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Predicting Factors of Peak Flow Performance among Teenagers

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Abstract
Physical inactivity among teenagers contributes to health issues, including reduced lung function. This cross-sectional study aimed to identify predictors of peak expiratory flow rate (PEFR) among 137 adolescents aged 13–17. PEFR was measured using the Mini Wright Peak Flow Meter, with the subjects' gender, age, height, and weight also recorded. Height showed a strong correlation with PEFR (r = 0.689), followed by gender (r = 0.498). Age (r = 0.259) and weight (r = 0.273) showed weaker correlations. Regression analysis identified gender and height as the strongest predictors of the outcome. These findings highlight the importance of anthropometric factors in evaluating adolescent respiratory health.

Keywords: Adolescents; Lung function; Peak expiratory flow; Predictive factors

1.0 Introduction

Peak Expiratory Flow Rate (PEFR), also known as peak flow, is a simple yet powerful indicator of pulmonary function that reflects the maximum speed of expiration following a full inhalation. It is widely used in clinical and community health settings as a surrogate marker for airway calibre, bronchial responsiveness, and overall respiratory efficiency (Quanjer et al., 2015). As a non-invasive and cost-effective tool, peak flow measurement plays a crucial role in early detection of respiratory dysfunction, particularly in conditions such as asthma, chronic obstructive pulmonary disease (COPD), and other airflow-limiting disorders (Bose et al., 2021). In healthy individuals, especially adolescents, PEFR is influenced by multiple physiological variables, including age, sex, height, and body composition (Demedts, 2006).

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Therefore, evaluating PEFR in this population offers not only insight into lung development and capacity but also the potential to identify early deviations from normal respiratory health.

Beyond its utility in clinical diagnostics, peak flow performance is increasingly recognised as an indicator of overall cardiorespiratory fitness. Reduced PEFR has been associated with diminished physical performance, increased cardiovascular risk, and all-cause mortality in later life (Schünemann et al., 2000). Among adolescents, undergoing rapid physiological changes, monitoring peak flow may help identify those at risk for compromised lung function due to factors such as a sedentary lifestyle, environmental exposure, or undiagnosed respiratory conditions. Additionally, tracking PEFR in this age group may encourage proactive health behaviours and inform public health strategies aimed at promoting respiratory health from a young age.

Respiratory diseases such as asthma and chronic bronchitis are rising among adolescents globally, with the World Health Organization (WHO) (2023) estimating that approximately 262 million people were affected by asthma in 2019 alone—many of them children and teenagers. This trend is compounded by increasing rates of physical inactivity, which contributes significantly to respiratory and cardiovascular deconditioning. Globally, more than 80% of adolescents aged 11–17 do not meet the minimum recommended physical activity levels, which places them at a higher risk for poor pulmonary health (WHO, 2022). In Malaysia, the National Health and Morbidity Survey (NHMS) 2017 reported that 63% of adolescents were insufficiently active, while asthma prevalence among school-going children ranged from 5% to 10%, particularly in urban areas (Institute for Public Health Malaysia, 2017; Mohd Zaki et al., 2020).

These findings underscore the importance of early screening tools, such as peak flow meters, in detecting respiratory issues before they progress. They also emphasise the importance of understanding the factors that predict peak flow performance in adolescents, particularly in populations with a high risk of complications related to inactivity. Despite the value of such data, limited research has been conducted among Malaysian youth to determine how demographic and anthropometric variables influence PEFR. This study is needed to address the lack of local data on adolescent lung function in Malaysia and to support early identification of at-risk youths through simple, non-invasive screening tools. Therefore, this study aims to identify key predictors, specifically gender, age, height, and weight, of peak flow performance among Malaysian secondary school students aged 14 to 17. The findings from this study may inform more effective health promotion, screening, and intervention strategies targeting respiratory wellness in this critical developmental stage.

2.0 Literature Review

2.1 Introduction

Peak Expiratory Flow Rate (PEFR) is a critical, non-invasive marker for assessing lung function, particularly among adolescents undergoing rapid physiological development. As various demographic and anthropometric factors influence respiratory health in youth, understanding the mechanisms and predictors of peak flow performance is essential. This literature review examines the concept and measurement of peak flow, the broader implications of pulmonary function for overall health, and the known predictors of peak flow performance among teenagers. These insights lay the foundation for identifying individuals at risk and guiding early interventions to promote respiratory wellness during adolescence.

2.2 Peak Flow: Definition, Measurement, Validity and Reliability

Peak Expiratory Flow Rate (PEFR), or peak flow, measures the maximum speed at which air can be expelled from the lungs during a forceful exhalation, following a full inspiration. It reflects airway patency and expiratory muscle strength and is widely used as a quick, non-invasive assessment of respiratory function (Quanjer et al., 2015; DeVrieze, 2024). PEFR is typically measured using handheld devices called peak flow meters, with the Mini Wright Peak Flow Meter being one of the most commonly used models in both clinical and community settings.

The Mini Wright Peak Flow Meter has demonstrated good validity and reliability. Regarding criterion validity, PEFR correlates significantly with forced expiratory volume in one second (FEV_1), a gold-standard spirometric parameter. Studies show correlation coefficients ranging from 0.70 to 0.90 between PEFR and FEV_1 in both healthy and asthmatic populations (Bose et al., 2021). Regarding test-retest reliability, the Mini Wright meter has shown strong intraclass correlation coefficients (ICCs) above 0.85 across multiple trials (Nikander et al., 2018). It produces consistent results over time when used under standard conditions.

Furthermore, its portability, ease of use, and cost-effectiveness make it highly suitable for field studies and school-based screenings. However, limitations include its effort dependence, variability in technique, and susceptibility to measurement error when misused. Therefore, standard instruction and practice trials are recommended to enhance measurement accuracy.

2.3 Pulmonary Function and Its Importance to Health

Pulmonary function refers to the mechanical ability of the lungs to move air in and out efficiently, exchange gases, and maintain proper oxygenation and ventilation. Parameters commonly used to assess pulmonary function include PEFR, FEV_1, forced vital capacity (FVC), and total lung capacity. These values provide insight into lung volume, airway resistance, and the mechanical integrity of the respiratory muscles (Demedts, 2006).

The importance of pulmonary function extends beyond the respiratory system. Reduced lung capacity and impaired ventilatory performance have been linked to an increased risk of cardiovascular disease, reduced physical fitness, impaired immune function, and early mortality (Schünemann et al., 2000). In adolescents, good lung function supports physical activity, academic performance, and healthy growth and development. Research has shown that respiratory impairments, even in the absence of overt disease, can lead to reduced participation in physical activity, increased fatigue, and poorer mental health outcomes (Katz et al., 2020).

Monitoring pulmonary function in young populations can facilitate the early detection of abnormalities, such as asthma, bronchitis, or environmental lung injuries. Early intervention based on pulmonary assessment can prevent disease progression and promote healthier lifelong behaviours. In Malaysia, recent studies have underscored the importance of strengthening asthma care and respiratory health services, particularly among school-aged populations (Hussein et al., 2023). As such, peak flow monitoring has been proposed as a valuable public health screening tool to assess respiratory health in school-based settings (WHO, 2022).

2.4 Peak Flow Performance Among Teenagers and Its Predictive Factors
Several physiological and anthropometric factors influence peak flow values in adolescents. Recent research, including Kyejo et al. (2024), reaffirms that height and sex are the strongest predictors of PEFR across populations. This supports earlier findings showing that height correlates with lung size and airway length (Quanjer et al., 2015), while males generally demonstrate higher PEFR due to greater thoracic dimensions and respiratory muscle strength (Schoenberg et al., 1978).

Age shows a moderate influence on PEFR, often mediated by growth-related changes in height and body composition. Weight may have a dual effect, where mild increases can improve lung volume, but excessive fat reduces pulmonary compliance (Becklake & Kauffmann, 1999).

In Malaysia, few studies have examined PEFR among adolescents. Local findings similarly identify height and gender as the main predictors, with weaker associations for age and weight (Zaki et al., 2020; Seman et al., 2024). Recent data, including NHMS (2022), highlight continued concerns about adolescent inactivity and respiratory risk factors. These observations reinforce the importance of early screening and locally relevant research to refine predictive models and promote respiratory health among Malaysian youths.

3.0 Methodology

3.1 Study Design and Setting
This study adopted a cross-sectional design and was conducted at Sekolah Menengah Kebangsaan Teluk Bahang, a government secondary school in Penang, Malaysia. A total of 137 adolescents, aged between 14 and 17 years, were recruited using convenience sampling. Convenience sampling was used because the study required access to a specific group of adolescents available within the school setting, and this method allowed efficient data collection within the limited timeframe and resources. Data collection was carried out in a single session. Participants were excluded if they had any known medical history of cardiopulmonary disease. Before participation, written informed consent was obtained from the parents or legal guardians of all participants, and written assent was secured from each adolescent following a detailed explanation of the study's objectives and procedures.

3.2 Participants and Ethical Considerations
Eligible participants were healthy adolescents enrolled in the selected school. The inclusion criteria required participants to be within the specified age range and be free from respiratory or cardiac conditions. The study was conducted in accordance with ethical standards, and all participants were allowed to withdraw at any point without consequences. Ethical approval was obtained from the relevant institutional review board prior to data collection.

3.3 Measurements
Anthropometric Assessment
Demographic data, including age, gender, height, and weight, were recorded. Height was measured using a wall-mounted tape while participants were barefoot and recorded to the nearest centimetre. Body weight was assessed using a calibrated digital portable scale, with the subject barefoot, and recorded to the nearest kilogram. The Body Mass Index (BMI) was calculated as weight in kilograms divided by the square of height in meters (kg/m^2).

Peak Expiratory Flow Rate (PEFR)
Pulmonary function was assessed using a Mini Wright Peak Flow Meter (measurement range: 60–850 L/min). Participants were instructed to wear appropriate attire and refrain from consuming heavy meals for at least two hours before the test. Standardised instructions and demonstrations were provided on the test day to ensure a consistent testing technique. While standing, participants were asked to take a deep breath and exhale into a disposable mouthpiece with maximum effort. Each participant performed three trials, with the device reset between attempts. The highest value obtained was recorded as the final PEFR. Rest was encouraged if participants felt dizzy or lightheaded during the test (Adeniyi & Erhabor, 2011; American Lung Association, 2022).

3.4 Data Analysis
All collected data were entered into and analysed using IBM SPSS Statistics version 26.0. Descriptive statistics were used to summarise demographic characteristics. The association between PEFR and variables such as age, height, weight, and BMI were assessed using Spearman's correlation coefficient. Linear regression analysis was conducted to determine the most significant predictor of PEFR. A p-value of less than 0.05 was considered statistically significant.

4.0 Findings

4.1 Participant Characteristics

A total of 137 adolescents participated in this study, with a mean age of 15.53 years. The average height was 158.08 cm, and the mean body weight was 51.38 kg. The mean Body Mass Index (BMI) was calculated at 20.33 kg/m² (SD = 5.24). Among the participants, 61 (44.5%) were male and 76 (55.5%) were female. The mean Peak Expiratory Flow Rate (PEFR) across all participants was 341.74L/min (SD = 93.51). A summary of the demographic and anthropometric data is provided in Table 1.

Table 1. Summary of demographic and anthropometric data

Variables	Mean (*SD*)
Age (years)	15.53 (*1.23*)
Height (cm)	158.08 (*9.94*)
Weight (kg)	51.38 (*14.62*)
BMI (kg/m²)	20.33 (*5.24*)
Peak Flow Rate (L/min)	341.74 (*93.51*)

Based on the Asian-Pacific BMI classification (Lim et al., 2017), the majority of participants (43.8%) were classified as underweight. Additionally, 34.3% fell within the normal weight category, 4.4% were classified as overweight, and the remaining were classified as obese (Table 2).

Table 2. BMI Classification

Asia-Pacific BMI Classification (kg/m2)	Category	Frequency (N=137)	Percentage (%)
< 18.5	Underweight	60	43.8
18.5 – 22.9	Normal range	47	34.3
23.0 – 24.9	Overweight	6	4.4
25.0 – 29.9	Obese I	17	12.4
> 30.0	Obese II	7	5.1

4.2 Correlation between PEFR and Demographic Variables

Pearson correlation analysis was performed to examine associations between PEFR and the variables of height, age, weight, and gender. The analysis revealed a strong positive correlation between PEFR and height (r = 0.689, p < 0.001). A moderate positive correlation was found between PEFR and gender (r = 0.498, p < 0.001). Additionally, weak but significant correlations were observed between PEFR and both age (r = 0.259, p = 0.002) and weight (r = 0.273, p =0.001) (Table 3).

Table 3. Correlation between peak flow and age, height, weight and gender

	Height		Age		Weight		Gender	
	r-value	*p*-value	*r*-value	*p*-value	*r*-value	*p*-value	*r*-value	*p*-value
PEFR (L/min)	0.689	<0.001	0.259	0.002	0.273	0.001	0.498	<0.001

4.3 Predictors of Peak Flow Performance

Linear regression analysis was conducted to determine which variables were significant predictors of PEFR. Among the predictors, gender was found to have the strongest association with PEFR (b = 50.703), followed by height (b =5.471). Weight had a minor positive contribution (b = 0.202), while age showed a slight negative influence on peak flow performance (b = –1.975) (Table 4). These findings highlight gender and height as the most influential predictors of pulmonary function in this adolescent population.

Table 4. Simple linear regression analysis of height, gender, age and weight with peak flow

	b (95% CI ß)	*t* statistic *(df)*	*p*-value
Gender	50.703 (26.012, 75.393)	4.062 (132)	<0.001
Height (cm)	5.471 (4.009, 6.932)	7.405 (132)	<0.001
Weight (kg)	0.202 (-0.675, 1.079)	0.456 (132)	0.001
Age (years)	-1.975 (-12.615, 8.665)	-0.367 (132)	0.001

5.0 Discussion

5.1 Overview of Key Findings

This study aimed to identify the predictors of Peak Expiratory Flow Rate (PEFR) among adolescents aged 14 to 17 years. The findings revealed that gender and height were the most significant predictors of peak flow performance, followed by weight and age. Male participants demonstrated significantly higher PEFR values than females, and height showed a strong positive correlation with PEFR. These results are consistent with prior studies highlighting anthropometric and biological differences as influential factors in adolescent lung function (Quanjer et al., 2015; Zaki et al., 2020).

5.2 Gender Differences in PEFR

The current findings showed that male participants had significantly higher PEFR values than females, consistent with previous reports. This difference is commonly attributed to anatomical and physiological factors, including larger thoracic dimensions, greater airway diameter, and stronger respiratory musculature in males (Becklake & Kauffmann,1999; Al-Bilbeisi et al., 2022). These distinctions become more pronounced during puberty due to testosterone-related increases in muscle mass, lung size, and ventilatory capacity (Harik-Khan et al., 2001).

Similar patterns have been reported internationally. For example, Al-Bilbeisi et al. (2022) found significantly higher PEFR among Jordanian boys, and Choudhury et al. (2019) reported comparable differences in Indian adolescents. Such consistency across populations reinforces established physiological theories that sex-based variations in lung development and respiratory muscle strength influence expiratory performance. These findings collectively underscore the importance of gender-specific reference values when interpreting peak flow among adolescents.

These consistent findings across different populations support established physiological theories that sex-based differences in lung development and respiratory muscle strength significantly influence expiratory performance.

5.3 Height as a Strong Predictor

Height was the strongest predictor of PEFR in this study, demonstrating a robust correlation ($r = 0.689$), which is well-aligned with existing pulmonary research. Taller individuals typically have a greater total lung volume and longer airways, enabling higher airflow velocities during forced expiration (Quanjer et al., 2015; Bock & Stocks, 2017). This explains the substantial predictive value of height in evaluating expiratory performance among adolescents still undergoing physical growth and development.

Other studies have similarly emphasised height as a critical determinant of pulmonary function. For instance, Shah et al. (2021) reported height as the best predictor of PEFR among school-going children aged 10–16 in Pakistan. Their regression model closely mirrored our findings, with height contributing significantly more to the prediction of PEFR than age or weight. These results highlight the consistency of height-PEFR associations across diverse populations and the value of including height in clinical and screening tools for respiratory health in youth.

5.4 Age and Weight as Secondary Predictors

Although age and weight were significantly correlated with PEFR, their effects were notably weaker than those of height and gender. The negative regression coefficient for age suggests that peak lung performance may plateau or vary non-linearly during adolescence, influenced by individual differences in pubertal growth (Malina et al., 2004). Shete and Kashid (2015) also reported that age alone was a poor predictor of PEFR once height and sex were accounted for, reinforcing the limited explanatory power of chronological age.

The relatively weak correlation between age and PEFR may also reflect the fact that chronological age does not reliably indicate biological maturation. Adolescents of the same age often differ considerably in pubertal timing, lung development, chest wall growth, and respiratory muscle conditioning, which weakens age as a predictor of expiratory capacity. Recent evidence supports this, showing that structural indicators such as height or limb length serve as better predictors of lung function compared to age alone (Ubuane et al., 2024).

Similarly, while greater body mass may correspond with higher lung volumes to some extent, excess weight, particularly when related to fat mass, can restrict thoracic expansion and diaphragm movement, thereby reducing ventilatory efficiency (Santamaria et al., 2020). Yılmaz and Doğan (2020) also noted that although lean body mass may contribute positively to lung function, higher fat mass tends to impair respiratory mechanics, suggesting competing influences within the weight variable. The weak association between weight and PEFR found in the present study aligns with these observations. Recent findings among rural adolescents demonstrated inverse correlations between PEFR and BMI or waist-height ratio, indicating that increases in fat mass may attenuate peak flow performance (Athmananda & Mahendrappa, 2023). Collectively, these findings suggest that weight alone is an imprecise indicator of respiratory function during adolescence, as it does not distinguish between the opposing effects of lean and fat mass.

5.5 BMI and PEFR: No Clear Association

The absence of a significant relationship between BMI and PEFR in this study suggests that BMI may not be a reliable standalone indicator of respiratory function in adolescents. As BMI does not differentiate between fat and muscle mass, it may mask important variations in body composition that affect lung mechanics. Previous research has pointed out that BMI's predictive ability is often limited in pediatric populations due to the dynamic nature of growth and development (Forno et al., 2018).

A study by Saad et al. (2021) examining Egyptian adolescents found no significant correlation between BMI and peak flow, echoing the present findings. They concluded that BMI might not effectively capture the functional burden of obesity or undernutrition on the lungs. Furthermore, Reilly et al. (2010) have highlighted that more detailed measures, such as waist circumference or body fat percentage, provide a better understanding of how excess weight impacts lung function. This supports the recommendation to use additional anthropometric assessments when evaluating PEFR in growing individuals.

5.6 Implications and Strengths

The results of this study highlight the value of utilising simple, non-invasive tools, such as the peak flow meter, in school-based health screenings. Identifying individuals with reduced peak flow performance enables the early detection of potential respiratory issues and the implementation of targeted health interventions. The inclusion of easily measurable variables, such as gender, height, weight, and age, enhances the practicality of applying these predictive models in large populations.

6.0 Conclusion & Recommendations

This study offers valuable insights into the factors that influence Malaysian adolescents' peak expiratory flow rates (PEFRs). Gender and height emerged as the strongest predictors of peak expiratory flow rate (PEFR) performance, with males and taller individuals demonstrating significantly higher PEFR values. Although age and weight showed weaker associations, BMI was not found to be a significant predictor of the outcome. These findings highlight the physiological relevance of sex-based and anthropometric differences in pulmonary function, reinforcing the need for individualised reference values when assessing respiratory health in adolescents. The results support the use of peak flow measurements as a practical, low-cost tool for early pulmonary function screening and monitoring, particularly in school settings. Recognising the key predictors of PEFR can aid clinicians, educators, and public health professionals in identifying individuals at risk and tailoring interventions to promote respiratory health from a young age.

This study has several limitations. The use of convenience sampling from a single school may limit the generalisability of the findings to adolescents in other regions or settings. The cross-sectional design prevents the determination of causal relationships between anthropometric factors and PEFR. Additionally, PEFR was assessed using a peak flow meter rather than full spirometry, which may not capture all dimensions of lung function and physiological variability.

Future research is recommended to include larger and more diverse adolescent samples across multiple geographical locations to improve representativeness. Longitudinal study designs would be valuable for examining developmental changes in lung function throughout puberty. Incorporating more comprehensive pulmonary assessments, including spirometry, body composition analysis, and consideration of environmental or lifestyle factors, may provide deeper insights into the mechanisms influencing PEFR and improve the accuracy of prediction models for adolescent lung health.

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Paper Contribution to Related Field of Study

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