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Original Research Article

Revisiting Forced Expiratory Time: Prospective Validation of a Simple Bedside Test for Airway Obstruction

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Abstract

Background: Chronic obstructive pulmonary disease (COPD) and bronchial asthma remain leading causes of respiratory morbidity and mortality worldwide. Despite effective treatment options, a large proportion of patients in low- and middle-income countries remain undiagnosed because spirometry—the reference standard for diagnosing airflow obstruction—is often unavailable outside specialised centres. Forced expiratory time (FET), measured with a stethoscope and stopwatch, offers a simple bedside alternative, but contemporary prospective validation data from South Asian populations remain limited.

Objectives: To evaluate the diagnostic accuracy of auscultated FET for detecting spirometry-confirmed airway obstruction, determine an optimal diagnostic threshold, and assess its feasibility and patient acceptability in routine outpatient practice.

Methods: We conducted a prospective cross-sectional diagnostic accuracy study in consecutive symptomatic adults attending a tertiary care teaching hospital in North India between June 2024 and June 2025. Participants underwent standardised FET measurement followed by spirometry performed according to American Thoracic Society/European Respiratory Society recommendations. Airway obstruction was defined as a post-bronchodilator FEV_1/FVC ratio <0.70. Diagnostic performance was assessed using sensitivity, specificity, predictive values, likelihood ratios, receiver operating characteristic (ROC) analysis, and area under the curve (AUC).

Results: Among 101 participants, 52 (51.5%) had spirometry-confirmed airway obstruction. At the pre-specified FET threshold of >6.0 seconds, sensitivity was 86.5% (95% CI 74.2–94.4), specificity 79.6% (95% CI 65.7–89.8), positive predictive value 81.8%, negative predictive value 84.8%, and overall diagnostic accuracy 83.2%. The positive and negative likelihood ratios were 4.24 and 0.17, respectively, with an AUC of 0.92. Mean FET increased progressively with disease severity, from 7.2 ± 0.7 seconds in mild obstruction to 9.1 ± 0.9 seconds in severe obstruction. FET took substantially less time to perform than spirometry (2.0 vs. 8.0 minutes) and was associated with higher patient acceptability.

Conclusions: Auscultated FET demonstrated good diagnostic performance as an initial screening test for airflow obstruction, particularly for excluding disease when spirometry is unavailable. Its simplicity, minimal equipment requirements, rapid administration, and favourable patient acceptance make it an attractive triage tool for primary care and resource-constrained healthcare settings. Larger multicentre studies are warranted to establish its role within contemporary respiratory screening pathways.

Keywords: Forced Expiratory Time; airway obstruction; COPD; spirometry; diagnostic accuracy; screening; resource-limited settings; India.

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Introduction

Chronic obstructive pulmonary disease (COPD) and bronchial asthma remain among the leading causes of chronic respiratory morbidity and premature mortality worldwide. Current global estimates place COPD prevalence above 390 million people and attribute more than three million deaths annually to the disease, while asthma affects an estimated 260 million individuals across all age groups [1,2]. This burden falls disproportionately on low- and middle-income countries (LMICs), where rapid urbanisation, ongoing tobacco use, household biomass fuel exposure, occupational dust, and worsening ambient air pollution continue to drive disease prevalence upward3. In India,

COPD affects approximately 4.2% of the adult population and is a major contributor to healthcare utilisation, disability-adjusted life years, and preventable mortality [3,4]. Beyond their direct clinical impact, chronic obstructive airway diseases carry a considerable socioeconomic cost through recurrent hospitalisations, lost productivity, and rising healthcare expenditure, which makes earlier diagnosis and timely intervention a public health priority [4,5].

Despite substantial advances in pharmacological therapy and pulmonary rehabilitation, most patients are still diagnosed only after considerable airflow limitation has already developed. Delayed diagnosis remains a principal barrier to improving long-term outcomes: many patients present initially with nonspecific respiratory symptoms that are attributed to smoking, recurrent infections, ageing, or environmental exposure rather than being objectively evaluated. Earlier recognition allows timely smoking cessation, initiation of inhaled therapy, vaccination, pulmonary rehabilitation, and appropriate follow-up, each of which improves symptom control, reduces exacerbations, and slows disease progression5. Improving access to simple and reliable methods for identifying airflow obstruction has therefore become an increasingly important objective in respiratory medicine, particularly where specialist diagnostic facilities remain limited.

Spirometry remains the accepted reference standard for diagnosing airflow obstruction and underpins contemporary international guidelines [1,6]. Measurements of forced expiratory volume in one second (FEV_1) and the FEV_1/FVC ratio provide objective confirmation of airflow limitation, allow disease staging, and guide treatment decisions [6]. Translating this guideline recommendation into routine practice, however, remains difficult in resource-constrained settings. High-quality spirometry requires calibrated equipment, trained personnel, regular quality assurance, patient cooperation, and enough time to obtain reproducible manoeuvres to American Thoracic Society/European Respiratory Society standards [6]. These requirements, together with equipment costs, maintenance, infection-control considerations, and limited technical expertise, restrict access outside specialised centres [8,9]. Consequently, many symptomatic individuals attending primary healthcare facilities and peripheral hospitals never undergo objective lung function testing, which perpetuates underdiagnosis and delays treatment.

These practical limitations have renewed interest in simple bedside tests that can identify patients most likely to benefit from confirmatory spirometry rather than attempting to replace it. Forced expiratory time (FET), obtained by timing a maximal forced expiration with only a stethoscope and stopwatch, is one such test [10,11]. Its physiological rationale is straightforward: progressive airway narrowing increases expiratory resistance, reduces expiratory flow, and prolongs the time needed for complete lung emptying during forced expiration [12,13]. Unlike spirometry, FET needs minimal equipment, can be performed quickly after limited training, and is readily applicable in outpatient clinics, community screening programmes, peripheral health centres, and other resource-limited environments—settings in which global health initiatives increasingly favour affordable point-of-care diagnostics and task-sharing within primary care.

Although FET has been described for more than six decades, the evidence base remains surprisingly limited and methodologically uneven. Early work by Rosenblatt and Stein and, later, by Lal and colleagues established the physiological relationship between prolonged expiratory time and airflow obstruction [10,11]. Later studies extended these findings across different patient populations, including occupational cohorts and general respiratory clinics [14,16]. Many of these studies, however, were conducted decades ago, enrolled small or highly selected referral/case-control cohorts, or used variable measurement techniques and diagnostic thresholds, making direct comparison difficult [14,19]. Relatively few contemporary prospective studies have evaluated FET against standardised ATS/ERS-compliant spirometry in consecutive symptomatic outpatients from South Asia, and data on patient acceptability, procedural feasibility, and implementation within routine outpatient practice remain sparse despite their importance for large-scale screening. [16,21]

The renewed relevance of FET extends beyond its historical role as a bedside sign. Contemporary healthcare systems need diagnostic approaches that are accurate, inexpensive, rapid, and scalable, particularly where access to spirometry remains inconsistent. Rather than competing with spirometry, FET may be most useful as a pragmatic triage tool that identifies individuals who need confirmatory lung function testing while reducing unnecessary referrals among those at low probability of obstruction, in keeping with established principles of screening [22-24].

The 2026 update of the Global Initiative for Chronic Obstructive Lung Disease (GOLD) strategy document reinforces this direction: it introduces a dedicated chapter on artificial intelligence and digital health in COPD and, for the first time, sets out a structured case-finding algorithm that explicitly distinguishes targeted case-finding—which it endorses—from unselected

population screening, which it does not1. Simple bedside tools such as FET sit naturally within this case-finding framework, and advances in digital acoustic sensing and machine learning raise the further possibility of semi-automated, smartphone- or wearable-assisted measurement of expiratory duration, extending its reach beyond specialist respiratory clinics [25,26].

We therefore conducted a prospective diagnostic validation study in consecutive symptomatic adults attending a tertiary care teaching hospital in North India. We hypothesised that auscultated FET, measured using a standardised protocol, and would show clinically useful diagnostic accuracy for identifying spirometry-confirmed airway obstruction while offering practical advantages in speed, feasibility, and patient acceptability. Accordingly, this study evaluated the diagnostic performance of FET against ATS/ERS-standardised spirometry, explored clinically relevant diagnostic thresholds, examined the relationship between FET and the severity of airflow obstruction, and assessed its potential role as a simple bedside triage tool in resource-limited healthcare settings.

Materials and Methods

Study Design and Setting: This prospective cross-sectional diagnostic validation study was conducted in the Department of Respiratory Medicine at Krishna Mohan Medical College and Hospital (KMMCH), Mathura, Uttar Pradesh, India, between June 2024 and June 2025. KMMCH is a tertiary care teaching hospital serving a large population from North India and provides specialised respiratory services through dedicated outpatient and pulmonary function laboratories.

All study procedures were performed in a dedicated pulmonary function testing laboratory under standard infection prevention and control measures. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Ethical approval was obtained from the Institutional Ethics Committee of Krishna Mohan Medical College (Reference No. KMU/RO/ECC/2023-24/61; approved 27 May 2024). Written informed consent was obtained from all participants before enrolment and before any study-related procedure.

Study Participants: Consecutive adult patients (≥18 years) attending the Respiratory Medicine outpatient department with symptoms suggestive of obstructive airway disease—chronic cough, dyspnoea, wheezing, or chest tightness—were screened for eligibility. Patients willing to undergo both auscultated FET measurement and spirometry were considered for inclusion. Patients requiring emergency management for acute respiratory distress, those who had undergone thoracic surgery within the preceding six months, pregnant women, individuals with neuromuscular disorders likely to impair respiratory effort, and those unable to provide informed consent were excluded.

During the study period, 110 patients were screened. Nine were excluded because of incomplete clinical data or technically unacceptable respiratory manoeuvres that did not meet ATS/ERS acceptability criteria[6]. The final study population therefore comprised 101 participants (Figure 1).

Measurement of Forced Expiratory Time: Forced expiratory time (FET) was measured using a standardised auscultatory technique. Before testing, the examiner explained and demonstrated the manoeuvre to each participant to ensure adequate understanding and cooperation. Participants were instructed to inhale maximally to total lung capacity and then exhale as forcefully, rapidly, and completely as possible through an open mouth.

The diaphragm of the stethoscope was positioned over the suprasternal notch. Timing began at the onset of audible expiratory airflow, using a digital stopwatch, and stopped when expiratory sounds ceased. Each participant performed three manoeuvres. To improve reliability and reduce random variation, the longest FET that fell within one second of at least one additional attempt was recorded for analysis, consistent with previously reported reliability criteria for the manoeuvre [17].

To limit observer bias, FET measurements were completed and documented before spirometry results were reviewed. Based on the threshold most consiste ntly reported in earlier studies, an FET >6.0 seconds was prospectively defined as an abnormal result [15,16].

Spirometry: Spirometry was performed by a trained respiratory technician using a calibrated commercial spirometer according to American Thoracic Society/European Respiratory Society (ATS/ERS) recommendations[6]. Participants were examined seated while wearing a nose clip. A minimum of three acceptable and reproducible forced expiratory manoeuvres were obtained for each participant, and the highest acceptable values were used for analysis. Post-bronchodilator spirometry was performed whenever clinically indicated, following administration of 400 µg salbutamol via a spacer device, with repeat measurements after 20–30 minutes. Airway obstruction was defined as a post-bronchodilator FEV_1/FVC ratio below 0.70, consistent with GOLD and ATS/ERS recommendations [1,6,7]. Disease severity was classified according to GOLD criteria as mild (FEV_1 ≥70% predicted), moderate (FEV_1

50–69% predicted), or severe (FEV_1 <50% predicted) [1].

Data Collection and Study Variables: Clinical and demographic data were collected prospectively on a standardised case record form. Spirometric measurements were transcribed directly from printed or digital reports to minimise transcription errors.

Variables recorded included age, sex, height, weight, body mass index (BMI), smoking status (current, former, or never smoker), presenting respiratory symptoms, FET, and spirometric parameters. BMI was categorised according to World Health Organization criteria as underweight (<18.5 kg/m²), normal weight (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²), or obese (≥30.0 kg/m²).

To assess practical applicability, feasibility outcomes included mean test duration and the proportion of participants unable to complete each procedure successfully. Patient acceptability was assessed immediately after testing using a five-point Likert scale ranging from 1 (very poor) to 5 (excellent).

Statistical Analysis: Continuous variables are presented as mean ± standard deviation (SD) or median with interquartile range (IQR), as appropriate; categorical variables are expressed as frequencies and percentages.

The diagnostic performance of FET was evaluated against spirometry as the reference standard. A 2 × 2 contingency table was constructed to calculate sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), overall diagnostic accuracy, positive likelihood ratio (LR+), and negative likelihood ratio (LR−), with corresponding 95% confidence intervals.

Receiver operating characteristic (ROC) curve analysis was performed with FET as a continuous variable to determine its overall discriminatory performance, expressed as the area under the ROC curve (AUC). Diagnostic performance was further evaluated at four pre-specified FET thresholds (>5.5, >6.0, >6.5, and >7.0 seconds). The optimal threshold was identified using the Youden Index (sensitivity + specificity − 1).

The relationship between FET and severity of airflow obstruction was explored descriptively. All statistical tests were two-tailed, and a p-value <0.05 was considered statistically significant.

Results

Participant Characteristics: A total of 110 symptomatic adults were screened, of whom 101 fulfilled the eligibility criteria and were included in the final analysis. Nine were excluded because of incomplete clinical data or technically unacceptable respiratory manoeuvres (Figure 1).

The study population comprised 61 men (60.4%) and 40 women (39.6%). Participants were predominantly middle-aged, with the largest proportion in the 41–50-year age group (25.7%), followed by 31–40 years (24.8%) and 51–65 years (20.8%).

Never-smokers formed the largest subgroup (39.6%), while current and former smokers accounted for 35.6% and 24.8% of the cohort, respectively.

Most participants had a normal (44.6%) or overweight (30.7%) body mass index. Chronic cough was the most frequent presenting symptom (68.3%), followed by dyspnoea (60.4%), wheezing (45.5%), and chest tightness (28.7%); multiple symptoms were commonly reported. Baseline characteristics are summarised in Tables 1 and 2.

Spirometric Findings and Forced Expiratory Time: Spirometry confirmed airflow obstruction in 52 of 101 participants (51.5%); the remaining 49 (48.5%) showed no evidence of obstruction. At the pre-specified FET threshold of >6.0 seconds, 55 participants (54.5%) had a positive result and 46 (45.5%) a negative result.

Comparison of FET with the spirometric reference standard yielded 45 true-positive and 39 true-negative results, with seven false-negative and ten false-positive classifications. FET correctly classified 84 of 101 participants, corresponding to an overall diagnostic accuracy of 83.2% (Table 3).

Diagnostic Performance of Forced Expiratory Time: At the pre-specified threshold of >6.0 seconds, auscultated FET performed well for identifying spirometry-confirmed airflow obstruction: sensitivity 86.5% (95% CI 74.2–94.4), specificity 79.6% (95% CI 65.7–89.8), PPV 81.8%, and NPV 84.8%. The positive and negative likelihood ratios were 4.24 and 0.17, respectively (Table 4).

ROC analysis showed excellent discriminatory ability, with an AUC of 0.92 (Figure 2).

Diagnostic Performance across Alternative Thresholds: Diagnostic performance varied with the threshold selected (Table 5). Lower thresholds favoured sensitivity, while higher thresholds improved specificity. A threshold of >5.5 seconds achieved the highest sensitivity (95%) but lower specificity (68%); raising the threshold to >7.0 seconds increased specificity to 92% at the cost of sensitivity (75%).

Among the four pre-specified thresholds, >6.5 seconds gave the best overall balance between sensitivity (86%) and specificity (85%), yielding

the highest Youden Index (0.71). The pre-specified >6.0-second threshold, however, maintained a favourable balance between accuracy and sensitivity, making it suitable as an initial screening cut-off.

Relationship between Forced Expiratory Time and Disease Severity: Among the 52 participants with confirmed airflow obstruction, 20 (38.5%) had mild disease, 19 (36.5%) had moderate disease, and 13 (25.0%) had severe disease by GOLD classification. Mean FET rose progressively with worsening obstruction: 7.2 ± 0.7 seconds in mild disease, 8.3 ± 0.6 seconds in moderate disease, and 9.1 ± 0.9 seconds in severe obstruction (Table 6; Figure 3), indicating a clear relationship between prolonged FET and severity of airflow limitation.

Feasibility and Patient Acceptability: FET took substantially less time to perform than spirometry—a mean of about 2.0 minutes versus 8.0 minutes—and patient-reported acceptability was also higher, with a mean Likert score of 4.4 compared with 3.6 for spirometry.

Only two participants were unable to complete FET satisfactorily, whereas nine were unable to produce spirometric manoeuvres meeting ATS/ERS acceptability criteria, underscoring the practical advantages of FET in routine clinical practice (Table 7).

Table 1: Age and Gender Distribution of the Study Cohort (N = 101)

Age Group (Years)	Male, n (%)	Female, n (%)	Total, n (%)
18–30	12 (11.9%)	8 (7.9%)	20 (19.8%)
31–40	15 (14.9%)	10 (9.9%)	25 (24.8%)
41–50	16 (15.8%)	10 (9.9%)	26 (25.7%)
51–65	13 (12.9%)	8 (7.9%)	21 (20.8%)
>65	5 (5.0%)	4 (4.0%)	9 (8.9%)
Total	61 (60.4%)	40 (39.6%)	101 (100%)

Table 2: Clinical Characteristics and Symptom Profile

Characteristic	Subgroup	Frequency, n (%)
Smoking Status	Never Smoker	40 (39.6%)
	Current Smoker	36 (35.6%)
	Former Smoker	25 (24.8%)
BMI Category	Underweight (<18.5)	5 (5.0%)
	Normal (18.5–24.9)	45 (44.6%)
	Overweight (25.0–29.9)	31 (30.7%)
	Obese (≥30.0)	20 (19.8%)
Symptoms*	Chronic Cough	69 (68.3%)
	Dyspnea	61 (60.4%)
	Wheezing	46 (45.5%)
	Chest Tightness	29 (28.7%)

***Participants could report more than one symptom.**

Table 3: Cross-tabulation of FET (>6.0 s) against Spirometric Obstruction

FET Result	Obstruction Present	Obstruction Absent	Total
Positive (>6.0 s)	45 (TP)	10 (FP)	55
Negative (≤6.0 s)	7 (FN)	39 (TN)	46
Total	52	49	101

Table 4: Diagnostic Accuracy Metrics for FET (>6.0 s Cut-off)

Metric	Value (95% CI)
Sensitivity	86.5% (74.2–94.4)
Specificity	79.6% (65.7–89.8)
PPV	81.8% (69.1–90.9)
NPV	84.8% (71.1–93.7)
Accuracy	83.2% (74.4–89.9)
LR+	4.24 (2.42–7.42)
LR−	0.17 (0.08–0.35)

Table 5: Performance Trade-offs across FET Thresholds

FET Threshold	Sensitivity	Specificity	PPV	NPV	Youden Index
>5.5 s	95.0%	68.0%	74.8%	93.3%	0.63
>6.0 s	86.5%	79.6%	81.8%	84.8%	0.66
>6.5 s	86.0%	85.0%	85.8%	85.2%	0.71
>7.0 s	75.0%	92.0%	90.7%	78.0%	0.67

Table 6. Mean FET Values across Obstruction Severity Strata

Severity (GOLD)	n	Mean FET (Seconds) ± SD
No Obstruction	49	5.2 ± 0.8
Mild	20	7.2 ± 0.7
Moderate	19	8.3 ± 0.6
Severe	13	9.1 ± 0.9

Table 7: Feasibility and Acceptability: FET vs Spirometry

Parameter	FET (Mean ± SD)	Spirometry (Mean ± SD)	p-value
Time Taken (Minutes)	2.0 ± 0.5	8.0 ± 1.5	<0.001
Acceptability (Likert 1–5)	4.4 ± 0.6	3.6 ± 0.8	<0.001
Technical Failure (n)	2	9	–

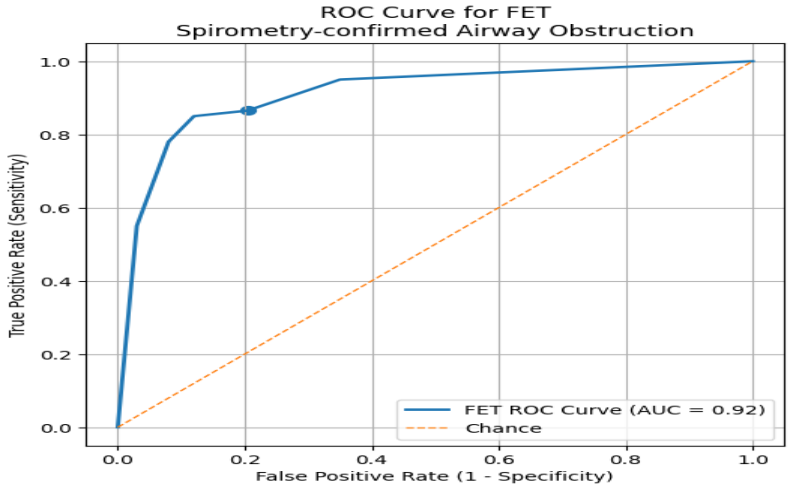

Figure 1: ROC curve for FET. The AUC of 0.92 reflects the overall discriminative performance of FET for spirometry-confirmed airway obstruction.

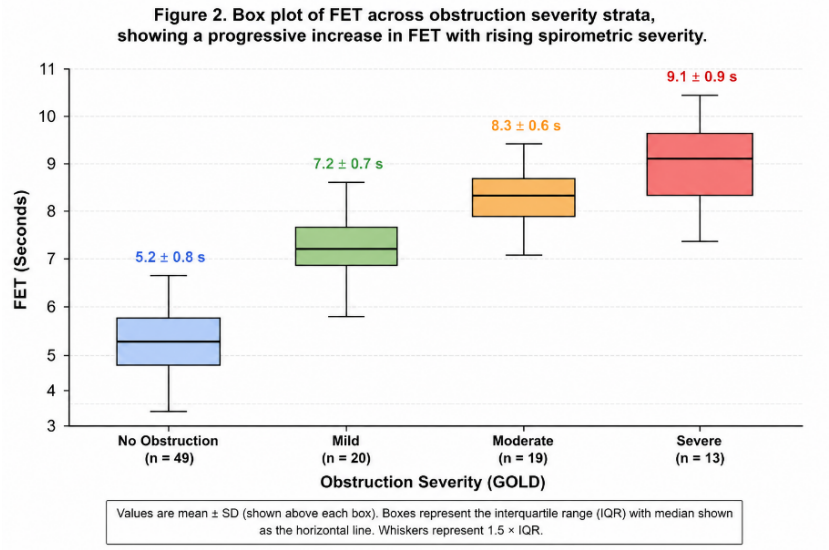

Figure 2: Box plot of FET across obstruction severity strata, showing a progressive increase in FET with rising spirometric severity.

Discussion

This prospective diagnostic validation study shows that auscultated forced expiratory time (FET) is a simple, rapid bedside test for identifying spirometry-confirmed airflow obstruction in symptomatic adults. At a pre-specified threshold of >6.0 seconds, FET achieved a sensitivity of 86.5%, specificity of 79.6%, overall accuracy of 83.2%, and excellent discrimination (AUC 0.92). FET cannot replace spirometry as the diagnostic reference standard, but these findings support its value as an initial screening and triage tool, particularly where access to formal pulmonary function testing remains limited. The favourable negative likelihood ratio (0.17), shorter testing time, higher patient acceptability, and lower failure rate together support a role in identifying patients who need confirmatory spirometry while sparing unnecessary referrals among those at low probability of obstruction.

Unlike many earlier studies, the present investigation prospectively enrolled consecutive symptomatic outpatients, used ATS/ERS-standardised spirometry as the reference standard, applied a pre-specified diagnostic threshold, and combined feasibility and acceptability assessment with conventional measures of diagnostic accuracy. These features strengthen the clinical applicability of the findings and add contemporary evidence to support re-evaluating FET within modern respiratory practice.

Comparison with Previous Literature: The diagnostic performance observed here is broadly consistent with previous work on FET, while extending the evidence through prospective validation in an Indian tertiary care outpatient population. Aggarwal and colleagues reported a sensitivity of 94.3% and specificity of 81.4% at a 5-second threshold in a case-control study16. Their higher sensitivity is expected, since lower thresholds generally maximise case detection at the expense of specificity; our own threshold analysis showed a comparable sensitivity of 95% at an FET threshold of >5.5 seconds. Their pooled estimates at the conventional 6-second threshold (sensitivity 80.2%, specificity 83.7%) likewise mirror the performance observed in our cohort [16].

Variability across published studies is not unexpected and likely reflects differences in study design, patient selection, disease spectrum, and measurement technique. Wali reported lower sensitivity (61%) but comparable specificity (79%) at the same 6-second threshold in patients referred to a pulmonary function laboratory [18]. Such referral populations typically include diagnostically complex patients with overlapping respiratory disorders, which can reduce the discriminative performance of a simple bedside test. Our study, by contrast, recruited consecutive symptomatic outpatients—a population that more closely matches the intended clinical use of FET as an initial screening tool.

Kern and Patel similarly found excellent sensitivity but relatively modest specificity among occupationally exposed workers, illustrating how disease prevalence and study population shape diagnostic estimates [14]. Schapira and colleagues evaluated FET in a large general medical clinic population and reported progressive increases in likelihood ratios with longer expiratory times, together with acceptable inter-observer agreement ($\kappa = 0.70$), supporting the reproducibility of the technique under routine conditions [15]. More recently, Straus and colleagues, in the multicentre CARE-COAD2 study, concluded that FET adds most value when interpreted alongside history and physical examination rather than as an isolated test19. Our findings support this interpretation: rather than positioning FET as a substitute for spirometry, we see its value in a structured diagnostic pathway, where it serves as an inexpensive bedside screen to identify patients most likely to benefit from confirmatory lung function testing.

Taken together, the available literature and the present findings suggest that the apparent variability in FET performance across studies reflects differences in patient spectrum and methodology rather than any inconsistency in the underlying physiological relationship between prolonged expiratory time and airflow obstruction. Applied in the appropriate clinical context, FET performs consistently well across diverse populations.

Clinical Implications of Likelihood Ratios: Sensitivity and specificity remain the conventional measures of diagnostic performance, but likelihood ratios are arguably more clinically useful because they directly modify disease probability after testing. Here, the positive likelihood ratio (LR+) of 4.24 indicates that a positive FET result produces a moderate rise in the probability of airflow obstruction: assuming a pre-test probability of about 30% in a symptomatic primary care population, a positive FET would raise the post-test probability to roughly 65%, which is sufficient justification for referral for confirmatory spirometry [20].

The negative likelihood ratio (LR−) of 0.17 is arguably the more clinically important finding. Using the same pre-test probability, a negative FET lowers the probability of airflow obstruction to roughly 7%, making clinically significant obstruction considerably less likely. This rule-out capability is especially valuable in primary care, peripheral health centres, and community screening

programmes where spirometry is either unavailable or reserved for selected patients. In such settings, FET can act as a practical triage tool, letting providers prioritise limited spirometry resources for individuals with a higher post-test probability of disease while reducing unnecessary investigations among those at lower risk.

These findings reinforce a broader principle of diagnostic testing: the value of FET lies not in replacing spirometry but in improving how efficiently patients are selected for spirometric confirmation. This is especially relevant in low- and middle-income countries, where resource limitations continue to restrict access to formal pulmonary function testing despite the substantial burden of chronic obstructive airway diseases.

Physiological Basis for Prolonged Forced Expiratory Time: The progressive rise in FET across increasing grades of airflow obstruction lends physiological support to the clinical validity of the test. Mean FET increased from 7.2 seconds in mild obstruction to 8.3 seconds in moderate disease and 9.1 seconds in severe obstruction, showing a clear relationship between expiratory duration and severity of airflow limitation.

This observation fits current understanding of respiratory mechanics. During forced expiration, airflow becomes progressively limited as airway narrowing, loss of elastic recoil, and dynamic airway compression impede lung emptying [12]. Involvement of the small airways further raises expiratory resistance, prolonging expiration even before FEV_1/FVC falls appreciably. Using a mathematical model of expiratory flow-volume behaviour, Skloot and colleagues showed that FET reflects the combined effects of airway calibre, expiratory flow limitation, and premature airway closure, and predicted an inverse relationship between FET and spirometric indices of airflow obstruction in a large retrospective cohort undergoing methacholine challenge testing12. Our findings provide prospective clinical evidence in support of these physiological observations.

Demographic characteristics also deserve mention. Mukherjee and Mahapatra reported significant associations between FET and age, body mass index, peak expiratory flow rate, and FEV_1/FVC among healthy North Indian adults, suggesting that normal physiological variation may contribute modestly to measured expiratory times [21]. Such factors should be considered when interpreting borderline FET values, but the progressive increase we observed across spirometric severity categories suggests that airflow obstruction remains the principal determinant of prolonged expiratory time in symptomatic patients.

Feasibility and Practical Utility: Beyond diagnostic accuracy, the main strength of FET lies in its practicality. The test took a mean of only two minutes compared with roughly eight minutes for spirometry, a substantial saving in assessment time that matters in busy outpatient clinics, peripheral healthcare facilities, and community-based respiratory screening programmes, where large patient volumes and limited technical resources often restrict access to formal pulmonary function testing.

Patient acceptability was also notably higher for FET than for spirometry, and fewer participants were unable to complete the examination. These findings likely reflect the relative simplicity of the manoeuvre, reduced technical demands, and the absence of the coaching needed to obtain acceptable spirometric recordings—advantages that matter particularly when evaluating elderly patients, those with limited educational background, or others unable to perform reproducible forced vital capacity manoeuvres.

Together, these findings suggest that FET satisfies many of the practical characteristics expected of an effective screening test: it is inexpensive, rapid, non-invasive, requires minimal equipment, can be performed after limited training, and is applicable across diverse healthcare settings [22]. These advantages substantially enhance its potential utility in regions where spirometry remains inaccessible or underused.

Interpretation of the Area under the ROC Curve: The AUC of 0.92 observed here indicates excellent overall discrimination between patients with and without spirometry-confirmed airflow obstruction. AUC values should be interpreted cautiously across different study populations, but our findings compare favourably with previously published reports and suggest that FET retains robust diagnostic performance when a standardised measurement protocol is used.

Several methodological factors may explain this high discriminatory performance. First, FET measurements were obtained by a single trained examiner using a standardised auscultatory technique, which minimised inter-observer variability. Second, using three expiratory manoeuvres and selecting the longest reproducible measurement was consistent with established recommendations for improving measurement reliability [17]. Third, prospective enrolment of consecutive symptomatic outpatients reduced the spectrum bias common in case-control studies while closely reflecting the population in which FET is most likely to be used clinically.

This diagnostic performance should not, however, be treated as definitive. Community

implementation will likely involve healthcare workers with varying levels of training and experience, which could affect measurement consistency. Future multicentre implementation studies should therefore evaluate the reproducibility of FET across multiple observers, healthcare settings, and patient populations before it is incorporated more widely into respiratory screening programmes.

Optimal Threshold Selection and Clinical Application: Selection of an appropriate FET threshold should ultimately depend on the intended clinical use. Our threshold analysis showed the expected inverse relationship between sensitivity and specificity, reflecting the trade-off inherent in all screening tests: lower thresholds maximise case detection but increase false positives, while higher thresholds improve specificity at the cost of missed cases.

For community-based screening or primary care, where the main objective is to identify as many patients with possible airflow obstruction as possible, an FET threshold of >5.5 seconds is advantageous because of its high sensitivity (95%); this approach will inevitably generate more false-positive referrals, but confirmatory spirometry can subsequently establish the diagnosis. Conversely, where spirometry is scarce or referral capacity limited, a higher threshold of >6.5 seconds gives a more balanced diagnostic profile, reducing unnecessary referrals while maintaining acceptable sensitivity.

The conventional >6.0-second threshold, selected prospectively here and used in several previous studies [15,16], offered a reasonable compromise between sensitivity (86.5%) and specificity (79.6%). Given its favourable negative likelihood ratio, this threshold seems well suited as an initial triage cut-off in routine practice, though the optimal value may need refinement according to disease prevalence, healthcare resources, and population characteristics—underlining the need for future multicentre validation across diverse geographical settings.

Integration into Contemporary Respiratory Screening Pathways: These findings support integrating FET into a tiered diagnostic approach rather than using it as a standalone test. Spirometry remains the accepted reference standard for confirming airway obstruction and is indispensable for disease staging, treatment decisions, and longitudinal follow-up [1,6,7]. The principal value of FET lies in identifying patients who should undergo spirometric evaluation, particularly where routine access to pulmonary function testing is limited—an approach that aligns closely with the case-finding algorithm introduced in the GOLD 2026 report, which favours targeted identification of high-risk symptomatic individuals over unselected population screening1.

A pragmatic two-step screening strategy may therefore be appropriate: patients with respiratory symptoms could first undergo bedside FET assessment, either alone or alongside validated symptom-based instruments such as the COPD Assessment Test (CAT) or the modified Medical Research Council (mMRC) dyspnoea scale [23,24]. Those with a prolonged FET or high clinical suspicion could then be referred for confirmatory spirometry, while those with a negative FET and low pre-test probability might avoid unnecessary investigation while remaining under appropriate clinical surveillance.

The simplicity of FET also opens opportunities for innovation beyond conventional clinical settings. Emerging digital technologies, including smartphone-based acoustic analysis and artificial intelligence-assisted signal processing, may allow semi-automated measurement of expiratory duration, reducing operator dependence and improving standardisation[25]. A recent wearable accelerometer-based system using deep learning to detect wheeze and quantify work of breathing directly from chest-wall vibrations illustrates how such sensor-based approaches could, in principle, be extended to automated timing of forced expiration for community use [26].

Such developments could support large-scale community screening led by primary healthcare workers, particularly in low- and middle-income countries where respiratory disease remains substantially underdiagnosed, and would sit squarely within the digital-health and artificial-intelligence agenda that GOLD has now formally incorporated into its strategy document1. Before such tools are adopted widely, however, multicentre validation studies across diverse populations, multiple observers, and real-world settings will be needed to establish reproducibility, define population-specific reference values, and determine cost-effectiveness.

Strengths and Limitations: This study has several strengths. To our knowledge, it is among the few contemporary prospective diagnostic validation studies of auscultated FET in an Indian population using ATS/ERS-standardised spirometry as the reference standard. Consecutive recruitment of symptomatic outpatients reduced the selection bias common to case-control designs and better reflected routine clinical practice. The prospective design, pre-specified diagnostic threshold, FET assessment blinded to spirometry interpretation, and the combined evaluation of diagnostic accuracy, feasibility, and patient acceptability together strengthen the validity and clinical relevance of the findings.

Several limitations should nonetheless be acknowledged. First, this was a single-centre study at a tertiary care teaching hospital, which may limit generalisability to primary care, rural facilities, and community screening programmes where disease prevalence and case mix may differ. Second, while the sample size was adequate to estimate the primary measures of diagnostic accuracy, it was not sufficient for robust subgroup analyses by age, sex, smoking status, body mass index, or specific respiratory diagnoses. Third, inter-observer variability was not formally evaluated here, although previous studies have shown acceptable reproducibility of FET measurements [15,17]. Fourth, while consecutive recruitment minimised selection bias, the study population consisted of symptomatic individuals referred for respiratory evaluation rather than an unselected community sample, so diagnostic performance may differ in true population-based screening. Finally, conditions that can influence expiratory duration independently of airflow obstruction—including obesity, heart failure, and restrictive lung disease—were not examined in dedicated subgroup analyses. Future multicentre studies with larger, more heterogeneous populations will be important to address these limitations and to further define the role of FET within contemporary respiratory diagnostic pathways.

Conclusion

This prospective diagnostic validation study shows that auscultated forced expiratory time is a simple, inexpensive bedside test for the initial assessment of suspected airflow obstruction. At a pre-specified threshold of >6.0 seconds, FET performed well, with a sensitivity of 86.5%, specificity of 79.6%, overall accuracy of 83.2%, and excellent discrimination (AUC 0.92) against spirometry.

The low negative likelihood ratio (0.17) points to particular value as a rule-out screening test, supporting its use in identifying patients unlikely to have clinically significant airflow obstruction.

The progressive rise in FET with worsening spirometric severity gives physiological support to its clinical application, while its rapid administration, minimal equipment requirements, lower failure rate, and high patient acceptability make it particularly well suited to primary care and resource-limited settings. Rather than replacing spirometry, FET is best viewed as a complementary triage tool that can help identify patients who need confirmatory lung function testing earlier and make better use of limited spirometry resources.

As the global burden of chronic respiratory disease continues to rise, particularly in low- and middle-income countries, simple bedside diagnostic tools that widen access to early detection become more important. Larger multicentre prospective studies across diverse populations, formal assessment of inter-observer reliability, and pragmatic implementation research are now needed to confirm these findings and establish the place of FET within future respiratory screening strategies and clinical practice guidelines.

Declarations

Ethics Approval and Consent to Participate: The Institutional Ethics Committee of Krishna Mohan Medical College and Hospital approved the study before enrolment (Ref. No. KMU/RO/ECC/2023-24/61, dated 27 May 2024). All participants gave written informed consent.

Availability of Data and Materials: The datasets generated and analysed during the study are available from the corresponding author on reasonable request.

Competing Interests: The authors declare no competing interests.

Authors' Contributions: RB conceptualised the study, collected and analysed the data, and drafted the manuscript. KM supervised the study design, provided intellectual input, and revised the manuscript. MT contributed to data collection, interpretation, and manuscript revision. All authors read and approved the final manuscript.

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