Comparative Cardiovascular Responses to Exercise Among Physically Active and Inactive Adolescents

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ABSTRACT
Physical activity is important for maintaining cardiovascular health and improving cardiorespiratory fitness among adolescents and young adults. Regular exercise enhances autonomic regulation and cardiovascular adaptation, whereas physical inactivity is associated with poor cardiovascular fitness and increased future cardiovascular disease risk. The study aimed to compare cardiovascular responses to exercise among physically active and inactive adolescents and young adults. A cross-sectional comparative study was conducted among 66 participants aged 13–19 years. Resting and post-exercise heart rate, systolic blood pressure, and diastolic blood pressure were measured using a pulse oximeter and digital blood pressure monitor. Height and weight were measured for body mass index calculation. Participants engaged in moderate physical activity involving running and field games. Independent and paired samples t-tests were used for statistical analysis at $p < 0.05$. Physically inactive participants demonstrated significantly higher post-exercise heart rates (139.59 ± 14.15 bpm) compared with physically active participants (120.62 ± 9.01 bpm) ($p < 0.001$). Heart rate change following exercise was also significantly greater among inactive participants (57.47 ± 17.55 bpm vs 34.94 ± 10.78 bpm; $p < 0.001$). Significant increases in systolic blood pressure and decreases in diastolic blood pressure were observed after exercise ($p < 0.001$). Physically inactive participants also had higher body mass index and resting blood pressure values. Physically active individuals demonstrated more favorable cardiovascular responses to exercise compared with inactive individuals, highlighting the importance of regular physical activity in promoting cardiovascular health.
Keywords: Cardiovascular response; physical activity; heart rate; blood pressure; adolescents; exercise.

INTRODUCTION

Exercise produces important physiological changes within the cardiovascular system to meet increased metabolic demands during physical activity. During exercise, heart rate, blood pressure, cardiac output, and oxygen consumption increase to maintain adequate perfusion of active muscles and vital organs [1]. These responses involve changes in stroke volume, vascular resistance, and autonomic regulation, with sympathetic nervous system activity increasing and parasympathetic influence decreasing, thereby enhancing cardiac activity and blood flow to active muscles [2]. As exercise intensity increases, heart rate and systolic blood pressure rise progressively to improve oxygen delivery and nutrient transport to working tissues [3]. In healthy adolescents, such adaptations contribute significantly to physical fitness and long-term cardiovascular health.

Adolescence represents a critical developmental stage during which lifestyle behaviours such as physical activity and sedentary habits strongly influence future cardiovascular outcomes [4]. Regular physical activity has been associated with improved cardiovascular efficiency, lower resting heart rate, enhanced autonomic regulation, healthier body composition, and better blood pressure control among adolescents [5]. In contrast, physical inactivity has become increasingly common worldwide and is strongly linked with obesity, poor cardiorespiratory fitness, elevated blood pressure, and increased cardiovascular disease risk later in life [6]. Among adolescents, cardiovascular responses are further influenced by age, sex, body composition, fitness level, and habitual physical activity [7].

Heart rate is one of the most sensitive indicators of cardiovascular adaptation during exercise. Parasympathetic withdrawal and sympathetic stimulation produce progressive increases in heart rate proportional to exercise intensity [2]. Physically active adolescents generally demonstrate lower resting heart rates and faster recovery following exercise because of improved autonomic function and cardiovascular conditioning [8]. Carnethon et al. reported that physically active individuals exhibit faster heart rate recovery due to rapid parasympathetic reactivation after exercise cessation [9], while delayed heart rate recovery has been associated with poor cardiovascular fitness and increased cardiovascular disease risk [10]. Conversely, inactive adolescents often exhibit elevated resting heart rates and delayed recovery, indicating reduced cardiovascular efficiency [11]. Heart rate variability (HRV), which reflects beat-to-beat fluctuations in cardiac rhythm, is also widely used to assess autonomic regulation, with higher HRV indicating enhanced parasympathetic activity and better cardiovascular adaptability [12]. Mongin et al. demonstrated that trained adolescents showed superior HRV responses during graded exercise testing compared with less active individuals [13].

Blood pressure response during exercise is equally important for assessing cardiovascular function. Normally, systolic blood pressure increases during exercise due to elevated cardiac output, whereas diastolic blood pressure remains relatively stable because of peripheral vasodilation [7]. Regular physical activity improves endothelial function, vascular elasticity, and nitric oxide-mediated vasodilation, thereby improving blood flow regulation [14], and has been shown to reduce resting blood pressure and improve vascular responsiveness among adolescents [15]. Physical inactivity, by contrast, has been associated with exaggerated blood pressure responses. Alvarez-Pitti et al. reported that such exaggerated responses may indicate early vascular dysfunction and increased future risk of hypertension [7], while Sasaki et al. observed abnormal systolic blood pressure responses during treadmill testing among children with lower fitness levels [16]. Obesity and sedentary behaviour further contribute to impaired vasodilatory responses and abnormal blood pressure regulation [17], and exaggerated responses have also been linked with endothelial dysfunction, arterial stiffness, and autonomic imbalance [18].

Body mass index (BMI) further influences cardiovascular adaptation to exercise. Elevated BMI among adolescents is strongly associated with hypertension, insulin resistance, dyslipidaemia, reduced physical fitness, and increased cardiovascular disease risk [19]. Obese adolescents generally demonstrate higher resting heart rates, elevated blood pressure, reduced exercise tolerance, and impaired autonomic regulation compared with adolescents with normal BMI [20]. Physical inactivity contributes substantially to elevated BMI, with Guthold et al. reporting increasing global prevalence of insufficient physical activity among adolescents [6]. Watts et al. demonstrated that exercise training significantly improved vascular function and cardiovascular adaptation among obese children [15], while aerobic and resistance exercise programmes have been shown to reduce BMI and improve blood pressure regulation among adolescents [21].

Assessment of cardiovascular responses to exercise is therefore important for early identification of cardiovascular abnormalities and future disease risk among adolescents, given that many cardiovascular risk factors originate during this developmental period. Despite growing evidence, comparative data on cardiovascular responses to exercise among physically active and inactive adolescents remain limited, particularly in developing countries.

This study aimed to compare heart rate, blood pressure, and BMI responses to exercise among physically active and inactive adolescents. The findings may contribute to improved understanding of adolescent cardiovascular health and reinforce the importance of regular physical activity in preventing future cardiovascular disease [22].

METHODOLOGY

Study Design

This study employed a cross-sectional comparative field-based design to assess and compare cardiovascular responses to exercise among physically active and physically inactive adolescents and young adults. The design was appropriate for evaluating physiological differences between two independent groups following a single standardized exercise session.

Study Setting

The study was carried out in selected school and community environments that provided suitable open spaces for physical activity, including school fields and sports courts. These settings allowed participants to engage in naturalistic yet structured physical activities such as running, football, and basketball under supervised conditions.

Study Population

The study population consisted of adolescents, most within 13 to 18 years. Participants were categorized into physically active and physically inactive groups based on their habitual physical activity levels. The physically active group included individuals who engaged in structured exercise at least three times per week, while the inactive group comprised individuals who did not participate in regular physical activity.

Sample Size and Sampling Technique

A total sample size of approximately 66 participants was recruited for the study based on availability and study feasibility, with relatively balanced representation between active and inactive groups. A purposive sampling technique was used to select participants based on predefined inclusion criteria and availability. Efforts were made to ensure a fair representation of both male and female participants within the sample.

Inclusion and Exclusion Criteria

Participants included in the study were apparently healthy individuals within the specified age range who were capable of performing moderate physical activity. Individuals with known cardiovascular, respiratory, or musculoskeletal conditions that could affect exercise performance were excluded. Participants who were unable to complete the exercise protocol or who withdrew during the study were also excluded from the final analysis.

Data Collection Instruments

Data were collected using standard field-based measurement tools. A digital pulse oximeter was used to measure heart rate in beats per minute (bpm), while a digital blood pressure monitor was used to measure systolic and diastolic blood pressure in millimetres of mercury (mmHg). A weighing scale and stadiometer were used to measure body weight and height, which were used to calculate body mass index (BMI).

Study Variables

The independent variable was physical activity status, categorized as active or inactive. The dependent variables included resting and post-exercise heart rate, systolic blood pressure, diastolic blood pressure, and body mass index.

Data Collection Procedure

Participants were assigned unique identification codes to maintain confidentiality. Anthropometric measurements, including height and weight, were taken to compute BMI. Participants were then allowed to rest in a seated position for five minutes to establish baseline cardiovascular readings. Resting heart rate was measured using a pulse oximeter, while resting blood pressure was recorded using a digital blood pressure monitor. Thereafter, participants engaged in a standardized exercise session involving continuous running or structured field games such as football or basketball for approximately fifteen to twenty minutes at moderate intensity. Immediately after exercise, heart rate and blood pressure were measured within 30 to 60 seconds to capture post-exercise cardiovascular responses.

Data Analysis

Data were entered and analyzed using SPSS software. Descriptive statistics, including means and standard deviations, were used to summarize participant characteristics and cardiovascular variables. Independent samples t-tests were used to compare cardiovascular responses between physically active and inactive groups, while paired samples t-tests were used to assess changes between resting and post-exercise values within each group. Statistical significance was set at $p < 0.05$.

Ethical Considerations

Ethical approval was obtained from the appropriate institutional authorities prior to data collection. Informed consent was obtained from all participants, and parental consent was secured for minors. Participation was voluntary, and participants were informed of their right to withdraw at any time without penalty. All data collected were treated with strict confidentiality and used strictly for academic purposes.

RESULTS

A total of 66 participants were included in the study, comprising 32 physically inactive participants and 34 physically active participants. Descriptive statistics for baseline cardiovascular characteristics and anthropometric variables are presented in Table 1. Assessment of normality using the Shapiro–Wilk test indicated that the study variables were approximately normally distributed ($p > 0.05$). Visual inspection of histograms and normal Q-Q plots also demonstrated acceptable distribution patterns for the cardiovascular variables. Therefore, parametric statistical tests, including independent samples t-tests and paired samples t-tests, were considered appropriate for further analysis.

Table 1: Baseline Characteristics and Descriptive Statistics of Participants

Variable	Inactive (n=32) Mean ± SD	Active (n=34) Mean ± SD
Age (years)	15.97 ± 1.43	15.24 ± 2.20
BMI (kg/m²)	28.71 ± 2.24	25.63 ± 1.11
HR Rest (bpm)	82.13 ± 8.67	85.68 ± 7.56
SBP Rest (mmHg)	117.91 ± 6.32	109.91 ± 7.81
DBP Rest (mmHg)	79.16 ± 10.05	70.62 ± 9.75

Table 1 presents the baseline characteristics and resting cardiovascular parameters of the study participants. Physically inactive participants were slightly older than physically active participants. The inactive group also demonstrated a higher mean body mass index compared with the active group. Resting heart rate was relatively comparable between both groups, although slightly higher among active participants compared with inactive In contrast, resting systolic and diastolic blood pressure values were higher among physically inactive participants. These findings suggest that physically inactive participants exhibited relatively higher baseline cardiovascular risk indicators compared with physically active participants.

Table 2: Comparison of Post-Exercise Cardiovascular Responses Between Physically Active and Inactive Participants

Variable	Inactive Mean ± SD	Active Mean ± SD	t-value	p-value
HR Post (bpm)	139.59 ± 14.15	120.62 ± 9.01	6.541	<0.001
HR Change	57.47 ± 17.55	34.94 ± 10.78	6.327	<0.001

SBP Change (mmHg)	15.25 ± 11.46	11.24 ± 18.29	1.061	0.293
DBP Change (mmHg)	-7.78 ± 9.89	-5.24 ± 10.45	-1.015	0.314

As shown in Table 2, physically inactive participants demonstrated significantly higher post-exercise heart rate responses and greater heart rate changes compared with physically active participants ($p < 0.001$). However, no statistically significant differences were observed in systolic or diastolic blood pressure changes between groups.

Table 3: Comparison of Resting and Post-Exercise Cardiovascular Parameters Among Participants

Variable	Rest Mean ± SD	Post-Exercise Mean ± SD	t-value	p-value
Heart Rate (bpm)	83.96 ± 8.25	129.82 ± 15.10	-20.373	<0.001
SBP (mmHg)	113.79 ± 8.14	126.97 ± 15.09	-6.962	<0.001
DBP (mmHg)	74.76 ± 10.72	68.29 ± 10.64	5.159	<0.001

Table 3 demonstrates significant cardiovascular responses following exercise. Heart rate and systolic blood pressure increased significantly after exercise, while diastolic blood pressure decreased significantly ($p < 0.001$).

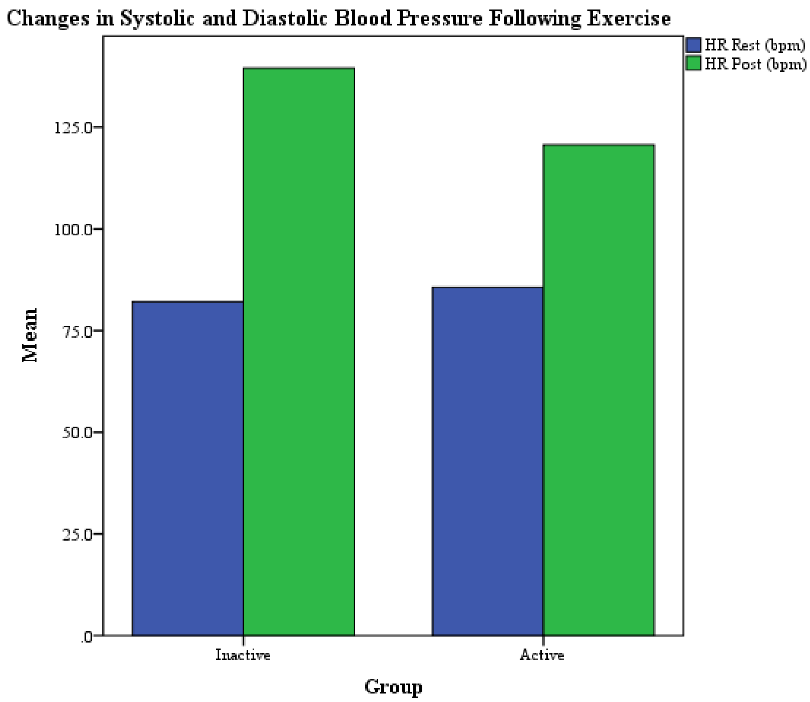

Figure 1: Comparison of Resting and Post-Exercise Heart Rate Between Physically Active and Inactive Participants

Figure 1 illustrates that physically inactive participants demonstrated higher post-exercise heart rate values compared with physically active participants, indicating greater cardiovascular strain and lower exercise adaptation among inactive individuals.

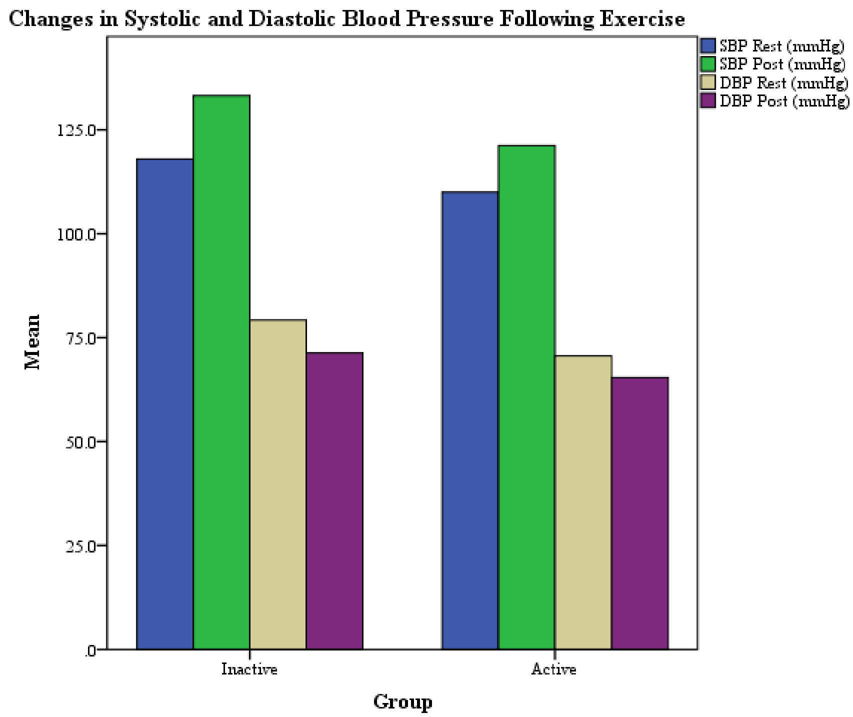

Figure 2: Changes in Systolic and Diastolic Blood Pressure Following Exercise

Figure 2 demonstrates that systolic blood pressure increased following exercise, whereas diastolic blood pressure decreased after exercise among both physically active and inactive participants.

DISCUSSION

This study compared cardiovascular responses to exercise between physically active and physically inactive adolescents and young adults using heart rate and blood pressure measurements obtained before and after exercise. The findings demonstrated significant differences in cardiovascular adaptation between both groups, particularly in heart rate response following exercise. Physically inactive participants exhibited significantly higher post-exercise heart rates and greater heart rate changes compared with physically active participants, suggesting lower cardiovascular efficiency and reduced exercise adaptation among inactive individuals.

The higher post-exercise heart rate observed among physically inactive participants is consistent with previous studies reporting poorer autonomic regulation and lower cardiorespiratory fitness among sedentary adolescents [6,13]. Regular physical activity improves vagal tone and autonomic balance, resulting in more efficient cardiovascular responses during exercise [5,12]. Physically active participants in this study demonstrated smaller increases in heart rate following exercise, indicating better cardiovascular conditioning and reduced physiological strain during physical activity. Similar findings were reported by Carnethon et al., who observed faster heart rate recovery and improved autonomic regulation among physically active individuals [14].

Although resting heart rate was slightly higher among physically active participants, the difference was not statistically significant. This finding differs slightly from studies reporting lower resting heart rates among trained individuals due to enhanced parasympathetic activity [6]. The similarity observed in this study may be related to differences in individual fitness levels, emotional state during measurement, exercise intensity, or age variations among participants.

The study also demonstrated significant increases in systolic blood pressure following exercise. This finding agrees with established physiological principles showing that systolic blood pressure rises during exercise because of increased cardiac output and oxygen demand [1,10]. Such increases are considered normal cardiovascular adaptations that support metabolic activity during exercise [7]. However, although inactive participants showed slightly greater systolic blood pressure changes than active participants, the difference between groups was not statistically significant. This may suggest that the exercise activities performed were not intense enough to produce marked differences between groups.

Diastolic blood pressure decreased significantly following exercise among participants, which is consistent with exercise-induced vasodilation and reduced peripheral vascular resistance [7,18]. Similar findings have been reported in previous studies involving adolescents and young adults [19]. Although inactive participants demonstrated slightly greater reductions in diastolic blood pressure, the difference between groups was not statistically significant.

An important finding of this study was the higher body mass index observed among physically inactive participants. Elevated BMI has been associated with impaired cardiovascular fitness, poor autonomic regulation, and abnormal cardiovascular responses during exercise

[20,21]. Increased adiposity increases cardiac workload and may contribute to reduced exercise tolerance and exaggerated cardiovascular strain. The findings therefore support previous reports linking sedentary lifestyles with obesity and poorer cardiovascular health among adolescents [4].

The results further support evidence that regular physical activity improves cardiovascular adaptation and cardiorespiratory fitness. Exercise training has been shown to enhance endothelial function, vascular elasticity, autonomic regulation, and oxygen utilization efficiency [18,23]. These physiological adaptations likely contributed to the more favorable heart rate responses observed among physically active participants.

The findings of this study are clinically important because abnormal exercise-induced cardiovascular responses such as exaggerated heart rate changes, elevated BMI, and poor exercise tolerance may indicate increased future cardiovascular risk [8,15,24]. Since many cardiovascular risk factors originate during adolescence, early identification of impaired cardiovascular adaptation may support preventive interventions.

Despite these findings, the study had limitations including a relatively small sample size and the use of field-based exercise activities rather than laboratory-controlled testing. Additionally, heart rate variability and oxygen consumption were not assessed because of limited equipment availability. Nevertheless, the study demonstrates that simple tools such as pulse oximeters and digital blood pressure monitors can effectively be used for cardiovascular fitness assessment in school and community settings.

CONCLUSION

This study demonstrated clear differences in cardiovascular responses to exercise between physically active and inactive adolescents and young adults. Inactive participants showed higher post-exercise heart rates and greater heart rate changes, indicating reduced cardiovascular efficiency. Exercise produced expected physiological changes, including increased systolic blood pressure and decreased diastolic blood pressure. Physically inactive individuals also had higher BMI and resting blood pressure, suggesting greater cardiovascular risk. These findings reinforce that regular physical activity improves cardiovascular fitness, autonomic regulation, and overall health. The study highlights the importance of promoting exercise in youth and supports the use of simple field-based tools for cardiovascular assessment.

Further studies involving larger sample sizes and more advanced cardiovascular measurements such as heart rate variability and oxygen consumption are recommended to provide deeper insight into exercise-induced cardiovascular adaptations among adolescents.

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