

Association Between Heart Rate Variability And Peak Expiratory Flow Rate In Adolescents With Cardiovascular Risk

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Abstract

Background: Heart rate variability (HRV) is a non-invasive marker of autonomic nervous system (ANS) function, while peak expiratory flow rate (PEFR) assesses airway patency. This study aimed to examine the association between HRV parameters and PEFR in adolescents with cardiovascular (CV) risk factors such as obesity and a family history of hypertension (HT) or diabetes mellitus (DM). **Methods:** A cross-sectional study was conducted among 29 adolescents (14 girls, 15 boys) aged 14–15 years from local schools. Participants were obese and/or had a family history of HT or DM. Anthropometric data, blood pressure (BP), HRV (time and frequency domain indices), and PEFR were recorded. HRV was derived from 15-minute ECG recordings. PEFR was measured using a calibrated peak flow meter. Statistical analysis involved Pearson correlation, with $p < 0.05$ considered significant. **Results:** Boys had significantly higher PEFR (419.33 ± 52.57 L/min) than girls (379.28 ± 35.40 L/min). HRV parameters showed no statistically significant gender differences, although average RR intervals and parasympathetic indices (RMSSD, pRR50) were slightly higher in boys. In boys, PEFR positively correlated with SDRR, LFnu, and LF/HF, but negatively with RMSSD and HFnu. In girls, PEFR showed negative correlations with LFnu and LF/HF, with RMSSD and HFnu showing weak positive associations.

Conclusion: HRV parameters exhibit gender-specific associations with pulmonary function in adolescents at CV risk. These findings suggest differential autonomic regulation of airway dynamics, with potential implications for early preventive strategies.

Keywords: Heart rate variability, peak expiratory flow rate, adolescents, cardiovascular risk, autonomic function

INTRODUCTION

The autonomic nervous system (ANS) maintains homeostasis through regulation of involuntary physiological processes including cardiovascular and respiratory functions. Heart rate variability (HRV), a measure of beat-to-beat fluctuations in heart rate derived from R-R intervals in an electrocardiogram (ECG), reflects ANS activity and has been employed in evaluating cardiovascular health, stress, and autonomic regulation [1,2].

Respiratory activity significantly influences HRV through a phenomenon called respiratory sinus arrhythmia (RSA), where heart rate increases during inspiration and decreases during expiration. The high-frequency (HF) component of HRV predominantly reflects parasympathetic (vagal) activity and has been used to quantify RSA [3,4]. RSA is thought to reflect cardiopulmonary coupling, and disturbances in this mechanism have been observed in various clinical conditions, including heart failure, asthma, and chronic obstructive pulmonary disease (COPD) [5,6].

Peak expiratory flow rate (PEFR) is a convenient, reproducible, and non-invasive measurement used to assess expiratory airflow and is a vital component in the diagnosis and monitoring of respiratory diseases [7,8]. Several studies have demonstrated that pulmonary function is influenced by factors such as obesity, smoking, hypertension, and sedentary lifestyle—all of which are associated with increased cardiovascular risk [9–12].

Emerging evidence suggests an interaction between cardiac autonomic regulation and respiratory function, particularly in individuals with respiratory or metabolic disorders. Studies by Bianchini et al. [13] and others have reported significant correlations between HRV indices and pulmonary function in adults. However, there is a paucity of data exploring these associations in adolescents, particularly those at heightened cardiovascular risk due to familial predisposition or obesity. Since adolescence represents a dynamic period of autonomic and pulmonary development, early identification of subclinical dysfunction may have important prognostic and preventive implications. This study aimed to assess the relationship between HRV parameters and PEFR in adolescents with cardiovascular risk factors such as obesity and familial hypertension or diabetes mellitus.

MATERIALS AND METHODS

Participants: A total of 29 adolescents (14 girls and 15 boys) aged 14–15 years were selected from nearby higher secondary schools. The participants were categorized based on their cardiovascular risk (CV risk), which included obesity and/or a family history of hypertension (HT) and diabetes mellitus (DM). Ethical approval was obtained from the Institutional Human Ethics Committee, and informed consent was obtained from both participants and their parents prior to the study.

Anthropometric Measurements: The following anthropometric parameters were recorded for each participant: height, weight, basal heart rate, systolic blood pressure (SBP), and diastolic blood pressure (DBP). Body Mass Index (BMI) was calculated by dividing weight (kg) by square of height (m^2). A mercury sphygmomanometer was used to record blood pressure.

HRV Measurement: Heart rate variability (HRV) was assessed using a Lead II electrocardiogram (ECG), recorded for 15 minutes in a quiet, comfortable room. During the recording, participants remained seated and relaxed. The ECG signal was sampled at 1000 samples per channel using a PowerLab system (AD Instruments, Australia), and the raw ECG was filtered using a bandpass filter (2–40 Hz). The RR intervals were extracted from the ECG, and HRV was analyzed using both time-domain and frequency-domain parameters. The time-domain parameters analysed were RR interval, SDNN (standard deviation of all RR intervals), and RMSSD (root mean square of successive differences). Frequency-domain parameters included LF (low frequency), HF (high frequency), and the LF/HF ratio.

PEFR Measurement: PEFR, a measure of the efficiency of the large airways during forced expiration, was measured using a peak flow meter (Wright Peak Flow Meter). The participants were instructed

to perform three maximal forced expirations, and the highest value obtained from these attempts was recorded as their PEFR.

Statistical Analysis: Data were presented as mean $\pm$ standard deviation (SD). Descriptive statistics were used to summarize the anthropometric parameters and HRV indices. Correlation analyses were conducted using Pearson's correlation to examine the relationships between HRV parameters and PEFR. A p-value of < 0.05 was considered statistically significant.

RESULTS

The study sample consisted of 29 adolescents aged 14–15 years, among which 15 were boys and 14 were girls.

Anthropometric Data: The mean height in girls was 156.79 cm, with a mean weight of 58.96 kg. The mean blood pressure was 84 mmHg. In boys, the mean height was 164.36 cm, with a mean weight of 64 kg. The mean blood pressure was 84 mmHg. No significant differences were observed between boys and girls in terms of anthropometric parameters and blood pressure.

HRV and Gender Differences: Table 1 summarizes the HRV parameters for boys and girls, presented as mean $\pm$ standard deviation (SD).

Table 1. HRV Parameters in adolescents with cardiovascular risk

Parameters	Gender	Mean $\pm$ SD
PRR50 (ms)	Boys	25.19 $\pm$ 25.41
	Girls	21.35 $\pm$ 20.36
SDRR (ms)	Boys	47.94 $\pm$ 17.81
	Girls	48.87 $\pm$ 20.97
RMSSD (ms)	Boys	45.38 $\pm$ 27.33
	Girls	44.61 $\pm$ 21.87
Aver-RR (ms)	Boys	754.84 $\pm$ 22.13
	Girls	683.47 $\pm$ 81.47
LFnu	Boys	45.04 $\pm$ 15.74
	Girls	45.41 $\pm$ 16.29
HFnu	Boys	48.31 $\pm$ 15.07
	Girls	46.66 $\pm$ 14.45
LF/HF	Boys	1.0 $\pm$ 0.64
	Girls	1.2 $\pm$ 0.46

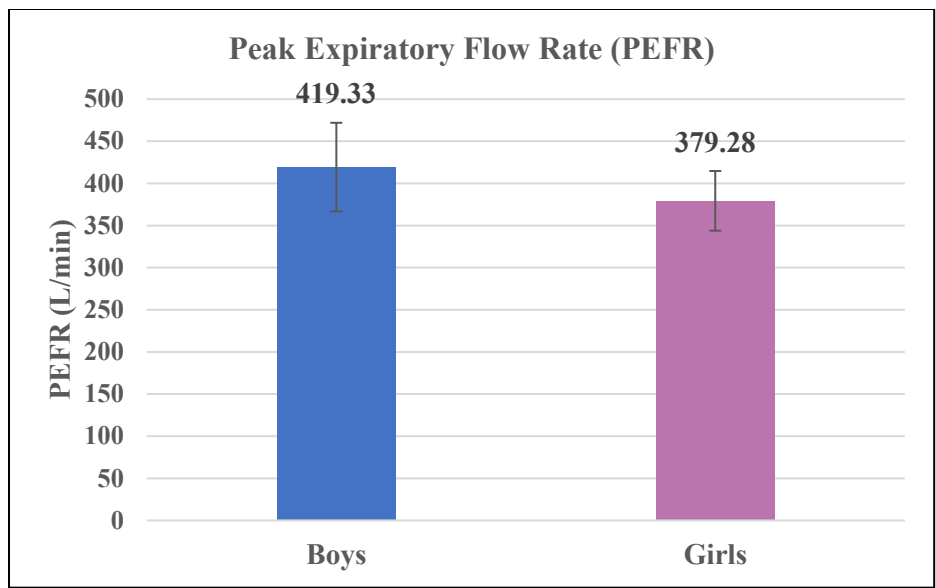
HRV: Heart rate variability; LFnu: LF in normalized units; HFnu: HF in normalized units; SDRR: Standard deviation of RR interval; RMSSD: Root mean square of the successive differences; RR50: RR interval differing by > 50 ms in the entire recording; pRR50: Percentage of RR50 counts

In terms of HRV parameters, both boys and girls showed similar values for most of the time-domain and frequency-domain measures, such as PRR50, SDRR, RMSSD, LFnu, and HFnu. However, there were notable differences in Aver-RR, where boys had a higher mean (754.84 $\pm$ 22.13 ms) compared to girls (683.47 $\pm$ 81.47 ms), indicating a longer average RR interval (and thus, lower heart rate) in boys. The LF/HF ratio was slightly higher in girls (1.2 $\pm$ 0.46) than in boys (1.0 $\pm$ 0.64), suggesting a relatively higher sympathetic tone in girls.

PEFR and Gender Differences:

The mean values of PEFR were significantly higher in boys as compared to girls. Specifically, the boys exhibited a mean PEFR of 419.33 $\pm$ 52.57 L/min, while the girls had a mean of 379.28 $\pm$ 35.40 L/min ($p < 0.05$) (Figure 1).

Figure 1. PEFR in adolescents with cardiovascular risk



Correlations between PEFR and HRV parameters: In boys, PEFR showed a positive correlation with average RR interval ($r = 0.38$), SDRR ($r = 0.13$), LFnu ($r = 0.36$), and LF/HF ratio ($r = 0.29$) (Figure 2), and a negative correlation with RMSSD ($r = -0.01$) and HFnu ($r = -0.27$). In girls, PEFR showed a positive correlation with SDRR ($r = 0.40$), RMSSD ($r = 0.25$), average RR interval ($r = 0.30$), HFnu ($r = 0.17$) and correlated negatively with LFnu ($r = -0.17$) and LF/HF ratio ($r = -0.25$) (Figure 3).

Figure 2. Correlation of PEFR with LF/HF ratio in boys

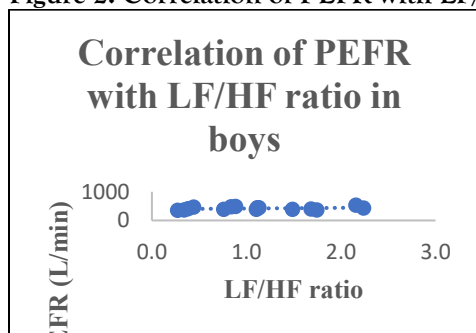
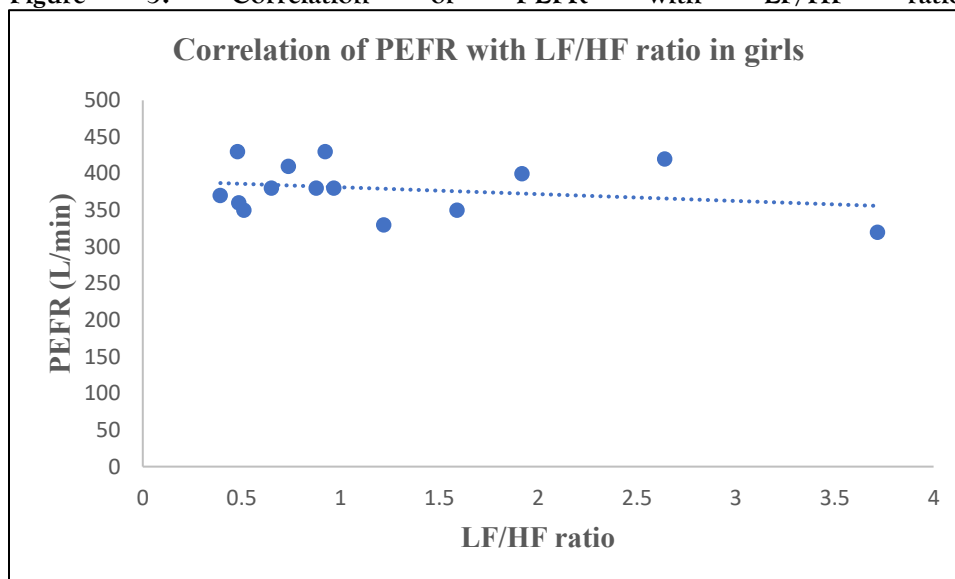


Figure 3. Correlation of PEFR with LF/HF ratio in girls



DISCUSSION

This study aimed to explore the relationship between HRV and PEFR in adolescents with obesity and/or a family history of hypertension and diabetes mellitus. The findings suggest a differential relationship between HRV and PEFR in boys and girls with cardiovascular risk factors. The results suggest a complex interplay between autonomic regulation, as reflected by HRV, and respiratory function in this population.

HRV and Gender Differences: The findings of the present study indicated some gender-specific differences in HRV parameters. Boys had higher mean values of Aver-RR, suggesting a lower resting heart rate, which is typically associated with better parasympathetic tone. Moreover, boys showed a positive correlation between PEFR and HRV indices such as average RR interval, RMSSD and pRR50, which are typically reflective of parasympathetic nervous system activity. These results suggest that in boys, improved pulmonary function is linked to better autonomic regulation, particularly parasympathetic activity, which is consistent with findings from other studies [14,15]. Boys exhibited higher PEFR and parasympathetic indicators, in line with previous research highlighting sex-based differences in lung function and autonomic tone during adolescence [16,17]. Higher Parasympathetic indicators of HRV in boys suggest relatively enhanced parasympathetic tone [15]. In contrast, girls showed a slightly higher LF/HF ratio, which can be interpreted as a higher sympathetic activity relative to parasympathetic tone. This finding suggests that autonomic regulation may differ between genders in this population. Additionally, the negative correlations between PEFR and LFnu and LF/HF ratio in girls suggest a potential inverse relationship between sympathetic nervous system activity and PEFR in girls, which may indicate altered autonomic control in this subgroup. Although the overall HRV indices did not differ significantly by gender, the trends revealed distinct autonomic modulation patterns between boys and girls. Heart rate variability values vary during adolescence and show sex-specific patterns, as established by normative data from previous investigations [15]. This also may suggest that sympathetic dominance may impair pulmonary function in girls with cardiovascular risk factors, which warrants further investigation.

PEFR and Gender differences: PEFR is an important clinical parameter that reflects the function of the large airways, and it is influenced by factors such as lung compliance, airway resistance, and overall respiratory health [14]. The results of this study align with previous findings that suggest a relationship between autonomic function and respiratory parameters. The higher PEFR values observed in boys are consistent with

the notion that males may generally exhibit better pulmonary function during adolescence [14]. However, the observed lower PEFR in girls, combined with their higher sympathetic tone (indicated by a higher LF/HF ratio), may reflect a more complex interaction between gender, autonomic control, and pulmonary health. These findings could imply that while boys may benefit from better autonomic regulation in terms of both heart rate and lung function, girls may experience greater challenges due to increased sympathetic activity, which could affect both cardiovascular and respiratory health in the long term [15]. Previous studies have also shown that psychological stress can also affect pulmonary function, influencing peak expiratory flow rate in various populations [14].

Correlations between PEFR and HRV: In boys, the analysis revealed positive correlations between PEFR and most HRV parameters. HRV is often considered an indicator of autonomic nervous system function, with higher HRV typically reflecting better autonomic balance and cardiovascular health [15]. The positive correlations between PEFR and HRV parameters in boys might suggest that those with higher PEFR, a marker of better respiratory function, also exhibit better autonomic regulation, which supports findings from studies linking respiratory function with HRV [16]. The positive correlation observed between PEFR and HRV parameters in boys is consistent with previous studies indicating that improved pulmonary function is associated with better autonomic regulation [16, 17]. Specifically, the higher mean PEFR in boys may be related to better sympathetic and parasympathetic balance, as reflected in the positive correlation with average RR interval, RMSSD and pRR50, and LF/HF ratio. These findings align with research indicating that a more balanced autonomic function is often associated with superior cardiovascular and respiratory health [17]. However, we found that RMSSD and HF did not follow the expected positive correlation. RMSSD and HF are commonly associated with parasympathetic activity and respiratory function. The lack of a significant positive correlation with these parameters could indicate that the autonomic regulation in boys with higher PEFR may be driven by other mechanisms, such as sympathetic modulation or other non-respiratory influences. Further research could examine the interplay of parasympathetic and sympathetic dominance in this context. In girls, the correlation between PEFR and HRV parameters was less straightforward. We found a negative correlation between PEFR and LF and the LF/HF ratio. The LF/HF ratio is often used as a marker of sympathetic to parasympathetic balance, with a higher ratio typically indicating sympathetic dominance. This negative correlation suggests that girls with higher PEFR may have a more parasympathetic-dominant autonomic profile, which contrasts with the positive correlation observed in boys. The difference in the relationship between PEFR and HRV parameters in boys and girls could reflect gender differences in autonomic nervous system regulation or hormonal influences, as suggested by previous studies indicating that females tend to have a higher parasympathetic tone [17,18]. Additionally, there was also correlation between PEFR and RMSSD in girls. These associations could point to a different underlying autonomic regulation in girls or reflect the complexity of factors influencing both respiratory and autonomic control mechanisms in females. These results warrant further investigation into gender-specific differences in autonomic regulation. The lack of consistent association between parasympathetic markers and PEFR in both sexes complicates interpretation. Vagal activity can cause bronchoconstriction via muscarinic receptor pathways [19], yet is also associated with better stress adaptation and inflammation control [20]. This dual role could explain the divergent correlations observed. Our findings align with studies showing that HRV components are modulated by lung mechanics and that these interactions may vary by sex and developmental stage [13]. Furthermore, the interplay between HRV and PEFR may reflect not only neural regulation but also mechanical factors such as lung recoil and airway resistance, which evolve with growth [21,22]. The benefits of autonomic regulation enhancement through non-pharmacological means such as yoga, physical activity, and mindfulness training are well-documented [23,24]. Targeted interventions in high-risk adolescents could bolster both pulmonary and cardiovascular health. **Clinical Implications:** The findings of this study have important clinical implications. Adolescents with obesity and/or a family

history of hypertension and diabetes are at heightened cardiovascular risk, and early detection of autonomic dysfunction and impaired pulmonary function could be valuable for early intervention. Given the interrelationship between HRV and PEFR, interventions aimed at improving both autonomic function (e.g., through exercise and stress management) and pulmonary function (e.g., through respiratory therapy or physical activity) may benefit adolescents at risk for cardiovascular and metabolic diseases. **Limitations of the present study:** This study's limitations include its small sample size and cross-sectional design, which restrict causal inferences. Further, we did not evaluate physical activity levels, dietary habits, or pubertal stage, which could modulate autonomic and pulmonary outcomes.

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