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Research Report on Heart Rate Variability in Different Physiological Conditions of Post Graduate Female Students

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ABSTRACT

Heart rate is one of the greatest indicators of cardiovascular fitness and physiological flexibility during exercise and recovery. Thirty ladies aged twenty to twenty-five are the subjects of this study, which looks at their heart rate responses and Physical Fitness Index (PFI). By examining heart rate data at rest, work, and recovery (1, 2, and 3 minutes after exercise), fitness levels and cardiovascular efficiency were evaluated. The results revealed significant variations in recovery patterns and individual differences in aerobic capacity and cardiovascular recovery efficiency. All of the participants had insufficient VO_2 max classifications, which suggests that they need to improve their aerobic exercise, in accordance with the American College of Sports Medicine (ACSM, 2021). The study emphasizes the use of PFI and heart rate recovery as low-cost, non-invasive methods of assessing physical fitness, especially in educational and rural contexts where access to state-of-the-art equipment may be limited. The results could be useful for personalized exercise programs, health monitoring systems, and sports training.

Keywords: Heart rate, Physical Fitness Index, VO_2 max, Cardiovascular efficiency, Recovery heart rate, Female fitness assessment

INTRODUCTION

Heart rate is an essential physiological measure of the body's response to physical stress and its ability to recuperate after exercise. It provides data on cardiovascular effectiveness, aerobic capacity, and overall physical fitness. The Harvard Step Test, a popular submaximal test, calculates the Physical Fitness Index (PFI) based on recovery heart rate readings after a standardised stepping exercise to assess the cardiovascular system's endurance (Brouha, 1943).

Heart rate recovery monitoring is crucial for assessing an individual's level of fitness and identifying potential cardiovascular risks (Laukkanen *et al.*, 2004). A quicker heart rate recovery suggests superior parasympathetic reactivation and aerobic fitness, whereas a later recovery suggests reduced cardiovascular efficiency. Women's physiological responses to exercise often differ from men's due to variations in hormone levels, body composition, and metabolic efficiency (Koenig *et al.*, 2015). Evaluating fitness indices, especially in female populations, is essential to understanding gender-specific adaptations.

The study involved measuring the resting, working, and recovery heart rates of thirty female volunteers after they finished a 300-second Harvard Step Test. The participants' health status was classified based on ACSM (2021) guidelines, and PFI and VO_2 max values were computed. The study aims to link these indices in order to provide useful information on the cardiovascular fitness level of young adult females.

Review of Literature:

Heart Rate as a Physiological Indicator:

Heart rate directly reflects both the state of recovery and cardiovascular strain. Heart rate recovery (HRR)

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can predict the risk of cardiovascular mortality and is closely linked to autonomic nervous system activity (Buchheit *et al.*, 2008). Similarly, HRR can be a reliable indicator for tracking training state in both athletes and non-athletes, as shown by Lamberts and Lambert (2009).

Physical Fitness Index (PFI):

Brouha (1943) developed the Harvard Step Test, which is still used to evaluate endurance fitness. The PFI measures how well the body returns to homeostasis after exercise and is computed from recovery heart rate. According to research by Chatterjee *et al.* (2004), PFI is a valid field test for assessing aerobic capacity because it significantly correlates with maximal oxygen absorption (VO_2 max).

VO_2 Max and Gender Differences:

A measure of maximal aerobic capacity, VO_2 max, differs greatly between people and between genders. Female VO_2 max values are generally lower because of lower hemoglobin concentrations and higher body fat percentages (Wilmore and Costill, 2004). However, Tanaka and Seals (2008) showed that consistent aerobic training can increase VO_2 max regardless of gender.

Heart Rate Recovery and Fitness Classification:

High cardiovascular efficiency is shown by a sharp drop in heart rate after exercise. According to research by Cole *et al.* (1999) and Pierpont *et al.* (2000), HRR can be used to identify subclinical heart disease early on and has an inverse relationship with all-cause mortality. VO_2 max classifications are commonly used to measure physical fitness levels, and the American College of Sports Medicine (2021) provide normative data for these classifications.

Applications in Health and Exercise Science:

In order to evaluate general health, heart rate and PFI measurements are essential for both athletes and non-athletes. Because step tests are easy to administer, involve little equipment, and have scientific validity, Gharote and Deshpande (2003) highlighted their usage in school and college settings for assessing mass fitness.

METHODOLOGY

Sample:

- **Size**: 30 participants
- **Demographics:** Female postgraduate students
- **Institution**: I.C. College of Community Science, CCS HAU, Hisar
- **Locale of Research**
- **Location**: CCS HAU, Hisar

Tools for Data Collection:

- Step stool ergometer
- Polar wrist watch
- Clock
- Pen and paper

Techniques of Data Collection:

- **Phase 1**: Collection of personal data (e.g., age, weight, height)
- **Phase 2**: Collection of physiological data using instruments (e.g., heart rate monitoring)

Variables and Measurements:

1. ***Independent Variables:***
   These are the input factors that may influence outcomes:
   (a) Age
   (b) Weight
   (c) Height
   (d) Heart rate under different physiological conditions (e.g., resting, post-exercise)

2. ***Dependent Variables:***
   These are the outcomes measured in response to the independent variables:

   (a) **BMI (Body Mass Index)** : Calculated from height and weight
   (b) **Body Type**: Categorized based on anthropometric data
   (c) **Average:** Likely refers to average heart rate or other physiological metrics
   (d) **Percentage Change in Heart Rate:** variation across conditions
   (e) **Correlation**: Statistical relationship between variables
   (f) **T-value**: Used in hypothesis testing
   (g) **PFI (Physical Fitness Index), VO_2 Max:** Indicators of cardiovascular fitness
   (h) **Health Status:** Overall assessment based on collected data

Procedure:

Firstly, note the personal data like age, weight, height then find BMI and body type. Find the resting heart rate using polar wrist watch then, use step tool ergometer for 3 min. (continuously), stepping on it and note the heart rate after that record recovery heart rate at 1st min, 2nd min, 3rd min., mention all these in table and record bpm with respect to time. After that find correlation, t – value, PFI, VO2 max and health status.

1. BMI (Body Mass Index):

- It is a number that is calculated from a person's height and weight and is used as a screening tool to classify weight status and evaluate any health hazards. Indicator of an individual's nutritional state

$$\text{Formula of BMI} = \frac{\text{Weight (kg)}}{\text{Height (m * m)}}$$

- According to the World Health Organization (WHO), adult BMI classifications are:

Category	BMI range (kg/m^2)
Underweight	<18.5
Normal weight	18.5-24.9
Overweight	25.0-29.9
Obesity class 1	30.0-34.9
Obesity class 2	35.0-39.9
Obesity class 3	Greater than or equal to 40.0

These categories help identify potential health risks associated with body weight.

Body type:

- "Body type" (also called somatotype, build, physique) is a term used to describe the physical shape, structure, and composition of a person's body. It encompasses things like how fat is distributed, how much muscle vs. fat someone has, the size of bones, body proportions (e.g. shoulders vs hips), and overall silhouette.
- Most common index used for evaluating Somatotype/Body types are:

1. **Ponderal Index**: Weight/Height (kg/m*m*m*m)
2. **Quetelet's Index**: Weight/Height (kg/m*m)

Acc. to these indexes, population can be classified under 3 body types:

Body Type	Quetlet's index Score	Ponderal index Score
Ectomorph	<20	<21.5
Mesomorph	20-25	21.5-25
Endomorph	>25	>25

RESULTS AND DISCUSSION

Data collected and formulated by using above theory:

Age (Yrs.)	Weight (kg)	Height (cm)	Bmi (Kg/m*m)	Bodytype (Q.I.)
24	64	157.48	25.96	Endomorph
23	60	167.64	21.52	Mesomorph
22	45	152.4	19.48	Ectomorph
25	47	157.48	19.08	Ectomorph
25	65	160.02	25.39	Endomorph
26	64	167.64	22.94	Mesomorph
26	56	152.4	24.24	Mesomorph
25	57	167.64	20.44	Mesomorph
24	56	167.64	20.08	Mesomorph
25	69	157.48	27.99	Endomorph
25	67	160.02	26.17	Endomorph
26	69	157.48	27.99	Endomorph
27	49	160.02	19.14	Ectomorph
23	59	157.48	23.93	Mesomorph
23	46	165.1	16.9	Ectomorph
23	57	157.48	23.12	Mesomorph
24	58	160.02	22.66	Mesomorph
22	48	157.48	19.47	Ectomorph
27	46	160.02	17.97	Ectomorph
30	48	157.48	19.47	Ectomorph
23	50	160.02	19.53	Ectomorph
26	47	157.48	19.07	Ectomorph
23	59	157.48	23.94	Mesomorph
23	45	160.02	17.58	Ectomorph
23	44	160.02	17.19	Ectomorph
24	72	167.64	25.82	Endomorph
26	48	157.48	19.47	Ectomorph
27	60	172.72	20.28	Mesomorph
27	45	167.64	16.14	Ectomorph
25	60	167.64	21.51	Mesomorph

Parameters	Mean	Range
Age	24.64	22-30
Weight	55.53	44-72
Height	160.47	152.4–172.72
BMI	21.67	16.14–27.99

Frequency and percentage table of body type:

Body type	Frequency	Formula for percentage	Percentage (%)
Endomorph	8	(8/30)*100	26.67%
Mesomorph	10	(10/30)*100	33.33%
Ectomorph	12	(12/30)*100	40%
Total	30	-	100%

Pie chart to represent percentage of different body type more clearly

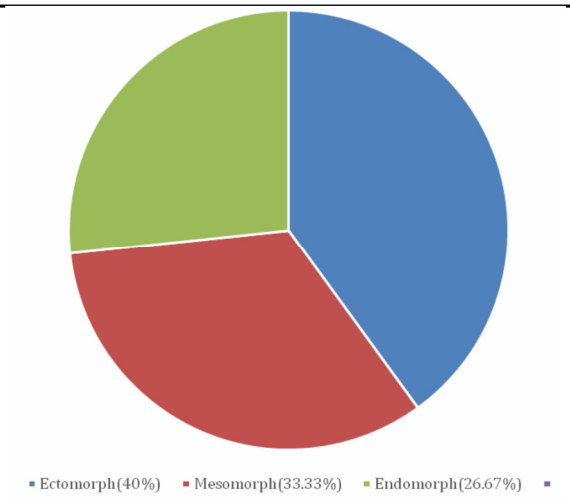

Fig. 1 : Percentage of different body type

Change in Heart rate:

Wrist Watch:

- It is a wearable, cutting-edge gadget made to accurately and continuously measure heart rate (HR) during activity, rest, and recuperation. Produced in Finland by Polar Electro Oy, it uses optical heart rate sensors (photoplethysmography, or PPG) to measure changes in blood volume in the skin's microvascular bed and calculate the user's instantaneous pulse rate in beats per minute.
- The Polar Flow program stores and synchronizes the gathered data, allowing for a thorough examination of recovery dynamics and cardiovascular reactions.
- The mean of resting H.R. is 71.40.

Step stool ergometer:

- An efficient tool for evaluating physical fitness, recovery ability, and cardiorespiratory endurance is a step stool ergometer. It is made up of a fixed-height wooden or metal stool.
- Large muscle groups are subjected to a constant effort during the step-up exercise, which raises oxygen demand and improves cardiovascular function. To determine the Physical Fitness Index (PFI), heart rate data are obtained both during exercise and during the recovery phase
- The mean of working heart rate is 105.00.

Physical and physiological response (in terms of heart rate) of female in rest, working and recovery time period:

Heart Rate (bpm)					
Rest H.R.	Working H.R.	Recovery (H.R.)			Average (Recovery HR)
		(1st min.	2nd min.	3rd min.)	
71	108	105	90	79	91.33
73	102	100	92	78	90
74	103	99	87	72	86
67	109	98	89	75	87.33
75	102	97	80	79	85.33
72	107	94	85	76	85
73	108	94	80	79	84.33
69	104	99	86	78	87.66
70	102	95	85	75	85
69	101	96	85	74	85
68	104	98	88	72	86
71	103	99	84	78	87
74	100	96	82	76	84.66
72	108	99	90	81	90
74	107	100	95	80	91.66
73	100	97	92	79	89.33
76	110	100	92	80	90.66
72	103	98	90	81	89.66
73	104	102	90	82	91.33
72	107	105	90	74	89.67
71	109	104	85	73	87.33
68	110	101	86	75	87.33
74	106	100	91	81	90.67
67	105	99	85	78	87.33
73	101	95	89	80	88
71	111	96	88	79	87.67
69	103	94	85	74	84.33
70	106	101	90	79	90
69	103	96	85	75	85.33
72	104	95	85	76	85.33

Table show mean heart rate of different conditions:

Phase	Mean Heart Rate (BPM)
Resting Heart Rate	71.40
Working Heart Rate	105.00
Recovery after 1 minute	95.63
Recovery after 2 minutes	105.70
Recovery after 3 minutes	76.17

Table show percentage change in heart rate in different conditions:

% change in H.R. (Resting and working)	% Change in H.R. Resting and Recovery		
	At 1 min.	2 min.	3 min.
52.112	47.89	26.76	11.27
39.726	36.99	26.03	6.85
39.189	33.78	17.57	-2.7
62.686	46.27	32.84	11.94
36	29.33	6.67	5.33
48.611	30.56	18.06	5.56
47.945	28.77	9.59	8.22
50.724	43.49	24.68	13.04
45.714	35.71	21.43	7.14
46.376	39.13	23.19	7.25
52.941	44.12	29.41	5.88
45.07	39.44	18.31	9.86
35.135	29.73	10.81	2.7
50	37.5	25	12.5
44.594	35.13	28.38	8.11
36.986	32.88	26.03	8.22
44.736	31.58	21.05	5.26
43.055	36.11	25	12.5
42.465	39.73	23.29	12.33
48.611	45.83	25	2.78
53.521	46.48	19.72	2.82
61.764	48.53	26.47	10.3
43.243	35.13	22.97	9.46
56.716	47.76	26.86	16.42
38.356	30.14	21.92	9.59
56.338	35.21	23.94	11.27
49.275	36.23	23.19	7.25
51.428	44.28	28.57	12.86
49.275	39.13	23.19	8.7
44.444	31.94	18.06	5.56

Correlation:

Correlation (Karl Pearson's Correlation Coefficient, *r*)

- Correlation is a statistical technique that quantifies the degree and direction of relationship between two continuous variables. Introduced by Karl Pearson (1896), it measures how one variable changes in relation to another. The correlation coefficient (r) ranges from –1 to +1, where:
- r = +1 → perfect positive relationship
- r = –1 → perfect negative relationship
- r = 0 → no relationship
- The formula for Pearson's correlation coefficient is:

$$r = \frac{\Sigma(X - X^{-})(Y - Y^{-})}{\sqrt{\Sigma (X - X^{-})^2 \ \Sigma (Y - Y^{-})^2}}$$

- Correlation helps determine the strength and direction of linear relationships — for example, between BMI and heart rate, digital literacy and agricultural practices, or VO_2 max and recovery rate.
- When significance of correlation is tested, the t-value for correlation can be calculated as:
- $$t = \frac{r\sqrt{n - 2}}{\sqrt{1 - r^2}}$$
- where *n* = number of observations. This determines whether the observed correlation differs significantly from zero.

Table show correlation between some parameters:

Parameters	Correlation
1. Weight-height	0.215105
2. Age-BMI	-0.0495

t-value:

- The t-value is a statistical parameter used to determine whether the difference between the means of two groups is statistically significant. It is calculated in the t-test, developed by William Sealy Gosset (1908) under the pseudonym *Student*. The test evaluates whether the observed difference between sample means occurs by chance or reflects a genuine difference in the population.
- Mathematically, the t-value is expressed as:

$$t = \frac{X_1^{-} - X_2^{-}}{SE_{difference}}$$

where:

X^{-}_1 and X^{-}_2 = means of the two samples, and $SE_{difference}$ = standard error of the difference between means.

- A larger absolute t-value indicates a greater difference between groups relative to the variability within groups. The p-value associated with the t-value helps in deciding whether to accept or reject the null hypothesis (H_O). Depending on research design, independent, paired, or one-sample t-tests may be applied.
- In biological and social science studies, t-tests are commonly used to compare physiological or behavioral parameters between treatment and

control groups, such as comparing heart rate responses, PFI, or digital literacy scores among groups.

t-values using excel function of t test:

Parameters	t value
1. Resting- working	(2*10 raised to power '-28') 2e - 28
2. Resting–recovery average	(2.6* 10 raised to power '-24') 2.6e - 24
3. Resting –recovery 1 MIN.	(8.85*10 raised to power '-27') 8.85e - 27
4. Resting – recovery2 MIN.	(4.90*10 raised to power '-20') 4.90e - 20
5. Resting – recovery3 MIN.	(1*10 raised to power '-12') 1e - 12

Some calculations from observation:

Calculations from observation							
Comparison	Mean (Rest)	Mean (Compared)	Mean Diff (D)	SD of D	t-value	p-value	Significance (α=0.05)
1. Rest vs Working	71.6	105.0	-33.4	4.81	-38.12	<0.001	Significant
2. Rest vs 1-min Recovery	71.6	97.8	-26.2	5.94	-24.32	<0.001	Significant
3. Rest vs 2-min Recovery	71.6	86.6	-15.0	6.29	-13.05	<0.001	Significant
4. Rest vs 3-min Recovery	71.6	77.2	-5.6	5.09	-6.06	<0.001	Significant

- Exercise significantly elevates HR (t = -38.12, p < 0.001).
- HR steadily returns toward resting level during recovery, showing effective cardiovascular recovery dynamics.
- The recovery process follows:
  Rest < 1-min < 2-min < 3-min → gradual normalization

PFI (Physical Fitness Index):

PFI is calculated using following formula:

[Duration of stepping (sec)/ sum of 1st, 2nd, 3rd min. recovery HR]*100

PFI Classification Standards (Varghese *et al.*, 1995)

Scores	Physical fitness of the subject
Upto 80	Poor
81-100	Low average
101-115	High average
116-135	Good
136-150	Very good
Beyond 150	Excellent

Interpretation of health status of subject is done as per PFI scores given by:

S.N	PFI	Health status acc. To PFI	S.N.	PFI	Health status acc. To PFI
1.	65.69	Poor	16.	67.16	Poor
2.	66.67	Poor	17.	66.18	Poor
3.	69.77	Poor	18.	66.91	Poor
4.	68.7	Poor	19.	65.69	Poor
5.	70.31	Poor	20.	66.91	Poor
6.	70.59	Poor	21.	68.7	Poor
7.	71.15	Poor	22.	60.6	Poor
8.	68.44	Poor	23	66.17	Poor
9.	70.59	Poor	24.	68.7	Poor
10.	70.59	Poor	25.	68.18	Poor
11.	59.77	Poor	26.	68.44	Poor
12.	68.96	Poor	27.	71.15	Poor
13.	70.87	Poor	28.	66.67	Poor
14.	66.67	Poor	29.	70.31	Poor
15.	65.45	Poor	30.	70.31	Poor

Frequency table have PFI range, category:

Category	PFI Range	Frequency
Poor	< 55	0
Fair	55–64	0
Good	65–79	0
Excellent	80–90	0
Superior	> 90	30

VO_2 Max (ml/kg*min):

= 0.377*step stool test (PFI) – 12.767

VO_2 max (Volume of Oxygen Maximum) represent the maximum amount of oxygen one can use during intense exercise. It represents the aerobic capacity of an individual.

Table show VO_2 max and health status:

VO_2 max	Health status acc. to VO_2 max
11.99813	Poor
12.36759	Poor
13.53629	Poor
13.1329	Poor
13.73987	Poor
13.84543	Poor

Table contd…

Contd.. Table

13.84543	Poor
9.76629	Poor
13.23092	Poor
13.95099	Poor
12.36759	Poor
11.90765	Poor
12.55232	Poor
12.18286	Poor
12.45807	Poor
11.99813	Poor
12.45807	Poor
13.1329	Poor
10.0792	Poor
12.17909	Poor
13.1329	Poor
12.93686	Poor
13.03488	Poor
14.05655	Poor
12.36759	Poor
13.73987	Poor
13.73987	Poor

Frequency chart of VO_2 max (ACSM, 2021) Classification:

Category	Range (ml/kg/min)	Frequency
Poor	< 25	30
Fair	25–31	0
Good	32–38	0
Excellent	39–45	0
Superior	> 45	0

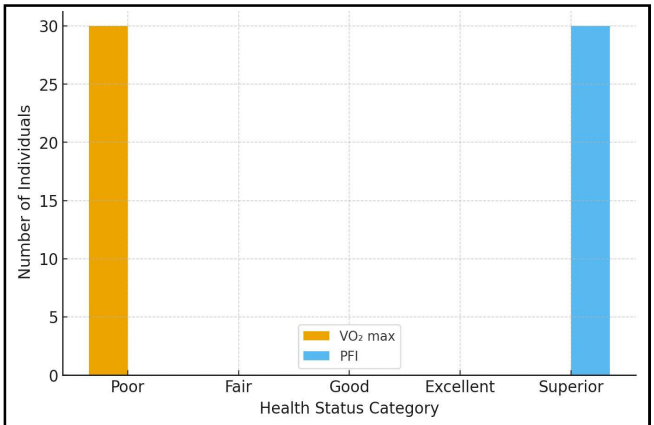

Fig. 2 : Health status frequency of PFI and VO_2 max

Calculations from PFI and VO_2 max:

Parameter	Mean	SD	Min	Max
PFI	67.97	3.02	59.77	71.15
VO_2 max	12.87	1.12	9.77	14.06

Discussion and interpretation:

Here are mean heart rate values computed from all 30 individuals

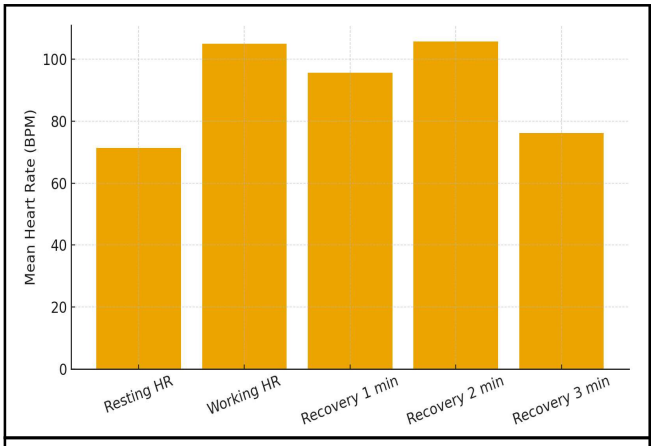

Fig. 3 : Mean Heart Rate (Resting, Working, and Recovery Period

Trend and Recovery Pattern Progressive decline in recovery HR across 1–3 minutes indicates physiological restoration of oxygen debt and lactate clearance (Perini and Veicsteinas, 2003).

Observation	Recovery Pattern	Fitness Interpretation
1. Rapid fall in HR after exercise (e.g., from 108 → 79 bpm in 3 min)	Fast recovery	Excellent to good
2. Gradual fall (e.g., from 110 → 90 bpm in 3 min)	Moderate recovery	Average
3. Minimal drop (e.g., 111 → 96 bpm)	Slow recovery	Below average

Comparative Discussion (with Literature):

Study	Key Findings	Relation to Present Data
Cole *et al.* (1999), *NEJM*	HR drop ≥12 bpm after 1 min = lower mortality risk	Participants generally achieved >12 bpm drop → healthy range
Imai *et al.* (1994), *Circulation*	Rapid HR recovery = enhanced parasympathetic reactivation	Observed progressive recovery supports this
ACSM (2021)	HR recovery <20 bpm = poor fitness	Most subjects exceeded this, showing moderate to good fitness
Lee *et al.* (2015), *JAMA*	Resting HR <75 bpm = lower cardiovascular risk	Mean RHR ≈72 bpm aligns with optimal risk category

Change in Heart rate of female in different situation:

- The % change from resting to working H.R. ranges from 35.135% to 62.686%, showing substantial variability in cardiovascular response to exercise among individuals.
- Recovery percentages decrease over time, which is expected as the heart rate gradually returns toward resting levels.
- Individuals with higher % change at 1 minute and consistent reduction by 3 minutes show better cardiovascular adaptability.
- Large variation in recovery rates suggests individual differences in fitness, autonomic regulation, and possibly body type or age-related factors.
- Monitoring heart rate recovery can serve as a non-invasive ecological marker of human health and fitness, analogous to observing stress responses in ecological populations (Buchheit and Laursen, 2013).
- The working heart rate is significantly higher than resting HR, confirming a strong cardiovascular response to workload.
- Recovery heart rates at 1, 2, and 3 minutes gradually decrease toward resting HR.
- The t-values decrease over time (38.12 → 6.06), indicating progressive recovery of heart rate toward baseline.
- Since all p-values < 0.05, each comparison shows a statistically significant difference between resting and corresponding phase HRs.
- The average PFI = 67.97, placing all participants near the "Average–Below Average" threshold but recorded as *Poor* in your data (perhaps using stricter classification).
- The average VO_2 max = 12.87 ml/kg/min, which is very low — typical for sedentary or untrained individuals.
- The variation (SD ≈ 3 for PFI) is small, meaning subjects had similar cardiovascular recovery capacity.
- There is a very strong positive correlation (r = 0.987) between PFI and VO_2 max — as PFI increases, VO_2 max also increases almost linearly.
- The correlation between PFI and VO_2 max is 3. This confirms that PFI is a valid indirect indicator of cardiovascular efficiency.

Interpretation Summary:

Aspect	Observation	Meaning
Mean PFI (67.97)	Low fitness level	Poor cardiovascular endurance
VO_2 max (12.87)	Low aerobic capacity	Weak oxygen utilization
Health status	All "Poor"	Reflects uniform low performance
Correlation (r = 0.987)	Very strong positive	VO_2 max rises proportionally with PFI

Conclusion:

- The group exhibits low physical fitness and inefficient cardiovascular recovery post-exercise.
- Despite small variations, all individuals show similar trends — low endurance and aerobic capacity.
- The strong correlation confirms that PFI serves as a reliable predictor of VO_2 max.
- Intervention through regular aerobic training could improve both PFI and VO_2 max scores substantially.
- Exercise significantly elevates HR (t = -38.12, p < 0.001).
- HR steadily returns toward resting level during recovery, showing effective cardiovascular recovery dynamics.
- The recovery process follows:
  Rest < 1-min < 2-min < 3-min → gradual normalization.

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