

**IMPACT OF CARDIORESPIRATORY FITNESS ON SELECTED  
PULMONARY CARDIOAUTONOMIC AND NEUROCHEMICAL  
MARKERS**

A Synopsis

Submitted to Jadavpur University for the

Degree of Doctor of Philosophy

In Physical Education

Faculty of Arts

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November, 2025

# 1. INTRODUCTION

## 1.1 Background of the Study

The current study presents the theoretical framework for the research, highlighting the interrelated impacts of cardiorespiratory fitness (CRF) on pulmonary function, cardioautonomic control, and neurochemical activities. CRF, an essential measure of overall health, signifies how efficiently the heart, lungs, and circulatory system supply oxygen during exercise and has been associated with enhanced endurance, cardiovascular health, and mental well-being. Evaluating pulmonary capacity, such as forced expiratory volume (FEV) and vital capacity (VC), is crucial and linked to CRF through effective oxygen exchange. Higher levels of CRF correlate with greater heart rate variability (HRV), suggesting enhanced autonomic adaptability, emotional resilience, and a better ability to cope with stress. Furthermore, CRF affects neurochemical elements: regular physical activity boosts beneficial neurochemicals like GABA and BDNF, which support mood regulation, cognitive abilities, and neural health, while also aiding in the regulation of cortisol levels, which can fluctuate under stress. In short the study emphasises that CRF significantly influences both physical and mental well-being by impacting respiratory efficiency, autonomic regulation, and neurochemical equilibrium.

## 1.2 Research Gap

Recent studies have looked at fitness, lung function, heart rate variability (HRV), and neurochemical markers, but primarily in isolation and mainly in response to exercise training. There has been no research examining how  $VO_2$  max, lung function, HRV, and neurochemical indicators are interconnected at baseline or how they naturally vary with fitness levels. Moreover, neurochemical research often emphasises changes induced by exercise rather than exploring the fundamental connections to fitness. Consequently, there remains a significant gap in comprehending the interrelated, cross-sectional relationships between different physiological and neurochemical factors in healthy young adults.

## 1.3 Formulation of research question

Recognising a research gap is crucial as it defines what has not yet been explored by existing studies, thereby providing a basis for the necessity of new research. In the context of investigating the relationship of cardiorespiratory fitness with pulmonary function, heart rate variability, and neurochemicals like GABA, BDNF, and cortisol, identifying the research gap emphasises the insufficient understanding of how these physiological and biochemical

systems interact as a whole rather than individually. It ensures that the study offers fresh perspectives instead of reiterating known information, enhances the scientific justification, aids in the choice of suitable methods and variables, and ultimately underlines the significance and potential influence of the research in promoting integrative health and exercise science. The development of the research question in specific domains, along with the resulting research question, is outlined in Figure 1 below.

#### 1.4 Addressing the research question

This study focuses on a key question that directs the inquiry and shapes the methods used and the analyses performed. A concise answer to this research question, together with a subsequent discussion of the results and interpretations related to it, can be found in the ‘Summary, Conclusion and Recommendation’ section. The final section of the research aims to integrate the findings, address the research question, and emphasise the study's implications.

#### 1.5 Formulation of research question/problem

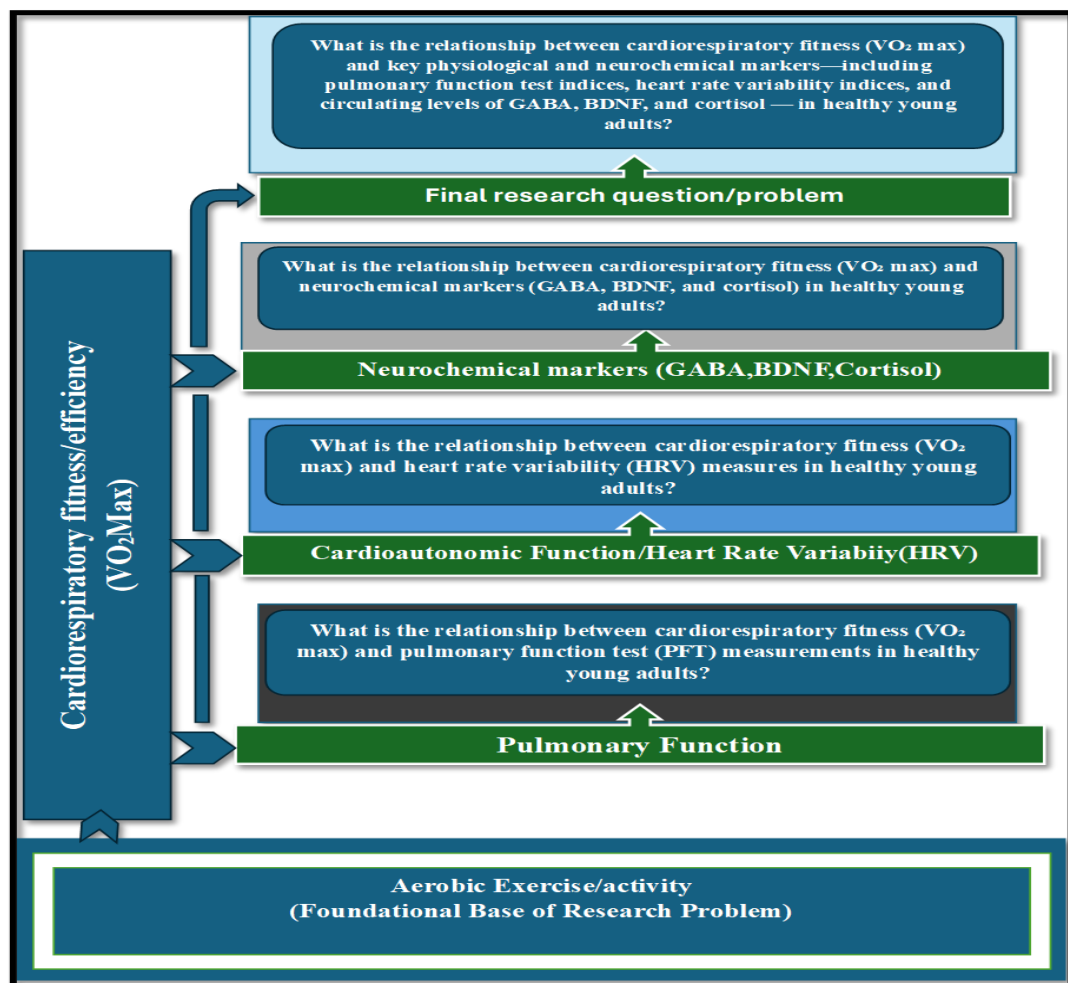


Figure 1: Schematic presentation for identifying and formulating a final research question/problem

### **1.6 Relevance of the Study**

This research is important as it addresses a significant gap in existing studies by incorporating often-ignored physiological and neurochemical aspects. By connecting fitness to various bodily systems—including cardiorespiratory health, respiratory efficiency, heart rate variability, and neurochemicals like GABA, BDNF, and cortisol—the study provides a more holistic understanding of overall health. The results can aid in creating more effective, evidence-based exercise and rehabilitation programs and pave the way for future interdisciplinary collaborations in exercise science, neurophysiology, and clinical health.

### **1.7 Aim of the Study**

The current study aims to investigate the relationship between cardiorespiratory fitness and different indicators from pulmonary function assessments, along with cardioautonomic and neurochemical markers.

### **1.8 Objectives of the Study**

- To assess and comprehend the impact of cardiorespiratory fitness on pulmonary function
- To evaluate and comprehend the impact of cardiorespiratory fitness on cardioautonomic function.
- To acknowledge and comprehend how cardiorespiratory fitness influences neurochemical markers.

## **2. REVIEW OF RELATED LITERATURE**

After an extensive evaluation of existing literature and a careful assessment of all relevant recorded data, a thorough analysis and investigation of the pertinent studies was conducted. The researcher conducted a comprehensive review of the existing literature, which is detailed below:

CRF is recognised as a vital factor influencing both physiological and neurochemical health, which may influence pulmonary function, HRV , and neurochemical markers like GABA,

BDNF, and cortisol. Mechanistically, heightened CRF could lead to better outcomes in pulmonary function tests (PFTs) by promoting improved lung ventilation and oxygen utilisation, which supports systemic oxygen distribution and metabolic stability. Similarly, regular aerobic exercise contributes positively to autonomic balance, as evidenced by increased HRV, by influencing parasympathetic activity and reducing sympathetic dominance. At the neurochemical level, CRF may boost BDNF expression, fostering neuroplasticity, while simultaneously modulating GABAergic functions to sustain inhibitory signalling in the central nervous system. Furthermore, elevated CRF is associated with lower baseline cortisol levels and reduced stress responses, suggesting a link between cardiovascular fitness and the regulation of the hypothalamic-pituitary-adrenal (HPA) axis. Collectively, these mechanisms suggest a theoretical connection where increased CRF is associated with more favourable outcomes in PFT, HRV, and neurochemical markers.

While interest in this complex relationship is growing, there remains a notable lack of research in this area. Most existing studies have focused on these variables in isolation, either examining cardiorespiratory fitness and autonomic regulation or neurochemical changes that occur post-exercise; rather than taking a holistic approach. There is a deficiency of longitudinal or interventional studies that explore the combined effects of CRF on pulmonary, autonomic, and neurochemical markers simultaneously. Additionally, the causal mechanisms linking CRF to neurochemical changes and HRV are not fully understood, and the potential for reciprocal effects is primarily speculative. Addressing these gaps through well-designed, multimodal research could illuminate the complex interactions among fitness, autonomic function, pulmonary capacity, and neurochemical signalling, ultimately resulting in targeted approaches to improve both physical and mental health.

## **3. METODOLOGY**

### **3. Methodology**

Research methodology refers to the structured and scientific method used to address a research question. This chapter delves into the detailed procedural precision and research plan of the study.

#### **3.1 Study Location and Laboratory setup**

The study was conducted in the Exercise and Sports Physiology Laboratory, Department of Physical Education, Jadavpur University, Kolkata, West Bengal, India. The instrumentation in laboratory was procured under Rashtriya Uchchar Shiksha Abhiyan (RUSA) 2.0 project of the Department and for the ELISA test the Department of Physical Education in guidance of Dr. Sridip Chatterjee, Associate Professor of the Department, procured the necessary instruments. The orientation of the research core team and the young adult participants and the technician set-up was also planned in the same venue.

#### **3.2 Description of population**

A comprehensive review conducted by the researcher highlighted that there are few studies addressing an observational approach finding out impact of cardiorespiratory fitness on pulmonary, cardioautonomic, and neurochemical markers of the healthy young population. As a result, a study was designed based on a review of the relevant literature concerning healthy young individuals who engage in regular exercise.

### 3.2.1 Sample Size

The sample size was determined through G\*Power software, version 3.1.9.7, resulting in 112 participants, which made the researcher select at least 115 participants to serve as a sample for this study. This number was based on a power ( $1-\beta = 0.90$ ), a significance level ( $\alpha = 0.05$ ), and an effect size ( $d = 0.3$ ) for the research study conducted at Jadavpur University.

### 3.2.2 Sampling Procedure

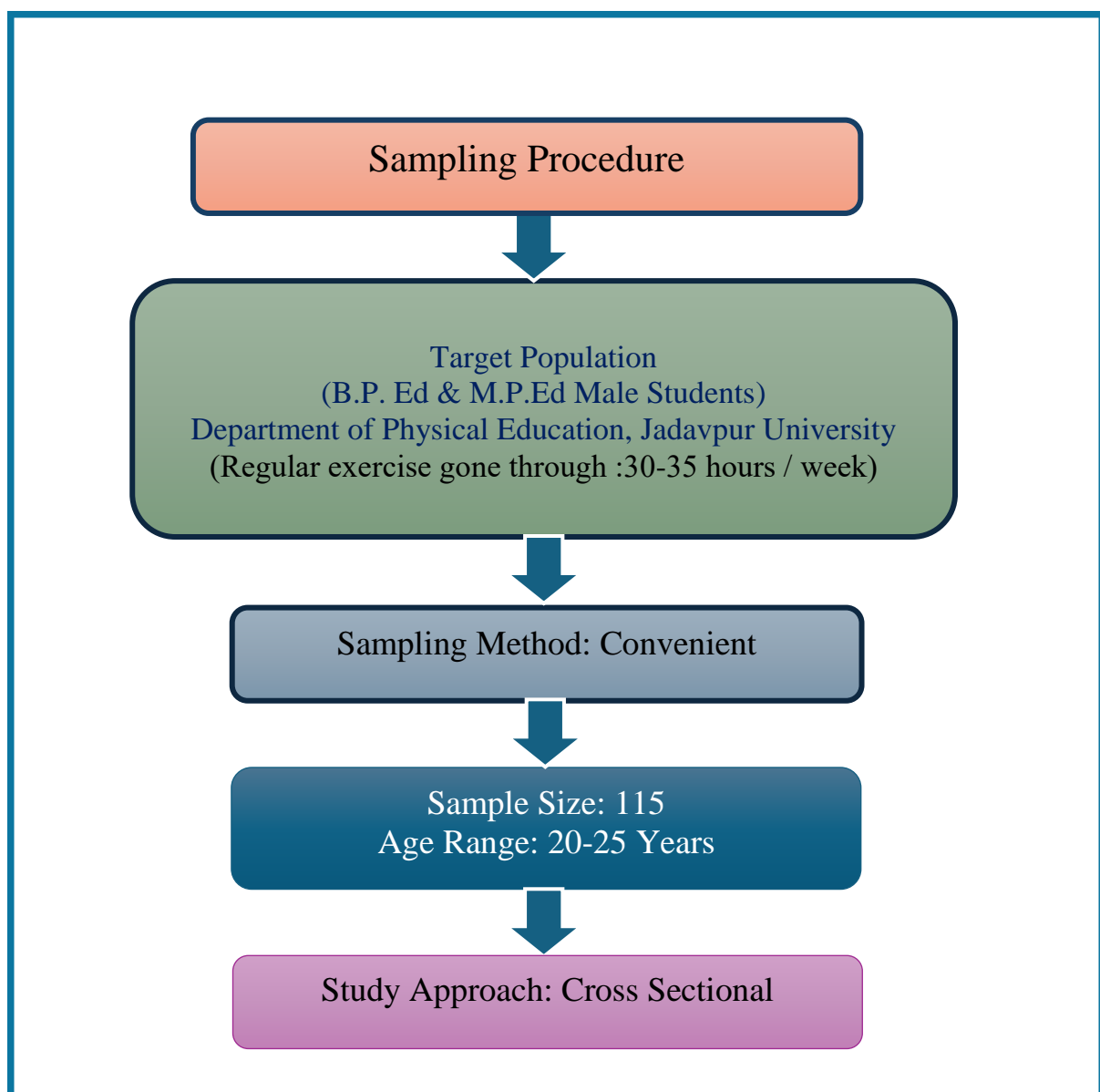


Figure 2: Layout of Sampling Procedure

### 3.2.3 Inclusion Criteria

Sl. No	Inclusion Criteria
1	Male students enrolled in the B.P.Ed and M.P.Ed programs.
2	Aged between 20 and 25 years' male young adults.
3	Students maintained a regular exercise routine, participating in physical activities for about 30-35 hours each week.

**Table 5: Inclusion Criteria**

### 3.2.4 Exclusion Criteria

Sl. No	Exclusion Criteria
1	Female students enrolled in the B.P.Ed and M.P.Ed programs.
2	Experiencing any short-term or long-term injuries.
3	Currently on any medication.

**Table 6: Inclusion Criteria**

### 3.3 Ethical Guidelines

The present investigation focused on adult males between the ages of 20 and 25. This research followed the standard protocols for studies involving human participants outlined by

the ICMR in 2017, which informed the checklist used in this study; the pertinent sections are as follows:

- The research proposal was based on solid scientific principles.
- The equation between possible benefits and likely hazards was slight, as the data gathering method in this research study posed no threat.
- The research emphasises the benefits of engaging in consistent aerobic activities and their impact on pulmonary, cardioautonomic, and neurochemical markers, which in turn improve overall cognitive abilities in human beings. Additionally, each participant will receive a personalised report after the completion and submit of the research study.
- The justification for this study was supported by a comprehensive review of existing literature, accompanied by a detailed evaluation of those references.
- The research, especially during the data collection stage, was conducted by a group of experts.

### **3.4 Ethical Consideration**

The current research was carried out on adult males enrolled in B.P.ED and M.P.ED programs and making ethical considerations is a crucial element of the study. These ethical considerations were categorised into two main sections:

- Ethical Norms
- Ethical Approvals and Policies

#### **3.4.1 Ethical Norms**

All participants of the present study have attained the legal age of consent, which is above 18 years. Therefore, the decision regarding their participation in the present research or withdrawal was supposed to be made independently. These guidelines were completely

aligned to the ICMR “National Ethical Guidelines for Bio-Medical Research studies involving human participants,2017” and the following criteria were met.

- The chosen subjects consisted of adults who are 18 years of age or older.
- The adult participants received thorough details about the study, explained in an easy-to-understand and straightforward way.
- In accordance with the standard guidelines for Informed Consent Forms (ICF), participants have provided consent for the study.
- The institutions where the students were affiliated were also consulted for approvals concerning their involvement in this study.

### **3.4.2 Ethical Approval and Policies**

Taking into account the ethical considerations in human research, the current study received approval from two authorizing body. The Institutional Ethics Committee (IEC) of Jadavpur University (Reference No: IEC/37/C/25 dated 22.01.2025) granted approval for this study. When conducting experimental research involving human subjects, it is crucial to adhere to norms and policies to ensure that the research is both legal and ethical. The researcher and their team considered all international clinical trial guidelines (WHO) and registered this study with the Clinical Trial Registry of India, following the principles set forth by the International Committee of Medical Journal Editors (ICMJE). As this research pertains to exercise physiology within the realm of typical biomedical research, it was accepted by the Clinical Trial Registry of India-CTRI, and the registration number is CTRI/2025/05/086537.

### **3.5 Variables Studied:**

The variables selected for the study have been pooled in two distinctive categories as mentioned below:

#### **3.5.1 Demographic variables**

<b>Sl. No</b>	<b>Demographic Variables</b>	<b>Measurement aids and instruments</b>	<b>Unit Of measurement</b>
1	Age	Birth certificate	Years

2	Height	Stadiometer	Cms
3	Weight	Weighing Machine	Kgs
4	BMI- Body Mass Index	Formula: weight (kgs)/ [height(m)] <sup>2</sup>	Ratio

**Table 7: Demographic Variables of the Study**

### 3.5.2 Physiological variables

SI No	Observational Variables /Physiological Variables	Instrument and Software used	Outcomes
1	<b>Aerobic Fitness</b>	<ul style="list-style-type: none"> <li>➤ The iworx TA (Model IX-TA-220)</li> <li>➤ iWireGA1 CO2/O2 Gas analyser with filter</li> <li>➤ 3-liter calibration syringe</li> <li>➤ Flow head tubing and A-FH -1000 flow head</li> <li>➤ A-GAK-201 reusable mask</li> <li>➤ 5 litre mixing chamber (Model: A-GAA-MC)</li> <li>➤ PHRM-220 heart rate watch</li> <li>➤ Treadmill (Nasan)</li> <li>➤ Labscribe Software(4.0)</li> </ul>	<b>VO2 Max</b> (Followed by Bruce Protocol)
2	<b>PFT Indices</b>	<ul style="list-style-type: none"> <li>➤ The iworx TA (Model IX-TA-220)</li> <li>➤ Flow head tubing and A-FH -1000 flow head</li> <li>➤ Labscribe Software(4.0)</li> </ul>	Forced Expiratory Volume in the first second (FEV-1), Forced Expiratory Volume in 3 seconds (FEV-3), Vital capacity (VC).
3	<b>HRV Indices (Time Domain and Frequency Domain)</b>	<ul style="list-style-type: none"> <li>➤ The iworx TA (Model IX-TA-220)</li> <li>➤ Iwire-B3G</li> <li>➤ Pulse Analyser</li> </ul>	Mean RR, Mean HR, RMSSD, SDNN, pNN50, LF power, LF (nu), HF power, HF (nu), LF/HF ratio
4	<b>Neurochemical Markers</b>	BeneSphera™ E21 ELISA Microplate machine (Mfg. Lic.No:MFG/IVD/2023/000032)	GABA, BDNF, Cortisol

		with the help of Immuno Tag's kit	
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**Table 8: Physiological variables of the study**

**3.5.3 Details of PFT Indices/Variables**

Variables	Description	Units
FEV-1	Forced Expiratory Volume in 1 second. (The amount of air a person can forcefully exhale in the first second of a breath )	Litre
FEV-3	Forced Expiratory Volume in 3 seconds. (the volume of air exhaled in the first three seconds of a forced breath)	Litre
VC	Vital Capacity (The summation of <b>Tidal Volume (TV) + Inspiratory Reserve Volume (IRV) + Expiratory Reserve Volume (ERV).</b>	Litre

**Table 9: Details of PFT Indices of the study**

**3.5.4 Details of HRV Indices/Variables**

	Variables	Description	Units	Dominance
<b>TIME</b>	<b>Mean RR</b>	Mean of all normal-to-normal (NN) intervals	ms	Reflects average cardiac cycle length (inverse of HR)

	<b>Mean HR</b>	Mean Heart Rate	beats per minute (bpm)	Reflects average autonomic tone (higher = more sympathetic)
	<b>RMSSD</b>	The Root Mean Square of Successive Differences between normal heartbeats	milli seconds (ms)	Parasympathetic dominance
	<b>SDNN</b>	Standard Deviation of the N-N intervals	milli seconds (ms)	Parasympathetic dominance
	<b>pNN50</b>	proportion of NN50 divided by the total number of NN intervals	percentage %	Parasympathetic dominance
<b>FREQUENCY DOMAIN</b>	<b>LF power</b>	Power in low frequency range	square milliseconds ( $ms^2$ )	Parasympathetic dominance
	<b>LF (nu)</b>	Low Frequency power in normalized units	nu	Relative sympathetic (and some parasympathetic) activity
	<b>HF power</b>	Power in high frequency range	square milliseconds ( $ms^2$ )	Parasympathetic dominance
	<b>HF(nu)</b>	High Frequency power in normalized units	nu	Relative parasympathetic (vagal) activity
	<b>LF/HF Ratio</b>	Ratio LF [ $ms^2$ ]/HF [ $ms^2$ ]	%	Sympathetic dominance

**Table 10: Details of Time Domain and Frequency Domain Indices of HRV**

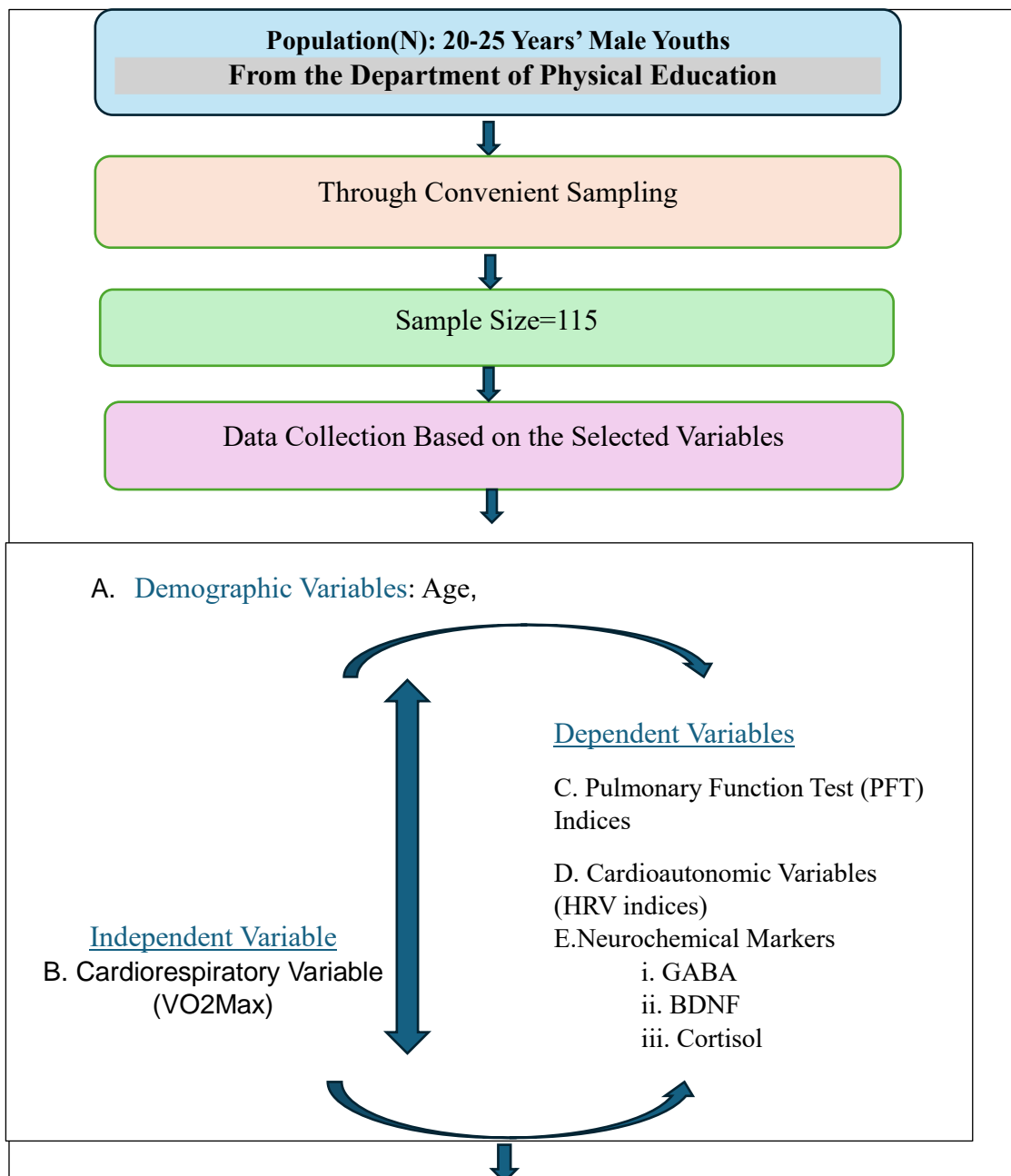
Indices	Description	Unit
<b>GABA</b>	<b>Gamma-Aminobutyric acid</b>  (A protein that supports <b>neuronal growth, survival, and synaptic plasticity</b> , important for learning, memory, and mood regulation.)	<b>µg/dl</b>

<b>BDNF</b>	<b>Brain-Derived Neurotrophic Factor</b>  (The main <b>inhibitory neurotransmitter</b> in the brain, reducing neuronal excitability and promoting <b>calmness and relaxation.</b> )	<b>ng/ml</b>
<b>Cortisol</b>	A <b>stress hormone</b> released by the adrenal glands, regulating <b>metabolism, immune response, and the body's stress response.</b>	<b>(Mcg/dl)</b>

**3.5.5 Details of neurochemical markers**

**Table 11: Details of Neurochemical Markers (GABA, BDNF, Cortisol)**

**3.6 Study Design**



### Figure 3: Cross-Sectional Study Design

#### 3.8 Statistical Analysis

In this study, the sample size was determined using G\*Power software, followed by an evaluation of normality for the participant population. Assessing normality ensures that the data is representative and provides more accurate comparative results. The Kolmogorov-Smirnov normality test was employed to identify the inherent distribution of the sample population; this test is applicable for sample sizes exceeding 50, unlike the Shapiro-Wilk normality test, when the sample sizes less than 50. If the test indicates significant results regarding the variables, the data can be considered normally distributed, allowing progression to parametric tests for comparison. Descriptive statistics, including mean and standard deviation, provided a summary of the basic characteristics of the subjects. For inferential statistics, a bivariate normal model of Pearson's correlation was utilised to assess the relationship between the dependent variables and the single independent variable. The significance level was set at 0.05 ( $P < 0.05$ ). The analysis was conducted using SPSS for Windows version 19.5.

Sl. No	Type of Test	Description
1	G*Power Analysis	Determination of Sample Size

2	Kolmogorov-Smirnov Test/ Shapiro-Wilk Test	Determination of Normal Distribution
3	Mean±SD	Descriptive Statistics
4	Correlation: Bivariate normal model	Inferential Statistics

**Table 12: Details of the Statistical Procedures**

### 3.9 Limitations of the Study

Every research endeavour has its boundaries, and these limits emerge from constraints in different aspects of the research field. The recent research study similarly faced restrictions; the points outlined below highlight the limitations of the study.

- The current research was not conducted as a randomised controlled trial.
- The participants who engaged in regular aerobic exercises were not supervised by us.
- The psychological states of the participants were not factored into the study
- We did not have full control over the consistency of the training or exercises.
- The researcher was unable to ensure that the exercisers were performing uniform aerobic exercises.
- Female subjects were not included in the study.

## 4. RESULTS AND DISCUSSION

### 4. Results and Discussion

This segment of the research is the most crucial as it showcases the findings obtained from the implemented methodology.

#### 4.1 Normality Test

Normality test has been performed based on the sample size as mentioned below:

##### 4.1.1 Normality test between VO2 Max and Spirometry Indices

Kolmogorov-Smirnov test			
Variables	Statistic	df	Sig.
VO <sub>2</sub> Max	.071	115	.200*
FEV1	.076	115	.099
FEV3	.077	115	.087
VC	.078	115	.081

Since  $p > 0.05$ , the data are normally distributed.

Table 13: Normality Test for VO2 Max and Spirometry Indices

##### 4.1.2 Normality Test between VO2 Max and HRV Indices

Kolmogorov-Smirnov test
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Variables	Statistic	df	Sig.
VO <sub>2</sub> Max	.071	115	.200*
RMSSD	.077	115	.090
MEAN HR	.076	115	.096
SDNN	.079	115	.073
MEAN RR	.076	115	.110
pNN50	.078	115	.084
LF(nu)	.081	115	.060
HF (nu)	.065	115	.200*
LF power	.055	115	.200*
HF power	.054	115	.200*
LF/HF Ratio	.072	115	.196

**Since p > 0.05, the data are normally distributed.**

#### 4.1.3 Normality Test between VO<sub>2</sub> Max and neurochemical markers

**Table 14: Normality Test for VO<sub>2</sub> Max and HRV Indices**

Variables	Statistic	df	Sig.
VO <sub>2</sub> Max	.972	35	.488
GABA( µg/dl)	.981	35	.788
BDNF(ng/ml)	.946	35	.088
Cortisol	.964	35	.303

**Since p > 0.05, the data are normally distributed.**

**Table 15: Normality Test for VO<sub>2</sub> Max and Neurochemical Markers**

#### 4.2 Results and Discussion of Demographic Variables

Demographic Variables	Measuring Unit	N	Mean	Std. Deviation
Age	Years	115	23.530	1.435
BMI	Kg/m <sup>2</sup>	115	21.115	1.609

**Table 16: Details of Demographic Variables, while the sample size=115**

Demographic Variables	Measuring Unit	N	Mean	Std. Deviation
Age	Years	35	23.171	1.248
BMI	Kg/m <sup>2</sup>	35	21.525	2.256

**Table 17: Details of Demographic Variables, while the sample size=35**

The above-mentioned tables 16 and 17 demonstrate the mean and standard deviation of age and BMI, the selected demographic variables of the current study. The study has not performed any correlation between CRF and demographic variables, unlike observational variables.

#### 4.3 Results and Discussion on the VO<sub>2</sub> Max and Pulmonary Function Test Variables

	Variables	Mean±SD
Aerobic fitness	VO <sub>2</sub> Max(ml/kg/min)	44.067 ±4.575
PFT indices	FEV-1 (L)	3.893 ±0.809
	FEV-3 (L)	2.231 ±0.489
	VC(L)	5.920 ±0.668

**Table 18: Descriptive statistics of CRF/Aerobic Fitness and PFT Indices' group**

Aerobic Fitness Variables	PFT Indices/Variables	N	df	(r) value	p value
VO <sub>2</sub> Max (ml/kg/min)	FEV-1 (L)	115	113	.219*	.019
	FEV-3 (L)	115	113	.192*	.040
	VC(L)	115	113	.399**	.000
Correlation is significant at the 0.05* and 0.01** level(2-tailed).					

**Table 19: Inferential statistics of CRF/Aerobic Fitness and PFT Indices' group**

The VO<sub>2</sub> Max variable related to cardiorespiratory fitness was evaluated alongside the Pulmonary Function Test variables, which included FEV-1, FEV-3, and VC. Descriptive

statistics revealed the mean and standard deviation of these PFT indices, as presented in Table 18. The correlational analysis presented in Table 19 revealed that VO<sub>2</sub>max demonstrated a significant positive correlation with all selected pulmonary function test (PFT) indices, specifically Forced Expiratory Volume in one second (FEV-1) ( $r = .219^*$ ,  $p = .019$ ), Forced Expiratory Volume in three seconds (FEV-3) ( $r = .192^*$ ,  $p = .040$ ), and Vital Capacity (VC) ( $r = .399^{**}$ ,  $p = .000$ ).

The results indicate that VO<sub>2</sub>max has a positive and significant correlation with important pulmonary function indices, such as FEV-1, FEV-3, and VC, suggesting that those with greater aerobic fitness have enhanced ventilatory efficiency and lung capacity. These persistent relationships emphasise the strong connection between cardiorespiratory fitness and respiratory function. In short, higher VO<sub>2</sub>max seems to be a dependable marker of better pulmonary health.

#### **4.4 Results and Discussion on the VO<sub>2</sub> Max and HRV Variables**

		Variables	Mean±SD
Aerobic fitness		VO <sub>2</sub> Max(ml/kg/min)	44.067 ±4.575
HRV indices	Time Domain	MEAN RR	834.261 ±81.905
		MEAN HR	64.104 ±4.447
		SDNN	54.657 ±12.612
		pNN50	32.249 ±15.401
		RMSSD	51.264 ±11.417
	Frequency Domain	LF (Power)%	43.257 ±14.482
		HF (power)%	51.675 ±16.377
		LF(nu)	48.246 ±10.884
		HF (nu)	54.101 ±16.203
		LF/HF Ratio	0.532 ±0.124

Table 20: Descriptive statistics of CRF /aerobic fitness and HRV Indices' group

Aerobic Fitness Variable	HRV Indices/Variables	N	df	(r) value	p value	
VO <sub>2</sub> Max (ml/kg/min)	Time Domain	MEAN RR	115	113	.219*	.019
		MEAN HR	115	113	-.003	.975
		SDNN	115	113	.159	.090
		pNN50	115	113	.180	.055
		RMSSD	115	113	.196*	.036
	Frequency	LF (Power)%	115	113	-.338**	.000

		HF (power)%	115	113	.343**	.000
		LF(nu)	115	113	-.265**	.004
		HF (nu)	115	113	.335**	.000
		LF/HF Ratio	115	113	.203*	.030
<b>Correlation is significant at the 0.05* and 0.01** level(2-tailed).</b>						

**Table 21: Inferential statistics of CRF /aerobic fitness and HRV Indices' group**

The descriptive and inferential statistics related to VO<sub>2</sub>max and specific HRV indices are outlined in Tables 20 and 21, respectively. The time-domain metrics comprised Mean HR, SDNN, Mean RR, and pNN50, whereas the frequency domain metrics included LH(nu), HF(nu), LF power, HF power, and the LF/HF Ratio.

Statistical analysis indicated the relationships between VO<sub>2</sub>max and the chosen HRV indices. Among the time-domain metrics, VO<sub>2</sub>max showed notable positive correlations with RMSSD ( $r=.196^*$ ,  $p=.036$ ) and Mean RR ( $r=.219^*$ ,  $p=.019$ ), while Mean HR ( $r=-.003$ ,  $p=.975$ ) did not present a similar association with VO<sub>2</sub>max, as the correlation coefficient ( $-0.003$ ) is nearly zero (0). Thus, it represents a very weak negative relationship. Regarding the other two variables, pNN50 ( $r=.180$ ,  $p=.055$ ) and SDNN ( $r=.159$ ,  $p=.090$ ), neither yielded significant results, but both exhibited a positive relationship with VO<sub>2</sub>max. Here,  $p = .055$  related to VO<sub>2</sub>max and pNN50 is slightly above the 0.05 threshold, indicating the correlation is not statistically significant at the 0.05 level, although it is on the cusp.

On the other hand, the frequency domain measures chosen for this analysis revealed both positive and negative associations with VO<sub>2</sub>max. The aerobic fitness indicator, VO<sub>2</sub>max, showed substantial positive correlations with HF (nu) ( $r=.335^{**}$ ,  $p=.000$ ) and HF power ( $r=.343^{**}$ ,  $p=.000$ ), whereas LF (nu) ( $r=-.265^{**}$ ,  $p=.004$ ) and LF power showed a strong negative correlation ( $r=-.338^{**}$ ,  $p=.000$ ). Additionally, the LF/HF Ratio ( $r=.203^*$ ,  $p=.030$ ) exhibited a noteworthy positive relationship. Notably, LF (nu) and HF (nu) displayed opposing directional relationships with VO<sub>2</sub>max independently, while LF power and HF power exhibited similar independent relationships with VO<sub>2</sub>max.

The analysis reveals that VO<sub>2</sub> max has a positive correlation with factors indicating parasympathetic activity, such as MeanRR, RMSSD, HF(power)%, and HFnu, which underscores improved vagal regulation in those with greater aerobic capacity. In contrast, VO<sub>2</sub> max exhibits negative correlations with measures related to sympathetic activity, including LF(power)% and LFnu, implying a decrease in sympathetic dominance. Some

relationships, such as MeanHR and SDNN, lacked statistical significance, suggesting that overall heart rate and total variability may not be as directly impacted by aerobic fitness. Notably, the positive correlation with the LF/HF ratio points to a complex dynamic between sympathetic and parasympathetic balance in well-trained individuals. In a precise way, a higher VO<sub>2</sub> max seems to enhance parasympathetic predominance, indicating better cardioautonomic control.

#### 4.5 Results and Discussion on the VO<sub>2</sub> Max and Neurochemical Markers or Variables

	Variables	Mean±SD
<b>Aerobic fitness</b>	VO <sub>2</sub> Max (ml/kg/min)	45.831 ±4.098
<b>Neurochemical Variables</b>	GABA( µg/dl)	0.640 ±0.146
	BDNF(ng/ml)	37.176 ±4.121
	Cortisol (Mcg/dl)	17.901 ±2.949

**Table 22: Descriptive statistics of CRF/Aerobic Fitness and neurochemical markers' group**

Aerobic Fitness Variables	Neurochemical Markers/Variables	N	df	(r) value	p value
VO <sub>2</sub> Max (ml/kg/min)	GABA( µg/dl)	35	33	.393*	.020
	BDNF(ng/ml)	35	33	.241	.164
	Cortisol (Mcg/dl)	35	33	-.075	.667
Correlation is significant at the 0.05* and 0.01** level(2-tailed).					

**Table 23: Bivariate correlation between CRF/Aerobic Fitness and Neurochemical Markers**

Descriptive statistics revealed the mean and standard deviation of Aerobic Fitness along with specific neurochemical variables, namely GABA, the main inhibitory neurotransmitter in the brain and a significant inhibitory neurotransmitter in the spinal cord; BDNF, a neurotrophin that can act as a neuromodulator; and Cortisol, a glucocorticoid, as presented in table 22.

The correlation analysis displayed in Table 23 indicated that VO<sub>2</sub>max exhibited a significant positive correlation with the chosen neurochemical marker, GABA ( $r = .393^*$ ,  $p = .020$ ), whereas BDNF ( $r = .241$ ,  $p = .164$ ) showed an insignificant but positive relationship, and Cortisol ( $r = -.075$ ,  $p = .667$ ) demonstrated an insignificant but negative correlation.

The findings show that increased VO<sub>2</sub>max is significantly correlated with neurochemical profiles that are associated with brain activity. VO<sub>2</sub>max demonstrated a noteworthy positive relationship with GABA, implying that improved aerobic fitness is connected to enhanced inhibitory neural control. While VO<sub>2</sub>max had a positive but not statistically significant association with BDNF, this trend aligns with the neurotrophic advantages linked to fitness. The negative, but insignificant, connection between VO<sub>2</sub>max and resting cortisol implies a tendency for lower stress hormone levels as fitness increases. In short, greater VO<sub>2</sub>max appears positively related to neurochemical markers, revealing significant improvements in GABA along with favourable trends in BDNF and cortisol. These observations suggest that enhanced aerobic fitness might promote healthier neural inhibition, better neurotrophic function, and improved stress management.

## **5. SUMMARY, CONCLUSION AND RECOMMENDATIONS**

### **5. Summary, Conclusion and Recommendations**

This segment represents the concluding and crucial aspect of the thesis documentation. It encompasses a summary of the findings alongside a succinct overview of the complete study. The conclusion presents broad statements, in addition to brief suggestions stemming from the difficulties and limitations recognised throughout the research.

#### **5.1 Summary**

The main goal of this research was to explore potential links between cardiorespiratory fitness (VO<sub>2</sub>Max), Pulmonary function, cardio autonomic (Heart Rate Variability), and selected neurochemical markers. Previous studies indicate that many have concentrated solely on the effects of exercise on cardiorespiratory fitness, lung function, cardio autonomic regulation (Heart Rate Variability), and neuroplasticity through neurochemical changes. By identifying particular gaps in existing literature across these areas, the researcher aimed to investigate the relationships across these domains simultaneously. Until now, no studies have directly investigated the relationship between cardiorespiratory fitness and individual elements from Pulmonary Function Tests, cardioautonomic and selected neurochemical markers in an integrated approach.

The method aligns with a cross-sectional study design where cardiorespiratory fitness serves as the independent variable, while the other dependent variables include indices from pulmonary function tests (PFT), cardiac autonomic indices (HRV), and neurochemical markers such as GABA, BDNF, and cortisol.

The current research was carried out in the Exercise and Sports Physiology Laboratory within the Department of Physical Education at Jadavpur University located in Jadavpur, Kolkata. A

sample of 115 male participants was chosen using a convenient sampling technique, following a G\*Power analysis to determine effect size. Normality tests were performed prior to conducting parametric tests to assess the distribution of the data. In this study, the Pearson's correlation using a bivariate normal model was employed to explore the relationship between the chosen independent and dependent variables, with significance levels established at 0.05. The outcomes addressing the research question were effectively clarified through the quantified results obtained from the study. The research question is framed as: "What is the relationship between cardiorespiratory fitness (VO<sub>2</sub>Max) and key physiological and neurochemical markers-including PFT indices, HRV indices, and circulating levels of GABA, BDNF and Cortisol in healthy young adults?" The study ultimately provided precise answers to this question based on its findings. Conclusion of the study reflected the comprehensive answer to the main research question framed in the introduction part.

The findings from the comparison between VO<sub>2</sub>Max and the chosen PFT indices revealed a notable positive correlation with all selected indices, specifically FEV-1, FEV-3, and Vital Capacity. A high VO<sub>2</sub>max alongside excellent performance in pulmonary function tests (like FEV1, FEV-3, and VC) is a crucial sign of improved cardiorespiratory health, a lower risk of chronic illnesses, and increased lifespan.

The correlation analysis indicated that VO<sub>2</sub>max had significant positive correlations with Mean RR, RMSSD, HF power, and HFnu, suggesting that increased cardiorespiratory fitness is linked to elevated parasympathetic activity and enhanced heart rate variability overall. Conversely, VO<sub>2</sub>max exhibited significant negative correlations with LF power and LFnu, implying a diminished sympathetic influence in those with higher aerobic capacity. Mean HR displayed a negative but non-significant correlation with VO<sub>2</sub>max, while SDNN and pNN50 demonstrated positive but also non-significant correlations. Collectively, these results imply

that a higher VO<sub>2</sub>max is primarily associated with improved vagal modulation and decreased sympathetic dominance, indicating a more advantageous autonomic balance in individuals with better fitness levels.

The analysis of correlation between VO<sub>2</sub>Max and the chosen neurochemical marker, GABA, revealed significant positive correlations, while BDNF exhibited a weak but positive association, and Cortisol displayed an insignificant yet negative correlation.

Considering the perspectives outlined above, the response to the research question can be understood as follows:

- The relationship between VO<sub>2</sub>max and pulmonary function test (PFT) measures such as FEV-1, FEV-3, and vital capacity (VC) suggests that enhanced cardiorespiratory fitness is associated with improved lung function.
- A significant relationship was found between VO<sub>2</sub>Max and certain HRV indices (both time domain and frequency domain), indicating improved regulation of the autonomic nervous system.
- The relationship between VO<sub>2</sub>max and specific neurochemical indicators was found to be robust, suggesting improved neurocognitive health via neurochemical regulation.

## **5.2 Conclusion:**

The current research reveals a notable link between aerobic capacity (VO<sub>2</sub>max) and various physiological and neurochemical factors. Results from pulmonary function tests (PFT)

indicated a strong positive correlation with VO<sub>2</sub>max, highlighting that improved respiratory efficiency is intimately connected to higher levels of aerobic fitness. Heart rate variability (HRV) metrics showed partial yet significant associations, implying that autonomic balance might play a role in aerobic performance, even though its impact seems to be more selective.


Within the neurochemical indicators, VO<sub>2</sub>max showed a positive relationship with gamma-aminobutyric acid (GABA) and brain-derived neurotrophic factor (BDNF), while exhibiting a negative correlation with resting cortisol levels. These results imply that greater aerobic fitness is linked to improved inhibitory neurotransmission and neuroplastic capacity, as well as lower levels of basal stress hormones.

The findings collectively suggest that enhanced aerobic fitness (VO<sub>2</sub>max) represents a comprehensive physiological condition characterized by effective lung function, balanced nervous system regulation, and positive neurochemical characteristics that promote resilience to stress and neural health. Future studies should investigate the causal relationships and training approaches that influence these systems to improve both physical health and neuropsychological well-being.

### 5.3 Recommendations:

- Upcoming research could be designed and conducted with a control group utilizing the current study's framework.
- A longitudinal study could be designed to gain a deeper insight into the underlying mechanisms that might contribute to the potential linear multiple relationships among the variables selected for this research. A study may be performed incorporating cognitive health variables with the existing study design.
- To reduce the risk of neurodegenerative diseases, it is recommended that everyone, irrespective of age or gender, engage in regular physical activity.

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14/11/25

  
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