International Journal of Research in Medical Sciences
Shinde BV et al. Int J Res Med Sci. 2025 Nov;13(11):4806-4809
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012

DOI: https://dx.doi.org/10.18203/2320-6012.ijrms20253605

Original Research Article

Circadian patterns of peak expiratory flow in healthy male individuals from different age groups

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Received: 18 August 2025
Revised: 10 September 2025
Accepted: 10 October 2025

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ABSTRACT

Background: The human respiratory system exhibits circadian variation, with peak expiratory flow rate (PEFR) typically lowest in the early morning and highest in the evening. This study aimed to assess diurnal variations in PEFR across different age groups and evaluate the influence of aging on this physiological rhythm.
Methods: A cross-sectional study was conducted on 145 healthy male volunteers aged 18–50 years, divided into two groups: 18-30 years (n=78) and 31-50 years (n=67). PEFR was recorded at four time points (7:00 AM, 12:00 PM, 7:00 PM, and 10:00 PM) over two days using mini-Wright's peak flow meters. Data were analyzed using unpaired t-test, ANOVA, and Tukey's post hoc test.
Results: Both groups exhibited significant diurnal variation in PEFR ($p<0.0001$), with morning troughs and evening peaks. The younger group consistently showed higher PEFR values at all-time points ($p<0.0001$) and a greater amplitude of variation. The largest increase occurred between 7 AM and 7 PM. No significant differences were observed between 12 pm and 10 pm in either group, indicating a plateau after the evening peak. BMI was comparable between groups, ruling it out as a confounder.
Conclusions: PEFR demonstrates a clear circadian pattern in healthy adult males, with aging associated with reduced values and diminished amplitude of variation. These findings underscore the importance of considering time-of-day and age in pulmonary function assessment. Clinically, they support time-based monitoring and interventions, particularly in conditions like asthma, where diurnal variation is exaggerated.

Keywords: Aging, Diurnal variation, Peak expiratory flow rate, Pulmonary function

INTRODUCTION

The human respiratory system demonstrates natural fluctuations in function over the course of the day, largely regulated by the body's internal circadian clock. Peak Expiratory Flow (PEF) is a simple, reliable measure of airway caliber and ventilatory capacity that has been shown to follow a distinct diurnal pattern, with the lowest values in the early morning and the highest values in the late afternoon or early evening.[1,2] This rhythmic variation is thought to result from physiological changes such as airway smooth muscle tone, autonomic nervous system activity, hormonal fluctuations, and body temperature changes. [3]

Several studies in young adults have documented this pattern consistently. For example, in healthy volunteers aged 20-40 years, PEF was lowest upon waking and rose steadily to a peak by late afternoon, with an average diurnal variation of 7-13%.[1,4] Similar findings have been reported in South Asian populations aged 18-24, where PEF values increased significantly from morning to evening in both males and females, though females often showed greater variability.[2,3]

Age-related factors may influence the magnitude or timing of these fluctuations. While some research suggests minimal daytime variation in PEF between younger and older healthy adults, other studies using extended home monitoring have found increased variability in small airway function in individuals aged 45-60 years, especially during the evening.[5,6] These differences may be due to reduced lung elasticity, altered respiratory muscle strength, or changes in circadian regulatory mechanisms with aging.

Given these observations, it becomes important to examine circadian patterns of PEF across different age groups in healthy males to better understand age-related respiratory physiology, refine reference values, and potentially guide time-based interventions in respiratory care.

METHODS

Study population

This is cross-sectional research, involving 145 healthy male volunteers aged between 18 and 50 years, all recruited from the MGM Medical College Aurangabad campus. Study was conducted between January 2025 and June 2025. Participants were selected randomly and shared similar daily routines and sleeping patterns. Before enrolment, the study's objectives and procedures were clearly explained, and each subject provided written informed consent. Institutional Ethics Committee approval was obtained.

Inclusion and exclusion criteria

A comprehensive medical history and physical examination were conducted to ensure the absence of any cardiopulmonary disorders. Individuals with a history of smoking, significant chest injury, chest or spinal deformities, or personal/family history of asthma, COPD, or other cardiopulmonary illnesses were excluded. Baseline pulmonary function tests were performed on all volunteers to detect any mild restrictive or obstructive abnormalities.

Initially, 150 participants were recruited; however, data from those with incomplete test records were removed. The final sample comprised 145 participants Group A (n = 78) aged 18-30 years and Group B (n = 67) aged 31–50 years.

Study protocol

For operational ease, subjects were organized into groups of five, each provided with a mini-Wright peak expiratory flow meter. Every participant received individual training to measure their Peak Expiratory Flow Rate (PEFR) in litres per minute (L/min). PEFR readings were taken at four time points-7:00 AM, 12:00 PM, 7:00 PM, and 10:00 PM across two consecutive days. At each session, a minimum of three attempts was made, and the highest value was recorded.

Supervision and data collection

Sessions were conducted under the close supervision of the principal investigator. During sessions without the investigator, a designated "group captain" from each team ensured proper procedure. Data collection sheets included demographic information, medical history, anthropometric data (height and weight), medication use, and PEFR measurements. To reduce any bias from the learning effect, only the 11:00 PM reading from day one and all four readings from day two were considered for analysis.

Statistical analysis

Data entry was done in Microsoft Excel and processed using SPSS software (version 16). Results are presented as mean±standard deviation (SD). Variations in PEFR across different times of day were assessed using ANOVA. If the F-test showed significance, Tukey's HSD post hoc test was applied for pairwise comparisons. A statistically significant $p<0.05$ was taken.

RESULTS

The study assessed diurnal variation in PEFR in two age groups (18-30 years (n-78) and 31-50 years (n-67) and compared values both between and within groups.

Table 1: Comparison of the diurnal variation of PEFR between different age groups.

Variables	18-30 (n=78)	31-50 (n=67)	p value
Age	22.14±3.956	40.45±6.098	0.0001(S)
BMI	25.36 ± 2.376	24.80±2.711	0.2208 (NS)
PEFR 7 AM	443.26±39.812	408.80±23.108	0.0001 (S)
12 Noon	481.04±42.141	440.56±24.930	0.0001 (S)
5 PM	515.76±46.497	471.78±25.823	0.0001 (S)
10 PM	493.58±42.887	445.85±25.060	0.0001 (S)

Table 1, Between-group comparison: BMI was similar between the groups (p=0.2208), ruling out body mass index as a confounder. At all four diurnal time points (7 AM, 12 Noon, 5 PM, and 10 PM), the younger group exhibited significantly higher PEFR values than the older group (all p=0.0001), indicating an age-related decline in pulmonary function.

Both groups showed significant diurnal variation in PEFR (p<0.0001). In 18-30-year-olds, PEFR was lowest in the morning (443.26±39.81 L/min) and peaked in the evening (515.76±46.49 L/min), followed by a slight decline at night. In 31-50-year-olds, the same pattern was observed, with a smaller amplitude of variation (Table 2).

Table 2: Age-wise comparison of the diurnal variation of PEFR.

Age (yrs)	7 AM (D1)	12 Noon (D2)	7 PM (D3)	10 PM (D4)	F ratio	p value
18-30	443.26±39.81	481.04±42.14	515.76±46.49	493.58±42.88	33.58	<0.000(S)
31-50	408.80±23.10	440.56±24.93	440.56±24.93	445.85±25.06	61.12	<0.000(S)

Table 3: Comparison between the PEFR at different diurnal times.

Age (yrs)	D1 Vs D2	D1 Vs D3	D1 Vs D4	D2 Vs D3	D2 Vs D4	D3 Vs D4
18-30	37.78	72.50	50.32	34.72	12.54	22.18
p value	0.0001(S)	0.0001(S)	0.0001(S)	0.0003(S)	0.3297(NS)	0.01594(S)
31-50	31.75	62.98	37.05	31.23	5.30	25.93
p value	0.0001(S)	0.0001(S)	0.0001(S)	0.0001(S)	0.669(NS)	0.0001(S)

Significant differences were found between most time points, except between 12 noon and 10 PM (p=0.3297, NS), suggesting similar evening and late-night PEFR values. The largest increase occurred from morning (7 AM) to evening (5 PM). 31-50 years: Most comparisons were significant except between 12 Noon and 10 PM (p=0.669, NS). The overall rise from morning to evening was smaller compared to the younger group (Table 3).

DISCUSSION

This characteristic morning trough and evening peak pattern is consistent with previously reported circadian influences on pulmonary function. Airway caliber and bronchial smooth muscle tone are known to exhibit time-of-day variation due to fluctuations in autonomic nervous system activity and circulating hormones.[7,8] Increased parasympathetic activity in the early morning causes bronchoconstriction, while enhanced sympathetic drive and increased circulating catecholamines during the day promote bronchodilation and improved airflow.[9]

In the present study, younger adults (18-30 years) consistently exhibited higher PEFR values at all measured time points compared to older adults (31-50 years). This finding is in agreement with earlier studies showing an age-related decline in expiratory flow rates, attributable to reduced lung elastic recoil, diminished respiratory muscle strength, and progressive stiffening of the thoracic cage.[10-12] Moreover, the amplitude of diurnal variation was greater in the younger group, suggesting that circadian modulation of pulmonary function may become attenuated with age, as previously reported by Mortola.[13]

Tukey's post hoc analysis revealed that in both groups, the most pronounced and statistically significant increase in PEFR occurred between 7 AM and 7 PM. No significant difference was noted between 12 Noon and 10 PM in either group, indicating that the major improvement in PEFR occurs between morning and late afternoon, with relative stabilization thereafter. These results align with findings by Hetzel and Clark et al and Spengler and Shea et al, who also reported late-afternoon peaks in pulmonary function indices.[14,15]

From a clinical standpoint, the recognition of diurnal variation in PEFR has practical importance. In patients with asthma and other obstructive airway diseases, diurnal fluctuation is often exaggerated, and morning dips in PEFR may signal increased airway hyperreactivity.[16,17] Understanding this rhythm can help clinicians standardize the timing of PEFR measurements for more accurate monitoring and may influence the scheduling of pharmacotherapy to optimize efficacy. Additionally, the observed age differences highlight the need for age-specific reference values in respiratory function assessment.

CONCLUSION

This study confirms that PEFR exhibits a significant diurnal variation in both young (18–30 years) and middle-aged (31–50 years) adults, with values lowest in the early morning and peaking in the evening. Younger adults demonstrated consistently higher PEFR values and a greater amplitude of variation compared to older adults, despite similar BMI. These findings suggest that aging is associated with a decline in pulmonary function and a blunting of circadian modulation of airway caliber. Recognition of this physiological rhythm is clinically relevant for standardizing PEFR measurement, interpreting respiratory function results, and optimizing the timing of therapeutic interventions, particularly in conditions with exaggerated diurnal fluctuation such as asthma.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Shinde BV, Irani FB, Joshi P. Circadian patterns of peak expiratory flow in healthy male individuals from different age groups. Int J Res Med Sci 2025;13:4806-9.