

FIXED RATIO VERSUS Z-SCORE/LLN INTERPRETATION IN SPIROMETRY: EFFECTS ON VENTILATORY PATTERN CLASSIFICATION

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Abstract

Spirometric interpretation depends not only on physiological measurements but also on the diagnostic thresholds used to classify ventilatory patterns. This study aimed to compare fixed ratio- and Z-score/lower limit of normal (LLN)-based interpretation strategies and evaluate their influence on spirometric classification. A total of 378 spirometry records meeting ATS/ERS acceptability and repeatability criteria were retrospectively analyzed. Ventilatory patterns were classified using two interpretation approaches: the fixed ratio method ($FEV_1/FVC < 0.70$ indicating obstruction; $FEV_1/FVC \geq 0.70$ with $FVC < 80\%$ predicted indicating a restrictive pattern) and the Z-score/LLN method based on GLI-2012 reference equations (LLN defined as $Z = -1.645$). Differences in classification were evaluated using the McNemar–Bowker test, and agreement between methods was assessed using weighted Cohen's kappa. According to the fixed ratio approach, 34.9% of cases were classified as normal, 47.4% as obstructive, and 17.7% as restrictive. In contrast, Z-score/LLN-based interpretation increased the proportion of normal classifications to 51.1%, while obstructive patterns decreased to 30.7%, and restrictive patterns accounted for 18.3% of cases ($p < 0.001$). Overall agreement between the two approaches was moderate ($\kappa = 0.42$; 95% confidence interval: 0.33–0.51). Reclassification

occurred more frequently among older individuals. These findings indicate that spirometric interpretation strategy substantially influences ventilatory pattern classification and may contribute to clinically relevant differences in respiratory assessment.

Key words: spirometry, reference values, lower limit of normal, Z-score, ventilatory pattern, respiratory function, forensic medicine

Introduction. Spirometry is one of the most widely used methods for evaluating respiratory function and classifying ventilatory abnormalities. Although spirometric parameters represent continuous physiological measurements, interpretation in clinical practice depends on predefined diagnostic thresholds [1, 2]. Two principal approaches are currently used for ventilatory classification: the fixed ratio criterion and the Z-score/lower limit of normal (LLN)-based approach. The fixed ratio method ($FEV_1/FVC < 0.70$) is simple and widely implemented; however, several studies have suggested that it may overestimate airflow obstruction, particularly in older individuals, because of the age-related physiological decline in the FEV_1/FVC ratio [3–5].

In contrast, the LLN/Z-score approach incorporates expected age-related variability and may reduce misclassification [2, 6]. Nevertheless, uncertainty remains regarding the practical implications of choosing one interpretive strategy over another [4, 7–9]. In addition, changes in spirometric thresholds have been shown to influence estimates of airway obstruction and chronic obstructive pulmonary disease prevalence [10, 11]. The present study aimed to compare fixed ratio- and Z-score/LLN-based interpretation approaches using the same spirometric dataset and to evaluate their effect on ventilatory pattern classification.

Material and methods. This cross-sectional observational study compared fixed ratio- and Z-score/lower limit of normal (LLN)-based spirometric interpretation using the same spirometric dataset. Digital spirometry records of individuals aged 18–80 years who underwent pulmonary function testing at a tertiary care hospital between August 1, 2024, and August 1, 2025, were retrospectively analyzed.

A total of 6274 spirometry records were screened. Sample size was estimated using the McNemar approach for paired comparisons, assuming 20% discordance between methods and a 7% absolute difference between discordant categories. A minimum of 321 tests was required for 80% power at a 5% significance level. To account for possible exclusions, 450 tests were randomly selected, and 378 records fulfilling ATS/ERS acceptability and repeatability criteria were included in the final analysis [2, 12].

Spirometry was performed according to ATS/ERS technical standards using an NDD Easy on-PC spirometer (Switzerland) by an experienced technician [12]. In the fixed ratio approach, airway obstruction was defined as $FEV_1/FVC < 0.70$ and restrictive pattern as $FEV_1/FVC \geq 0.70$ with $FVC < 80\%$ predicted [7]. In

the LLN-based approach, interpretation was performed using GLI-2012 reference equations, with the lower limit of normal defined as $Z = -1.645$ [2, 6].

All records were independently evaluated by three pulmonologists, and discrepant classifications were resolved by consensus. Interobserver agreement assessed in 50 randomly selected cases excluded from the final dataset showed 82% agreement (Fleiss' $\kappa = 0.80$).

Statistical analyses were performed using IBM SPSS Statistics version 29. Categorical variables were expressed as frequencies and percentages, and continuous variables as median and interquartile range. Differences between methods were analyzed using the McNemar–Bowker test, while agreement was assessed using weighted Cohen's kappa coefficient. Relative classification performance was evaluated using sensitivity, specificity, positive predictive value, negative predictive value, and accuracy. Since no physiological reference standard was available, these measures reflect relative agreement rather than diagnostic accuracy. A p value < 0.05 was considered statistically significant.

The study was approved by the institutional ethics committee (03/12/2025) and conducted in accordance with the Declaration of Helsinki.

Results. A total of 378 spirometry records were included in the analysis. The median age of participants was 57 years (interquartile range [IQR], 44–67), and the median body mass index was 27.5 kg/m^2 (IQR, 24.2–30.8). Females accounted for 50.0% of the study population ($n = 189$).

According to the fixed ratio approach, 34.9% of cases were classified as normal, 47.4% as obstructive, and 17.7% as restrictive. In contrast, LLN-based interpretation increased the proportion of normal classifications to 51.1%, while obstructive patterns decreased to 30.7%; restrictive classifications remained comparable (18.3%). The difference in ventilatory pattern distribution between methods was statistically significant ($p < 0.001$) (Table 1).

T a b l e 1

Distribution of ventilatory patterns according to interpretation method ($n = 378$)

Interpretation method	Normal n (%)	Obstructive n (%)	Restrictive n (%)	p value*
Fixed ratio	132 (34.9)	179 (47.4)	67 (17.7)	<0.001
Z-score (LLN)	193 (51.1)	116 (30.7)	69 (18.3)	

Overall, concordant classification was observed in 300 cases (79.4%), whereas reclassification occurred in 78 (20.6%) cases (Table 2). Most discrepancies were observed among participants classified as obstructive by the fixed ratio method who were reclassified as normal using LLN-based interpretation. Agreement between methods was moderate ($\kappa = 0.42$; 95% confidence interval, 0.33–0.51).

Participants with discordant classifications were older than those with concordant classifications (median age: 61.5 vs. 55 years, $p = 0.036$), whereas body

T a b l e 2

Cross-classification of ventilatory patterns according to fixed ratio and Z-score (LLN) approaches ($n = 378$)

Fixed ratio	Z-score Normal	Z-score Obstructive	Z-score Restrictive	Total
Normal	126	2	4	132
Obstructive	60	114	5	179
Restrictive	7	0	60	67
Total	193	116	69	378

Agreement analysis: Weighted Cohen's $\kappa = 0.42$ (95% CI 0.33–0.51), indicating moderate agreement.

mass index did not differ significantly between groups ($p = 0.136$).

Using the fixed ratio method as the comparator framework, LLN-based interpretation showed high agreement for restrictive classification (accuracy 95.8%) but lower agreement for obstructive classification (accuracy 82.3%) (Table 3).

T a b l e 3

Relative classification performance of the Z-score (LLN) approach using the fixed ratio as the reference framework.

Metric	Restrictive pattern % (95% CI)	Obstructive pattern % (95% CI)
Sensitivity	89.6 (79.7–95.7)	63.7 (56.4–70.4)
Specificity	97.1 (94.5–98.6)	99.0 (96.4–99.7)
PPV	87.0 (76.4–93.6)	98.3 (93.9–99.5)
NPV	97.7 (95.2–99.0)	75.2 (69.6–80.0)
Accuracy	95.8 (93.2–97.6)	82.3 (78.1–85.8)

Abbreviations: CI, confidence interval; PPV, positive predictive value; NPV, negative predictive value.

Note: These metrics reflect relative classification agreement between methods rather than true diagnostic accuracy, as no physiological reference standard was available.

Discussion. The present study demonstrates that spirometric classification may substantially change depending on the interpretive strategy applied to the same physiological dataset. LLN-based interpretation reduced obstructive classifications and increased normal classifications, whereas restrictive patterns remained relatively stable. Reclassification occurred in approximately one-fifth of cases, with moderate agreement between methods. These findings indicate that interpretation thresholds are not merely technical criteria but important determinants of ventilatory classification [2, 12].

The age-related reclassification pattern observed in this study is consistent with previous reports describing limitations of the fixed ratio approach, partic-

ularly in older adults [3–5, 13]. Because the FEV_1/FVC ratio physiologically declines with ageing, fixed thresholds may classify some individuals as obstructive despite age-appropriate pulmonary function. In contrast, the LLN/Z-score approach incorporates expected age-related variability and therefore reduces this type of reclassification [2, 6]. The relative stability of restrictive patterns suggests that FVC-based thresholds are less sensitive to interpretive variation.

Our findings further support previous observations that spirometric categorization is influenced by the choice of reference equations and interpretive thresholds [6, 8, 9]. Population studies have shown that different spirometric definitions may substantially alter estimates of airway obstruction and chronic obstructive pulmonary disease prevalence [10, 11]. By applying both approaches to the same dataset, the present study directly quantifies this threshold-dependent variability.

These differences are clinically relevant because spirometric classification influences diagnostic labelling, follow-up, and treatment decisions. Different spirometric definitions may identify partially distinct patient groups with different outcomes [14, 15]. In addition, spirometry is frequently used in assessments of functional capacity, occupational fitness, and disability; therefore, interpretation strategy may also influence medico-legal evaluation [10, 16–18].

Several limitations should be acknowledged. Restrictive patterns were defined according to spirometric criteria without lung volume confirmation [2]. Clinical variables such as symptoms, bronchodilator response, and imaging findings were unavailable, and GLI-2012 reference equations were used without population-specific validation.

Despite these limitations, the study provides direct evidence that ventilatory classification is partly threshold-dependent. Differences between fixed ratio- and Z-score/LLN-based interpretation are not solely methodological but may influence clinical and medico-legal assessment. Clear reporting and greater standardization of interpretation strategies may therefore improve consistency in respiratory evaluation.

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