

Correlation between Heart Rate Variability and Pulmonary Function Tests in Healthy Young Adults: A Gender-Specific Analysis

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Abstract

Background: The autonomic nervous system (ANS) regulates both cardiac and pulmonary functions. Heart Rate Variability (HRV) is a non-invasive marker of autonomic activity, but its correlation with pulmonary function tests (PFTs) in healthy young adults is not well-established, particularly regarding gender differences.

Objective: This study aimed to investigate the correlation between short-term HRV indices and PFT parameters in healthy young adults and to assess gender-based variations in this relationship.

Methods: A cross-sectional study was conducted on 80 healthy participants (40 males, 40 females) aged 18-21 years. Short-term HRV (5-minute recording) was analyzed for Low-Frequency (LF), High-Frequency (HF) power, and LF/HF ratio. Spirometry was performed to measure Forced Expiratory Volume in 1 second (FEV1), Forced Vital Capacity (FVC), and FEV1/FVC ratio. Statistical analysis was performed using paired t-tests and Pearson's correlation.

Results: Males had significantly higher FEV1 and FVC values than females ($p < 0.001$), while the FEV1/FVC ratio was comparable. No significant gender differences

were found in BMI, blood pressure, heart rate, or any HRV indices (LF, HF, LF/HF). Correlation analysis revealed weak and gender-specific associations. In males, weak negative correlations were found between LF & FVC ($r = -0.248$) and HF & FVC ($r = -0.171$). In females, a very weak negative correlation was observed between HF and FVC ($r = -0.070$). The LF/HF ratio showed a weak positive correlation with FEV1/FVC in males ($r = 0.284$).

Conclusion: While significant gender differences exist in lung volumes, the correlation between resting autonomic tone (as measured by HRV) and pulmonary function is weak in healthy young adults. This suggests that in a healthy, baseline state, pulmonary function is predominantly influenced by anatomical and physical factors rather than acute autonomic modulation. The subtle gender-specific correlation patterns may indicate different autonomic-respiratory interactions warranting further investigation.

Keywords: Heart Rate Variability, Autonomic Nervous System, Pulmonary Function Test, Spirometry, Young Adults, Gender Differences.

Introduction

The Autonomic Nervous System (ANS) is a critical regulator of involuntary physiological processes, maintaining homeostasis through the synergistic and antagonistic actions of its sympathetic and parasympathetic divisions¹. It exerts precise control over cardiovascular function, modulating heart rate, contractility, and vascular tone². Heart Rate Variability (HRV), the beat-to-beat variation in heart rate, has emerged as a simple, non-invasive electrocardiographic method to quantify autonomic nervous system activity³. Spectral analysis of HRV provides indices such as Low-Frequency (LF) power, often associated with sympathetic modulation (and baroreceptor activity), High-Frequency

(HF) power, a marker of parasympathetic (vagal) activity, and the LF/HF ratio, considered by many to reflect sympatho-vagal balance⁴.

Simultaneously, the ANS plays a vital role in regulating pulmonary function. The airways receive dual autonomic innervation: parasympathetic nerves cause bronchoconstriction via muscarinic receptors, while sympathetic influences lead to bronchodilation primarily through circulating catecholamines acting on β_2 -adrenergic receptors⁵. Given this shared autonomic control, a functional link between cardiac autonomic regulation and respiratory performance is plausible.

While studies have explored the relationship between HRV and PFTs in disease states like COPD and among smokers^{6,7}, data on healthy young populations are limited and inconsistent. Furthermore, gender differences in both autonomic tone and pulmonary anatomy are well-documented, but their interplay is not fully understood^{8,9}. This study aimed to bridge this gap by investigating the correlation between short-term HRV and PFT parameters in healthy young adults, with a specific focus on identifying gender-based variations in this relationship.

Materials and Methods

Study Design and Participants

A cross-sectional observational study was conducted in the Department of Physiology, Government Medical College, Kota, over one year. A total of 80 healthy young adults (40 males and 40 females) aged 18-21 years were recruited. Participants were asymptomatic, with a Body Mass Index (BMI) between 18.5 and 24.9 kg/m². Individuals with any recent or chronic infections, history of cardiorespiratory diseases, thoracic deformities, use of medications affecting the CNS/ANS, or habits like smoking were excluded. The study was approved by the

Institutional Ethical Committee, and written informed consent was obtained from all participants.

Study Procedure

All measurements were taken in a quiet, dedicated room. After a 10-minute rest, blood pressure and heart rate were recorded.

Heart Rate Variability (HRV) Analysis

A 10-minute ECG was recorded in a supine position using a 3-channel computerized Physiograph with HRV software. Analysis focused on a stable 5-minute segment. Frequency domain analysis using Fast Fourier Transform (FFT) was performed to obtain the following indices:

- **LF (ms²):** Power in the low-frequency range (0.04–0.15 Hz).
- **HF (ms²):** Power in the high-frequency range (0.15–0.40 Hz).
- **LF/HF Ratio:** Ratio of low-frequency to high-frequency power.

Pulmonary Function Test (PFT)

Spirometry was performed using a computerized spirometer. The best of three maneuvers was recorded for analysis. The parameters recorded were:

- **FEV1:** Forced Expiratory Volume in the first second.
- **FVC:** Forced Vital Capacity.
- **FEV1/FVC Ratio.**

Statistical Analysis

Data were analyzed using Jamovi (Version 2.3.28) and JASP (0.19.3.0) software. Descriptive statistics were presented as Mean ± Standard Deviation. Gender-based comparisons were made using a paired t-test. Pearson’s correlation coefficient (r) was used to assess the relationship between HRV indices and PFT parameters. A p-value of < 0.05 was considered statistically significant.

Results

Baseline Characteristics

The mean age of participants was 18-21 years. There were no significant differences between males and females in BMI, systolic blood pressure (SBP), diastolic blood pressure (DBP), or resting heart rate (HR) (p > 0.05 for all) (Table 1).

Table 1: Baseline characteristics of the study participants

| Parameter | Males (Mean ± SD) | Females (Mean ± SD) | p-value |
|--------------------------|-------------------|---------------------|---------|
| BMI (kg/m ²) | 21.12 ± 1.62 | 20.80 ± 1.77 | 0.301 |
| SBP (mmHg) | 117.40 ± 5.9 | 115.40 ± 7.8 | 0.159 |
| DBP (mmHg) | 78.37 ± 4.0 | 78.25 ± 5.2 | 0.900 |
| HR (bpm) | 74.55 ± 5.2 | 76.55 ± 6.4 | 0.190 |

Heart Rate Variability and Pulmonary Function Parameters

No significant gender differences were observed in any of the HRV indices (LF, HF, LF/HF) ($p > 0.05$) (Table 2). In contrast, PFT parameters FEV1 and FVC were significantly higher in males compared to females ($p < 0.001$). The FEV1/FVC ratio was not significantly different between the groups (Table 2).

Table 2: Comparison of HRV and PFT parameters between males and females

| Parameter | Males (Mean \pm SD) | Females (Mean \pm SD) | p-value |
|-----------------------|-----------------------|-------------------------|---------|
| HRV Indices | | | |
| LF (ms ²) | 3469 \pm 3461 | 3362 \pm 4943 | 0.91 |
| HF (ms ²) | 6474 \pm 6156 | 6646 \pm 9787 | 0.93 |
| LF/HF Ratio | 0.61 \pm 0.31 | 0.65 \pm 0.39 | 0.69 |
| PFT Parameters | | | |
| FEV1 (L) | 3.70 \pm 0.56 | 2.39 \pm 0.35 | <0.001 |
| FVC (L) | 4.07 \pm 0.64 | 2.59 \pm 0.37 | <0.001 |
| FEV1/FVC (%) | 91.07 \pm 5.21 | 92.67 \pm 7.09 | 0.323 |

Correlation between HRV and PFT Parameters

The correlation analysis revealed weak associations that differed by gender (Table 3).

In Males, weak negative correlations were observed between LF and FVC ($r = -0.248$) and between HF and

FVC ($r = -0.171$). The LF/HF ratio showed a weak positive correlation with the FEV1/FVC ratio ($r = 0.284$). In Females, the correlations were even weaker. A minimal positive correlation was seen between LF and FEV1 ($r = 0.127$), while HF showed a minimal negative correlation with FEV1 ($r = -0.040$) and FVC ($r = -0.070$).

Table 3: Pearson's correlation (r) between PFT and HRV parameters

| PFT Parameter | Males | | | Females | | |
|---------------|--------|--------|-------|---------|--------|-------|
| | LF | HF | LF/HF | LF | HF | LF/HF |
| FEV1 | -0.165 | -0.159 | 0.043 | 0.127 | -0.040 | 0.006 |

| | Males | | Females | | | |
|----------|--------|--------|---------|-------|--------|-------|
| FVC | -0.248 | -0.171 | -0.061 | 0.091 | -0.070 | 0.112 |
| FEV1/FVC | 0.281 | 0.106 | 0.284 | 0.020 | 0.013 | 0.164 |

Discussion

This study investigated the correlation between short-term HRV and pulmonary function in healthy young adults, with a key focus on gender differences. Our findings can be summarized as follows: 1) Males had significantly larger lung volumes (FEV1, FVC) than females, consistent with known anatomical differences ⁹; 2) There were no significant gender differences in resting autonomic tone as measured by HRV; and 3) The correlations between HRV indices and PFT parameters were weak and displayed gender-specific patterns.

The significantly higher FEV1 and FVC in males are attributable to larger thoracic dimensions, greater respiratory muscle strength, and differences in airway caliber ⁹. The lack of a significant difference in the FEV1/FVC ratio indicates similar airway patency relative to lung size between genders in this healthy cohort. The absence of significant gender differences in HRV indices (LF, HF, LF/HF) suggests that at rest, the overall autonomic balance is comparable between healthy young men and women. This aligns with some studies in adolescent populations which found minimal sex-based differences in resting HRV ¹⁰.

The primary finding of this study is the generally weak correlation between HRV and PFT parameters. In males, the weak negative correlations between LF/HF and FVC might suggest that a higher vagal dominance at rest is associated with slightly lower lung volumes, possibly due to a baseline level of vagally-mediated

bronchoconstriction. The weak positive correlation between the LF/HF ratio and FEV1/FVC in males could indicate a subtle link between a relative sympathetic shift and better large airway efficiency.

In females, the minimal negative correlation between HF (vagal activity) and FEV1/FVC supports the hypothesis of estrogen-enhanced M2-muscarinic receptor activity, potentially leading to a more pronounced vagal bronchoconstrictive effect ¹¹. The overall weaker correlations in females might be due to the complex interaction of hormonal factors on both autonomic and respiratory systems.

The weak correlations observed overall suggest that in healthy, resting individuals, pulmonary function is primarily determined by anatomical and mechanical factors. Autonomic influence, while present, may play a more secondary role unless challenged by physiological stress or underlying pathology, such as in asthma or COPD [6, 7]. This is a crucial distinction from studies conducted on patient populations, where stronger correlations are often found due to underlying autonomic dysfunction.

Limitations

This study has limitations, including its cross-sectional design, relatively small sample size, and reliance on short-term HRV recordings. The study was conducted on physiologically normal individuals, which might limit the generalizability of the findings to clinical populations. Future longitudinal studies with larger samples, including

24-hour HRV monitoring and controlled for menstrual cycle phases in females, could provide more nuanced insights.

Conclusion

In conclusion, this study demonstrates that while significant gender differences in pulmonary volumes exist among healthy young adults, the correlation between these parameters and resting cardiac autonomic tone, as measured by short-term HRV, is weak. This indicates that in a baseline healthy state, lung function is largely independent of major fluctuations in acute autonomic control. The subtle gender-specific patterns in correlation hint at different autonomic-respiratory physiology, meriting further investigation. HRV may be a more valuable tool for assessing autonomic involvement in respiratory diseases rather than predicting pulmonary function in healthy populations.

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