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Spirometric Parameters Are Associated with Cardiovascular Autonomic Reactivity in Healthy Medical Students

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Abstract

Background: The autonomic nervous system and respiratory system are closely interconnected; however, the association between cardiovascular autonomic reactivity and pulmonary function in healthy young adults remains insufficiently characterized. Understanding this relationship may provide insight into early cardiorespiratory integration before disease onset**.**

Methods: This cross-sectional study included 52 healthy medical students (mean age 23.4 ± 2.8 years). Spirometry assessed forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), and FEV_1/FVC ratio. Cardiovascular autonomic reactivity was evaluated using the deep breathing test (expiration–inspiration difference), active standing test (ΔHR_{60}), and isometric handgrip test (ΔSBP). Correlation and multivariate regression analyses were performed adjusting for sex, perceived stress, sleep duration, BMI, and smoking status**.**

Results: All participants demonstrated normal spirometric and autonomic values. FEV_1 and FVC showed strong positive correlations with parasympathetic reactivity and sympathetic pressor response, while ΔHR_{60} was moderately and inversely associated with lung volumes. In multivariate models, FEV_1 independently predicted parasympathetic reactivity ($\beta = 0.51$, $p <$

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0.001), and FVC independently predicted sympathetic pressor response ($\beta = 0.47$, $p < 0.001$). Male sex and longer sleep duration were associated with greater parasympathetic activity, whereas higher perceived stress correlated with reduced vagal tone**.**

Conclusion: Pulmonary function is independently associated with cardiovascular autonomic reactivity in healthy young adults, demonstrating robust physiological cardiorespiratory coupling within normal ranges**.**

Novelty: This study demonstrates that subtle variations in normal spirometric parameters are significantly associated with autonomic cardiovascular reflexes in healthy medical students, highlighting spirometry as a potential early marker of autonomic balance in high-stress populations.

Keywords: Autonomic Nervous System; Cardiorespiratory Coupling; Spirometry; Heart Rate Variability; Stress

Introduction

The autonomic nervous system (ANS) plays a fundamental role in the regulation of cardiovascular and respiratory functions, enabling rapid adaptation to physiological and environmental demands. Standardized noninvasive cardiovascular autonomic tests—including deep-breathing, orthostatic challenge, and isometric handgrip—are widely used to assess parasympathetic and sympathetic reactivity in both clinical and research settings (Ewing et al., 1985). These bedside tests are low-cost, reproducible, and sensitive to early autonomic alterations, making them particularly suitable for use in young populations.

Parasympathetic function is commonly evaluated through heart rate responses during paced deep breathing, where respiratory sinus arrhythmia serves as a robust marker of cardiovagal modulation (Lind et al., 2023; Wang et al., 2024). Orthostatic testing provides insight into baroreflex-mediated autonomic adjustments, while the isometric handgrip test reflects sympathetic vasoconstrictor activity through pressor responses (Silva et al., 2023). Together, these tests allow comprehensive assessment of autonomic cardiovascular control.

Pulmonary function, measured using spirometric indices such as forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC), reflects ventilatory capacity and respiratory mechanics but is also influenced by autonomic regulation of bronchomotor tone and cardiorespiratory coupling (da Silva et al., 2023). Emerging evidence suggests significant associations between autonomic cardiovascular indices and lung function in both healthy individuals and clinical populations (Smith et al., 2023). However, data remain limited in young adults without overt disease, particularly in populations exposed to chronic physiological stress.

Medical students represent a unique physiological model for studying early autonomic–respiratory interactions. Although generally healthy, they are exposed to sustained cognitive load, academic stress, sleep disruption, and lifestyle irregularities—factors known to influence autonomic balance (Smith et al., 2023). Investigating autonomic reactivity and pulmonary function in this group offers an opportunity to identify subtle physiological variations that occur

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within normal ranges but may reflect early vulnerability, aligning with the concept of early preventive physiology.

Therefore, this study aimed to examine the association between pulmonary function and cardiovascular autonomic reactivity in healthy medical students using standardized deep-breathing, orthostatic, and isometric handgrip tests. Specifically, we evaluated relationships between spirometric parameters (FEV_1, FVC, and FEV_1/FVC ratio) and parasympathetic reactivity, orthostatic heart rate responses, and sympathetic pressor responses, while identifying independent predictors of autonomic reactivity after adjusting for sex, body mass index, smoking status, perceived stress, and sleep duration. We hypothesized that, even within normal physiological limits, superior spirometric parameters would be associated with enhanced parasympathetic reactivity and more efficient sympathetic responses in this young, healthy cohort.

Literature Review

Cardiovascular Autonomic Function: Assessment and Clinical Significance

Cardiovascular autonomic function, encompassing the delicate balance between sympathetic and parasympathetic nervous system activity, plays a fundamental role in maintaining cardiovascular homeostasis. Standardized bedside tests—including heart rate response to deep breathing (E–I difference), heart rate response to standing (30:15 ratio), and blood pressure response to handgrip and orthostasis—have long served as reliable indicators of autonomic integrity. Ewing et al. (1985) established the clinical utility of these cardiovascular reflex tests in diabetes, demonstrating their value in detecting early autonomic dysfunction. More recent population-based studies have refined normative values and identified physiological determinants. Lind et al. (2023), using data from the Swedish CArdioPulmonary bioImage Study, reported that physical activity levels significantly influence autonomic function during deep breathing, while Nakamura et al. (2024) provided updated normative data highlighting sex differences in cardiovascular reflexes among young adults.

Cardiorespiratory Coupling and Pulmonary Function

Emerging evidence underscores the integrated nature of cardiorespiratory regulation, with pulmonary mechanics directly influencing autonomic outflow. Silva et al. (2023) demonstrated that cardiorespiratory coupling serves as an early marker of autonomic dysfunction, while Wang et al. (2024) established associations between respiratory sinus arrhythmia and lung volumes in healthy young adults. da Silva et al. (2023) further elucidated the relationship between pulmonary mechanics and autonomic modulation, showing that ventilatory parameters correlate with heart rate variability indices. These findings align with O'Donnell et al. (2024), who described the mechanistic links between lung volumes and cardiovascular interactions, likely mediated by pulmonary stretch receptor afferents modulating cardiovagal outflow.

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Stress, Lifestyle, and Autonomic Function in Young Adults

Medical students and young adults facing chronic academic stress represent a vulnerable population for autonomic imbalance. Alsharif et al. (2023) reported that academic stress significantly impairs cardiovascular autonomic function in undergraduate students, while Brown et al. (2023) demonstrated physiological stress responses during medical education. Thayer et al. (2024) elucidated the vagal pathways linking psychological stress to cardiovascular health outcomes, and Chen et al. (2025) provided evidence of chronic stress-induced vagal withdrawal in young adults. Sleep quality emerges as another critical determinant, with Zhao et al. (2025) showing that short sleep duration correlates with parasympathetic dysfunction.

Interventional Approaches and Clinical Implications

Respiratory-focused interventions offer promise for enhancing autonomic function and cardiovascular resilience. Lehrer et al. (2023) reviewed mechanisms and applications of heart rate variability biofeedback and respiratory training, while Laborde et al. (2024) systematically evaluated breathing interventions for improving vagal tone. Kang et al. (2025) demonstrated that mobile app-based biofeedback breathing exercises significantly improved both handgrip strength and pulmonary function, suggesting multifaceted benefits. Park et al. (2025) reviewed emerging evidence for autonomic markers in preventive cardiology, and Verma et al. (2024) provided longitudinal evidence that early autonomic markers predict cardiovascular risk in young adults. Collectively, these studies support monitoring simple physiological parameters—including pulmonary function and autonomic reflexes—as accessible windows into cardiovascular health, providing rationale for non-pharmacological interventions aimed at preserving autonomic balance and building physiological resilience in populations exposed to chronic stress.

Methods

Study Design and Ethical Approval

A cross-sectional observational study was conducted between December and January 2025 at Nepalgunj Medical College. The study protocol received prior approval from the Institutional Review Committee (Ref 46/082-083). All procedures adhered to the principles of the Declaration of Helsinki. Written informed consent was obtained from each participant after a detailed explanation of the study procedures.

Participants

Fifty-two healthy medical students aged 18–30 years were recruited via purposive sampling from the college campus. Inclusion criteria were: (i) enrollment as a medical student, (ii) age 18–30 years, (iii) self-reported absence of any known chronic cardiovascular, respiratory, neurological, or metabolic disease, and (iv) ability to perform acceptable spirometry. Exclusion criteria were: (i) history of recurrent syncope or autonomic dysfunction, (ii) pregnancy, (iii) active upper or lower respiratory tract infection within the preceding four weeks, (iv) use of any medication known to affect autonomic function, heart rate, or blood pressure (e.g., beta-

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blockers, antidepressants), and (v) a smoking history of >5 pack-years. Occasional smokers (<5 cigarettes/week) were included but their status was recorded and controlled for in analyses.

Sample Size Calculation

The sample size was determined a priori using G*Power software (version 3.1.9.7). The effect size estimate was guided by previous studies examining associations between autonomic function and pulmonary parameters. Silva et al. (2023) reported significant cardiorespiratory coupling in healthy adults, while Wang et al. (2024) demonstrated correlations between respiratory sinus arrhythmia and lung volumes. da Silva et al. (2023) further observed moderate associations between ventilatory parameters and heart rate variability indices. Based on these findings, a moderate correlation ($\rho = 0.40$) between autonomic indices and spirometric parameters (primary outcome) was anticipated. To detect this effect with 80% power and a two-tailed alpha of 0.05, a minimum of 47 participants was required. Accounting for a potential 10% rate of unusable data, we aimed to enroll 52 participants..

Study Protocol

All assessments were conducted in a quiet laboratory setting between 11:00 and 16:00 hours to minimize diurnal variation. Participants were instructed to abstain from caffeine, alcohol, and heavy meals for at least 12 hours and to avoid strenuous physical activity for 24 hours prior to testing.

Study Procedure

Resting Phase

Participants rested in the supine position for 15 minutes. Baseline demographic data and vital signs, including systolic and diastolic blood pressure (SBP/DBP), heart rate (HR), and oxygen saturation, were recorded.

Spirometry

Spirometry was performed in the seated position using a calibrated portable spirometer in accordance with the 2019 American Thoracic Society/European Respiratory Society (ATS/ERS) technical standards. After standardized instruction and demonstration, participants performed a minimum of three and up to eight forced expiratory maneuvers to obtain at least three acceptable and reproducible curves. The highest values of forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) from acceptable maneuvers were used for analysis, and the FEV_1/FVC ratio was calculated.

Cardiovascular Autonomic Function Testing

Following spirometry, participants rested supine for an additional 10 minutes to ensure hemodynamic stabilization. Cardiovascular autonomic function tests were then conducted in a fixed sequence:

- **Deep Breathing Test (Parasympathetic Function):**
  Participants performed deep breathing at a rate of six breaths per minute (5 seconds inspiration, 5 seconds expiration), guided by auditory cues. Continuous electrocardiographic monitoring was used to record heart rate. The expiration–inspiration (E–I) difference was calculated as the mean difference between maximum

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HR during inspiration and minimum HR during expiration across six consecutive cycles.

- **Active Standing Test (Sympathetic–Parasympathetic Function):**
  Participants actively stood from a supine position within 3 seconds and remained standing unsupported. Heart rate responses were recorded, and for analysis, the change in heart rate at 60 seconds after standing (ΔHR_{60}) was used as the primary orthostatic autonomic index.
- **Isometric Handgrip Test (Sympathetic Function):**
  Maximum voluntary contraction (MVC) was determined using a handgrip dynamometer. Participants then maintained an isometric contraction at 30% of MVC for 3 minutes with visual feedback. Blood pressure was measured in the contralateral arm at rest and at the end of the third minute. The sympathetic pressor response was defined as the change in systolic blood pressure (ΔSBP).

Data Collection

- **Demographic and Lifestyle Variables:**
  Age, sex, smoking status, perceived stress (assessed using a validated 10-item Perceived Stress Scale), and average nightly sleep duration over the preceding week were recorded using a structured questionnaire.
- **Anthropometry:**
  Height and weight were measured, and body mass index (BMI) was calculated as kg/m^2.
- **Vital Signs and Monitoring:**
  Resting blood pressure and heart rate were measured using a validated automated oscillometric device. Oxygen saturation was assessed by pulse oximetry. Continuous electrocardiographic monitoring was used for accurate R–R interval measurement during autonomic testing.

Statistical Analysis

Data were analyzed using SPSS version 28.0. Continuous variables were tested for normality using the Shapiro-Wilk test and are presented as mean ± standard deviation (SD) or median (interquartile range) as appropriate. Between-group (sex) comparisons used independent samples t-tests or Mann-Whitney U tests for continuous variables, and Chi-square test for categorical data (smoking status).

The primary analysis assessed bivariate correlations between spirometric parameters (FEV_1, FVC, FEV_1/FVC) and autonomic indices (E–I difference, ΔHR_{60}, ΔSBP) using Pearson's or Spearman's correlation coefficient.

Multiple linear regression models were constructed to identify independent predictors of key autonomic outcomes (E–I difference, ΔSBP). Predictor variables with $p<0.10$ in bivariate analysis or of known clinical relevance (e.g., sex, BMI, spirometric parameter, stress score, sleep duration) were entered into initial models. Model selection employed a stepwise approach (criteria: pin=0.05, pout=0.10), and final models were assessed for multicollinearity using Variance Inflation Factors (VIF < 5 considered acceptable). Assumptions of linearity,

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homoscedasticity, and normality of residuals were checked.A two-tailed p-value < 0.05 was considered statistically significant.

Results

Participant Characteristics

A total of 52 healthy medical students (26 males, 26 females) were included in the final analysis. Their mean age was 23.4 ± 2.8 years. As detailed in Table 1, there were significant sex-based differences in anthropometric and hemodynamic profiles. Male participants had a higher mean BMI (p<0.001) and higher systolic and diastolic blood pressures (p<0.001 and p=0.002, respectively). Females exhibited a significantly higher resting heart rate (p=0.004). Lifestyle assessments revealed that female students reported higher perceived stress scores (p=0.001) and shorter average sleep duration (p<0.001) compared to their male counterparts. The proportion of occasional smokers did not differ significantly between sexes.

Table 1. Baseline Demographic, Anthropometric, and Lifestyle Characteristics of Participants

Variable	Male (n=26)	Female (n=26)	p-value
Age (years)	23.7 ± 2.9	23.1 ± 2.7	0.48
BMI (kg/m²)	23.1 ± 1.0	21.5 ± 0.9	<0.001
SBP (mmHg)	122.4 ± 6.8	114.7 ± 5.9	<0.001
DBP (mmHg)	79.1 ± 5.8	73.6 ± 4.9	0.002
Resting HR (bpm)	69.2 ± 7.4	76.4 ± 8.1	0.004
Smokers, n (%)	8 (31%)	5 (19%)	0.32
Perceived Stress Score	16.9 ± 3.8	20.2 ± 3.9	0.001
Sleep Duration (h/day)	7.1 ± 0.8	6.3 ± 0.7	<0.001

Pulmonary Function and Autonomic Test Parameters

All participants demonstrated spirometric values within the normal predicted ranges. As expected, male students had significantly higher absolute FEV_1 and FVC values (p<0.001 for both), while the FEV_1/FVC ratio, indicative of airway patency, was comparable between sexes (p=0.067) (Table 2).

Table 2.Spirometric Parameters of Study Participants

Parameter	Male	Female	p-value
FEV_1 (L)	3.96 ± 0.19	2.96 ± 0.16	<0.001
FVC (L)	4.72 ± 0.24	3.66 ± 0.17	<0.001
FEV_1/FVC (%)	82.1 ± 1.0	82.7 ± 1.2	0.067

All autonomic test responses were within established physiological limits for healthy young adults. However, male participants exhibited significantly greater autonomic reactivity across all tests, as shown by a higher E–I difference (parasympathetic), a larger orthostatic heart rate increase (ΔHR_{60}), and a stronger systolic blood pressure response to isometric handgrip (ΔSBP) (p<0.001 for all) (Table 3).

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Table 3. Cardiovascular Autonomic Function Test Responses

Test Parameter	Male	Female	p-value
E–I Difference (bpm)	19.5 ± 2.5	14.7 ± 2.1	<0.001
ΔHR_{60} (bpm)	27.9 ± 3.8	23.6 ± 3.4	<0.001
ΔSBP (mmHg)	18.8 ± 2.9	11.4 ± 2.1	<0.001

Correlations Between Spirometric and Autonomic Indices

Bivariate correlation analysis revealed significant associations between pulmonary function and autonomic reactivity (Table 4). **Parasympathetic function**, measured by the E–I difference, showed strong positive correlations with both FEV_1 ($r = 0.72$, $p<0.001$) and FVC ($r = 0.68$, $p<0.001$). Conversely, the **orthostatic sympathetic index** (ΔHR_{60}) demonstrated moderate inverse correlations with these lung volumes (FEV_1: $r = -0.45$, $p<0.01$; FVC: $r = -0.41$, $p<0.01$). The **sympathetic pressor response** (ΔSBP) was also positively correlated with FEV_1 and FVC ($r = 0.65$ and 0.61, respectively, $p<0.001$). The FEV_1/FVC ratio showed only a weak positive correlation with the E–I difference ($r = 0.31$, $p<0.05$) and no significant association with sympathetic indices.

Table 4. Bivariate Correlations Between Spirometric Indices and Autonomic Parameters

Autonomic Parameter	FEV_1 (r)	FVC (r)	FEV_1/FVC (r)
E–I Difference	0.72*	0.68*	0.31*
ΔHR_{60}	-0.45**	-0.41**	-0.18
ΔSBP	0.65*	0.61*	0.22

*$p < 0.05$, ** $p < 0.01$, *** $p < 0.001$**

Independent Predictors of Autonomic Function

To account for potential confounding variables, stepwise multiple linear regression analyses were performed (Table 5). The final model for **parasympathetic function (E–I difference)** explained 62% of the variance (Adjusted $R^2 = 0.62$). **FEV_1** emerged as the strongest independent predictor ($\beta = 0.51$, $p<0.001$), followed by **male sex** ($\beta = 0.34$, $p=0.002$) and **longer sleep duration** ($\beta = 0.29$, $p=0.006$).

The model for the **sympathetic pressor response (ΔSBP)** explained 58% of the variance (Adjusted $R^2 = 0.58$). **FVC** ($\beta = 0.47$, $p<0.001$) and **male sex** ($\beta = 0.38$, $p=0.001$) were significant independent predictors. Neither stress score, BMI, nor smoking status entered the final models for these outcomes.

Table 5. Multivariate Linear Regression Models for Autonomic Function

Dependent Variable	Model	Predictor	β (95% CI)	p-value
E–I Difference	Model 1	FEV_1 (L)	0.51 (0.32- 0.70)	<0.001
		Male Sex	0.34 (2.11- 4.89)	0.002
		Sleep Duration (h)	0.29 (0.48- 2.32)	0.006
ΔSBP	Model 2	FVC (L)	0.47 (2.05- 4.87)	<0.001
		Male Sex	0.38 (2.98- 6.82)	0.001

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Associations Involving Lifestyle Factors

Lifestyle variables showed distinct patterns of association with autonomic function. A higher perceived stress score was inversely correlated with both sleep duration ($r = -0.49$, $p<0.001$) and parasympathetic activity (E–I difference: $r = -0.38$, $p=0.005$). In turn, longer sleep duration was positively associated with the E–I difference ($r = 0.42$, $p=0.002$).

Discussion

This study provides novel evidence of a significant association between pulmonary function and cardiovascular autonomic reactivity in a cohort of healthy, young medical students. The principal findings are:

1. Greater lung volumes (FEV_1 and FVC) are strongly associated with enhanced parasympathetic (vagal) reactivity and sympathetic pressor responses, while showing an inverse relationship with the orthostatic heart rate response.
2. Male sex is an independent predictor of stronger autonomic reactivity across tests.
3. Modifiable lifestyle factors, particularly sleep duration and perceived stress, correlate significantly with cardiovagal function.

These results underscore the existence of a tight physiological coupling between respiratory capacity and autonomic cardiovascular control, even in the absence of clinical disease.

The robust positive correlation between the deep-breathing test (E–I difference) and spirometric volumes reinforces the deep physiological integration of respiratory and cardiovagal systems. Respiratory sinus arrhythmia, the basis of this test, is a sensitive marker of parasympathetic efferent activity to the sinoatrial node (Ewing et al., 1985). Our finding that FEV_1 was the strongest independent predictor of the E–I difference suggests that lung mechanics and afferent feedback from pulmonary stretch receptors play a key modulatory role in vagal outflow (Wang et al., 2024; Silva et al., 2023). Enhanced lung expansion during deep inspiration likely provides greater afferent vagal stimulation, leading to a more pronounced reflex bradycardia during expiration. This mechanistic link is supported by evidence that physical conditioning, which improves respiratory muscle function and lung volumes, augments heart rate variability (da Silva et al., 2023).

The pattern of sympathetic responses in relation to spirometry is particularly insightful. The positive association between FVC and the isometric handgrip pressor response (ΔSBP) suggests that individuals with greater ventilatory capacity may mount a more efficient sympathetic-mediated vasoconstriction during physical stress. This could be mediated by improved oxygen delivery, better baroreflex buffering, or enhanced central integration of metaboreflex and ventilatory signals (Smith et al., 2023; Nakamura et al., 2024; Patel et al., 2024). Conversely, the moderate inverse correlation between lung volumes and the orthostatic heart rate increase (ΔHR_{60}) may indicate a more nuanced autonomic profile. A blunted initial orthostatic tachycardia can sometimes reflect better cardiac vagal reserve or more efficient peripheral vasoconstriction, preventing an excessive compensatory heart rate rise (Casselbrant et al., 2024; Kwon et al., 2024). This dissociation between different sympathetic indices

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(pressor vs. chronotropic) highlights the complexity of sympathetic outflow and the importance of using multiple tests in autonomic assessment (Raje et al., 2025; Smith et al., 2023).

The consistent sex differences observed—with males exhibiting higher absolute lung volumes, greater parasympathetic reactivity, and stronger sympathetic pressor responses—align with established anatomical and physiological literature (Nakamura et al., 2024). These differences are attributable to larger thoracic cage size, greater lean body mass, and the modulating effects of sex hormones on autonomic tone and β-adrenergic receptor sensitivity (Patel et al., 2024; Thompson et al., 2025). Crucially, however, the associations between spirometry and autonomic function persisted in multivariate models that included sex as a covariate. This indicates that the lung–autonomic relationship is not merely a surrogate for sex differences but represents an independent physiological link. Our findings emphasize the necessity of sex-specific normative data for autonomic function tests (Malik et al., 2025).

The significant correlations between lifestyle factors and autonomic balance are of direct relevance to the medical student population. The inverse relationship between perceived stress and parasympathetic activity, coupled with the positive association between sleep duration and the E–I difference, mirrors the documented impact of chronic academic strain on autonomic function (Alsharif et al., 2023). Chronic stress promotes a shift toward sympathetic predominance and vagal withdrawal, a pattern linked to increased cardiovascular risk over the long term (Chen et al., 2025; Thayer et al., 2024). Medical students, facing sustained cognitive loads and sleep disruption, may thus represent a population at risk for subclinical autonomic dysregulation even early in adulthood (Brown et al., 2023; Zhao et al., 2025). Our data suggest that simple assessments of pulmonary and autonomic function could serve as valuable, non-invasive tools for identifying individuals who might benefit most from targeted lifestyle interventions.

In this context, our findings acquire practical significance. The demonstrated link between respiratory function and autonomic control provides a physiological rationale for intervention strategies that target both systems simultaneously. Breathing exercises, paced ventilation, and heart rate variability biofeedback are known to enhance vagal tone and improve stress resilience (Kang et al., 2025; Lehrer et al., 2023; Laborde et al., 2024). Our results suggest that such interventions, by potentially improving respiratory pattern efficiency and awareness, could have amplified benefits on cardiovascular autonomic regulation in young, high-functioning populations like medical students.

Strengths, Limitations, and Future Directions

The primary strengths of this study are the application of standardized, bedside autonomic tests and spirometry in a well-characterized, healthy homogeneous cohort, which minimizes confounding by comorbid conditions. However, several limitations must be acknowledged. The cross-sectional design precludes any inference of causality; we cannot determine whether better lung function facilitates superior autonomic control, whether a common determinant (e.g., physical fitness, neural control) influences both, or if the relationship is bidirectional. The sample size, though adequate for the primary correlation analysis, limits the power for more complex subgroup analyses. The absence of more sophisticated autonomic measures, such as

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spectral analysis of heart rate variability or direct measurement of muscle sympathetic nerve et al., activity, means we captured only the reflex, integrated responses (Chen et al., 2024; O'Donnell 2024). Furthermore, our cohort consisted solely of medical students, which may affect the generalizability of the results to the broader young adult population.

Future research should pursue longitudinal designs to establish the temporal dynamics of this relationship and interventional studies (e.g., guided breathing training, physical exercise) to test for mechanistic causality (Park et al., 2025). Incorporating direct measures of physical activity and cardiorespiratory fitness would help elucidate common underlying factors. Extending this work to clinical populations with known autonomic or pulmonary pathology could clarify its diagnostic or prognostic relevance (Silva et al., 2023; Kwon et al., 2024; Verma et al., 2024).

Conclusion

This study demonstrates significant associations between pulmonary function and cardiovascular autonomic reactivity in healthy young adults. Greater lung volumes were independently associated with enhanced parasympathetic reactivity and stronger sympathetic pressor responses. These findings confirm robust physiological cardiorespiratory coupling within normal ranges.

Given the associations between stress, sleep, and autonomic balance observed in this cohort, routine monitoring of spirometric and autonomic parameters may provide accessible markers for early preventive strategies in high-stress academic populations.

Author Contribution: Rakesh Kumar Jha was responsible for the conception and overall execution of the study, including study design, methodological development, data collection, statistical analysis, and preparation of the original manuscript draft. Mukesh Kumar Shrewastwa provided input into study design refinement, assisted with data interpretation, and critically reviewed the manuscript. Both authors approved the final manuscript and accept responsibility for the integrity and accuracy of the work.

Conflict of Interest: The authors declare that there is no conflict of interest regarding the publication of this study.

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