Comparison of Aerobic and Anaerobic Exercise Training on Primary Hemodynamic Parameters in Stage 1 Hypertension- A Pilot Study

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Abstract

Background: Hypertension is a growing public health problem and a major cause of cardiovascular disease worldwide. In India, the prevalence of Stage 1 hypertension is rising due to sedentary lifestyle habits and reduced physical activity. Exercise therapy is widely recommended as a non-pharmacological approach for blood pressure management. However, limited evidence is available comparing aerobic and anaerobic exercise in individuals with Stage 1 hypertension.

Objective: The study aimed to compare the effects of aerobic and anaerobic exercise training on blood pressure and cardiovascular parameters in individuals with Stage 1 hypertension.It also evaluated which exercise modality produced greater improvement in systolic blood pressure, diastolic blood pressure, and resting heart rate after an 8-week intervention program.

Discussion: Both aerobic and anaerobic exercise interventions improved cardiovascular outcomes in hypertensive individuals. The anaerobic resistance training group demonstrated greater reductions in systolic blood pressure, diastolic blood pressure, and resting heart rate compared to the aerobic and conventional exercise groups. These findings may be associated with improved vascular function, autonomic regulation, and muscular efficiency produced by resistance training.

Conclusion: Both exercise programs were effective in managing Stage 1 hypertension however, anaerobic resistance exercise showed superior cardiovascular benefits. Incorporating moderate-intensity resistance training into rehabilitation programs may improve blood pressure control and help reduce future cardiovascular risk in hypertensive individuals.

INTRODUCTION

Stage 1 hypertension represents an early but clinically significant phase of the disease, where lifestyle modification is strongly recommended as the first-line intervention before pharmacological therapy. Despite the availability of effective antihypertensive medications, control rates remain suboptimal in India, as highlighted by systematic reviews and meta-analyses of population-level studies

[2]. Poor blood pressure control is often attributed to lack of awareness, medication non-adherence, and limited access to structured lifestyle intervention programs. Consequently, non-pharmacological approaches such as exercise training play a critical role in early hypertension management.

According to ScienceDirect Topics, blood pressure (BP) and heart rate (HR) are considered primary hemodynamic parameters, as they are the most fundamental and readily measurable indicators of cardiovascular function. Other advanced hemodynamic parameters such as cardiac output, stroke volume, and vascular resistance are derived measures and reflect secondary cardiovascular responses. Hypertension is clinically classified based on blood pressure values; as per the **Ministry of Health and Family Welfare, Government of India (2016) guidelines, Grade 1 (Stage 1) hypertension** is defined by a systolic blood pressure ranging from **140–159 mmHg** and/or a diastolic blood pressure ranging from **90–99 mmHg**. Therefore, BP and HR serve as essential primary hemodynamic parameters for evaluating cardiovascular responses and therapeutic interventions in individuals with Stage 1 hypertension.

Exercise training has been extensively recognized as an effective and safe intervention for blood pressure reduction. Aerobic exercise is traditionally considered the cornerstone of exercise prescription for hypertensive individuals. Regular aerobic activity improves endothelial function, enhances nitric oxide bioavailability, reduces arterial stiffness, and modulates autonomic balance, leading to sustained reductions in systolic and diastolic blood pressure [7, 12, 18]. Current clinical guidelines consistently recommend moderate-intensity aerobic exercise for individuals with hypertension due to its well-established cardiovascular benefits [10, 12].

In contrast, anaerobic or resistance exercise was historically discouraged in hypertensive populations due to concerns regarding acute elevations in blood pressure during high-intensity lifting. However, emerging evidence has demonstrated that mild-to-moderate intensity resistance training is not only safe but also beneficial for individuals with hypertension. Resistance exercise has been shown to reduce peripheral vascular resistance, improve cardiac workload, enhance muscular strength, and positively influence lipid profiles in hypertensive individuals [4, 5,8]. Systematic reviews and meta-analyses have further supported the role of resistance training as an adjunct or alternative to aerobic exercise in blood pressure management [5, 18].

Comparative studies evaluating aerobic and anaerobic exercise modalities have suggested that both forms of training may produce clinically meaningful reductions in blood pressure, though the underlying physiological mechanisms differ. Aerobic exercise predominantly influences cardiovascular endurance and vascular adaptations, while anaerobic exercise targets muscular strength and metabolic efficiency, which may indirectly contribute to improved cardiovascular regulation [11, 15, 17]. Despite growing evidence, limited studies have directly compared these two exercise modalities in individuals specifically diagnosed with Stage 1 hypertension, particularly within the Indian population.

In addition to blood pressure reduction, hypertension significantly affects health-related quality of life due to physical limitations, psychological stress, and long-term cardiovascular risk. Previous research has demonstrated that structured exercise interventions can improve both physical and mental components of quality of life in hypertensive individuals [1]. Therefore, evaluating exercise interventions using multidimensional outcome measures such as cardiovascular fitness, physical activity levels, and quality of life is essential.

Given the high prevalence of hypertension in India, poor control rates, and increasing emphasis on lifestyle-based management, there is a need for evidence-based exercise protocols tailored to individuals with Stage 1 hypertension. Comparing the effectiveness of aerobic and anaerobic exercise training may provide valuable insights for clinicians and physiotherapists in designing individualized and safe exercise prescriptions.

Hence, the present study aims to evaluate and compare the effectiveness of aerobic and anaerobic exercise training on blood pressure and selected cardiovascular and functional outcomes in individuals with Stage 1 hypertension.

METHODOLOGY

Study Design

A comparative experimental study design was used.

Participants

30 participants were randomly assigned, with 10 participants in each group. Individuals diagnosed with Stage 1 hypertension were recruited. Participants were medically stable and cleared for exercise participation according to ACSM guidelines [9].

Inclusion Criteria

- Minimum 6 months diagnosed with hypertension
- Individual who is fit to participate according to the PARQ scale & clearance to do exercises from a physician
- According to risk stratification criteria- low to moderate risk
- Patient under only one antihypertensive medication.
- Age - 30 to 50 years.
- Gender -Male and female.
- No history of respiratory disorder / distress 6 months before the study.
- Individual with the ability to understand the purpose of the study
- Voluntary concern for participation.

Exclusion Criteria

- Any other severe cardiac risk factor (angina, cardiac arrest, MI)
- Individual suffers from any type of obstructive or restrictive lung disease
- Any musculoskeletal-related dysfunctions that will hamper the results of the six-minute walk test
- Uncontrolled hypertension above 160 mm Hg
- Diabetics
- Any addiction example: tobacco, smoking & alcohol
- Obesity – BMI < 30
- Major vision or auditory problem
- Major neurological or neuromuscular disorder
- Presence of serious cognitive and psychiatric diseases

Intervention Protocol

Participants were divided into three groups:

Group A - Aerobic Exercises + General Mobility (3 times/week)

Aerobic exercises were given to Group A subjects. Initially, general mobility warm-up exercises were administered for 5–10 minutes, which included active range of motion (AROM) exercises of the upper and lower limbs involving all joints. The intervention included static cycling for 20 minutes, and subjects were instructed not to hold their breath while performing the exercise. The intensity selected for this group was 40%–60% of heart rate reserve (moderate intensity), with a frequency of alternate days three times per week for a duration of eight weeks.

Each exercise session concluded with a cool-down period of 5–10 minutes, which included stretching of the biceps, triceps, pectorals, lateral flexors of the trunk, quadriceps, hamstrings, and calf muscles. The subjects’ blood pressure and heart rate were recorded at baseline and after eight weeks of the training intervention.

FIIT Principle According to ACSM

Frequency: 3 times/week

Intensity-40% to 60% HRR - Mild to moderate, RPE-11 to 13 on a (6–20) scale

Type: static cycling

Time—20 minutes aerobic exercise (5 minutes warm-up / 5 minutes cool-down) – General mobility exercises

Total time – 30 minutes

Vital parameters will be monitored throughout the exercise session by using the Polar band H7.

Group B-Anaerobic exercise + general mobility (3 times/week)

Anaerobic exercises were given to Group B subjects. Initially, general mobility warm-up exercises were administered for 5–10 minutes, which included active range of motion (AROM) exercises of the upper and lower limbs involving all joints. The intervention included anaerobic (resistance) exercises using dumbbells and weight cuffs for the upper and lower extremities. Repetition maximum (RM) was used as one of the safest methods to determine baseline muscle strength and to establish the training load for anaerobic resistance exercises in the clinical setup. One-repetition maximum (1RM) was defined as the greatest amount of weight that a person could lift through the full range of motion for one repetition, and the Epley formula was used to calculate the one-repetition maximum.

After calculating 1RM, eight upper- and lower-limb muscle groups were targeted for exercises, namely the biceps, triceps, deltoids, gluteus maximus, back muscles, quadriceps, hamstrings, and calves. These large muscle groups contain type II fast-twitch muscle fibers, which help the heart pump more blood to meet increased oxygen demands, thereby leading to improvements in cardiac output and overall heart function. Mild to moderate intensity resistance training (30%–40% of one-repetition maximum [1RM] for upper-body exercises and 50%–60% of 1RM for lower-body exercises) was administered on alternate days three times per week; after every week, workload increased by 0.5 kg if patients tolerated it.

According to the American College of Sports Medicine (ACSM), one set of anaerobic resistance exercises consisted of 8–12 repetitions for each muscle group. Participants were given two sets for each muscle group (16–24 repetitions) with a 30-second rest interval between sets of the anaerobic resistance exercise protocol. The frequency of exercise sessions was three alternate days per week for a duration of eight weeks. A total of 24 sessions were completed within eight weeks, with a time duration of 15 minutes per exercise session. Each exercise session concluded with a cool-down period of 5-10 minutes, which included stretching of the biceps, triceps, pectorals, lateral flexors of the trunk, quadriceps, hamstrings, and calf muscles. The total duration of the anaerobic exercise intervention protocol was approximately 25–30 minutes. The subjects' blood pressure and heart rate were recorded at baseline and after eight weeks of the training intervention.

Sr. No.	Exercise Technique Name	Position	Tool Required	Safety Precautions	Duration	sets and Repetitions
1	Biceps Curls	Standing erect, feet shoulder-width apart, knees slightly flexed	Dumbbells	Avoid swinging weights, keep elbows close to body, maintain neutral spine, controlled movement	2 to 3minutes	2 sets with 8 to12 repetitions
2	Triceps Curls (Overhead Extension)	Standing upright, feet shoulder-width apart	Dumbbell	Keep elbows close to head, avoid lumbar hyperextension, move slowly	2 to 3minutes	2 sets With 8 to12 repetitions
3	Deltoid Exercise-Forward Raise	Standing with arms by sides, palms facing thighs	Dumbbells	Avoid shrugging shoulders, keep elbows extended, Maintain core engagement	2 to 3minutes	2 sets With 8 to 12 repetitions
4	Pectoralis Major Exercise (Chest Press)	Supine lying on bench	Dumbbells, Bench	Avoid locking elbows, control descent, Maintain wrist alignment	2 to 3minutes	With 8 to 12 repetitions
5	Quadriceps Curls (Seated Knee Extension)	Sitting on chair with back support	Weight cuff	Avoid jerky movements, hold briefly without locking knee	2 to 3minutes	2 sets with 8 to12 repetitions
6	Hamstring Curls	Prone lying	Weight cuff	Avoid pelvic lifting, move within pain-free range	2 to 3 minutes	with 8 to 12 repetitions
7	Squats with Weights	Standing, feet hip-to-shoulder-width apart	Dumbbells	Maintain neutral spine, knees aligned with toes, avoid forward trunk lean	2 to 3 minutes	2 sets with 8 to 12 repetitions
8	Back Extension with Dumbbells (Hip Hinge)	Standing, feet ankle-to-hip width	Dumbbells	Avoid spinal flexion, hinge at hips, engage core and glutes	2 to 3 minutes	2 sets with 8 to 12 repetitions

FIIT Principle According to ACSM

Frequency: 3 times/week
Intensity-
30% to 40% of 1 RM upper limb
50% to 60% of 1 RM lower limb (mild to moderate)
RPE: 11-13 (on a 6-20 scale)
Type-15 minutes of anaerobic exercise
(5 minutes warm-up / 5 minutes cool-down)-General mobility exercises
Anaerobic resistance exercises of the upper and lower limbs & general mobility
Total Time: 25 - 30 minutes
Vital parameters were monitored throughout the exercise session by using the Polar Band H7.
The exercise was prematurely terminated if any one of the following events occurred:
A rise in heart rate above the upper limit of the targeted heart rate
Oxygen saturation of less than 90%
Borg rate of perceived exertion scale > 8
At the request of the patient

Group C: Conventional Physiotherapy - General Mobility Exercises (3 times/week)

Group C received conventional physiotherapy in the form of general mobility exercises. In this group, awareness was provided regarding the importance of exercises and lifestyle modifications. Participants were motivated to perform exercises at least three times per week. They were provided with pamphlets related to general mobility exercises and were taught to self-monitor their heart rate and rate of perceived exertion (RPE). The subjects' blood pressure, heart rate, VO_2, International Physical Activity Questionnaire (IPAQ), and SF-36 quality of life scores were recorded at baseline and after eight weeks of the training intervention.

FIIT Principle According to ACSM

Frequency: - 3 times / week
Intensity: - RPE- 11-13 on a (6 – 20 scale)
Time: 30 minutes
Type: The type of exercises, including AROM exercises and stretching.
Total time : 25 - 30 minutes

The comparison of 3 group base on intensity (mild to moderate) & energy expenditure MET value i.e 3 to 6 METs (6,8,12)

RESULTS

A total of 30 participants completed the 8-week exercise intervention program without any adverse cardiovascular events 10 participantsin each group . Baseline characteristics, including systolic blood pressure (SBP), diastolic blood pressure (DBP), and resting heart rate (HR), were comparable between the aerobic exercise group (Group A), anaerobic exercise group (Group B), & control group C. The normality of data was assessed using the Shapiro–Wilk test. Since the data followed normal distribution, a paired t-test was used for within-group (pre vs. post) comparison, and a one-way ANOVA was used for between-group comparison.

Table 1: Within-Group Comparison of Systolic Blood Pressure (SBP)

Group	Mean Pre (mmHg)	Mean Post (mmHg)	Mean Difference	SD	p-value
Group A	150.1	145.4	−4.70	3.89	0.003*
Group B	150.1	135.4	−14.70	4.22	<0.001*
Group C	147.4	144.5	−2.90	2.81	0.061

Within-group analysis using paired t-test showed a statistically significant reduction in systolic blood pressure in all three groups. The anaerobic exercise (Group B) group demonstrated the maximum reduction in systolic blood pressure compared to aerobic (Group A) exercise and general mobility (Group C) groups, indicating effectiveness of anaerobic training in reducing systolic blood pressure.

Table 2: Within-Group Comparison of Diastolic Blood Pressure (SBP)

Group	Mean Pre (mmHg)	Mean Post (mmHg)	Mean Difference	SD	p-value
Group A	90.8	90.3	−0.50	0.71	0.083
Group B	90.8	88.9	−1.90	1.2	0.004*
Group C	90.4	90.3	−0.10	0.32	0.412

Paired t-test analysis demonstrated a statistically significant reduction in diastolic blood pressure in the anaerobic exercise (group B).

Aerobic exercise and general mobility groups did not show statistically significant changes in diastolic blood pressure, suggesting that anaerobic exercise had a more pronounced effect on diastolic blood pressure reduction.

Table 3: Within-Group Comparison of Heart Rate (HR)

Group	Mean Pre (bpm)	Mean Post (bpm)	Mean Difference	SD	p-value
Aerobic Exercise	95.3	89.8	−5.50	3.63	0.002*
Anaerobic Exercise	90.1	78.4	−11.70	4.08	<0.001*
General Mobility	95.5	92	−3.50	2.67	0.041*

Using paired t-test showed a statistically significant reduction in Heart Rate in all three groups. The anaerobic exercise (Group B) group demonstrated the maximum reduction in Heart Rate compared to aerobic (Group A) exercise and general mobility ((Group C) groups, indicating effectiveness of anaerobic training in reducing Heart Rate.

Table 4: Between-Group Comparison of Mean Change in SBP

	Df	F-value	p-value
Between post SBP	2	18.62	<0.001*

One-way ANOVA revealed a statistically significant difference in post-intervention systolic blood pressure among aerobic, anaerobic, and general mobility groups. This indicates that the magnitude of systolic blood pressure reduction differed significantly between the interventions, with anaerobic exercise showing the greatest improvement.

Table 5: Between-Group Comparison of Mean Change in DBP

	Df	F-value	p-value
Between post DBP	2	6.41	0.005*

One-way ANOVA showed a statistically significant difference in post-intervention diastolic blood pressure among the three groups. This indicates that the interventions had differing effects on diastolic blood pressure, with anaerobic exercise producing greater reduction compared to aerobic exercise and general mobility.

Table 6 : Between-Group Comparison of Mean Change in HR

	Df	F-value	p-value
Between Post HR	2	14.89	<0.001*

One-way ANOVA indicated a highly statistically significant difference in post-intervention heart rate among the three groups. This confirms that anaerobic exercise was significantly more effective in reducing resting heart rate compared to aerobic exercise and general mobility.

Discussion

The current study compared the effects of aerobic and anaerobic exercise training on blood pressure and cardiovascular responses in individuals with Stage-1 hypertension. Both exercise programs resulted in improvement in systolic blood pressure, diastolic blood pressure, and resting heart rate after the intervention period. However, participants who performed anaerobic resistance training demonstrated greater improvement than those in the aerobic exercise and general mobility groups. These findings indicate that exercise-based rehabilitation can play an important role in the early management of hypertension, particularly when lifestyle modification is recommended before aggressive pharmacological treatment. [5,13,19].

Analysis within each group showed a reduction in systolic blood pressure following both aerobic and anaerobic exercise training, with the largest decrease observed in the resistance training group. Earlier studies have also reported that resistance exercise can lower blood pressure by improving muscular efficiency and decreasing peripheral vascular resistance [3,9,18]. Farhad et al. (2021) observed that resistance training reduced cardiac workload and vascular resistance in young adults with hypertension, leading to improved blood pressure regulation. Although aerobic exercise has traditionally been recommended as the primary form of exercise for hypertensive individuals, recent evidence suggests that moderate-intensity resistance training may provide similar or even greater benefits in controlling systolic blood pressure.

For diastolic blood pressure, significant improvement was observed mainly in the anaerobic exercise group, whereas the aerobic and general mobility groups showed minimal change. One possible explanation is that resistance training may improve arterial compliance and vascular tone more effectively, which can contribute to better regulation of diastolic pressure [3,16]. Cardoso et al. (2010) also reported both short-term and long-term reductions in ambulatory blood pressure following resistance exercise programs. In addition, several comparative studies have shown that resistance exercise positively influences autonomic balance and cardiovascular adaptation, which may further support improvement in diastolic blood pressure [8,12].

Resting heart rate decreased in all three groups, but the greatest reduction was again seen in participants performing anaerobic exercise. Lower resting heart rate is generally associated with improved cardiovascular efficiency and better autonomic control. Previous research has demonstrated that both aerobic and resistance exercise can increase parasympathetic activity while reducing sympathetic overactivity in hypertensive individuals [8,13]. The greater improvement observed after resistance training may be related to enhanced muscular strength and metabolic efficiency, which reduce cardiovascular stress during physical activity and at rest [6,18].

Comparison between groups using one-way ANOVA showed significant differences in systolic blood pressure, diastolic blood pressure, and heart rate after intervention, indicating that the type of exercise influences cardiovascular outcomes. Among all interventions, anaerobic resistance training produced the most pronounced improvement. Similar findings have been described in earlier comparative studies, where controlled resistance exercise improved cardiovascular health and functional performance in hypertensive individuals [11,15,21]. These observations also support current clinical recommendations that consider moderate resistance exercise safe and beneficial for patients with hypertension. [10,11].

These findings are especially relevant in the Indian population, where hypertension prevalence continues to rise and blood pressure control remains inadequate due to limited awareness and insufficient lifestyle intervention programs [2,7,20]. Exercise therapy is a practical and cost-effective approach that can easily be incorporated into physiotherapy and community-based rehabilitation settings. Since Stage-1 hypertension represents an early and potentially manageable phase of the disease, timely exercise intervention may help delay disease progression and reduce long-term dependence on medication [5,13].

In many Indian rehabilitation settings, treatment commonly focuses on walking and mobility exercises. The present findings suggest that adding structured resistance training may provide greater improvement in blood pressure control and cardiovascular efficiency. Previous evidence has shown that resistance exercise improves vascular function, decreases peripheral resistance, and enhances autonomic regulation. Cornelissen and Smart (2013) demonstrated significant reductions in both systolic and diastolic blood pressure following resistance training, while Ghadieh and Saab (2015) reported better cardiovascular regulation when resistance exercise was combined with aerobic activity.

Overall, both aerobic and anaerobic exercise interventions were effective in improving cardiovascular parameters in individuals with Stage-1 hypertension. Nevertheless, resistance training produced greater reductions in systolic blood pressure, diastolic blood pressure, and resting heart rate over the 8-week intervention period. Therefore, inclusion of mild-to-moderate intensity resistance exercise along with aerobic activity may provide additional benefit while designing physiotherapy rehabilitation programs for hypertensive patients. Future studies involving larger sample sizes and longer follow-up periods are recommended to further validate these findings and develop standardized exercise guidelines for hypertension management. [6,19,21].

CONCLUSION

The present study concludes that both aerobic and anaerobic exercise training are effective non-pharmacological interventions for individuals with Stage-1 hypertension; however, anaerobic exercise demonstrated greater improvement in systolic blood pressure, diastolic blood pressure, and resting heart rate after the 8-week training program. The greater effectiveness of anaerobic exercise may be due to its ability to reduce peripheral vascular resistance, improve muscular strength, enhance autonomic balance, and decrease cardiac workload, which together contribute to better cardiovascular regulation. Since Stage-1 hypertension is an early and manageable stage of the disease, incorporating structured resistance training along with aerobic exercise can provide better blood pressure control and may help prevent progression to severe hypertension, making exercise therapy an important and cost-effective strategy in clinical and physiotherapy practice.

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