascular populations, is now also recognized as a safe and beneficial modality when appropriately dosed, with favorable effects on muscular strength, functional performance, vascular health, and overall cardiometabolic risk (7,8). Because aerobic and resistance exercise differ in their physiological demands and hemodynamic responses, they may not exert identical effects on exercise tolerance, symptom perception, and estimated aerobic capacity in patients with hypertension (7,8).

Most exercise-based research in hypertension has centered on lower-extremity or whole-body training, including walking, cycling, and combined exercise regimens, while comparative evidence regarding upper-extremity training remains limited. This is an important gap because upper-extremity exercise may offer a practical rehabilitation option for patients who have reduced lower-limb tolerance, limited mobility, deconditioning, obesity-related movement restriction, or poor adherence to conventional ambulatory exercise programs. Upper-limb ergometry and resistance-based upper-extremity conditioning are already used in rehabilitation settings and may improve exercise tolerance and oxygen consumption, yet their comparative value in hypertensive individuals has not been adequately clarified (8,9). From a clinical standpoint, determining whether upper-extremity aerobic training or upper-extremity resistance training yields greater improvement in cardiorespiratory fitness could help refine exercise prescription for this high-risk population.

Cardiorespiratory fitness can be examined through practical functional and physiological measures such as the 6-minute walk distance, rating of perceived exertion, and estimated maximal oxygen consumption. These indicators provide complementary information regarding submaximal functional capacity, subjective exercise tolerance, and aerobic performance, and they are commonly used in rehabilitation research because they are feasible, clinically interpretable, and responsive to training effects (10–12). In hypertensive patients, improvement across these domains may indicate not only better exercise efficiency but also greater confidence and tolerance for sustained physical activity, which is relevant for long-term risk reduction and secondary prevention.

Against this background, the present study was designed to compare the effects of upper-extremity aerobic training and upper-extremity resistance training on cardiorespiratory fitness in patients with hypertension. It was hypothesized that both interventions would improve functional and physiological outcomes, but that upper-extremity aerobic training would produce greater gains in 6-minute walk distance, perceived exertion, and estimated VO2max than upper-extremity resistance training (5,7–9).

MATERIALS AND METHODS

This study was conducted as a parallel-group randomized clinical trial to compare the effects of upper-extremity aerobic training and upper-extremity resistance training on cardiorespiratory fitness in patients with hypertension. The trial was carried out at the Multan Institute of Cardiology, Multan, Pakistan, after approval from the institutional research ethics committee, and all participants provided written informed consent before enrollment. Trial registration was reported under ClinicalTrials.gov identifier NCT05936892. Data collection was undertaken during the prespecified study period, and all baseline and post-intervention assessments were performed at the same study site using a uniform evaluation procedure for both groups.

Adults aged 35 to 65 years with previously diagnosed hypertension and resting blood pressure above 140/90 mmHg were considered eligible for participation. Both men and women were included. Patients were recruited from the outpatient and rehabilitation-linked clinical population of the study center and were screened for eligibility through history taking, blood pressure assessment, and clinical review. Individuals were excluded if they had regularly engaged in structured physical exercise during the preceding four weeks, had secondary hypertension, were receiving more than one antihypertensive medication, or had recent myocardial infarction, congestive heart failure, or uncontrolled cardiac arrhythmia, as these conditions could alter exercise tolerance, introduce clinical instability, or confound the interpretation of cardiorespiratory outcomes (13,14).

After screening and consent, participants underwent baseline assessment and were allocated in a 1:1 ratio to one of two intervention groups using a simple randomization procedure with sealed opaque envelopes. Group A received upper-extremity aerobic training and Group B received upper-extremity resistance training. Allocation concealment was maintained until the envelope was opened for assignment. The intervention period lasted four weeks, with three supervised sessions per week on alternate days. Baseline measurements were repeated at the end of the intervention using the same instruments and procedures to ensure comparability of pre- and post-treatment values.

The primary outcome domain was cardiorespiratory fitness, operationalized through 6-minute walk distance, rating of perceived exertion, and estimated maximal oxygen consumption. Additional baseline clinical variables included age, sex, body weight, heart rate, and blood pressure. Functional exercise capacity was assessed using the 6-minute walk test, a standardized field test that measures the maximum distance a participant can walk on a flat, hard surface over six minutes and is widely used as an indicator of submaximal functional performance in cardiopulmonary rehabilitation settings (15). Perceived exertion during activity was recorded using the Borg rating of perceived exertion scale, which provides a validated subjective estimate of exercise intensity and symptom burden during physical effort (16). Aerobic capacity was expressed as estimated VO2max in mL/kg/min using the study formula derived from participant characteristics and exercise-test performance variables. Heart rate and blood pressure were measured at baseline and during study assessment visits according to routine clinical procedures.

Participants assigned to the aerobic group performed upper-extremity aerobic exercise using an arm cycle ergometer. Each session incorporated a brief warm-up consisting of deep breathing exercises, coordinated arm movements, and low-intensity stretching of the upper limbs for approximately 5 to 10 minutes, followed by aerobic arm ergometry and a cool-down period. The full session duration was approximately 40 minutes. Exercise intensity was progressed gradually across the four-week training period to achieve approximately 75% to 85% of peak heart rate, with tolerance monitored during supervised sessions. This intervention strategy was selected to provide a sustained rhythmic upper-limb activity stimulus intended to enhance aerobic conditioning and exercise efficiency (9,14).

Participants assigned to the resistance-training group completed an upper-extremity strengthening program three times weekly for four weeks. Sessions lasted approximately 30 to 45 minutes and included warm-up and cool-down periods of 5 to 10 minutes with low-intensity stretching of the upper limbs. Resistance was provided using elastic bands and dumbbells, and the program included chest press, biceps curl, triceps extension, seated row, and scaption exercises. Exercises were performed in three sets of ten repetitions, with each repetition executed in a slow and controlled manner, approximately two seconds during the concentric phase and four seconds during the eccentric phase, while maintaining regular breathing and avoiding breath holding. Progression was introduced across sessions according to participant tolerance to provide a structured upper-limb resistance stimulus aimed at improving muscular endurance and functional performance without excessive hemodynamic strain (8,14).

To reduce measurement bias, all participants were assessed with the same outcome tools at baseline and after completion of the intervention, and the same predefined outcome variables were recorded for both groups. Uniform treatment frequency and duration were maintained across the two study arms to improve internal comparability. Eligibility restrictions were used to reduce clinical heterogeneity arising from unstable cardiovascular conditions, secondary hypertension, and recent structured exercise exposure. Standardized test administration and consistent data recording procedures were followed to support reproducibility and data integrity. Outcome data were entered into a structured proforma and analyzed using SPSS version 25.

Statistical analysis was planned to evaluate both within-group change and between-group differences. Descriptive statistics were calculated for demographic and baseline clinical variables and reported as mean with standard deviation for continuous variables and as frequency with percentage for categorical variables. Data normality was assessed using the Shapiro-Wilk test. For normally distributed continuous outcomes, within-group pre- to post-intervention differences were analyzed using paired-samples t tests, while between-group comparisons were analyzed using independent-samples t tests. A two-sided p-value of less than 0.05 was considered statistically significant. The principal comparative analyses focused on post-intervention 6-minute walk distance, rating of perceived exertion, and estimated VO2max, alongside within-group pre-post changes in each treatment arm (15,16).

RESULTS

A total of 40 participants were analyzed, with 20 participants in the upper-extremity aerobic training group and 20 participants in the upper-extremity resistance training group. Baseline descriptive analysis showed that the mean age was 45.75±8.59 years in the aerobic group and 48.65±7.74 years in the resistance group. The aerobic group included 13 men (65.0%) and 7 women (35.0%), whereas the resistance group included 5 men (25.0%) and 15 women (75.0%). Mean body weight was 72.30±8.22 kg in the aerobic group and 69.35±8.68 kg in the resistance group. Baseline heart rate was 104.70±7.26 beats/min in the aerobic group and 101.85±5.37 beats/min in the resistance group. Mean systolic blood pressure was 155.15±35.75 mmHg in the aerobic group and 163.65±17.42 mmHg in the resistance group, while mean diastolic blood pressure was 99.50±9.01 mmHg and 106.00±10.33 mmHg, respectively. Shapiro-Wilk testing showed no statistically significant departure from normality for age, heart rate, systolic blood pressure, diastolic blood pressure, body weight, baseline 6-minute walk distance, baseline RPE, or baseline VO2max, supporting the use of parametric tests for subsequent analyses.

Table 1. Baseline demographic and clinical characteristics of the study groups

Variable	Aerobic Training (n=20)	Resistance Training (n=20)
Age, years	45.75 ± 8.59	48.65 ± 7.74
Male, n (%)	13 (65.0)	5 (25.0)
Female, n (%)	7 (35.0)	15 (75.0)
Weight, kg	72.30 ± 8.22	69.35 ± 8.68
Heart rate, beats/min	104.70 ± 7.26	101.85 ± 5.37
Systolic blood pressure, mmHg	155.15 ± 35.75	163.65 ± 17.42
Diastolic blood pressure, mmHg	99.50 ± 9.01	106.00 ± 10.33

Table 2. Normality assessment of baseline continuous variables

Variable	Shapiro-Wilk Statistic	df	p-value
Age	0.950	40	0.079
Heart rate	0.961	40	0.181
Systolic blood pressure	0.956	40	0.123
Diastolic blood pressure	0.967	40	0.285
Weight	0.973	40	0.457
Pre-intervention 6MWD	0.968	40	0.322
Pre-intervention RPE	0.971	40	0.384
Pre-intervention VO2max	0.952	40	0.091

Within-group analysis demonstrated statistically significant improvement in all prespecified cardiorespiratory fitness outcomes in both intervention arms. In the aerobic training group, mean 6-minute walk distance increased from 203.20±45.35 m to 543.50±44.51 m, representing an absolute gain of 340.30 m and a relative increase of 167.5%, with p<0.001. Mean RPE decreased from 6.55±0.94 to 1.90±0.64, corresponding to an absolute reduction of 4.65 points and a relative reduction of 71.0%, with p<0.001. Estimated VO2max increased from 26.50±1.96 to 47.70±5.08 mL/kg/min, an absolute increase of 21.20 mL/kg/min and a relative increase of 80.0%, with p<0.001. In the resistance training group, 6-minute walk distance improved from 221.90±44.89 m to 421.00±24.03 m, an absolute gain of 199.10 m and a relative increase of 89.7%, with p<0.001. Mean RPE decreased from 6.35±1.18 to 4.00±1.12, an absolute reduction of 2.35 points and a relative reduction of 37.0%, with p<0.001. Estimated VO2max improved from 26.15±2.49 to 30.75±2.29 mL/kg/min, an absolute increase of 4.60 mL/kg/min and a relative increase of 17.6%, with p<0.001.

Table 3. Within-group pre- and post-intervention comparison of outcome measures

Outcome	Time Point	Aerobic Training (n=20) Mean ± SD	Mean Change	Relative Change (%)	p-value	Resistance Training (n=20) Mean ± SD	Mean Change	Relative Change (%)	p-value
6-minute walk distance, m	Pre	203.20 ± 45.35				221.90 ± 44.89			
	Post	543.50 ± 44.51	+340.30	+167.5	<0.001	421.00 ± 24.03	+199.10	+89.7	<0.001
RPE score	Pre	6.55 ± 0.94				6.35 ± 1.18			
	Post	1.90 ± 0.64	-4.65	-71.0	<0.001	4.00 ± 1.12	-2.35	-37.0	<0.001
VO2max, mL/kg/min	Pre	26.50 ± 1.96				26.15 ± 2.49			
	Post	47.70 ± 5.08	+21.20	+80.0	<0.001	30.75 ± 2.29	+4.60	+17.6	<0.001

Between-group analysis based on post-intervention values favored upper-extremity aerobic training across all three principal outcomes. The mean post-treatment 6-minute walk distance was 543.50±44.52 m in the aerobic group compared with 421.00±24.04 m in the resistance group, yielding a mean difference of 122.50 m, t=10.83, p<0.001. The standardized effect size for this between-group difference was very large (Cohen's d=3.42). Similarly, post-intervention RPE was lower in the aerobic group than in the resistance group, with mean values of 1.90±0.64 and 4.00±1.12, respectively, producing a mean difference of -2.10 points, t=-7.26, p<0.001, with a very large standardized effect size (Cohen's d=-2.30). Post-intervention estimated VO2max was also markedly higher after aerobic training than after resistance training, with mean values of 47.70±5.08 and 30.75±2.29 mL/kg/min, respectively, corresponding to a mean difference of 16.95 mL/kg/min, t=13.58, p<0.001, with a very large standardized effect size (Cohen's d=4.30).

Table 4. Between-group comparison of post-intervention outcomes

Outcome	Aerobic Training (n=20) Mean ± SD	Resistance Training (n=20) Mean ± SD	Mean Difference	t-value	p-value	Cohen's d
Post 6-minute walk distance, m	543.50 ± 44.52	421.00 ± 24.04	+122.50	10.83	<0.001	3.42
Post RPE score	1.90 ± 0.64	4.00 ± 1.12	-2.10	-7.26	<0.001	-2.30
Post VO2max, mL/kg/min	47.70 ± 5.08	30.75 ± 2.29	+16.95	13.58	<0.001	4.30

Taken together, these findings indicate that both interventions were associated with statistically significant within-group gains in cardiorespiratory fitness-related measures, but the magnitude of improvement was consistently greater in the upper-extremity aerobic training group. The largest comparative separation was observed for estimated VO2max, where aerobic training produced a mean post-treatment advantage of 16.95 mL/kg/min over resistance training, followed by a 122.50 m higher post-treatment walking distance and a 2.10-point lower perceived exertion score. These differences between-group were not only statistically significant but also clinically substantial in magnitude.

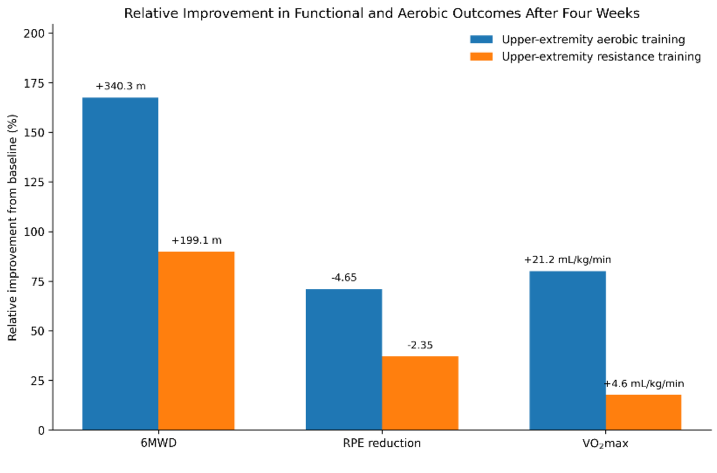

Figure 1. Relative improvement in functional and aerobic outcomes after four weeks of training.

The figure demonstrates a consistently steeper improvement gradient in the upper-extremity aerobic training group across all major outcomes. Relative to baseline, 6-minute walk distance increased by 167.5% after aerobic training compared with 89.7% after resistance training, while RPE decreased by 71.0% versus 37.0%, respectively. The most pronounced divergence was observed in estimated VO2max, which rose by 80.0% in the aerobic group but by only 17.6% in the resistance group. In absolute terms, aerobic training yielded gains of 340.3 m in walking distance and 21.2 mL/kg/min in VO2max, compared with 199.1 m and 4.6 mL/kg/min after resistance training, indicating a broader and more clinically meaningful training response in aerobic conditioning.

DISCUSSION

The present randomized clinical trial found that both upper-extremity aerobic training and upper-extremity resistance training produced statistically significant improvements in cardiorespiratory fitness-related outcomes in patients with hypertension, but the magnitude of improvement was consistently greater in the aerobic training group. Participants receiving aerobic training demonstrated larger gains in 6-minute walk distance, greater reductions in perceived exertion, and markedly higher improvement in estimated VO2max than those receiving resistance training. These findings suggest that although both upper-limb exercise strategies may be beneficial in a short-term rehabilitation context, rhythmic aerobic conditioning appears to provide a stronger stimulus for improving functional exercise tolerance and aerobic efficiency in hypertensive adults.

The superiority of aerobic training in this study is physiologically plausible. Aerobic upper-extremity exercise performed at progressively targeted heart-rate intensities is more likely to induce sustained cardiopulmonary loading, improve peripheral oxygen extraction, enhance circulatory efficiency, and reduce the relative effort required for submaximal activity. In contrast, upper-extremity resistance training, while beneficial for neuromuscular performance and local muscular endurance, may not generate the same continuous metabolic demand needed to maximize improvement in functional walking capacity and estimated aerobic performance over a brief intervention period. The marked decline in Borg RPE in the aerobic group further supports improved exercise tolerance and suggests that patients were able to perform physical activity with less symptom burden after training, which is clinically relevant because lower perceived exertion may facilitate adherence to long-term exercise prescriptions.

The present findings are broadly consistent with earlier exercise-based cardiovascular rehabilitation literature showing that aerobic training can substantially improve fitness and hemodynamic outcomes in high-risk cardiovascular populations. In the EnRicH randomized clinical trial, a 12-week aerobic exercise program in resistant hypertension reduced ambulatory blood pressure and improved cardiorespiratory fitness compared with usual care, reinforcing the central role of aerobic conditioning in hypertensive management. Similarly, upper-extremity aerobic exercise has previously been shown to improve peak oxygen consumption, exercise capacity, dyspnea, and quality of life in patients with pulmonary arterial hypertension, supporting the concept that structured upper-limb aerobic conditioning can generate clinically meaningful cardiopulmonary adaptations even when lower-limb-focused training is not the primary modality. Evidence from resistance-based interventions also suggests benefit, as self-selected resistance training improved cardiorespiratory fitness and functional performance in inactive older women, indicating that resistance exercise remains a valuable therapeutic option, though perhaps less potent than aerobic conditioning for the specific outcomes prioritized in the present trial. In addition, combined aerobic and resistance exercise has been reported to improve autonomic indices similarly in normotensive and hypertensive postmenopausal women, suggesting that multiple exercise modalities may confer cardiovascular benefit, even when the pattern and magnitude of response differ. From a clinical perspective, the study supports the use of upper-extremity exercise training as a practical intervention for hypertensive patients, particularly in rehabilitation environments where conventional lower-extremity exercise may be limited by deconditioning, obesity, orthopedic constraints, or poor tolerance. The larger treatment effect observed with aerobic arm ergometry suggests that clinicians seeking short-term improvements in cardiorespiratory fitness may prioritize upper-extremity aerobic protocols when feasible, while still recognizing the supportive role of resistance training in comprehensive exercise prescription. At the same time, the findings should be interpreted with caution. The intervention period was short, the sample size was modest, the study was conducted at a single center, and there was baseline imbalance in sex distribution between groups. In addition, VO2max was estimated rather than directly measured, and between-group inference relied on post-intervention comparisons without more advanced baseline-adjusted modeling. These issues limit generalizability and reduce confidence in the precision of the observed effect magnitude. Future trials should use larger and more balanced samples, longer follow-up, direct cardiopulmonary exercise testing where feasible, and adjusted statistical models to confirm whether the observed superiority of upper-extremity aerobic training is robust across broader hypertensive populations.

CONCLUSION

In this randomized clinical trial, both upper-extremity aerobic training and upper-extremity resistance training improved cardiorespiratory fitness-related outcomes in patients with hypertension; however, upper-extremity aerobic training produced greater improvement in 6-minute walk distance, perceived exertion, and estimated VO2max over the short intervention period. These findings suggest that upper-extremity aerobic conditioning may be the more effective rehabilitation strategy when the primary goal is to enhance functional exercise capacity and aerobic performance in hypertensive adults.

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