The Research of Medical Science Review
ISSN: 3007-1208 & 3007-1216 Volume 3, Issue 6, 2025

CHRONOTROPIC RESPONSE TO EXERCISE AND HEART RATE RECOVERY IN YOUNG ADULTS

Esha Ter Razia[1], Dr. Syeda Sumaira Batool[2], Shafaq Majeed[3], Syeda Nida Batool[4], Iqra Shafiq[5], Dr. Sana Bashir[6], Dr Iqra Taj[7], Dr Saba Murad[8], Dr. Inayat Ullah*[9]

[1]*(PT) Doctor of Physical Therapy, Former Student, Foundation University College of Physical Therapy (FUCP), Foundation University, Islamabad*
[2]*(PT) Lecturer, FUCP, Foundation University, Islamabad*
[3,4,5]*Doctor of Physical Therapy, Former Student, FUCP, Foundation University, Islamabad*
[6]*(PT)Assistant Professor, FUCP, Foundation University, Islamabad*
[7]*(PT)MS Cardiopulmonary Physical Therapy, Student, FUCP, Foundation University, Islamabad*
[8]*Former Senior Lecturer, FUCP, Foundation University Islamabad*
[*9]*(PT) Assistant Professor, Sarhad University of Science And Information Technology, Peshawar*

[1]eshaterrazia@gmail.com, [2]sumaira.batool@fui.edu.pk, [3]shafaq.majeed.50@gmail.com, [4]syedanidabatool34@gmail.com, [5]iqrashafiq944@gmail.com, [6]drsana.bashir@fui.edu.pk, [7]iqisraran@gmail.com, [8]saba.murad@fui.edu.pk, [*9]inayatullah.siahs@suit.edu.pk

DOI: https://doi.org/10.5281/zenodo.15737078

Keywords
Blood pressure, BMI, chronotropic response, 3 minute step test, heart rate recovery, waist hip ratio

Article History
Received on 17 May 2025
Accepted on 17 June 2025
Published on 24 June 2025

Corresponding Author: *
Dr. Inayat Ullah

Abstract

OBJECTIVE: *The primary objectives of the study was to determine the chronotropic response to exercise and heart rate recovery in young adults.*
METHODOLOGY: *A descriptive cross-sectional study was conducted on 377 young healthy adults, belonging to the age range of 18-24 years. The population was recruited from the Foundation University School of Health Sciences. Screening of participants was performed using the PAR-Q+ questionnaire, while BMI, waist-hip ratio, resting blood pressure, and heart rate were measured. Warm-up was performed, followed by a 3-minute step test using a 12-inch step. Lastly, blood pressure and heart rate were recorded again after activity cessation at 1 min, 2 min, and 3 min.*
RESULTS: *The mean and corresponding standard deviations for heart rate, HR resting was 94.39 ± 12.55, HR peak was 139.85 ± 19.08, HR_1 min was 136.98 ± 20.12, and HR_2 min was 116.03 ± 16.30, HR_3 min 98.61 ± 12.97. Healthy young individuals showed a mean Chronotropic Index of 48.05 ± 11.25, all of the participants reported to be chronotropically incompetent, i.e., 100%. The mean heart rate recovery of the total sample was 27.72 ± 11.60. About 260 participants reported normal heart rate recovery, i.e., 69%, and 117 showed abnormal heart rate recovery, i.e., 31%, respectively.*
CONCLUSION: *The results of the current study concluded that the heart rate recovery of young, healthy adults during 3-minute step testing was found to be normal in the majority of participants, whereas the chronotropic response of all participants was found to be incompetent.*

INTRODUCTION

Cardiovascular diseases (CVDs) are a leading cause of morbidity and mortality worldwide, with a notable prevalence among young adults, particularly those under 45 years of age (1). In the United States, CVDs remain the most common cause of death and illness. Similarly, in Asia, the burden of cardiovascular mortality has escalated dramatically, with the number of deaths due to CVDs rising from 5.6 million in 1990 to 10.8 million in 2019 (2). Globally, it is estimated that 18.6 million deaths in 2019 were attributable to cardiovascular diseases, with 58% of these occurring in Asia, highlighting the region's disproportionate challenges in managing CVDs (2).

Premature mortality, defined as death before 70 years of age, accounts for approximately 39% of all CVD-related deaths. Ischemic heart disease is the predominant cause, responsible for 47% of CVD deaths overall, with even higher proportions in Central (62%), Western (60%), and Southern Asia (57%) (3). Demographic changes, including aging populations and lifestyle shifts, contribute to the continuous rise in CVD mortality rates among both men and women in Asia.

Understanding the distinct transition stages of the CVD epidemic within Pakistan is critical for prioritizing resource allocation, public health strategies, and research initiatives. Notably, epidemiological data indicate a 2% increase in the incidence of myocardial infarctions among young adults across Asia from 2006 to 2016. Despite technological advancements, traditional exercise testing, monitoring heart rate before, during, and after physical activity, remains a valuable tool for cardiovascular risk stratification. (4)

Two important physiological markers in this context are the chronotropic response to exercise and heart rate recovery (HRR). The chronotropic response refers to the heart's ability to increase its rate commensurate with exercise intensity and metabolic demand (5). This response is quantified by the chronotropic index (CI). A CI value below 80% indicates chronotropic incompetence, while normal values range between 0.8 and 1.3 (4). The increase in heart rate during exercise is primarily mediated by a combination of sympathetic nervous system activation and parasympathetic withdrawal (6). Heart rate recovery, defined as the reduction in heart rate after cessation of exercise, reflects parasympathetic reactivation and autonomic nervous system function (7). An abnormal HRR is typically characterized by a decrease of less than 22 beats per minute at 2 minutes post-exercise and is an independent predictor of cardiometabolic risk factors (4). While HRR has gained recognition as a clinical tool for predicting cardiovascular outcomes, its underlying physiological significance warrants further investigation.

The chronotropic response is influenced by age, resting heart rate, and functional capacity. This response remains consistent across different protocols, but accurate assessment requires careful consideration of these variables (8). Heart rate recovery (HRR) is a strong and independent predictor of cardiovascular mortality, particularly when measured two minutes post-exercise (9). Despite its prognostic value, previous studies have been limited by small sample sizes, gender bias, and restricted populations, such as only males or those on beta blockers (4, 10, 11).

Methods

This study was a "descriptive cross-sectional" study. The complete duration of the study was 6 months from August 2023 to January 2024. The population was recruited from the Foundation University School of Health Sciences. The study was performed in the multidisciplinary laboratory at Foundation University College of Physical Therapy. Non-probability convenience sampling was used for sampling of the data. A sample of 377 (calculated through Raosoft sample size calculator at 95% confidence interval, 5% margin of error, and response distribution 50%) was selected. Both genders aged 18 - 24 years, with any BMI category were included in the study. The PAR-Q+ questionnaire for screening was filled and who marked "No" were included, and those who marked "yes" to any question in PAR-Q + were not included in the current study. Also participants with history of known cardiovascular disease, metabolic, neurological, pulmonary and orthopedic disorders that could limit exercise performance were excluded from the study.

The study used a range of validated data collection tools to ensure accurate assessment of participants' health and fitness. The PAR-Q+ was used as a subjective screening tool to identify potential health risks before physical activity (reliability 0.99). Measuring tape assessed waist and hip circumferences (reliability 0.8–0.9), while a weight machine and stadiometer measured body weight and height for BMI calculation (reliability 0.85 and \~0.95, respectively). The Three Minute Step Test (3MST) with a metronome evaluated autonomic response and endurance (reliability 0.89), followed by heart rate monitoring using a pulse oximeter (reliability

0.97) and blood pressure assessment with a sphygmomanometer (reliability 0.8–0.85). The Modified Borg Scale gauged perceived exertion, while a structured demographic questionnaire collected background information and ensured ethical consent. Data collection started after securing an approval letter from FUIC Ethical Review Committee and Institutional Research Committee FUCP. Data had been analyzed using SPSS version 21, descriptive statistics had been reported as Mean ±S.D. frequency, percentages and represented in the form of graphs and pie charts.

Results

The study after analysis concluded that overall 377 healthy young individuals showed mean chronotropic index of 48.05 ± 11.25, with all the population being chronotropically incompetent i.e. <80%.

The heart rate recovery was overall normal with a mean value of 27.72 ± 11.60, with majority of the participants 260 had normal heart rate recovery of >22beats/min and 117 showed values of <22beats/min.

DESCRIPTIVE STATISTICS:

Descriptive Statistics of Variables

The mean values and corresponding standard deviations for demographics. Reported mean value for Age 21.10 ± 1.74, Height was 162.83 ±10.02, Weight was 58.22 ±10.82, waist circumference was 28.99 ± 3.66, and Hip circumference was 33.62 ± 3.99 respectively.

S. No.	Parameters	Mean ± SD
1	Age (years)	21.10 ± 1.74
2	Height (cm)	162.83 ±10.02
3	Weight (kg)	58.22 ±10.82
4	Waist_circumference (cm)	28.99 ± 3.66
5	Hip_circumference (cm)	33.62 ± 3.99
6	BMI (kg/m2)	21.96±3.59
7	Waist_Hip_Ratio	0.86 ± 0.89

Table 1: Descriptive statistics of demographics.

Distribution of Gender

300 participants were females (79.6%) and male participants were 77(20.4%)

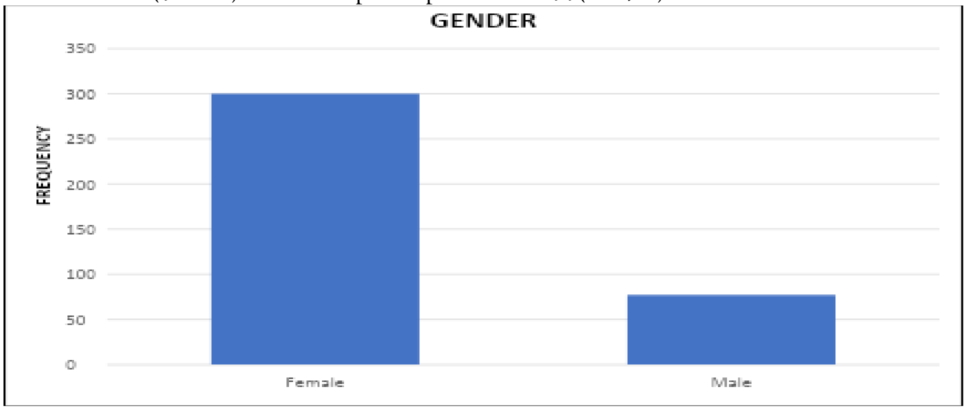

Figure 1 : Column showing Gender Distribution

In a sample of 377 individuals, both males and females were included. 300 participants were identified as females, which accounts for approximately 79.6% of the total sample. The remaining 77 participants were males, representing around 20.4% of the sample.

	Frequency n (%)
Male	77 (20.4%)
Female	300 (79.6)
Total	377 (100.0)

Table 2: Percentage of Gender

7.1.3. Distribution of Field of Study
The distribution of field of study was the following:
The frequency of FUCP was 226(59.9%), FUCN was 50(13.3%) and FUMC was 101(26.8%)

	Frequency	Percent
FUCP	226	59.9
FUCN	50	13.3
FUMC	101	26.8
Total	377	100.0

Table 3: Frequency and percentage of field of study

The frequency of sample taken from the fields of study i.e. FUCP =226, FUMC= 101 and FUCN= 50

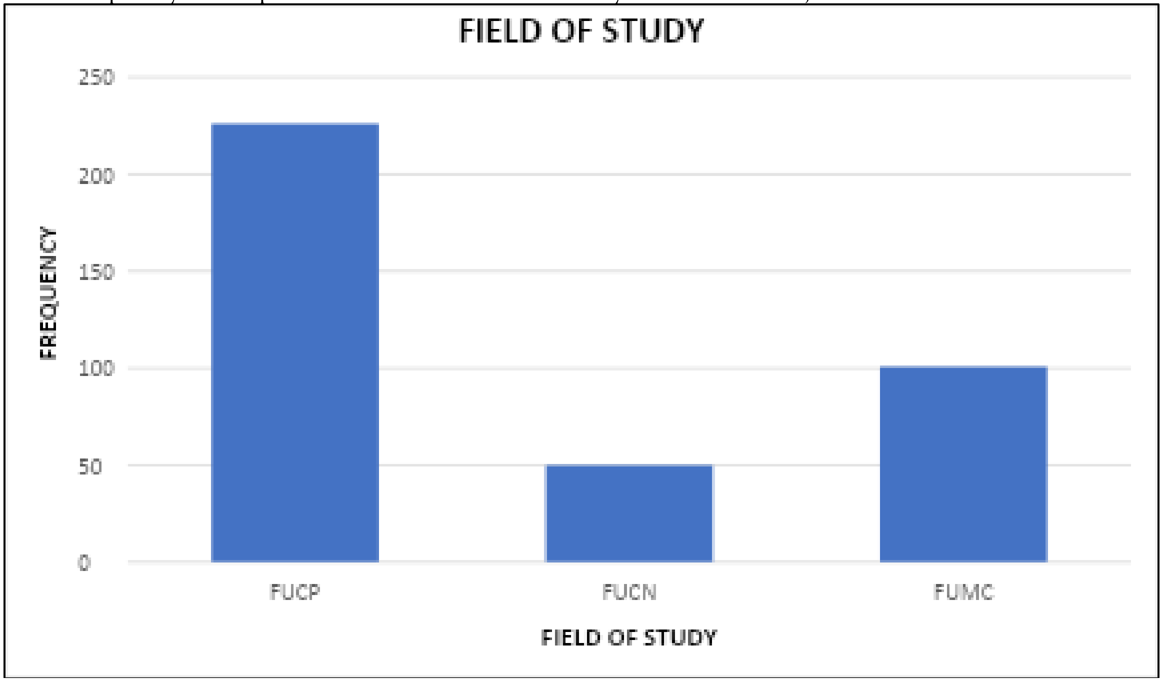

Figure 2: Frequency of Field of Study

The mean and corresponding standard deviations for Heart Rate, HR Resting was 94.39 ± 12.55, HR Peak was 139.85 ± 19.08, HR Immediate was 136.98 ± 20.12, HR_1min was 116.03 ± 16.30, HR_3min 98.61 ± 12.97

S. No.	Parameters	Mean ± SD
1.	Heart Rate Resting	94.39 ± 12.55
2.	Heart Rate Peak	139.85 ± 19.08
3.	Heart Rate Immediate	136.98 ± 20.12
4.	Heart Rate 1 Minute	116.03 ± 16.30
5.	Heart Rate 3 Minute	98.61 ± 12.97

Table 4: Heart Rate

The mean and corresponding standard deviations for BP Resting, SBP (Resting) was 117.83 ± 9.20, DBP (Resting) was 75.83 ± 7.96

S.no.	Parameters	Mean ± SD
1.	Resting Systolic Blood Pressure	117.83 ± 9.20
2.	Resting Diastolic Blood Pressure	75.83 ± 7.96

Table 5: Blood Pressure (Resting)

The mean and corresponding standard deviations for PEAK BP, SBP (Peak) was 152.45 ± 8.74, DBP (Peak) 101.68 ± 6.30

S. No.	Parameters	Mean ± SD
1	Peak Systolic Blood Pressure	152.45 ± 8.74
2	Peak Diastolic Blood Pressure	101.68 ± 6.30

Table 6: Blood Pressure (Peak)

The mean and corresponding standard deviations for SPO2 (Resting and Peak), SPO2_Resting was 97.26 ± 1.72, SP02_Peak was 97.34 ± 1.74

S.No	Parameters	Mean ± SD
1	Resting SPO2	97.26 ± 1.72
2	Peak SPO2	97.34 ± 1.74

Table 7: SPO2 (Resting and Peak)

The mean and corresponding standard deviations for RPE (Rate of Perceived Exertion), RPE was 9.30 ± 2.51(very light).

S.No	Parameters	Mean ± SD
1	RPE	9.30±2.51

Table 8: RPE (Rate of Perceived Exertion)

The mean chronotropic of total sample was 48.05 ± 11.25 respectively

Variables	N	Mean	St. Deviation
Chronotropic Index	377	48.05	11.25

Table 9: CI (Chronotropic Index) and HRR (Heart Rate Recovery)

All of the participants reported to be chronotropically incompetent i.e. 100%

		Frequency	Valid Percent
Valid	.00	377	100.0
	1.00	0	0

Table 10: CI (Frequency and Percentage)

The mean heart rate recovery of total sample was 27.72 ± 11.60 respectively

Variables	N	Mean	St.Deviation
Heart Rate Recovery	377	27.72	11.60

Table 11: HRR (Heart Rate Recovery)

Out of the total 377 participants, 117 reported slowed heart rate recovery i.e. 31% and 260 showed normal heart rate recovery i.e. 69%

		Frequency	Percent
Valid	.00	117	31.0
	1.00	260	69.0
	Total	377	100.0

Table 12: HRR (Frequency and Percentage)

Discussion

This descriptive cross-sectional study was conducted among university students aged 18 to 24 years to evaluate chronotropic response and heart rate recovery (HRR). A total of 377 students from three departments

participated in the study. In Pakistan, such research focusing on cardiovascular responses to exercise among healthy young adults remains limited. The 3-Minute Step Test (3MST) was employed to assess HRR, while the PAR-Q+ questionnaire served as a pre-activity screening tool. Measurements were recorded at rest and at 1, 2, and 3 minutes post-exercise. Additionally, the Modified Borg Scale was used to assess perceived exertion levels during the test.

The mean age of participants was 21.10 ± 1.74 years, with a meanBMI of 21.96 ± 3.59 kg/m², which falls within the normal BMI range (20–25 kg/m²). In contrast, a parent study referenced had a significantly older sample (mean age 57 ± 12 years) with a higher BMI (29 ± 5 kg/m²) (4). While the current study did not analyze the relationship between BMI and HRR, existing literature, such as a 2020 study on sedentary students, has reported a strong correlation between these variables when BMI, gender, physical activity levels, and VO_2max were considered. Notably, all participants in this study were within the normal BMI range, whereas comparative studies included both healthy and overweight individuals (10).

The present findings highlight that both chronotropic index (CI) and heart rate recovery serve as valuable physiological markers for evaluating cardiovascular health in young adults. The study revealed chronotropic incompetence (CI < 80%) in 100% of participants, with a mean CI of 48.05 ± 11.25, considerably lower than the recommended threshold (≥80%). This aligns with a 2009 study which reported chronotropic incompetence defined by a percentage of predicted maximal heart rate < 0.001 (13). Conversely, heart rate recovery results were more favorable: 260 out of 377 participants (69%) exhibited normal HRR (>22 beats/min), while 117 participants (31%) demonstrated abnormal HRR.

These results are consistent with previous studies that underscore the importance of incorporating chronotropic response and HRR into exercise evaluations. For example, studies have reported CI values between 1.7 to 4.8 and HRR between 1.1 to 3.5 at 95% confidence intervals, particularly when measured through VO_2max testing (9). The current study supports this recommendation, though it relied on more accessible tools, such as pulse oximetry, due to resource constraints.

Oxygen saturation (SpO_2) levels measured via pulse oximeter were found to be within normal physiological limits, with mean SpO_2 at rest of 97.34 ± 1.74 and at peak exercise of 97.26 ± 1.72. Unlike studies that used VO_2max and reported values such as 11.42 post submaximal exercise, the pulse oximeter was chosen for its availability, cost-effectiveness, and established accuracy in estimating hemoglobin saturation (HbO%) between 72% and 99% during exercise (14). Blood pressure readings taken pre- and post-exercise remained within normal ranges, consistent with the young, healthy sample. A UK-based study in 2020 found that gender significantly influenced systolic blood pressure (SBP), with females exhibiting lower SBP than males ($F = 42.121$; $P < 0.0001$) (12). However, the current study found no significant gender-based differences in SBP, with mean SBP at rest and peak recorded as 117.83 ± 9.20 and 152.45 ± 8.74, respectively.

Conclusion

The results of current study concluded that heart rate recovery of young healthy adults during 3 mins step testing was found to be normal in majority of participants, whereas the chronotropic response of all participants was found as incompetent.

Limitations

This study had several limitations that may have impacted the generalizability and depth of its findings. Firstly, it was a single-centered study, limiting the diversity of the participant pool. Secondly, gender-based differences in responses related to Chronotropic Index (CI) and Heart Rate Recovery (HRR) were not explored. Additionally, the individual physical activity status of participants was not taken into account, which could have influenced cardiovascular responses. During the data collection phase, there were challenges related to obtaining permissions, which caused delays and restricted access. Lastly, some participants were either unwilling to engage fully or refused to give consent, reducing the overall sample size and potentially introducing selection bias. Multi-center studies should be conducted to enhance the generalizability of results across diverse populations. The use of the International Physical Activity Questionnaire (IPAQ) is recommended to better compare cardiac conditioning, physical activity levels, and chronotropic response. Future studies should explore the relationship between Chronotropic Index

(CI) and anthropometric measures such as BMI and waist-hip ratio. To improve the objectivity of assessing CI and Heart Rate Recovery (HRR), it is also suggested that chronotropic response be evaluated using VO_2 max testing in subsequent research.

References

Nadeem M, Ahmed SS, Mansoor S, Farooq S. Risk factors for coronary heart disease in patients below 45 years of age. Pakistan journal of medical sciences. 2013;29(1):91.

Peltzer K, Pengpid S, Samuels TA, Özcan NK, Mantilla C, Rahamefy OH, et al. Prevalence of overweight/obesity and its associated factors among university students from 22 countries. International journal of environmental research and public health. 2014;11(7):7425-41.

Zhao D. Epidemiological features of cardiovascular disease in Asia. JACC: Asia. 2021;1(1):1-13.

Myers J, Tan SY, Abella J, Aleti V, Froelicher VF. Comparison of the chronotropic response to exercise and heart rate recovery in predicting cardiovascular mortality. European Journal of Preventive Cardiology. 2007;14(2):215-21.

Zweerink A, van der Lingen A-LC, Handoko ML, van Rossum AC, Allaart CP. Chronotropic incompetence in chronic heart failure: a state-of-the-art review. Circulation: Heart Failure. 2018;11(8):e004969.

White DW, Raven PB. Autonomic neural control of heart rate during dynamic exercise: revisited. The Journal of physiology. 2014;592(12):2491-500.

Dewar A, Kass L, Stephens RC, Tetlow N, Desai T. Heart Rate Recovery Assessed by Cardiopulmonary Exercise Testing in Patients with Cardiovascular Disease: Relationship with Prognosis. International Journal of Environmental Research and Public Health. 2023;20(6):4678.

Wilkoff BL, Corey J, Blackburn G. A mathematical model of the cardiac chronotropic response to exercise. Journal of Electrophysiology. 1989;3(3):176-80.

Cole CR, Foody JM, Blackstone EH, Lauer MS. Heart rate recovery after submaximal exercise testing as a predictor of mortality in a cardiovascularly healthy cohort. Annals of internal medicine. 2000;132(7):552-5.

Shetler K, Marcus R, Froelicher VF, Vora S, Kalisetti D, Prakash M, et al. Heart rate recovery: validation and methodologic issues. Journal of the American College of Cardiology. 2001;38(7):1980-7.

Obaid S, Nasir M, Younis A, Ahmad MW, Ahmad MA, Khalid N. Compare Heart Rate Recovery and Cardiopulmonary Endurance of Badminton and Squash Player. Pakistan Journal of Medical & Health Sciences. 2022;16(08):484-.

Fan LM, Collins A, Geng L, Li J-M. Impact of unhealthy lifestyle on cardiorespiratory fitness and heart rate recovery of medical science students. BMC public health. 2020;20(1):1-8.

Phan TT, Shivu GN, Abozguia K, Davies C, Nassimizadeh M, Jimenez D, et al. Impaired heart rate recovery and chronotropic incompetence in patients with heart failure with preserved ejection fraction. Circulation: Heart Failure. 2010;3(1):29-34.

Martin D, Powers S, Cicale M, Collop N, Huang D, Criswell D. Validity of pulse oximetry during exercise in elite endurance athletes. Journal of applied physiology. 1992;72(2):455-8.