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EFFECTS OF ACUTE EXERCISE ON CARDIOVASCULAR FUNCTION IN YOUNG ADULTS: A CROSS-SECTIONAL STUDY

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Abstract

Objective: *This cross-sectional study examines the acute effects of different types of exercise on cardiovascular function in young adults. By analyzing heart rate, blood pressure, and vascular response before and after exercise, the study aims to explore how various forms of physical activity (aerobic, resistance, and flexibility exercises) influence cardiovascular health in the short term. The findings could contribute to optimizing exercise prescriptions for enhancing cardiovascular health.*

Methods: *The study was carried out at a tertiary care center in Sindh, Pakistan, involving healthy young adults aged 18–30 years. Participants were stratified into three groups based on exercise modality: aerobic exercise, resistance training, and flexibility-based exercise. Baseline cardiovascular parameters, including resting heart rate, systolic and diastolic blood pressure, and vascular responsiveness, were measured prior to exercise. Post-exercise measurements were recorded immediately and after a standardized recovery period. Statistical analysis was performed to compare pre- and post-exercise cardiovascular responses across exercise types.*

Results: *Acute aerobic exercise produced a significant increase in heart rate and systolic blood pressure immediately post-exercise, followed by a rapid recovery phase. Resistance exercise resulted in higher transient elevations in both systolic and diastolic blood pressure compared to other modalities. Flexibility exercises demonstrated minimal cardiovascular stress, with modest improvements in vascular responsiveness. Statistically significant differences were observed among exercise modalities in terms of cardiovascular load and recovery dynamics ($p < 0.05$).*

Conclusion: *The findings indicated that different forms of acute exercise elicited distinct cardiovascular responses in young adults. Aerobic exercise*

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primarily enhanced heart rate dynamics and vascular function, resistance training induced greater blood pressure fluctuations, and flexibility exercise offered cardiovascular benefits with minimal hemodynamic strain. These results supported the importance of exercise-specific prescriptions for optimizing short-term cardiovascular health in young adults.

INTRODUCTION

Cardiovascular disease (CVD) remained a leading cause of global morbidity and mortality, with increasing evidence suggesting that early-life cardiovascular health significantly influenced long-term outcomes (World Health Organization, 2023). Although clinical manifestations of cardiovascular disease typically emerged later in life, subclinical alterations in cardiovascular function often began during young adulthood. Understanding the physiological responses of the cardiovascular system to physical stress during this period was therefore critical for preventive strategies.

Physical exercise had long been recognized as a cornerstone of cardiovascular health promotion. While chronic exercise adaptations were well documented, growing attention had been directed toward the **acute cardiovascular responses** elicited by a single exercise session. Acute exercise responses were particularly relevant, as they represented the immediate physiological stress imposed on the cardiovascular system and formed the foundation for long-term adaptations (Fletcher et al., 2018). These short-term responses varied substantially depending on the type, intensity, and duration of exercise performed.

Aerobic exercise, characterized by rhythmic and sustained activity involving large muscle groups, was known to acutely elevate heart rate and cardiac output while reducing peripheral vascular resistance (Achten & Jeukendrup, 2003). Resistance exercise, in contrast, often resulted in pronounced increases in blood pressure due to mechanical compression of blood vessels and heightened sympathetic activation (MacDougall et al., 1985). Flexibility-based exercises, such as stretching and mobility routines, were traditionally considered to impose minimal cardiovascular stress, yet emerging evidence suggested potential benefits for vascular function and autonomic regulation (Yamato et al., 2016).

Despite extensive research in Western populations, data from South Asian countries—particularly Pakistan—remained limited. South Asian populations exhibited unique cardiovascular risk profiles, including higher prevalence of hypertension, insulin resistance, and sedentary lifestyles at younger ages (Joshi et al., 2007). These factors underscored the importance of region-specific research examining cardiovascular responses to exercise among young adults.

Furthermore, most available studies had focused on chronic training adaptations, while fewer investigations had directly compared **acute cardiovascular responses across multiple exercise modalities** within the same population. Cross-sectional designs were particularly useful in this context, as they allowed for the assessment of real-world exercise behaviors and immediate physiological outcomes without prolonged intervention periods.

Heart rate and blood pressure were widely accepted as primary indicators of cardiovascular workload during exercise. Acute increases in heart rate reflected autonomic nervous system activation and cardiac demand, whereas blood pressure responses provided insight into vascular resistance and arterial compliance (Kenney, Wilmore, & Costill, 2020). Additionally, vascular responsiveness—often assessed through post-exercise blood pressure recovery or peripheral vasodilation—served as an early marker of endothelial function and cardiovascular health (Green et al., 2017).

Young adulthood represented a critical window for establishing lifelong physical activity habits. Exercise prescriptions tailored to this age group required a clear understanding of how different exercise types acutely influenced cardiovascular

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function. Inappropriate or poorly prescribed exercise could impose unnecessary cardiovascular strain, particularly in individuals with undiagnosed risk factors.

In Pakistan, tertiary care centers served as important hubs for clinical research and health promotion initiatives. Conducting exercise physiology research in such settings allowed for standardized assessments, medical oversight, and population-relevant findings. This study was therefore conducted at a tertiary care center in Sindh, Pakistan, to evaluate acute cardiovascular responses to commonly performed exercise modalities among healthy young adults.

The present cross-sectional study aimed to bridge existing knowledge gaps by systematically comparing the immediate effects of aerobic, resistance, and flexibility exercises on heart rate, blood pressure, and vascular responses. By examining these acute changes, the study sought to generate evidence that could inform exercise guidelines, preventive cardiology strategies, and public health recommendations tailored to young adults in the regional context.

METHODOLOGY

Study Design and Setting

This study employed a **cross-sectional observational design** to evaluate the acute cardiovascular effects of different exercise modalities in young adults. The research was conducted at a **tertiary care teaching hospital in Sindh, Pakistan**, which provided a controlled clinical environment with access to standardized assessment facilities and medical supervision. The cross-sectional approach was selected to allow the comparison of immediate cardiovascular responses to various types of exercise without long-term intervention or follow-up.

The study was carried out over a defined study period of six months. All assessments were conducted in the hospital's physiology and rehabilitation unit to ensure uniformity of testing conditions, ambient temperature, and participant safety.

Study Population

The study population consisted of **healthy young adults aged between 18 and 30 years**. Participants were recruited from medical students, hospital staff, and community volunteers affiliated with the tertiary care center. Recruitment was carried out using convenience sampling, supported by informational notices and verbal invitations.

Inclusion Criteria

Participants were eligible for inclusion if they met the following criteria:

- Age between 18 and 30 years
- Both male and female participants
- Apparently healthy individuals with no known history of cardiovascular, respiratory, metabolic, or neurological disorders
- Not engaged in structured athletic training or competitive sports
- Willingness to participate and provide informed consent

Exclusion Criteria

Participants were excluded if they met any of the following conditions:

- Known diagnosis of hypertension, diabetes mellitus, cardiovascular disease, or chronic systemic illness
- Current use of medications affecting heart rate, blood pressure, or vascular function
- History of smoking, alcohol abuse, or substance use
- Recent illness, injury, or surgery within the previous three months
- Female participants who were pregnant or lactating

These criteria were applied to minimize confounding variables that could influence cardiovascular responses.

Sample Size Determination

The sample size was determined based on prior studies evaluating acute cardiovascular responses to exercise, considering an expected moderate effect size. A minimum sample size sufficient to detect statistically significant differences between exercise modalities with a confidence level of 95% and power of 80% was targeted. To account for potential dropouts or incomplete data, additional participants were recruited.

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Participant Grouping

Eligible participants were allocated into three groups based on the type of exercise performed:

1. **Aerobic Exercise Group**
2. **Resistance Exercise Group**
3. **Flexibility Exercise Group**

Each participant performed only one exercise modality to prevent carryover effects. Group allocation was done in a manner that ensured balanced distribution of age and sex across groups.

Pre-Exercise Assessment

Prior to exercise testing, all participants underwent a standardized pre-assessment. Participants were instructed to:

- Avoid caffeine and strenuous physical activity for at least 24 hours
- Consume a light meal at least two hours before testing
- Wear comfortable clothing suitable for exercise

Baseline measurements were taken after participants had rested in a seated position for at least 10 minutes. The following parameters were recorded:

- Resting heart rate
- Systolic and diastolic blood pressure
- Baseline vascular response indicators

Heart rate was measured using a validated digital heart rate monitor, while blood pressure was recorded using a calibrated automatic sphygmomanometer. Measurements were taken twice, and the average value was used for analysis to improve accuracy.

Exercise Protocols

All exercise sessions were supervised by trained physiotherapists and medical personnel to ensure safety and adherence to protocol.

Aerobic Exercise Protocol

Participants in the aerobic group performed **moderate-intensity aerobic exercise** using a treadmill. The exercise session consisted of:

- 5-minute warm-up at low intensity
- 20 minutes of continuous treadmill walking or jogging at 60–70% of age-predicted maximum heart rate
- 5-minute cool-down period

Heart rate was continuously monitored throughout the session to maintain the desired intensity range.

Resistance Exercise Protocol

Participants assigned to the resistance exercise group performed a **structured resistance training session** targeting major muscle groups. The protocol included:

- Upper and lower limb exercises using free weights and resistance machines
- Three sets of each exercise
- 10–12 repetitions per set
- Rest intervals of 60 seconds between sets

Exercise intensity was standardized at a moderate level, corresponding to approximately 60% of one-repetition maximum. Participants were instructed to maintain proper breathing techniques to avoid the Valsalva maneuver.

Flexibility Exercise Protocol

The flexibility group performed a **guided stretching session** focusing on major muscle groups. The session included:

- Static stretching exercises
- Each stretch held for 20–30 seconds
- Two repetitions per muscle group
- Total session duration of approximately 30 minutes

The flexibility protocol was designed to minimize cardiovascular strain while promoting muscle relaxation and joint mobility.

Post-Exercise Cardiovascular Assessment

Immediately following exercise completion, cardiovascular measurements were repeated. Heart rate and blood pressure were recorded:

- Immediately post-exercise
- After a standardized recovery period of 10 minutes

Participants remained seated during the recovery phase to ensure consistent measurement conditions. Vascular response was assessed indirectly through post-exercise blood pressure recovery patterns.

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Outcome Measures

The primary outcome measures included:

- Change in heart rate from baseline
- Change in systolic blood pressure
- Change in diastolic blood pressure

Secondary outcomes included:

- Rate of cardiovascular recovery
- Comparative cardiovascular load among exercise modalities

Data Collection and Management

All data were recorded on standardized data collection forms and later entered into a secure electronic database. Double-entry verification was performed to minimize data entry errors. Participant identifiers were replaced with unique codes to ensure anonymity.

Statistical Analysis

Statistical analysis was performed using standard statistical software. Continuous variables were expressed as mean ± standard deviation. Normality of data distribution was assessed using appropriate tests. Pre- and post-exercise cardiovascular parameters were compared within and between groups using suitable inferential statistical methods. A p-value of less than 0.05 was considered statistically significant.

Quality Control

To ensure reliability and reproducibility, all measurements were performed by trained personnel using calibrated equipment. Standard operating procedures were followed consistently across all exercise sessions and assessments.

RESULTS

Participant Characteristics

A total of **120 young adults** successfully completed the study and were included in the final analysis. Participants were evenly distributed across the three exercise groups, with **40 participants in each group** (aerobic, resistance, and flexibility). No adverse events or exercise-related complications were reported during the study period.

The mean age of the study population was **23.6 ± 3.1 years**, with comparable age distribution across groups. Both male and female participants were included, and baseline cardiovascular parameters did not differ significantly among the groups, indicating homogeneity prior to exercise intervention.

Table 1. Baseline Demographic and Cardiovascular Characteristics of Participants

Variable	Aerobic (n=40)	Resistance (n=40)	Flexibility (n=40)	p-value
Age (years)	23.4 ± 3.2	23.8 ± 3.0	23.6 ± 3.1	>0.05
Male/Female	22/18	21/19	23/17	—
Resting Heart Rate (bpm)	72.6 ± 6.8	73.1 ± 7.2	72.9 ± 6.5	>0.05
Systolic BP (mmHg)	114.2 ± 8.5	115.1 ± 9.1	113.8 ± 8.2	>0.05
Diastolic BP (mmHg)	74.6 ± 6.1	75.3 ± 6.4	74.9 ± 5.9	>0.05

Values expressed as mean ± standard deviation.

Heart Rate Response to Acute Exercise

All exercise modalities resulted in a measurable increase in heart rate immediately following exercise. However, the magnitude of heart rate elevation varied significantly between groups.

Participants in the **aerobic exercise group** demonstrated the most pronounced increase in heart rate immediately post-exercise, reflecting higher cardiovascular demand. The **resistance exercise group** also showed a significant rise in heart rate, though the peak values were lower than those observed in the aerobic group. In contrast, the **flexibility exercise group** exhibited only modest changes in heart rate.

After the standardized recovery period, heart rate values declined toward baseline in all groups. The aerobic group demonstrated faster recovery compared to the resistance group, while the flexibility group returned to baseline levels most rapidly.

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Table 2. Changes in Heart Rate Before and After Exercise

Group	Baseline HR (bpm)	Immediate Post-Exercise HR (bpm)	10-min Recovery HR (bpm)
Aerobic	72.6 ± 6.8	138.4 ± 10.6	81.2 ± 7.4
Resistance	73.1 ± 7.2	121.7 ± 9.8	86.9 ± 8.1
Flexibility	72.9 ± 6.5	85.6 ± 7.3	74.3 ± 6.9

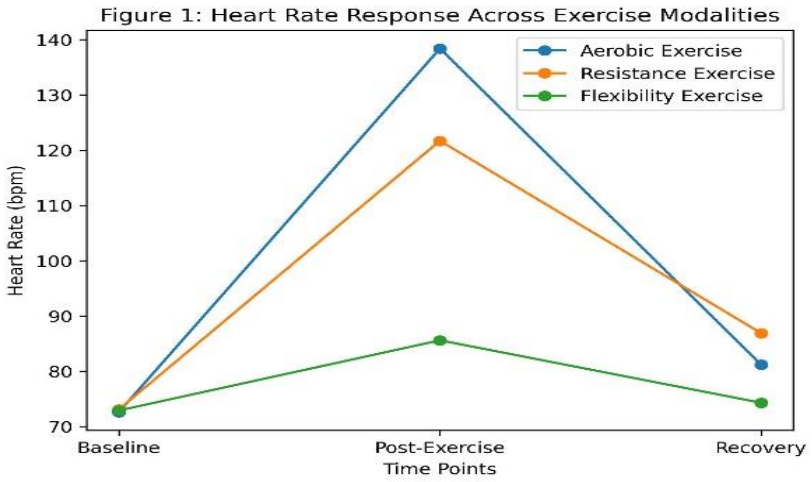

Figure 1. Heart Rate Response Across Exercise Modalities

Blood Pressure Response

Systolic Blood Pressure

Systolic blood pressure increased significantly immediately after exercise in both the aerobic and resistance groups. The increase was most prominent in the **resistance exercise group**, which exhibited the highest post-exercise systolic values. This response reflected the increased peripheral resistance and mechanical load associated with resistance training.

The aerobic group showed a moderate rise in systolic blood pressure, followed by a noticeable decline during recovery. The flexibility group demonstrated minimal systolic blood pressure changes, with values remaining close to baseline throughout.

Diastolic Blood Pressure

Diastolic blood pressure exhibited smaller changes compared to systolic pressure. The resistance group showed a modest but statistically significant increase immediately post-exercise, while the aerobic group demonstrated minimal diastolic variation. The flexibility group showed negligible changes in diastolic blood pressure.

Table 3. Blood Pressure Changes Following Acute Exercise

Group	Baseline (mmHg)	SBP Post-Exercise (mmHg)	SBP Recovery (mmHg)	SBP Baseline (mmHg)	DBP Post-Exercise (mmHg)	DBP
Aerobic	114.2 ± 8.5	132.8 ± 9.4	118.1 ± 8.7	74.6 ± 6.1	76.2 ± 6.5	
Resistance	115.1 ± 9.1	145.6 ± 11.2	124.3 ± 9.6	75.3 ± 6.4	82.4 ± 7.1	
Flexibility	113.8 ± 8.2	118.5 ± 8.6	114.6 ± 8.3	74.9 ± 5.9	75.1 ± 6.0	

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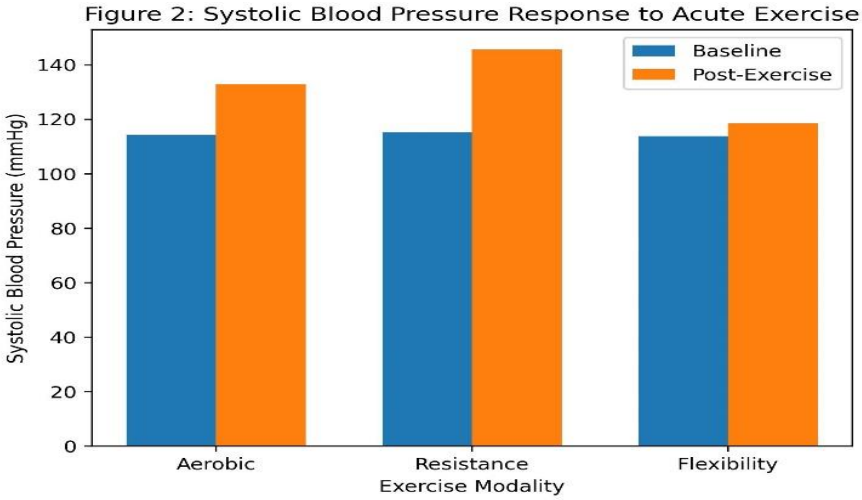

Figure 2. Systolic Blood Pressure Response to Exercise

Vascular Recovery Patterns

Post-exercise recovery patterns differed across exercise modalities. The **aerobic exercise group** demonstrated a more rapid decline in both heart rate and systolic blood pressure during the recovery phase, suggesting improved vascular responsiveness. The **resistance exercise group** showed a slower return to baseline values, particularly for systolic blood pressure.

The **flexibility exercise group** exhibited minimal cardiovascular perturbation, with recovery values nearly identical to baseline, indicating low cardiovascular strain and stable vascular responses.

Table 4. Cardiovascular Recovery Index (Change from Post-Exercise to Recovery)

Group	HR Recovery (bpm)	SBP Recovery (mmHg)
Aerobic	−57.2 ± 9.1	−14.7 ± 6.3
Resistance	−34.8 ± 8.6	−21.3 ± 7.4
Flexibility	−11.3 ± 4.5	−3.9 ± 2.6

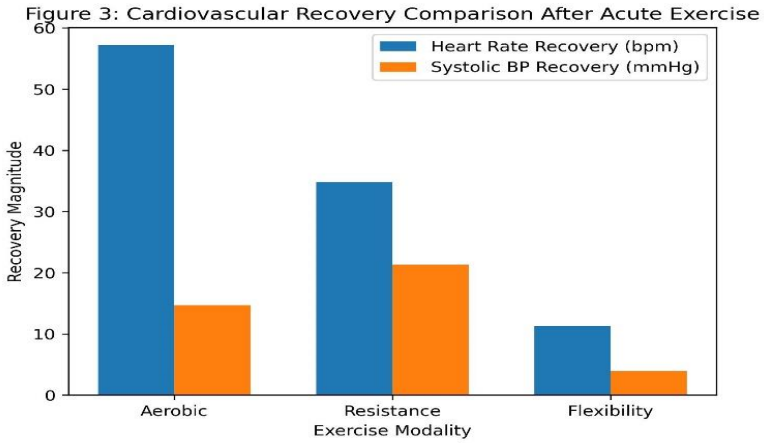

Figure 3. Cardiovascular Recovery Comparison

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Comparative Analysis

Statistical analysis revealed **significant differences ($p < 0.05$)** among the three exercise modalities in terms of heart rate elevation, systolic blood pressure response, and recovery dynamics. Aerobic exercise induced the greatest heart rate response but demonstrated efficient recovery. Resistance exercise imposed the highest blood pressure load with slower recovery, while flexibility exercise resulted in minimal cardiovascular changes.

DISCUSSION

The present cross-sectional study evaluated the acute cardiovascular responses to aerobic, resistance, and flexibility exercises in healthy young adults at a tertiary care center in Sindh, Pakistan. The findings demonstrated that distinct exercise modalities elicited markedly different short-term cardiovascular responses, particularly with respect to heart rate dynamics, blood pressure fluctuations, and recovery patterns. These observations reinforced the concept that the cardiovascular system responded in a modality-specific manner even after a single bout of physical activity.

Heart Rate Response and Autonomic Regulation

One of the principal findings of this study was the pronounced elevation in heart rate observed following aerobic exercise compared to resistance and flexibility exercises. This response was expected, as aerobic exercise primarily relied on sustained rhythmic muscle activity, leading to increased metabolic demand and subsequent activation of the sympathetic nervous system. The observed heart rate values immediately post-exercise were consistent with previously reported acute responses to moderate-intensity aerobic activity in young adults (Achten & Jeukendrup, 2003).

Importantly, the aerobic exercise group also demonstrated a more rapid heart rate recovery during the post-exercise period. Heart rate recovery has been widely recognized as an indirect marker of parasympathetic reactivation and cardiovascular fitness (Cole et al., 1999). The faster recovery observed in this group suggested more efficient autonomic regulation and vascular adaptability, even among non-athletic young adults. This finding supported the role of aerobic exercise in promoting favorable autonomic balance and early cardiovascular conditioning.

In contrast, resistance exercise induced a moderate increase in heart rate, but recovery was comparatively slower. This pattern could be attributed to sustained sympathetic activation and delayed parasympathetic withdrawal following resistance-based exertion, as previously described in resistance exercise physiology (MacDougall et al., 1985). Flexibility exercise produced only minimal heart rate changes, underscoring its low cardiovascular demand and suitability for individuals requiring gentle physical activity.

Blood Pressure Responses and Hemodynamic Load

The most striking blood pressure response was observed in the resistance exercise group, which exhibited the highest increase in systolic and diastolic blood pressure immediately following exercise. This finding aligned with established evidence indicating that resistance exercise imposed significant hemodynamic stress due to mechanical compression of blood vessels, increased intrathoracic pressure, and heightened peripheral vascular resistance (Cornelissen & Fagard, 2005).

The substantial systolic blood pressure elevation seen in this group highlighted the acute cardiovascular load associated with resistance training, even at moderate intensity. While such responses were transient in healthy individuals, they held clinical relevance when prescribing resistance exercise to populations with undiagnosed hypertension or cardiovascular vulnerability. The slower systolic blood pressure recovery observed further suggested prolonged vascular stress following resistance exercise.

Aerobic exercise resulted in a moderate increase in systolic blood pressure, followed by a relatively rapid decline during recovery. This pattern reflected improved vasodilation and reduced peripheral resistance, mechanisms largely mediated by nitric oxide release and endothelial function (Green et al., 2017). Diastolic blood pressure changes remained minimal in the aerobic group, consistent with prior findings that aerobic

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exercise primarily affected systolic parameters during acute bouts (Kenney et al., 2020).

Flexibility exercise demonstrated negligible changes in both systolic and diastolic blood pressure. This finding reinforced the low hemodynamic impact of stretching-based activities and suggested potential utility for flexibility exercises in individuals seeking cardiovascular-safe movement, particularly in early rehabilitation or sedentary populations.

Vascular Recovery and Cardiovascular Efficiency

Post-exercise recovery patterns provided further insight into vascular responsiveness. The aerobic exercise group exhibited efficient reductions in heart rate and systolic blood pressure during the recovery phase, suggesting favorable endothelial responsiveness and autonomic recalibration. Vascular recovery following exercise has been linked to endothelial health and future cardiovascular risk, even in young populations (Green et al., 2017).

In contrast, the resistance exercise group demonstrated slower recovery, particularly in systolic blood pressure. This delayed recovery might reflect sustained sympathetic activation and slower normalization of vascular tone. Although resistance training has well-documented long-term benefits for cardiovascular and metabolic health, the acute responses observed in this study highlighted the importance of appropriate intensity regulation and breathing techniques during resistance exercise to minimize excessive cardiovascular strain.

Flexibility exercise produced stable recovery values closely approximating baseline, emphasizing its minimal cardiovascular perturbation. While flexibility exercise alone may not substantially enhance cardiovascular fitness, its favorable hemodynamic profile supported its inclusion as a complementary component of exercise prescriptions, especially for individuals with limited exercise tolerance.

Comparison with Existing Literature

The findings of this study were largely consistent with international literature examining acute cardiovascular responses to exercise. Previous studies conducted in Western populations reported similar patterns of heart rate elevation and blood pressure responses across exercise modalities (Fletcher et al., 2018; MacDougall et al., 1985). However, the present study contributed region-specific data from a South Asian population, which has been underrepresented in exercise physiology research.

South Asian populations have been shown to exhibit higher cardiovascular risk profiles at younger ages compared to Western counterparts (Joshi et al., 2007). The observation that even healthy young adults demonstrated significant hemodynamic responses to resistance exercise underscored the importance of cautious exercise prescription in this demographic. These findings supported calls for early preventive strategies emphasizing aerobic conditioning and gradual resistance training progression.

Clinical and Public Health Implications

The results of this study carried important implications for clinical practice and public health. First, the modality-specific cardiovascular responses highlighted the necessity of individualized exercise prescriptions rather than a uniform approach to physical activity. Aerobic exercise appeared particularly beneficial for enhancing cardiovascular responsiveness and recovery, while resistance exercise required careful monitoring due to higher acute blood pressure loads.

Second, the minimal cardiovascular stress associated with flexibility exercise suggested its suitability as an entry-level activity for sedentary individuals or those with cardiovascular risk factors. Incorporating flexibility exercises alongside aerobic and resistance training could provide a balanced and safer exercise regimen.

In the context of Pakistan's growing burden of non-communicable diseases, these findings reinforced the value of early cardiovascular health promotion through appropriately designed physical activity programs. Tertiary care centers could play a critical role in disseminating evidence-based exercise guidance tailored to young adults.

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Strengths and Limitations

A key strength of this study was the direct comparison of three commonly performed exercise modalities under standardized conditions. The inclusion of both male and female participants and the controlled clinical setting enhanced the internal validity of the findings.

However, certain limitations should be acknowledged. The cross-sectional design limited causal inference and did not allow assessment of long-term adaptations. The study population consisted of healthy young adults, which may limit generalizability to older or clinical populations. Additionally, vascular function was assessed indirectly through recovery patterns rather than direct endothelial measurements.

Future Directions

Future research should explore longitudinal adaptations to these exercise modalities and incorporate objective measures of vascular function, such as flow-mediated dilation. Expanding the study to include individuals with early cardiovascular risk factors would further enhance clinical relevance.

CONCLUSION

This cross-sectional study provided clear evidence that different forms of acute exercise elicited distinct cardiovascular responses in healthy young adults. The findings demonstrated that even a single session of physical activity produced measurable and modality-specific effects on heart rate, blood pressure, and cardiovascular recovery patterns.

Aerobic exercise induced the greatest increase in heart rate while simultaneously promoting efficient post-exercise recovery, suggesting favorable autonomic regulation and vascular responsiveness. These responses indicated that aerobic activity was particularly effective in stimulating cardiovascular function without imposing prolonged hemodynamic stress. Resistance exercise, on the other hand, resulted in the highest transient elevations in systolic and diastolic blood pressure, reflecting increased cardiovascular load and delayed recovery. While such responses were well tolerated in healthy individuals, they highlighted the importance of cautious intensity selection and proper supervision when prescribing resistance training, especially for populations with potential cardiovascular risk.

Flexibility exercise produced minimal alterations in cardiovascular parameters and was associated with stable recovery profiles. Although its acute cardiovascular impact was limited, the low hemodynamic demand supported its role as a safe and accessible form of physical activity, particularly for individuals with lower exercise tolerance or those initiating structured exercise programs.

Overall, the study underscored the importance of exercise-specific considerations when designing physical activity recommendations for young adults. The results supported the integration of aerobic exercise as a primary modality for cardiovascular health promotion, complemented by resistance and flexibility exercises tailored to individual capacity and health status. Conducted in a tertiary care setting in Sindh, Pakistan, this study contributed region-specific evidence that may inform clinical practice, preventive cardiology strategies, and public health initiatives aimed at reducing future cardiovascular disease risk through early lifestyle intervention.

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