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Predicted Value and Interpretation of Impulse Oscillometry Lung Function Test Among Different Types of Population Model

Thangamani V[1], Nalinijayanthi .J[2], Pugazhendhi . S [3], Nagarjun[4], Karniha[5]
[1]Lecturer, Department of Respiratory Medicine, SRM medical College hospital and Research centre. Kattankulathur, Chengalpattu.
[2]Professor &HOD, Department of Respiratory Medicine, SRM medical College hospital and Research centre. Kattankulathur, Chengalpattu.
[3]Assistant professor, Department of Respiratory Medicine, SRM medical College hospital and Research centre. Kattankulathur, Chengalpattu.
[4]Assistant professor, Department of Respiratory Medicine, SRM medical College hospital and Research centre. Kattankulathur, Chengalpattu.
[5]Assistant professor - Department Of Respiratory Medicine, SRM medical College hospital and Research centre. Kattankulathur, Chengalpattu.

ABSTRACT
Background: *Impulse oscillometry (IOS) is an increasingly adopted method for evaluating pulmonary function due to its minimal effort requirements and sensitivity to small airway changes. While IOS offers advantages over conventional spirometry, there is substantial variability in reference values across populations, raising concerns about its diagnostic consistency.*
Objective: *This systematic review aims to evaluate and synthesize existing literature on IOS reference values in healthy populations, with a focus on identifying demographic, methodological, and regional factors influencing these standards.*
Methods: *A comprehensive search was conducted in PubMed, Scopus, and Web of Science for studies published between January 2018 and January 2025. The review adhered to PRISMA guidelines. Inclusion criteria consisted of peer-reviewed studies reporting IOS reference values in healthy, non-smoking individuals. Data on study design, sample characteristics, measurement devices, and reported IOS parameters (e.g., R5, R20, X5, AX) were extracted and analyzed. Study quality was assessed using an adapted version of the Newcastle-Ottawa Scale.*
Results: *A total of 12 studies met the inclusion criteria, encompassing over 6,000 participants from diverse geographic regions, including Europe, Asia, Africa, and the Americas. The review found consistent associations between IOS parameters and anthropometric factors, particularly height and age. However, substantial differences were noted across populations, partly due to variations in ethnicity, testing equipment, and prediction equations. Many reference values were derived from predominantly Caucasian cohorts, limiting their generalizability. Some studies proposed locally developed equations, highlighting the need for context-specific standards.*
Conclusion: *This review demonstrates that IOS reference values are not universally applicable and are influenced by a range of demographic and methodological variables. The lack of standardized global reference equations limits the clinical utility of IOS, especially in non-Western populations. Future research should focus on developing harmonized, population-specific norms and standardizing testing protocols to enhance the clinical relevance of IOS worldwide.*
Keywords: *Impulse Oscillometry (IOS), (R_5)Respiratory Resistance at 5Hz , (R_{20})Respiratory Resistance at 20Hz, (X_5)Rractence at 5Hz ,(AX) Are of Reactance ,*

INTRODUCTION:

Pulmonary function tests (PFTs) are essential for evaluating, diagnosing, and monitoring respiratory disorders [1–2]. Among newer, complementary methods to traditional PFTs is the forced oscillation technique (FOT), particularly impulse oscillometry (IOS) [3,4]. FOT evaluates respiratory impedance, encompassing both resistance (real part) and reactance (imaginary part), across varying frequencies [5].
First introduced in 1956 [6], oscillometry offers a passive, non-invasive alternative that requires no forced expiratory effort. This makes it suitable for patients who cannot perform spirometry, including young children, the elderly, or those on ventilators. The technique applies pressure or flow oscillations via the mouth, measuring the mechanical response of the respiratory system. The ratio of oscillatory pressure to flow yields impedance, a comprehensive indicator of lung mechanics [7].

Assessing lung function is a cornerstone of respiratory medicine [8], particularly in the context of obstructive airway diseases (OADs), which contribute significantly to global morbidity and mortality [9]. In India, where nearly one-fifth of the global population resides, the burden of chronic respiratory diseases is rising [9]. A key advantage of IOS is its ability to detect small airway abnormalities during normal tidal breathing [10], which is particularly beneficial for pediatric and geriatric populations [9]. Liu et al. demonstrated the effectiveness of IOS in diagnosing and staging chronic obstructive pulmonary disease (COPD) in the elderly. [11]

Though introduced six decades ago [6], the forced oscillation technique remains relevant due to its ease of use and minimal patient cooperation. IOS, a variant of FOT, delivers pressure oscillations—often generated by a loudspeaker—superimposed on spontaneous breathing [12]. It is especially sensitive to peripheral airway dysfunction [13], which is often overlooked by traditional spirometry. Resistance measured at 5 Hz (R5) reflects total airway resistance, while 20 Hz (R20) indicates central airway resistance. Additional parameters such as reactance at 5 Hz (X5), the area under the reactance curve (AX), and resonant frequency (fres) provide insights into tissue elasticity and peripheral airway function [14].

Clinical correlations between spirometry and patient symptoms are often weak [13]. In diseases like COPD, spirometric findings may not reflect the severity of symptoms [2]. IOS, however, has shown stronger associations with symptom burden and patient-reported quality of life, and has a moderate correlation with spirometry [15]. For asthma, IOS is particularly valuable in detecting early airway obstruction, monitoring disease progression, and predicting loss of control more effectively than spirometry [16]. While some small-scale studies support its use in COPD assessment, IOS adds limited diagnostic value in established cases and shows uncertain utility in cystic fibrosis [14]. Notably, abnormal IOS results may appear even when spirometry is normal, suggesting early pathological changes. Emerging evidence also links IOS findings to symptoms in individuals with occupational exposures or systemic sclerosis, though these studies often have limited sample sizes [14,17].

Technically, IOS employs rectangular pressure pulses overlaid onto tidal breathing. Using Fourier transformation, it calculates impedance metrics—such as resistance, reactance, and inertance—across frequencies (5–35 Hz), offering a detailed view of lung mechanics. Its non-invasive, repeatable nature and minimal cooperation requirement make it suitable for patients as young as three years old [18].

However, reference values are critical to interpreting any lung function test. Many earlier studies included smokers or individuals with undiagnosed conditions, and often relied on small sample sizes [19]. Among First Nations Australians, spirometry values are 20–30% lower than in the general Australian population [20], leading to possible misclassification of disease. One study of 930 healthy individuals from rural Queensland found spirometry values were 7–8% below GLI-2012 Caucasian predictions, though the "other/mixed" GLI-2012 equations were more accurate [20, 21]. Since more First Nations individuals live in rural or remote areas, socio-environmental differences must be considered [22]. Still, data comparing urban and remote First Nations populations are sparse.

The accuracy of PFT interpretation hinges on validated reference equations [1, 2]. While spirometry standards are globally established, oscillometry lacks unified reference values and often relies on regional datasets [23]. The widely used adult equations by Oostveen et al. [24] were developed from Caucasian populations and applied globally, despite minimal validation in other ethnic groups. This raises the risk of misclassification. Moreover, their dataset was compiled using five devices with differing signal processing features. Participants were from four countries, and inter-individual differences in body composition were not fully accounted for. Other population-specific oscillometry equations also suffer from small cohorts [23, 24], sampling biases (e.g., inclusion of smokers), or mathematical complexity that limits clinical use [25].

Lung function is influenced by numerous anthropometric, genetic, and environmental factors. Recent studies have expanded to include Mexican, Thai, Emirati, Korean, Taiwanese, Turkish, and Indian children aged 3–17 [26]. Though Caucasian-based equations may suit white South Africans, census data show South Africa's population is predominantly Black African (80.7%), with mixed ancestry (8.8%) and Indian/Asian backgrounds (2.6%) [27]. Yet, no African-specific oscillometry reference values exist despite the continent's high respiratory disease burden. Normative data for intra-breath oscillometry, particularly beyond infancy, also remain scarce [26]. Recognizing this gap, the European Respiratory Society (ERS) has recently underscored the urgent need for population-specific pediatric references, especially in underrepresented groups [28]. This systematic review aims to evaluate the predicted values and clinical interpretation of impulse oscillometry across various population models, with particular attention to how existing reference equations perform across different demographic and ethnic groups, including their applicability and potential limitations.

METHODS:

Study Design

This research is a systematic review aimed at evaluating the predicted values and interpretation of impulse oscillometry (IOS) lung function tests across various population models. The objective is to assess the applicability and limitations of current IOS reference equations, particularly across diverse demographic groups. The review was conducted following the PRISMA guidelines for methodological rigor and transparency.

Eligibility Criteria

Studies included in this review were required to meet several key criteria. Only peer-reviewed studies published between 2018 and 2025 were considered. These studies needed to either develop or utilize IOS reference equations for respiratory parameters, focusing on resistance and reactance. Participants had to be healthy individuals with no history of chronic respiratory conditions such as asthma, chronic obstructive pulmonary disease (COPD), or any related diseases. The studies were required to provide data on predicted IOS parameters, including total airway resistance (R5), central airway resistance (R20), total airway reactance (X5), and the area under the reactance curve (AX). Clear demographic information, including age, height, weight, and ethnicity, was also necessary. Only full-text studies were included.
Studies were excluded if they did not meet these criteria. This included studies that were not published in English, those that were not peer-reviewed, or studies lacking clear demographic details. Additionally, studies focusing on populations with chronic respiratory conditions, smokers, or those with unclear age distributions were excluded. Studies that did not develop reference equations for IOS parameters or were not available in full-text format were also excluded.

Information Sources and Search Strategy

A comprehensive search was conducted across multiple bibliographic databases, including PubMed, MEDLINE, Scopus, Web of Science, and the Cochrane Library. The search was limited to studies published between 2018 and 2025 and focused on those that provided IOS reference equations for healthy individuals. Keywords used in the search included terms such as “impulse oscillometry,” “reference equations,” “predicted values,” “lung function,” and “respiratory resistance/reactance.” Grey literature was also considered, with searches conducted on platforms like ResearchGate. The search was performed in January 2024.

Study Selection Process

The initial search yielded a total of 1245 studies. After duplicates were removed, two authors independently screened the titles and abstracts. Studies that appeared to meet the eligibility criteria underwent full-text review by both authors. Any disagreements were resolved by a third author. The study selection process is shown in Figure 1.

Data Extraction and Management

Data extraction was carried out by two authors independently, using a standardized extraction form. Key data points included study characteristics (author, year, sample size, study design) and participant details (age, height, weight, gender, ethnicity). IOS parameters measured (R5, R20, X5, AX) and the methods used to develop the reference equations were also extracted. The data were compiled into a spreadsheet and cross-checked for accuracy. Any discrepancies in the extracted data were resolved through discussion and consensus.

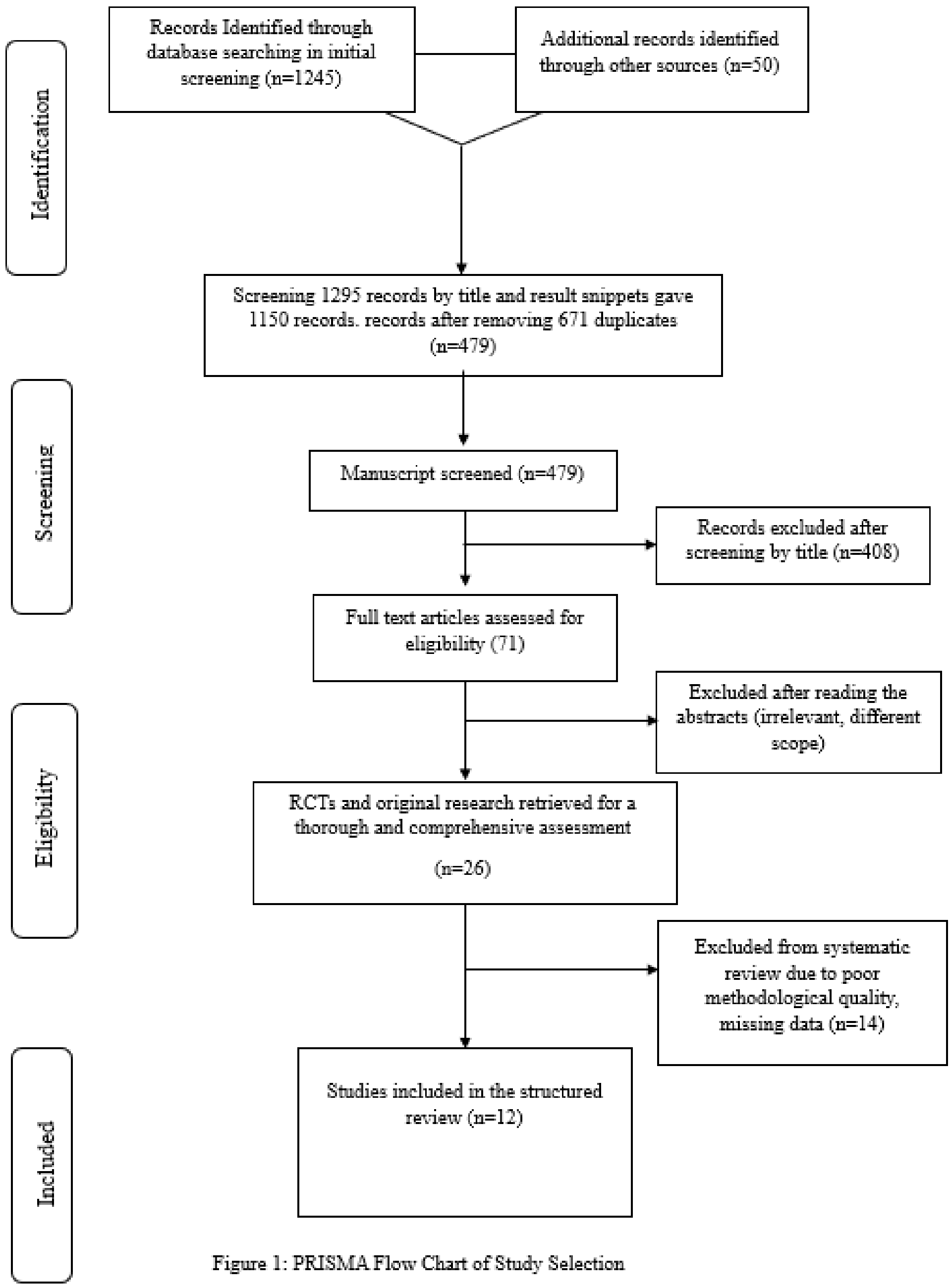

Figure 1: PRISMA Flow Chart of Study Selection

Quality Assessment of Included Studies

The quality of the included studies was assessed using a standardized tool for observational studies. This tool evaluated the study design, potential bias in participant selection, sample size adequacy, and statistical methods used in developing the reference equations. The transparency and reproducibility of the methods were also assessed. Each study was rated as high, medium, or low quality. Studies rated as low quality were excluded from the final synthesis to ensure that only reliable and rigorous evidence was included.

Data Synthesis and Analysis

The data were synthesized using a narrative approach. The findings were organized based on IOS parameters (such as resistance and reactance) and population characteristics (age, gender, ethnicity). Due to methodological differences among the studies, a meta-analysis was not conducted. Instead, the predicted values across different demographic groups were compared in detail. Trends were identified, and gaps in the literature were noted. The implications of these findings for various population models were discussed.

RESULT:

A total of 1,245 records were identified through database searching during the initial screening. After applying inclusion and exclusion criteria, 12 studies were selected for review. These assessed respiratory impedance using oscillometry in diverse populations, employing devices such as the MasterScreen IOS and Resmon Pro® Full. The studies spanned regions including Brazil, China, Egypt, India, Mexico, South Africa, Sweden, Thailand, Turkey, and the USA, covering a wide age range—from children to older adults. Key parameters like resistance (R), reactance (X), and resonance frequency (Fres) were analyzed. Height, age, sex, and body mass were consistently identified as significant predictors, with height being the most prominent across multiple studies.

Table 1: Summary of Key Studies on Respiratory Impedance Using Oscillometry

Author (Year)	**Country / Population**	**Sample Size**	**Age Range (years)**	**Key Results**	**Prediction Equation Variables**	**Study Population**	**Oscillometry Device(s)**	**Signal Type**	**Frequencies Considered (Hz)**	**Reference Parameters**
Ribeiro, F.C.V. (2025) [29]	Brazil / Adult population (Non-smokers)	288	20 to 86	Reduced resistance with age, higher in females, height is the best predictor for impedance.	Age, Body mass, Height	Non-smoking Brazilian adults, 20-86, sex-based groups	Not specified	Whole-breath impedance measurements	4 Hz, 6 Hz, 8 Hz, 10 Hz, 12 Hz, 14 Hz, 16 Hz, 18 Hz, 20 Hz, 22 Hz	Height, Body Mass, Age, Resistance
Wu, J. (2025) [30]	China / Healthy children	6270	4 to 17	Significant IOS differences by age group, height, age, and weight are key predictors.	Height, Age, Weight	Healthy children 4–17 years from China	Master Screen IOS (Jaeger Co, Germany)	Impulse Oscillometry (IOS)	5 Hz, 10 Hz, 15 Hz, 20 Hz, 25 Hz, 30 Hz, 35 Hz	Height, Age, Weight, Resistance (R), Reactance (X), Zrs, Fres, X5
Liang, X.L. (2025) [31]	China / Healthy adults	567	Not specified	Height, not age, is the main factor in IO indices, R5 and X5 predicted by reference equations.	Height, Weight, Age	Healthy adults from 20 hospitals in China (2016-2018)	Masterscreen Impulse Oscillometry (CareFusion, Hoechberg, Germany)	Impulse Oscillometry (IO)	5 Hz, 10 Hz, 15 Hz, 20 Hz, 25 Hz, 30 Hz	Height, R5, X5, R5-R20, Resonant Frequency (fres), Low-frequency Reactance Area (AX)
Ishak, S.R. (2025) [32]	Egypt / Children and Adolescents	113	3 to 18	Height and age most predictive in IOS regression equations for Egyptian	Age, Height, Weight, BMI	Egyptian children and adolescents (3-18 years)	VIASYS Healthcare (Jaeggar,	Impulse Oscillometry (IOS)	5 Hz, 10 Hz, 20 Hz, 25 Hz	Z5, R5, R20, X5, Fres, AX

				children and adolescents.			Germany)			
De, S. (2025) [33]	India / Healthy adults	253	18 to 81	Higher resistance at 5 Hz (R5) and reactance at 5 Hz (X5) in women, height is the main determinant.	Height, Weight, Age	Healthy Indian adults (323 screened, 253 analyzed)	Resmon Pro® Full device (Restech, Milan, Italy)	Forced Oscillation Technique (FOT)	5 Hz, 11 Hz, 19 Hz	R5, X5, Whole-breath Resistance (Rrs), Whole-breath Reactance (Xrs)
Moitra, S. (2025) [34]	India / Healthy adults	191	18 to 88	Significant IOS differences between males and females, with weight and height as best predictors.	Age, Height, Weight	Non-smoking Indian adults, 18–88, excluding asthma/ COPD	Jaeger Master Screen PFT system (Jaeger Co, Wurzburg, Germany)	Impulse Oscillometry (IOS)	5 Hz, 10 Hz, 15 Hz, 20 Hz	R5, R20, R5–20, X5, Z5, AX, Fres, FEV1%
Gochicoa-Rangel (2023) [35]	Mexico / Healthy Mexicans	830	2.7 to 90	Segmented regression found age breakpoints at 7 and 17 years for most IOS variables.	Sex, Age, Height, BMI	Healthy non-smoking Mexican mestizo population (children & adults)	MS-IOS (Jaeger, CareFusion, USA)	Impulse Oscillometry (IOS)	5 Hz, 10 Hz, 15 Hz, 20 Hz	R5, R10, R15, R20, X5, X10, X15, X20, R5-R20, Fres, AX
Shaakira Chaya (2022) [36]	South Africa / African children and adolescents	692	3 to 17	Developed first respiratory oscillometry reference equations for South African children and adolescents.	Height, Sex, Ancestry	Healthy African children and adolescents	INCIRCLE wavetube system (University of Szeged, Hungary)	Conventional Spectral Oscillometry & Intra-breath Oscillometry	6–32 Hz (conventional), 10 Hz (intra-breath tracking)	Rrs (6 Hz, 8 Hz, 10 Hz), Xrs (6 Hz, 8 Hz, 10 Hz), Frequency dependence (R6–R20), Resonance frequency (Fres), Absolute area (Ax), ReI, ReE, XeE, XeI, ΔR, ΔX

Björn Qvarnström (2022) [37]	Sweden / General adult population	10,360 (3,664 for IOS)	50 to 64	Abnormal IOS (16% of participants) linked to increased respiratory symptoms, even with normal spirometry.	Age, Height, Weight (separately by sex)	General population sample from Uppsala and Malmö (SCAPIS)	Jaeger Master Screen IOS	Fixed square wave	5–35 Hz (multiples of 5 Hz)	R5, R20, X5, Fres, AX; Abnormal = R5/R20/AX/Fres >95th percentile, X5 <5th percentile
Athavudh Deesomchok (2023) [38]	Thailand / Healthy adults	127	22 to 92	Women had higher R5, R20, and AX; age, height, and weight were key predictors. Separate equations by sex.	Age, Height, Weight (sex-specific models)	Healthy Thai adults with normal spirometry and no chronic respiratory disease	Not specified	Not specified	5 Hz, 20 Hz, Fres	R5, R20, R5–R20, X5, AX
İlkay Er et al. (2019) [39]	Turkey / Healthy preschoolers	151 (93 girls)	3 to 7	Resistance correlated with height, reactance with age. Boys/girls showed different patterns.	Age, Height, Weight, BMI (separately for boys/girls)	Healthy Turkish children, free of respiratory disease	Jaeger Master Screen IOS (Germany)	Pressure oscillation	5–20 Hz	R5, R20, R5–R20, X5–X20, Fres, AX, Z5
Kenneth I. Berger et al. (2020) [40]	USA / Healthy urban adults	439	Adults (exact range not specified)	Normative IOS equations created with BMI, age, height; BMI stronger than weight. Increased BMI linked to resistance.	Age, Height, BMI (preferred over Weight)	Healthy, asymptomatic adults from NYC, lifetime nonsmokers	Jaeger Master Screen IOS (Germany)	Pressure oscillation	5, 10, 15, 20 Hz (R); X5, X10; Fres, AX	R5, R10, R15, R20, R5–15, R5–20, X5, X10, Fres, AX

Table 1 presents key findings from various studies that assessed respiratory impedance parameters using oscillometry techniques across diverse populations. It includes details on sample size, age range, study population, key results, and oscillometry devices used. The table provides an overview of the factors influencing respiratory impedance measurements, highlighting variations in age, height, weight, sex, and BMI across different geographical regions and age groups. Additionally, it outlines differences in oscillometry devices, signal types, and frequencies used, offering insights into how these factors affect respiratory health measurements in both children and adults.

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Author Name	Country / Population	Male	Female
Ribeiro, F.C.V. (2025) [29]	Brazil / Adult population (Non-smokers)	R0: 2.47 ± 0.12 Rm: 2.44 ± 0.11 R4: 3.17 ± 0.14 Xm: 0.45 ± 0.06 Fr: 11.66 ± 0.58	R0: 3.11 ± 0.15 Rm: 2.97 ± 0.14 R4: 4.02 ± 0.20 Xm: 0.30 ± 0.09 Fr: 13.88 ± 0.78
Wu, J. (2025) [30]	China / Healthy children	R0: 1.894 - 0.007H - 0.028A + 0.002W Rm: 1.087 - 0.004H - 0.010A + 0.001W R4: 1.934 - 0.008H - 0.017A + 0.002W Xm: 31.885 - 0.094H - 0.257A + .035W	R0: 1.834 - 0.008H - 0.019A + 0.003W Rm: 0.964 - 0.003H - 0.009A R4: 1.970 - 0.009H - 0.020A + 0.003W Xm: 33.941 - 0.104H - 0.303A + 0.040W
Liang, X.L. (2025) [31]	China / Healthy adults	R0: 0.6811 – 0.0032 × H + 0.0019 × W Rm: 0.6275 – 0.0030 × H + 0.0019 × W R4: 0.2485 – 0.0018 × H + 0.0010 × W Xm: 1.9238 – 0.0068 × H + 0.0033 × W	R0: 0.9110 – 0.0042 × H + 0.0023 × W – 0.0008 × A Rm: 0.8103 – 0.0038 × H + 0.0024 × W – 0.0005 × A R4: 0.2360 – 0.0019 × H + 0.0017 × W Xm: 1.8261 – 0.0067 × H + 0.0051 × W
Ishak, S.R. (2025) [32]	Egypt / Children and Adolescents	Fres: 26.742 - (0.525 × Age)A X: 6.778 - (0.037 × Height) R5Hz: 1.596 - (0.021 × Age) - (0.005 × Height) X5Hz: -0.520 + (0.023 × Age)	Fres: 35.454 - (0.115 × Height)A X: 7.517 - (0.041 × Height) R5Hz: 1.751 - (0.019 × Age) - (0.006 × Height) X5Hz: -0.796 + (0.012 × Age) + (0.003 × Height)
De, S. (2025) [33]	India / Healthy adults	R5: 10.498 - 0.056 × Ht + 0.028 × Wt X5: −3.667 + 0.016 × Ht	R5: 9.487 - 0.042 × Ht + 0.022 × Wt X5: −4.545 + 0.019 × Ht + 0.009 × Wt - 0.005 × Age
Moitra, S. (2025) [34]	India / Healthy adults	lnR5 = 0.30 + 0.003(Age) + 0.01 (Weight) – 0.83(Height) lnR20 = 0.14 + 0.001(Age) + 0.01 (Weight) – 0.99(Height) lnR5–20 = 4.05 + 0.02(Age) + 0.004 (Weight) + 0.68(Height) lnZ5 = 0.79 + 0.008(Age) + 0.008 (Weight) – 1.42(Height) X5 = 0.23 – 0.002(Age) – 0.002 (Weight) + 0.15(Height) lnFres = 2.44 + 0.39(lnAge) + 0.001 (Weight) – 0.55(Height)	lnR5 = 0.003 + 0.004(Age) + 0.007(Weight) – 0.66(Height) lnR20 = 0.164 + 0.0003(Age) + 0.007(Weight) – 0.92(Height) lnR5–20 = 3.35 + 0.007(Age) + 0.01(Weight) + 0.68(Height) lnZ5 = 0.68 + 0.27(lnAge) + 0.003(Weight) – 0.53(Height) X5 = 0.60 – 0.004(Age) – 0.001(Weight) + 0.37(Height) lnFres = 1.19 + 0.27(lnAge) + 0.0002(Weight) + 0.68(Height)
Gochicoa-Rangel (2023) [35]	Mexico / Healthy Mexicans	R5 = 0.446 − 0.0154×1 − 0.055×Age + 100.38/Height − 2.61/BMI R10 = 0.508 − 0.0093×1 − 0.056×Age + 75.93/Height − 2.08/BMI R15 = 0.477 − 0.0141×1 − 0.053×Age + 64.43/Height − 1.23/BMI R20 = 0.468 − 0.0210×1 − 0.049×Age + 54.52/Height − 0.80/BMI R5–R20 = 0.013 − 0.0075×Age + 43.01/Height − 1.79/BMI (R5–R20)/R5 = 0.767 + 2.21×Age + 3347.06/Height − 251.39/BMI + 1.25×1	R5 = 0.446 − 0.0154×0 − 0.055×Age + 100.38/Height − 2.61/BMI R10 = 0.508 − 0.0093×0 − 0.056×Age + 75.93/Height − 2.08/BMI R15 = 0.477 − 0.0141×0 − 0.053×Age + 64.43/Height − 1.23/BMI R20 = 0.468 − 0.0210×0 − 0.049×Age + 54.52/Height − 0.80/BMI R5–R20 = 0.013 − 0.0075×Age + 43.01/Height − 1.79/BMI (R5–R20)/R5 = 0.767 + 2.21×Age + 3347.06/Height − 251.39/BMI + 1.25×0
Chaya, S.	South Africa /	R6 = exp(4.34 – 0.0189Ht) R8 = exp(4.29 – 0.0190Ht)	R6 = exp(4.34 – 0.0189Ht) R8 = exp(4.29 – 0.0190Ht)

(2022) [36]	African children and adolescents	R10 = exp(4.27 – 0.0191Ht) R6–R20 = 5.67 – 0.0311Ht ΔX = 1.80 — 0.0117Ht Fres = exp(3.74 – 0.0062Ht)	R10 = exp(4.27 – 0.0191Ht) R6–R20 = 5.67 – 0.0311Ht ΔX = 1.80 — 0.0117Ht Fres = exp(3.74 – 0.0062Ht)
Qvarnström, B. (2022) [37]	Sweden / General adult population	R0: 1.33 (1.10–1.60) Rm: 1.31 (1.08–1.60) S: 1.18 (0.98–1.42) R4: 1.15 (0.95–1.39) Xm: 1.07 (0.89–1.30) Fr: 1.19 (0.77–1.45) Z4: 1.06	R0: 1.33 (1.10–1.60) Rm: 1.31 (1.08–1.60) S: 1.18 (0.98–1.42) R4: 1.15 (0.95–1.39) Xm: 1.07 (0.89–1.30) Fr: 1.19 (0.77–1.45) Z4: 1.06
Deesomchok, A. (2023) [38]	Thailand / Healthy adults	R5: 3.29 ± 0.99 R20: 2.79 ± 0.79 R5–R20: 0.38 (0.20, 0.71) X5: −0.90 ± 0.44 Fres: 12.38 ± 3.71 AX: 2.15 (1.30, 4.08)	R5: 4.17 ± 1.11 R20: 3.57 ± 0.87 R5–R20: 0.52 (0.33, 0.78) X5: −1.08 ± 0.57 Fres: 12.37 ± 3.82 AX: 3.98 (2.03, 5.41)
Er, İ. (2019) [39]	Turkey / Healthy preschoolers	R5: 0.86 (0.70–1.03) R20: 0.65 (0.56–0.79) R5–R20: 0.19 (0.11–0.27) X5: −0.25 (−0.34 to −0.18) Fres: 19.36 (16.90–21.99) AX: 1.53 (0.86–1.95)	R5: 0.86 (0.70–1.03) R20: 0.65 (0.56–0.79) R5–R20: 0.19 (0.11–0.27) X5: −0.25 (−0.34 to −0.18) Fres: 19.36 (16.90–21.99) AX: 1.53 (0.86–1.95)
Berger, K.I. (2020) [40]	USA / Healthy urban adults	R5: 2.07069 R10: 2.00342 R15: 1.92723 R20: 1.95570 R5-15: 0.51755 R5-20: 0.37755 X5: 1.14127 X10: 4.36142 AX: 2.72388fres: 2.07069	R5: 2.22395 R10: 2.15420 R15: 2.05048 R20: 2.01077 R5-15: 0.59340 R5-20: 0.59582 X5: 1.07282 X10: 4.67153 AX: 3.30330fres: 2.22395

R0, R4, R5, R10, R15, R20 – Respiratory resistance at respective frequencies ($cmH_2O \cdot s \cdot L^{-1}$);Rm – Mean resistance; Xm, X5 – Mean reactance or reactance at 5 Hz; Fres – Resonant frequency (Hz); AX – Area of reactance (cmH_2O/L); Ht – Height (cm); Wt/W – Weight (kg); A – Age (years); BMI – Body Mass Index; exp() – Exponential function; ln – Natural logarithm

Table 2: Respiratory Impedance Reference Values and Predictive Equations from Global Oscillometry Studies

Table 2 presents the population-based studies that established normative values and predictive equations for respiratory impedance using oscillometry techniques. These studies, conducted across various countries and age groups, report key impedance parameters—such as resistance (e.g., R5, R20, R4), reactance (e.g., X5, Xm), resonance frequency (Fres), and area under the reactance curve (AX)—stratified by sex. Regression models incorporate anthropometric and demographic predictors including height, age, weight, and body mass index. The findings, derived using devices such as the MasterScreen IOS and Resmon Pro® Full, underscore both physiological and regional variability in respiratory mechanics across healthy populations.

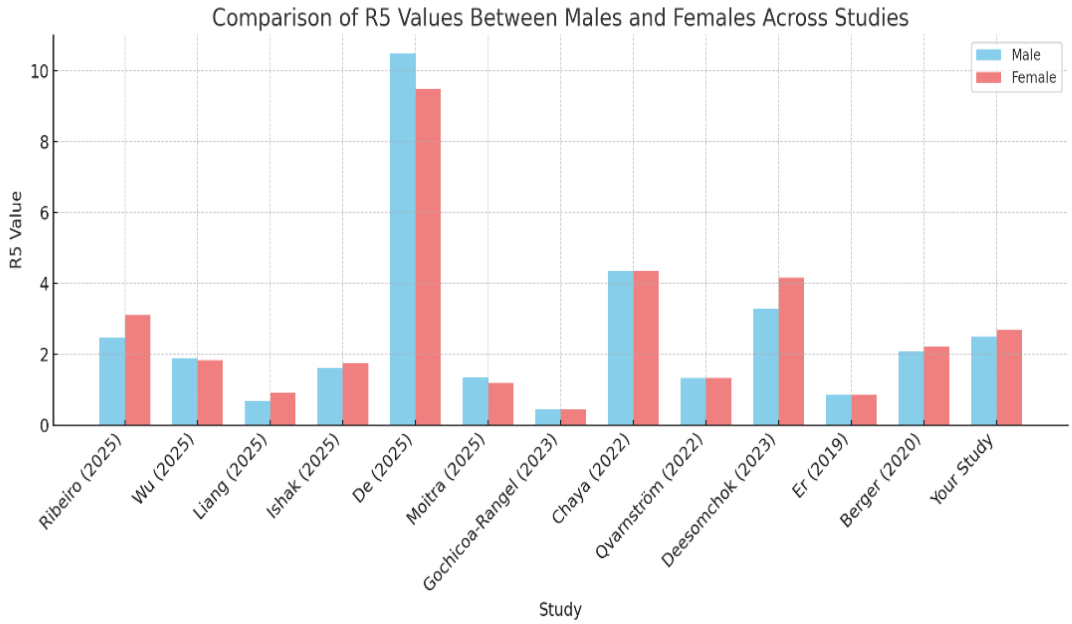

Figure 1: Graphical Comparison of R5 Values Across Multiple Studies

Figure 1 presents a comparative analysis of R5 values between males and females as reported across several population-based oscillometry studies. The data illustrate a consistent pattern wherein females generally exhibit higher respiratory resistance at 5 Hz (R5) compared to males. This trend is particularly pronounced in the study by De (2025), which reported the highest R5 values for both sexes. Similar sex-related differences are observed in the findings of Chaya (2022) and Er (2019). In contrast, studies such as those by Gochicoa-Rangel (2023) and Ishak (2025) show smaller disparities between sexes. The results from the present study align with this overall pattern, demonstrating moderately elevated R5 values in females. These findings highlight the influence of sex on airway resistance and underscore the importance of considering sex-specific reference values in the interpretation of oscillometric measurements.

DISCUSSION:

The evaluation of respiratory impedance across various studies using oscillometry provides valuable insights into factors influencing respiratory mechanics. The integration of demographic variables, geographical factors, and device-specific influences enhances the understanding of variability in impedance measurements. These factors must be carefully considered when interpreting data and developing reference equations for clinical and research purposes.

Age and Height as Key Predictors

Height consistently emerged as one of the most influential predictors of respiratory impedance measures across all studies, particularly for parameters like resistance (R5) and reactance (X5) at specific frequencies. For instance, studies conducted by Ribeiro et al. (2025) in Brazil [29] and Liang et al. (2025) in China [31] demonstrated that taller individuals typically exhibited lower airway resistance, especially at higher frequencies (R5, X5, Fres). This finding is supported by the general understanding that taller individuals tend to have larger airway volumes, reducing resistance at higher frequencies. In line with this, studies in Sweden [37] and Thailand [38] also reported similar trends, emphasizing the influence of height in adult populations.
The impact of age on respiratory impedance measures, however, showed variation depending on the population. In pediatric populations, age was consistently a strong predictor of resistance and reactance, as shown in the studies by Wu et al. (2025) [30] and Ishak et al. (2025) [32], where significant age-related changes were observed. These changes in younger populations are attributed to the developmental processes in the respiratory system, which contribute to increased resistance and reactance as children age. In contrast, in adult populations, particularly in studies from Brazil [29] and India [33], the influence of age was less pronounced than height, suggesting that airway structure and function stabilize with age.

Sex Differences in Respiratory Parameters

Sex differences were highlighted in several studies, showing that men and women may exhibit distinct respiratory mechanics, particularly in adulthood. Ribeiro et al. (2025) [29] found that women generally exhibited higher resistance values, especially at lower frequencies (R0 and R4), which might be linked to smaller airway diameters in females. Similarly, Deesomchok (2023) [38] found that females had higher resistance and reactance (R5, R20, AX) values in Thailand, potentially due to factors such as hormonal variations, airway size, and body fat distribution.

Interestingly, studies by Gochicoa-Rangel et al. (2023) [35] in Mexico, Shaakira Chaya et al. (2022) [36] in South Africa, and Berger et al. (2020) [40] in the USA found that age and BMI had a more significant effect on respiratory impedance in males compared to females. These findings suggest that while sex differences in airway dimensions and hormonal factors may play a role, other factors such as age and BMI may have a differential impact on respiratory function in males and females.

Influence of Weight and BMI

The role of weight and BMI as predictors of respiratory impedance was significant across many studies. In Moitra et al. (2025) [34], increased body weight was strongly associated with higher resistance at lower frequencies (R5), indicating that higher BMI individuals may experience more airway constriction due to fat deposition around the chest wall. This is consistent with findings from Berger et al. (2020) [40] in the USA, where BMI showed a stronger association with airway resistance compared to weight alone. Obesity impacts airway mechanics by contributing to increased resistance and decreased lung volumes, particularly at higher frequencies.

However, Gochicoa-Rangel et al. (2023) [35] observed that in the Mexican population, height had a stronger effect on respiratory impedance compared to BMI, suggesting that the influence of anthropometric factors on respiratory function may differ across populations. This highlights the importance of considering region-specific factors when assessing the role of BMI and height in respiratory health.

Impulse Oscillometry (IOS) Devices and Frequencies

Variations in the type of IOS devices used across studies were also noted as a source of potential discrepancies in the results. Different devices, such as the Jaeger MasterScreen IOS (used in Brazil, South Africa, Mexico, and other studies) and the Resmon Pro® Full device (used in India) [33], may introduce variations in how resistance and reactance are measured. Studies from Turkey [39] and Sweden [37] highlighted these variations, emphasizing that the type of signal (e.g., square wave vs. impulse wave) and the frequencies considered (ranging from 5 Hz to 35 Hz) could contribute to discrepancies in the interpretation of respiratory parameters. Given these technological differences, consistency in device use is crucial when making comparisons across populations and regions.

Reference Equations and Predictors

Each study developed its own reference equations based on demographic factors, with variations in the significance of predictors such as height, weight, and age. For example, Wu et al. (2025) [30] proposed equations for Chinese children that emphasized height, weight, and age as important predictors of respiratory impedance. Similarly, Liang et al. (2025) [31] developed reference equations for Chinese adults where height was the dominant predictor, and age had less influence on resistance and reactance. These findings align with the study by De et al. (2025) [33] in India, where height and weight were found to be significant predictors of R5 and X5 in adults.

In contrast, the study by Moitra et al. (2025) [34] in India presented more complex interactions between age, weight, and height, with weight being a significant predictor of resistance at various frequencies. This complexity underscores the need for population-specific reference equations that account for the unique demographic characteristics of different regions. For instance, the study by Gochicoa-Rangel et al. (2023) [35] in Mexico and Shaakira Chaya et al. (2022) [36] in South Africa emphasized the regional differences in how age, BMI, and height interact to influence respiratory impedance, further supporting the idea that ethnic and regional factors play a role in the development of reference models.

CONCLUSION

The review underscores the critical influence of demographic variables—such as age, height, and weight—on oscillometric measurements of respiratory function. Although there is some variation in findings across different populations, the evidence consistently supports the necessity for region-specific reference equations to provide accurate interpretations of respiratory data. These models contribute to a more precise understanding of lung function, particularly in diverse populations that have historically been underrepresented in respiratory research. The results also emphasize the importance of standardizing oscillometric methodology, while accounting for the impact of regional, cultural, and environmental factors. As respiratory health can be influenced by a variety of elements, future studies should aim to enhance these reference models and explore the role of chronic diseases and lifestyle factors in shaping pulmonary health outcomes.

Limitations

Many studies are cross-sectional, limiting the ability to assess long-term changes in respiratory impedance. Additionally, the exclusion of individuals with chronic respiratory diseases leaves their implications underexplored. Future research should include longitudinal data from diverse populations, including both healthy individuals and those with respiratory conditions, to enhance the generalizability and clinical relevance of oscillometric measurements.

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