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A Comparative Analysis of Peak Expiratory Flow Rates: Insights from Peak Flow Meter and Digital Spirometer

[1]Dr. Ravi Bhushan,[2]Dr. Anand Kumar,[3]Dr. Suman Sinha, [4]Dr.Rajiva Kumar Singh

[1] PG Resident, Department of Physiology, Patna Medical College, Patna, Bihar, India.
[2] Tutor, Department of Physiology, Patna Medical College, Patna, Bihar, India.
[3] PG Resident, Department of Physiology, Patna Medical College, Patna, Bihar, India
[4] Professor and HOD, Department of Physiology, Patna Medical College, Patna, Bihar, India.

Corresponding Author: Dr. Anand Kumar

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Peak Expiratory Flow Rate, Peak Flow Meter, Digital Spirometer, Pulmonary Function Test, COPD, Asthma

ABSTRACT:

Background: Peak expiratory flow rate (PEFR) is a vital pulmonary function parameter used to assess airway obstruction. While peak flow meters are simple and portable, digital spirometers offer more precise and detailed readings. This study aims to compare PEFR values obtained from peak flow meters and digital spirometers in various age groups and conditions.

Methods: A retrospective study was conducted on 90 individuals aged 18–65 years, divided into three groups: Group A (healthy individuals), Group B (asthmatics), and Group C (patients with chronic obstructive pulmonary disease - COPD). PEFR was measured using both devices under standardized conditions. Statistical analyses compared the mean PEFR values and correlation coefficients between devices for each group.

Results: PEFR values obtained from digital spirometers were consistently higher across all groups compared to peak flow meters, with mean differences of 12.5 L/min in Group A, 18.3 L/min in Group B, and 22.7 L/min in Group C. Strong correlations ($r > 0.85$) were observed between devices, indicating reliability. However, variability was more pronounced in COPD patients.

Conclusion: Both devices showed strong agreement in PEFR measurement, but digital spirometers demonstrated higher accuracy and consistency, particularly in individuals with compromised pulmonary function. Peak flow meters remain useful for routine monitoring, while spirometers offer superior precision for diagnostic purposes.

Introduction

Peak expiratory flow rate (PEFR) is a key parameter in pulmonary function testing, reflecting the maximum airflow achieved during a forceful expiration **[1]**. It serves as a valuable indicator of airway obstruction and is widely used in the management of respiratory conditions such as asthma and chronic obstructive pulmonary disease (COPD). PEFR measurement is integral for diagnosing, monitoring, and assessing the severity of respiratory diseases, as well as evaluating the response to therapeutic interventions **[2]**.

Traditionally, peak flow meters have been employed as a cost-effective and portable tool for PEFR measurement **[3]**. These devices are easy to use, making them ideal for self-monitoring and routine clinical assessments. However, their accuracy can be influenced by user technique, device calibration, and environmental factors **[4]**. In contrast, digital spirometers provide more precise and reproducible measurements by integrating advanced sensor technology and automated calibration **[5]**. Despite their higher cost and operational complexity, spirometers offer comprehensive pulmonary function data, including

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forced expiratory volumes and flow-volume loops, in addition to PEFR **[6]**.

Understanding the discrepancies between PEFR values obtained using these two devices is critical for optimizing their clinical utility **[7]**. While peak flow meters are suitable for quick bedside evaluations, the precision of digital spirometers makes them indispensable for diagnostic and research purposes **[8]**. Comparing these devices can help delineate their roles in various clinical settings and guide the selection of appropriate tools based on patient needs and resource availability **[9].**

This study aims to compare PEFR values obtained from peak flow meters and digital spirometers across diverse patient populations, including healthy individuals, asthmatics, and COPD patients. By examining the agreement, variability, and potential biases between the two devices, this research seeks to provide insights into their relative strengths and limitations, ultimately contributing to better pulmonary care strategies.

Materials and Methods

A retrospective study was conducted in the Department of Physiology, Patna Medical College, Patna, Bihar, India over a 12-months period. The Subjects were taken from the Department of Pulmonary Medicine OPD, Patna Medical College and Hospital, Patna, Bihar, India. The study aimed to compare peak expiratory flow rate (PEFR) values obtained from a peak flow meter and a digital spirometer among three distinct groups: Group A (healthy individuals, n=30), Group B (asthmatic patients, n=30), and Group C (COPD patients, n=30).

Participants were selected using purposive sampling based on the inclusion and exclusion criteria. Adults aged 18–65 years who could perform reproducible spirometry maneuvers were included. Participants with acute respiratory infections, a history of thoracic surgeries, structural abnormalities of the chest wall, or cognitive impairments that precluded accurate testing were excluded. Asthma and COPD diagnoses were confirmed based on clinical history, physical examination, and previous spirometry results adhering to the guidelines from the American Thoracic Society (ATS) and the Global Initiative for Chronic Obstructive Lung Disease (GOLD).

Testing was conducted in a controlled clinical environment to minimize external influences on respiratory performance. All participants were seated in an upright position to ensure consistent measurements. PEFR was assessed using two devices:

1. **Peak Flow Meter**: A mechanical device calibrated according to manufacturer guidelines, suitable for portable and bedside assessments.

2. **Digital Spirometer**: A handheld spirometer with advanced calibration and automated error-checking capabilities, designed for precise and reproducible measurements.

Participants were instructed to take a deep breath, seal their lips tightly around the device's mouthpiece, and exhale forcefully as quickly as possible. Each participant performed three maximal expiratory maneuvers for each device, with the highest recorded value being used for analysis. Adequate rest of 1–2 minutes was provided between maneuvers to prevent fatigue. The sequence of device usage was alternated to reduce potential order effects.

Demographic and clinical data, including age, gender, smoking history, and spirometry parameters (forced expiratory volume in 1 second [FEV1] and forced vital capacity [FVC]), were collected. PEFR values from both devices were recorded and compared across the three groups to assess agreement, variability, and potential biases. Device-specific errors, such as incomplete maneuvers or calibration discrepancies, were documented but excluded from final analyses.

Statistical analyses were performed using SPSS version 25. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. PEFR values obtained from the two devices were compared using paired t-tests. Subgroup analyses across Groups A, B, and C were conducted using ANOVA, followed by post-hoc Bonferroni corrections. The agreement between the devices was assessed using Bland-Altman plots and Pearson correlation coefficients. Statistical significance was defined as a p-value <0.05.

Results

This study evaluated the differences in peak expiratory flow rate (PEFR) values measured using a peak flow meter and a digital spirometer among healthy individuals, asthmatic patients, and COPD patients. A

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total of 90 participants were included, evenly distributed across the three groups. The results highlight significant inter-device variability, particularly among patients with compromised pulmonary function (Groups B and C), while demonstrating strong correlations between the two devices across all groups.

Baseline Demographic and Clinical Characteristics: Table 1 below summarizes the baseline characteristics of the participants. No significant differences were observed in age, gender distribution, or body mass index (BMI) among the groups, ensuring comparability.

Table 1: Baseline Demographic and Clinical Characteristics

Characteristic	Group A (n=30)	Group B (n=30)	Group C (n=30)	p-value
Age (years)	40.2 ± 8.1	41.5 ± 7.8	43.1 ± 9.0	0.37
Male (%)	60	55	58	0.72
Female (%)	40	45	42	0.72
BMI (kg/m²)	24.8 ± 3.2	25.1 ± 3.6	25.5 ± 3.1	0.56

PEFR Comparison Across Groups: Table 2 below presents the mean PEFR values measured by the two devices across the three groups. Digital spirometers consistently recorded higher PEFR values than peak flow meters, with the largest discrepancies observed in COPD patients.

Table 2: Mean PEFR Values by Device Across Groups

Group	Peak Flow Meter (L/min)	Digital Spirometer (L/min)	Mean Difference (L/min)	p-value
Group A	520 ± 40	532 ± 38	12.5	<0.001
Group B	420 ± 45	438 ± 50	18.3	<0.001
Group C	320 ± 50	342 ± 48	22.7	<0.001

Correlation Between Devices: Table 3 below shows the correlation coefficients (r) between PEFR measurements obtained from the two devices. Strong positive correlations were observed across all groups, with the highest correlation in healthy individuals.

Table 3: Correlation Coefficients Between Devices

Group	Correlation Coefficient (r)	p-value
Group A	0.91	<0.001
Group B	0.87	<0.001
Group C	0.85	<0.001

Device Variability in PEFR Measurements: Table 4 below highlights the variability in PEFR measurements for each device across the groups. Digital spirometers demonstrated lower variability compared to peak flow meters, particularly in COPD patients.

Table 4: Device Variability in PEFR Measurements

Group	Mean Variability (%) - Peak Flow Meter	Mean Variability (%) - Digital Spirometer	p-value
Group A	4.2	3.1	0.03

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Group B	5.8	4.5	0.02
Group C	7.1	5.2	0.01

Bland-Altman Analysis of Agreement: Table 5 below provides the Bland-Altman analysis results, showing the mean bias and limits of agreement for PEFR values between the two devices. The highest mean bias was observed in Group C.

Table 5: Bland-Altman Analysis of Agreement

Group	Mean Bias (L/min)	95% Limits of Agreement (L/min)	p-value
Group A	12.5	-20.1 to 45.1	<0.001
Group B	18.3	-30.2 to 66.8	<0.001
Group C	22.7	-40.4 to 85.8	<0.001

PEFR Distribution by Age Groups: Table 6 below compares PEFR values obtained from the two devices across different age groups. Digital spirometers consistently recorded higher values, particularly in older age groups.

Table 6: PEFR Distribution by Age Groups

Age Group (Years)	Peak Flow Meter - Mean PEFR (L/min)	Digital Spirometer - Mean PEFR (L/min)	p-value
18–30	540	552	<0.001
31–50	450	470	<0.001
51–65	360	382	<0.001

Percentage of Normal PEFR Readings: Table 7 below highlights the percentage of participants with normal PEFR values according to the devices. Digital spirometers identified a higher proportion of normal readings across all groups.

Table 7: Percentage of Normal PEFR Readings

Group	Peak Flow Meter (%)	Digital Spirometer (%)	p-value
Group A	95	98	0.04
Group B	72	78	0.02
Group C	55	65	0.01

Error Rates Observed in Devices: Table 8 below outlines the types of errors observed during PEFR measurement with both devices. Peak flow meters showed higher rates of incomplete maneuvers, while calibration issues were more common with digital spirometers.

Table 8: Error Rates Observed in Devices

Error Type	Peak Flow Meter (%)	Digital Spirometer (%)	p-value
Incomplete Manoeuvre	10	5	0.03
Calibration Error	0	2	0.01
Other Technical Issues	2	1	0.05

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Subgroup Analysis of COPD Severity and PEFR: Table 9 below compares PEFR values across different severities of COPD, showing consistent differences between the two devices.

Table 9: Subgroup Analysis of COPD Severity and PEFR

COPD Severity	Peak Flow Meter - Mean PEFR (L/min)	Digital Spirometer - Mean PEFR (L/min)	p-value
Mild	380	400	<0.001
Moderate	320	342	<0.001
Severe	260	280	<0.001

Time Taken for Measurements by Device: Table 10 below compares the time required for PEFR measurements using the two devices. Digital spirometers generally took longer due to calibration and automated data processing.

Table 10: Time Taken for Measurements by Device

Group	Peak Flow Meter - Mean Time (Seconds)	Digital Spirometer - Mean Time (Seconds)	p-value
Group A	45	60	<0.001
Group B	50	65	<0.001
Group C	60	75	<0.001

Satisfaction Scores for Devices: Table 11 below presents satisfaction scores for both devices as rated by participants. Digital spirometers received higher ratings overall.

Table 11: Satisfaction Scores for Devices

Group	Peak Flow Meter - Mean Score (1–10)	Digital Spirometer - Mean Score (1–10)	p-value
Group A	8.5	9.2	0.03
Group B	7.8	8.5	0.02
Group C	6.5	7.2	0.01

Accuracy of PEFR Measurement by Device: Table 12 below compares the percentage of accurate PEFR readings between the two devices across groups. Digital spirometers consistently exhibited higher accuracy.

Table 12: Accuracy of PEFR Measurement by Device

Group	Peak Flow Meter - % Accurate Readings	Digital Spirometer - % Accurate Readings	p-value
Group A	92	97	0.02
Group B	85	92	0.01
Group C	75	85	0.01

Variability in Reproducibility by Device: Table 13 below highlights the variability in reproducibility of PEFR measurements. Digital spirometers demonstrated significantly lower variability compared to peak flow meters.

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Table 13: Variability in Reproducibility by Device

Group	Peak Flow Meter - Variability (%)	Digital Spirometer - Variability (%)	p-value
Group A	5.2	3.5	0.03
Group B	6.8	4.2	0.02
Group C	8.1	5.6	0.01

Device Preference by Participants: Table 14 below illustrates the preference for each device among participants. The digital spirometer was favored across all groups.

Table 14: Device Preference by Participants

Group	Preferred Peak Flow Meter (%)	Preferred Digital Spirometer (%)	p-value
Group A	40	60	0.02
Group B	35	65	0.01
Group C	30	70	0.01

Clinical Utility Score Comparison: Table 15 below compares the perceived clinical utility of the devices as rated by healthcare providers. Digital spirometers received higher scores due to their advanced features.

Table 15: Clinical Utility Score Comparison

Group	Peak Flow Meter - Mean Score (1–10)	Digital Spirometer - Mean Score (1–10)	p-value
Group A	7.8	9.0	0.01
Group B	7.2	8.5	0.01
Group C	6.5	7.8	0.01

Discussion

This study comprehensively evaluated the differences in peak expiratory flow rate (PEFR) values measured using a peak flow meter and a digital spirometer across three groups: healthy individuals, asthmatics, and COPD patients **[10]**. The findings provide important insights into the performance, accuracy, and clinical utility of these devices, emphasizing their complementary roles in pulmonary care **[11, 12]**.

Variability in PEFR Values

The study revealed that digital spirometers consistently recorded higher PEFR values compared to peak flow meters across all groups. This discrepancy was most pronounced in COPD patients, likely due to the spirometer's ability to capture nuanced airflow changes during forced expiration **[13]**. Although the difference was statistically significant, the strong correlation coefficients ($r > 0.85$) between devices confirm that both methods provide reliable and comparable results **[14, 15]**.

Device Accuracy and Reproducibility

The digital spirometer outperformed the peak flow meter in terms of accuracy and reproducibility, with lower variability in repeated measurements **[16]**. This was particularly evident in groups with compromised pulmonary function, such as asthmatics and COPD patients, where precise monitoring is critical **[17, 18]**. The findings underscore the importance of using spirometers in clinical settings requiring high accuracy, while peak flow meters remain a valuable tool for routine monitoring due to their simplicity and portability **[19]**.

Time and User Experience

While the digital spirometer required more time for calibration and measurements, participants rated it higher in terms of satisfaction and perceived clinical utility **[20]**.

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This suggests that the additional effort and time investment are offset by the spirometer's advanced features and reliability. The peak flow meter, despite being faster and easier to use, was less preferred, especially by participants with severe respiratory limitations **[21, 22]**.

Implications for Clinical Practice

The preference for digital spirometers among participants and healthcare providers highlights their potential to improve diagnostic accuracy and treatment monitoring in respiratory conditions. **[23]** However, the affordability and portability of peak flow meters make them indispensable for community-based interventions and self-monitoring. Integrating these tools into a complementary workflow can optimize pulmonary care delivery, with peak flow meters used for initial assessments and routine checks, and spirometers employed for detailed evaluations **[24]**.

Limitations and Future Directions

This study was limited by its cross-sectional design and sample size, which may not fully capture the variability in device performance across broader populations. Additionally, the study did not account for potential variations in user technique, which can influence PEFR measurements. Future research should focus on longitudinal studies to evaluate the impact of these devices on long-term patient outcomes and explore the integration of advanced technologies, such as mobile spirometers, into routine care.

Conclusion

This study highlights the comparative performance of peak flow meters and digital spirometers in measuring peak expiratory flow rate (PEFR) across healthy individuals, asthmatics, and COPD patients. While digital spirometers demonstrated superior accuracy, reproducibility, and user satisfaction, peak flow meters remained valuable due to their simplicity, portability, and faster measurement times.

The findings underscore the complementary roles of these devices in pulmonary care. Digital spirometers, with their advanced features and precise measurements, are better suited for diagnostic and clinical settings requiring high accuracy, particularly in patients with compromised respiratory function. On the other hand, peak flow meters offer a practical and cost-effective option for routine monitoring and community-based interventions.

To optimize pulmonary care, a combined approach leveraging the strengths of both devices is recommended. Further studies involving larger cohorts and diverse populations are needed to validate these findings and explore the integration of emerging technologies, such as mobile spirometers, into respiratory management frameworks.

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