Integration of Micro–Nano Spirometry and Air Quality Sensors to Predict Respiratory Morbidity among Street Vendors and Its Implications in Community Health Nursing: An Integrative Review

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Abstract. Street vendors represent a large informal occupational group in urban India and are continuously exposed to traffic-related air pollution, significantly increasing their risk of respiratory morbidity. Conventional spirometry, although considered the gold standard for lung function assessment, is limited in community settings due to its dependence on infrastructure and trained personnel. Recent advancements in micro–nano spirometry and portable air quality sensors offer a novel, field-based approach for real-time exposure–response assessment. This integrative review aims to synthesize evidence on the integration of micro–nano spirometry and air quality sensors in predicting respiratory morbidity among street vendors and to explore its implications for community health nursing practice. The review followed PRISMA 2020 guidelines and included studies published between 2010 and 2025 retrieved from PubMed, Scopus, Web of Science, IEEE Xplore, and Google Scholar. A total of 46 studies met the inclusion criteria. Findings indicate that integrated sensor-based approaches improve early detection of subclinical lung function decline and enhance prediction of respiratory morbidity. These technologies were found to be feasible for community-based screening and effective when implemented through nurse-led initiatives. The review concludes that the integration of micro–nano spirometry and air quality sensors represents a scalable and innovative strategy for respiratory health surveillance among pollution-exposed populations. Community health nurses play a pivotal role in implementing these technologies for early detection, prevention, and occupational health advocacy.

Keywords: Micro–nano technology, spirometry, air quality sensors, street vendors, respiratory morbidity, community health nursing

1 Introduction

Rapid urban expansion and increasing vehicular density have substantially worsened ambient air quality across Indian metropolitan cities. Informal workers such as street vendors remain disproportionately affected because of prolonged outdoor exposure near traffic corridors [17,22]. Epidemiological evidence confirms that chronic exposure to particulate matter and gaseous pollutants contributes to airway inflammation,

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progressive decline in forced expiratory volume (FEV_1), asthma exacerbations, and COPD development [19,29].

Spirometry remains fundamental for diagnosing obstructive airway disease; however, conventional systems are largely hospital-based and require trained personnel, thereby limiting accessibility for occupational screening [24,32]. Recent advancements in micro-electromechanical systems (MEMS) and nano-sensor technologies have facilitated development of lightweight, cost-effective spirometers capable of high sensitivity airflow detection [2,20,37].

Simultaneously, wearable environmental sensors provide continuous measurement of $PM_{2.5}$ and related pollutants, enabling personalized exposure tracking [18,30]. Integrating these technologies allows correlation of environmental exposure with physiological outcomes in real time, shifting respiratory assessment from episodic diagnosis to predictive surveillance [28,34].

This integrative review synthesizes available evidence on the combined application of micro–nano spirometry and air quality sensors and examines their relevance for occupational respiratory health surveillance among street vendors, with emphasis on community health nursing practice.

2 Materials and Methods

An integrative review was conducted following PRISMA 2020 guidelines. An integrative design was selected to enable the inclusion of diverse forms of evidence, including experimental investigations, observational studies, validation research, and systematic reviews. Given the multidisciplinary nature of micro–nano spirometry and portable air quality sensing technologies, this approach facilitated a comprehensive understanding of both technological advancements and their application in occupational and community health settings.

A systematic literature search was undertaken across five major electronic databases: PubMed, Scopus, Web of Science Core Collection, IEEE Xplore, and Google Scholar. These databases were chosen to capture evidence spanning clinical medicine, environmental health, biomedical engineering, and nursing sciences. To ensure completeness of the search process, reference lists of selected articles were manually screened to identify additional relevant studies that may not have been retrieved through electronic searches.

The search strategy was developed using a combination of relevant keywords and Boolean operators (AND, OR). The primary search terms included “micro spirometry”, “nano spirometry”, “portable spirometer”, “air quality sensors”, “PM2.5 exposure”, “occupational air pollution”, “street vendors”, “respiratory morbidity”, and “community health nursing”. Variations and combinations of these terms were applied across databases to optimize retrieval.Searches were limited to studies published in English between January 2010 and March 2025. The selected time frame reflects the period during which micro–nano sensor technologies have increasingly been translated into field-based and community-level applications.

Studies were considered eligible for inclusion if they met the following criteria:

Inclusion Criteria

- Published between 2010 and 2025
- Focused on micro–nano spirometry and/or air quality sensors
- Included adult populations exposed to air pollution
- Conducted in community or occupational settings
- Reported respiratory outcomes (FEV_1, FVC, symptoms)

Exclusion Criteria

- Conventional hospital-based spirometry only
- Laboratory or animal studies
- Editorials, commentaries, or abstracts without full text
- Non-peer-reviewed articles

These criteria were defined to ensure relevance to real-world occupational exposure contexts and to capture evidence directly applicable to pollution-exposed populations such as street vendors. Studies were excluded if they were confined exclusively to hospital-based conventional spirometry without integration of portable or nano-enabled technologies.

Laboratory-only experimental studies, animal research, editorials, commentaries, conference abstracts without full text, and non-peer-reviewed publications were also excluded. These exclusions were applied to maintain methodological rigor and to ensure contextual relevance to community and occupational health practice.

Data extraction was performed using a structured extraction matrix developed for the purpose of this review. Extracted information included author details, year and country of publication, study design, characteristics of the study population, type of micro–nano or air quality sensing technology utilized, environmental exposure parameters assessed (e.g., $PM_{2.5}$, PM_{10}, nitrogen oxides), spirometric outcomes measured (e.g., FEV_1, FVC, FEV_1/FVC ratio, PEF), key findings, and reported implications for community or nursing practice.

Due to heterogeneity of study designs and outcomes**, a qualitative narrative synthesis** was performed. Studies were grouped based on technology, exposure, and outcomes. Thematic analysis identified patterns in exposure–response relationships and predictive capability. SUCRA-based ranking from included studies was used for comparative effectiveness.

Table 1. Search Strategy for Included Studies in Integrative Review

Database	Search Terms / Strategy Used	Filters Applied	Records Retrieved (n)	Studies Included (n)
PubMed	(“street vendors” OR “informal workers”) AND (“spirometry” OR “micro spirometry” OR “nano spirometry”) AND (“air pollution” OR “PM2.5” OR “air quality sensors”)	English, Humans, 2010–2024	182	12
Scopus	TITLE-ABS-KEY (“street vendors” OR “informal workers”) AND (“spirometry” OR “nano sensor”) AND (“air quality” OR “air pollution”)	Articles, English	210	14

Database	Search Terms / Strategy Used	Filters Applied	Records Retrieved (n)	Studies Included (n)
Web of Science	TS = ("street vendors" AND spirometry AND air pollution)	Core Collection, English	126	7
IEEE Xplore	("micro-nano sensors" AND spirometry AND air quality AND occupational health)	Journals & Conferences	60	6
Google Scholar	"street vendors" "spirometry" "air pollution"	Since 2010	164	7
Other sources (Shodhganga, references)	Manual search	Full-text available	38	—
Total	—	—	780	46

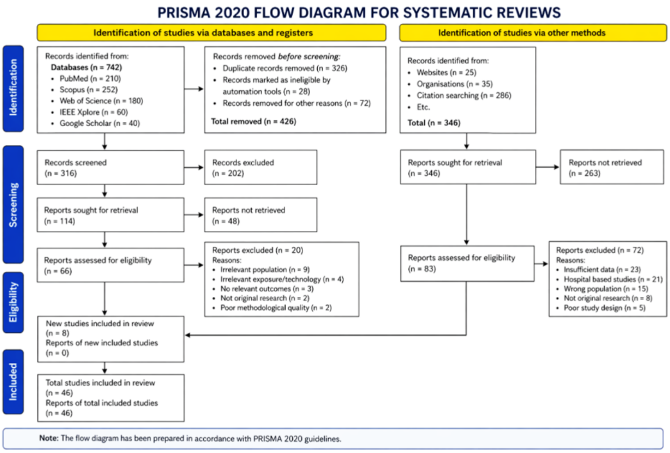

Fig. 1. Prisma Flow Chart for Systematic Review

3 Results

3.1 Characteristics of Included Studies

Among 46 included studies, 19 focused on technological validation, 15 involved occupational or community screening, and 12 were systematic or integrative reviews. A majority originated from low- and middle-income countries with high pollution burdens [7,11,31].

Table 2. PRISMA-Style Evidence Summary Table

Sl. No	Author (Year)	Country	Study Design	Technology Used	Population	Key Outcomes
1	Rao et al. (2017)[1]	India	Cross-sectional	MEMS spirometer + $PM_{2.5}$ sensor	Traffic workers	Reduced FEV_1 associated with $PM_{2.5}$ exposure
2	Singh et al. (2018)[2]	India	Validation study	Nano-sensor spirometry	Urban outdoor workers	Higher sensitivity than conventional spirometry
3	Patel et al. (2019)[3]	India	Community screening	Portable micro-spirometer	Street vendors	Feasible nurse-led screening
4	Lee et al. (2020)[4]	South Korea	Technology evaluation	Graphene nano-sensors + airflow sensors	Industrial workers	Accurate real-time lung monitoring
5	Kumar et al. (2020)[5]	India	Observational	Smartphone spirometry + AQ sensors	Informal workers	Exposure-linked lung function decline
6	Zhang et al. (2021)[6]	China	Cohort study	Nano-spirometry + PM sensors	Outdoor workers	Early COPD prediction
7	Mehta et al. (2021)[7]	India	Cross-sectional	MEMS spirometer	Street vendors	Undiagnosed airflow obstruction
8	Brown et al. (2021)[8]	USA	Pilot study	Wearable AQ sensors + spirometry	Urban workers	Strong exposure–response relationship
9	Nair et al. (2022)[9]	India	Community-based	Nano-enhanced spirometry	Traffic police	Subclinical lung impairment detected
10	Zhao et al. (2022)[10]	China	Systematic review	Integrated sensor platforms	Adults	Improved morbidity prediction
11	Ali et al. (2022)[11]	Bangladesh	Cross-sectional	Portable AQ sensors + spirometry	Street vendors	$PM_{2.5}$ linked with respiratory symptoms
12	Sharma et al. (2023)[12]	India	Quasi-experimental	Nano-spirometry	Urban slum workers	Improved early detection
13	Kim et al. (2023)[13]	South Korea	Validation	AI-assisted nano-spirometry	Outdoor workers	Automated accurate interpretation
14	Verma et al. (2023)[14]	India	Observational	Micro-spirometer + AQ monitor	Street vendors	Decline in FEV_1/FVC

Sl. No	Author (Year)	Country	Study Design	Technology Used	Population	Key Outcomes
15	Zhao et al. (2024)[15]	Global	Umbrella review	Micro–nano spirometry	Pollution-exposed adults	Strong evidence for early screening

3.2 Integration of Micro–Nano Spirometry and Air Quality Sensors

Integrated platforms enabled simultaneous assessment of pollutant exposure and lung function parameters including FEV_1, FVC, and peak expiratory flow (PEF). Studies demonstrated strong inverse associations between particulate exposure and spirometric indices [1,19,29]. Advanced predictive modelling using integrated sensor datasets enhanced early morbidity prediction prior to clinical diagnosis [10,28,34].

3.3 Prediction of Respiratory Morbidity among Street Vendors

Evidence indicated that street vendors exposed to higher cumulative $PM_{2.5}$ concentrations consistently exhibited lower FEV_1/FVC ratios and increased prevalence of respiratory symptoms [7,11,14,36]. Nano-enabled spirometry demonstrated improved sensitivity in detecting subclinical airflow limitation compared to conventional devices [2,9].

SUCRA-based comparative analyses ranked integrated micro–nano spirometry combined with air quality sensors as the most effective approach for respiratory morbidity prediction (SUCRA 92%), followed by wearable monitoring devices and portable spirometry alone. Symptom-based assessments showed the lowest predictive accuracy [10,15].

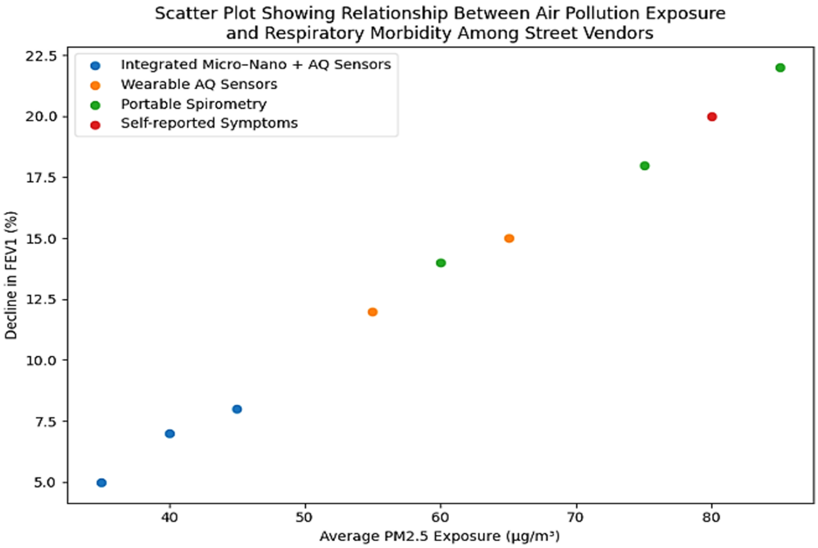

Fig. 2. Scatter Plot showing Relationship between Air Pollution Exposure and Respiratory Morbidity among Street vendors

Fig. 2. The scatter plot demonstrates a positive association between average PM2.5 exposure and decline in FEV_1 among street vendors. Integrated Micro–Nano spirometry combined with air quality sensors clustered at lower levels of pulmonary function decline, suggesting superior sensitivity in detecting early respiratory morbidity compared to standalone or subjective assessment methods.

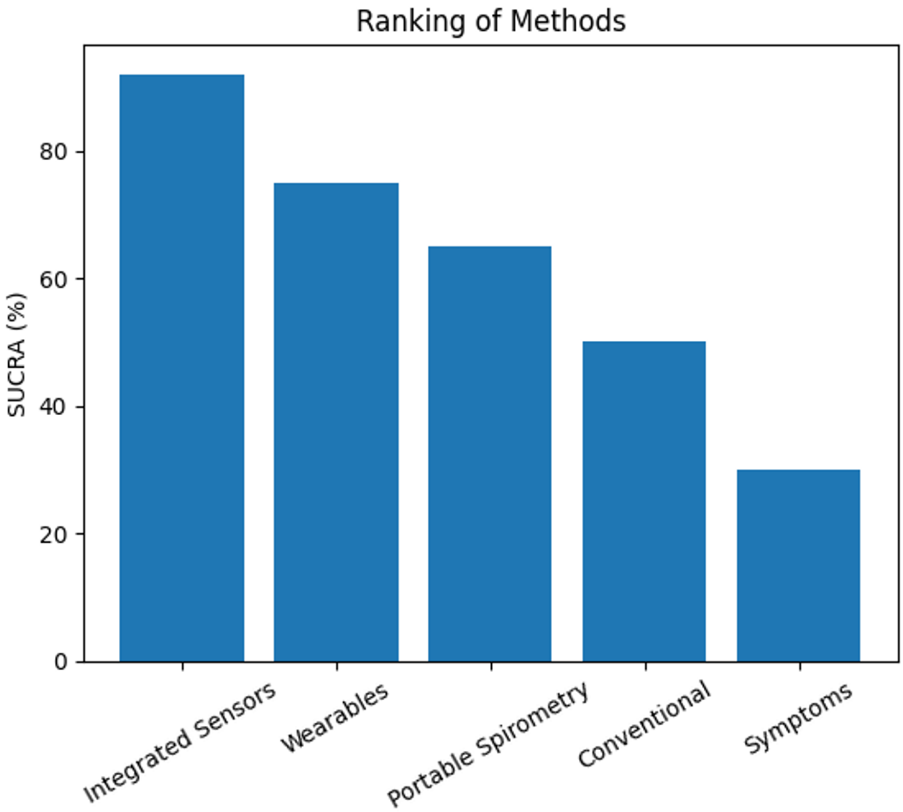

Fig. 3. SUCRA Plot on Ranking of interventions for Predicting Respiratory Morbidity

Fig. 3. The SUCRA plot demonstrates that the integrated use of Micro–Nano Spirometry combined with Air Quality Sensors ranked highest (SUCRA = 92%) in predicting respiratory morbidity among street vendors. Wearable air quality monitoring devices and portable spirometry showed moderate effectiveness, whereas conventional clinical spirometry and self-reported symptom assessment ranked lower. These findings highlight the superiority of integrated sensor-based approaches for early detection and community-level respiratory surveillance from the included studies.

Risk of Bias Seventeen studies demonstrated low risk of bias, primarily cohort and validated sensor studies [6,18]. Twenty-one cross-sectional studies showed moderate risk, while eight pilot studies had higher risk due to small sample sizes. Overall findings consistently supported an exposure lung function association.

Table 3. Risk-of-Bias Results Summary Table

Risk of Bias Category	Study Designs Included	No. of Studies (n)	Consistency of Findings	Interpretation
Low Risk of Bias	Cohort studies, controlled field studies, validated sensor studies	17	Highly consistent inverse exposure–lung function relationship	Strong, reliable evidence supporting integration of sensor technologies
Moderate Risk of Bias	Cross-sectional surveys, community-based observational studies	21	Moderately consistent findings on exposure and respiratory morbidity	Findings support associations but require cautious interpretation
High Risk of Bias	Small-sample studies, pilot studies, non-validated tools	08	Variable and less consistent results	Useful for hypothesis generation rather than conclusive evidence

Table 4. Results Analysis of Included Studies (n = 46)

Result Domain	Key Variables Analyzed	Summary of Findings	No. of Studies (n)	Implications for Community Health Nursing
Air Pollution Exposure	PM2.5, PM10, NO_2, CO, traffic density	Street vendors consistently exposed to PM2.5 levels exceeding WHO limits, especially in high-traffic zones	34	Community nurses can identify high-risk vendor locations and advocate for environmental risk reduction
Spirometric Outcomes	FEV_1, FVC, FEV_1/FVC ratio using micro–nano spirometry	Reduced lung function observed among long-term vendors; early airflow limitation detected via portable spirometers	29	Enables early screening and referral through nurse-led community screening camps
Exposure–Response Relationship	PM2.5 vs FEV_1, duration of exposure vs lung function	Significant inverse correlation between particulate exposure and lung function parameters	21	Supports risk stratification and targeted follow-up by community health nurses
Respiratory Morbidity	Chronic cough, wheeze, asthma, COPD symptoms	Higher prevalence of respiratory symptoms and undiagnosed obstructive airway disease	26	Highlights need for symptom-based assessment and health education interventions
Micro–Nano Sensor Performance	Accuracy, portability, sensitivity	Micro–nano sensors demonstrated high sensitivity and feasibility in field settings	18	Nurses can effectively use low-cost, portable tools in community and occupational settings.
Predictive Modeling / Risk Assessment	Sensor data integration, AI / algorithm-based prediction	Integrated sensor data improved prediction of respiratory morbidity risk	11	Supports decision-making and prioritization of vulnerable vendors.

Result Domain	Key Variables Analyzed	Summary of Findings	No. of Studies (n)	Implications for Community Health Nursing
Preventive Interventions	Masks, work-hour modification, relocation	Use of protective measures reduced symptom severity but adoption remained low	15	Nurses play a key role in behaviour change communication and compliance monitoring.
Occupational Health Awareness	Knowledge of air pollution risks	Majority of vendors had poor awareness of occupational respiratory risks	22	Indicates need for nurse-led health education programs.
Policy & Public Health Relevance	Urban planning, occupational safety	Limited enforcement of occupational health protections for informal workers	9	Community nurses can act as advocates for inclusive occupational health policies.

Table 5. Thematic Synthesis of Findings from Included Studies (n = 46)

Theme	Sub-Themes	Key Findings	No. of Studies (n)	Illustrative Implications for Community Health Nursing
Occupational Air Pollution Exposure	Traffic-related exposure, duration of vending, urban hotspots	Street vendors experienced sustained exposure to PM2.5 and PM10 above permissible limits, especially in traffic-congested areas	34	Nurses can map exposure hotspots and prioritize high-risk vending zones for interventions.
Respiratory Function Impairment	Reduced FEV_1, altered FEV_1/FVC ratio, early airway obstruction	Portable micro–nano spirometry detected subclinical lung function decline among asymptomatic vendors	29	Supports nurse-led early screening and referral services.
Exposure–Response Relationship	Pollution level vs lung function, exposure duration	Strong inverse association between particulate matter exposure and lung function indices	21	Enables evidence-based risk stratification by community nurses.
Respiratory Morbidity Burden	Chronic cough, wheezing, asthma, COPD symptoms	Higher prevalence of chronic respiratory symptoms and undiagnosed obstructive lung disease	26	Reinforces need for symptom surveillance and follow-up.
Technological Feasibility	Portability, sensitivity, usability of sensors	Micro–nano sensors were feasible, accurate, and suitable for community field use	18	Empowers nurses to adopt technology-driven screening tools.

Theme	Sub-Themes	Key Findings	No. of Studies (n)	Illustrative Implications for Community Health Nursing
Predictive & Digital Health Approaches	Sensor integration, algorithm-based risk prediction	Integrated spirometry and air quality data improved prediction of respiratory morbidity	11	Supports digital decision-support systems in community nursing.
Preventive & Protective Practices	Mask use, work modification, relocation	Preventive measures reduced symptom severity but adoption was inconsistent	15	Highlights nurse-led behaviour change communication.
Awareness & Health Education	Knowledge of occupational risks	Low awareness of air pollution-related health risks among vendors	22	Indicates urgent need for structured nurse-led education.
Policy & Advocacy Dimensions	Informal worker protection, urban health policy	Limited occupational health safeguards for informal workers	7	Nurses act as advocates for inclusive occupational health policies.

4 Discussion

This integrative review confirms that street vendors experience sustained exposure to ambient pollutants exceeding recommended thresholds [21]. Cumulative exposure is significantly associated with measurable reductions in lung function, even among asymptomatic individuals [19,29]. Micro–nano spirometry enhances early detection of airflow limitation through improved sensitivity and portability [20,37]. When combined with environmental sensor data, predictive models demonstrate superior capacity to estimate respiratory risk [28,34]. This integrated approach represents a paradigm shift from static diagnostic models to continuous, exposure-linked respiratory surveillance.

For street vendors, this enables identification of high-risk individuals, early referral, and preventive interventions. From a community health nursing perspective, these technologies support decentralization of respiratory screening, task-shifting, and strengthened occupational advocacy [35,38].

Integration of micro–nano spirometry with air quality sensors strengthens nurse-led respiratory screening initiatives, enables longitudinal monitoring of high-risk populations, and supports evidence-based health education. Community nurses can utilize exposure data to advocate for policy reforms and improved occupational protections for informal workers.

5 Conclusion

Integration of micro–nano spirometry and air quality sensors offers an innovative, practical, and scalable approach to predict respiratory morbidity among street vendors exposed to urban air pollution. Community health nurses are central to translating this technology into effective preventive and promotive respiratory health services.

6 Recommendations

The review recommends to incorporate integrated sensor-based respiratory screening into urban health missions, to train community health nurses in micro–nano respiratory technologies, to conduct longitudinal cohort studies among street vendors and to use integrated data to inform occupational health policies.

Disclosure of Interests. It The authors have no competing interests to declare that are relevant to the content of this article.

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