Accepted Manuscript (Uncorrected Proof)

Title: Hand Grip Strength as a Predictor of Pulmonary Function: A Regression Analysis of Peak Expiratory Flow with Height, Weight, and BMI Adjustments

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To appear in: ***Physical Treatments***

Received date: 2025/04/03

Revised date: 2025/07/09

Accepted date: 2025/07/13

First Online Published: 2025/08/08

Please cite this article as:

Kumar P, Rathee R, Sangwan N, Nara K, Fitrianto AT, Rahman H. Hand Grip Strength as a Predictor of Pulmonary Function: A Regression Analysis of Peak Expiratory Flow with Height, Weight, and BMI Adjustments. ***Physical Treatments.*** Forthcoming 2026.

Abstract

Purpose: This study examines the association amid hand grip strength (HGS) and peak expiratory flow rate (PEFR), while controlling for height, weight, and body mass index (BMI). **Methods**: A cross-sectional study was carried out on healthy young adults, measuring HGS and PEFR. Multiple regression was applied separately for male and female participants. To evaluate the independent contribution of HGS to PEFR, zero-order, partial, and part correlations were calculated after adjusting for height, weight, and body mass index (BMI).

Results: HGS depicted a significant positive correlation with PEFR in both male ($r = 0.353$, $p = 0.007$) and female ($r = 0.245$, $p = 0.041$). In regression analysis, HGS persisted a significant predictor of PEFR in male ($\beta = 0.385$, $p = 0.015$) and female ($\beta = 0.293$, $p = 0.035$) after adjusting for height, weight, and BMI. Other anthropometric variables showed weak and non-significant associations with PEFR. The partial correlation of HGS with PEFR was $r = 0.329$ in men and $r = 0.258$ in women, indicating its independent contribution beyond body composition measures. **Conclusion**: HGS emerged as a significant and independent predictor of PEFR, underscoring the importance of muscle strength in pulmonary function. These results indicate that HGS assessment may serve as a practical, non-invasive method for evaluating respiratory health in both clinical and fitness environments.

Keywords: Pulmonary Function, Hand Grip Strength, Body Composition, Physical Education

Highlights

- HGS showed a positive degree correlation with PEFR in healthy adults.
- The correlation coefficient between HGS and PEFR remained significant even after adjusting for height, weight, and BMI, reinforcing the independent role of muscular strength in respiratory function.
- Grip strength independently predicted lung function in both male and female.
- Traditional body measures showed weak or no association with pulmonary performance.
- Muscle strength may serve as a practical marker for respiratory health assessment.

Plain Language Summary

Breathing is a vital function that can reflect our overall health. In this study, we explored whether a person's hand grip strength a simple way to measure muscle power could help predict how well their lungs work, specifically through a measure called peak expiratory flow rate (PEFR), which indicates how quickly someone can exhale.

We studied healthy young male and female and found that those with stronger grip strength also had better lung function. This relationship remained true even after accounting for their BMI, weight and height which are commonly considered when evaluating physical health. Interestingly, grip strength turned out to be a better predictor of lung function than those traditional body measurements.

Why does this matter? Because hand grip strength is easy, quick, and inexpensive to measure. Our findings suggest that it could be used in fitness settings or clinics to screen respiratory health, especially when access to complex lung testing equipment is limited. It also highlights the importance of maintaining muscle strength not just for mobility, but potentially for breathing efficiency too.

Introduction

HGS is a crucial measure of the force exerted by the muscles of the hand and forearm, commonly considered a reflection of overall muscle strength and physical health [1]. It reflects the strength of fingers, hand, wrist, and forearm. HGS is also recommended as a simple, Non-invasive standardized clinical measure that can be used to diagnose muscle related disease like sarcopenia, which is age-related loss of muscle mass strength and functions. Apart from the muscular strength, HGS is often used as an indicator of physical performance and functional mobility. Literature is also evident significant association of HGS with cardiovascular and metabolic health. Research indicates grip strength as a powerful predictor of all-cause mortality. A study in the Lancet revealed that lower grip strength was associated with an increased risk of early death, independent of other factors like blood pressure and BMI [2,3]. In some recent studies, HGS is used as a predictor of post exercise recovery as well biomarker of muscle damage [4,5].

PEFR is a measurement of how quickly a person can forcefully exhale air from the lungs after a maximum inhalation, serving as an important indicator of airway function and respiratory health [6]. It is an important indicator of lung function, frequently utilized in identifying and tracking conditions like asthma and chronic obstructive pulmonary disease (COPD) [7]. PEFR is measured using a peak flow meter, a small handheld device that patients blow into forcefully. The reading is typically given in liters per minute (L/min).

Various studies reported a significant association between respiratory volumes and HGS at different age and health status. Most of studies focusing patients with COPD [8–11] and older adults [8,12–15]. Research conducted on 1427 adolescents of both sexes between the ages of 11 to 18.9 years revealed significant association between HGS and PEFR and body mass density was predicted with HGS [16]. Another study conducted on healthy volunteers, aged ranged 18 to 21 year shown moderate but significant correlation between PEFR and HGS [17].

Extensive literature supports the association between HGS and respiratory indices. However, several confounding factors influence this relationship. A study by Nara et al. reported a significant relationship between HGS and body composition parameters [18,19]. Similarly, Sartorio et al. found that gender, body dimensions, and body composition significantly impact HGS [20]. Respiratory indices are also influenced by body structure, with anthropometric and body composition parameters showing strong associations with spirometry variables such as forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) [21]. Without accounting for these confounding factors, the results may be misleading. Therefore, the present study aims to examine the true relationship between HGS and PEFR while considering height, weight, and BMI as confounding variables. Moreover, the study will analyse the extent to which HGS contributes to variations in PEFR, providing a clearer understanding of its predictive value in respiratory function. Since spirometry is complex and expensive to conduct, this study utilizes HGS as a predictor of respiratory health, particularly in schools, colleges, and low-income countries where access to advanced diagnostic facilities is limited.

Methods

Participants

The participants in the present study were students of universities from diverse academic backgrounds, aged between 21 and 27 years. Participants were selected using simple random sampling from their respective classes. A random sequence was generated using the RAND function in Microsoft Excel, and the list was sorted to ensure unbiased selection. The inclusion criteria required participants to be apparently healthy individuals and to engage in moderate physical activity. Health status and levels of physical activity were self-reported by participants using a structured questionnaire. No clinical examinations were conducted to verify health status. In Table 1 the demographic and physiological traits of the sample illustrated, which included 57 male and 70 female. Significant differences were observed between men and women in height, weight, BMI, skeletal muscle mass (SMM), HGS, and PEFR ($p < 0.05$). Men exhibited higher values in these parameters, with a mean height of 173.24 cm compared to 159 cm in women, and a significantly greater mean PEFR (521.49 ± 101.35 L/min vs. 341.21 ± 68.65 L/min). However, body fat percentage did not differ significantly between the sexes ($p = 0.095$). These characteristics provide a comprehensive overview of the sample population, highlighting key physiological differences between male and female participants. Informed consent was obtained from all participants prior to data collection, and the study received approval from the Institutional Review Board of Chaudhary Ranbir Singh University, Jind. The research adhered to the ethical guidelines outlined in the Declaration of Helsinki [22].

Measurement of Body Composition Indices

The height of participants was recorded using a standard stadiometer. They stood erect, barefoot, on the stadiometer platform, ensuring proper posture for accurate measurement. Height was recorded to the nearest 0.01 centimetre. Body composition was assessed using the Omron HBF-702T Body Composition Monitor [23]. This device employs bioelectrical impedance analysis (BIA) to evaluate parameters such as body mass (kg), BMI, body fat percentage, and SMM. The HBF-702T features eight electrodes positioned on the foot and palm areas. Prior to Bioelectrical Impedance Analysis (BIA), participants were instructed to fast for at least 4–6 hours, avoid alcohol for 24 hours, and refrain from vigorous physical activity for 12 hours to minimize variations in body water content. They were also asked to empty their bladder within 30 minutes before the test and to remove any metal objects or electronic devices. Female participants were advised to avoid testing during menstruation when possible. These precautions were taken to ensure the accuracy and reliability of BIA measurements. During measurement, participants stood barefoot on the device's foot electrodes and held the handgrips at a 90-degree angle, ensuring proper electrode contact for accurate impedance measurement. The device also used in various research work including clinical and general research settings [24–26].

Measurement of PEFR

The measurement of PEFR was conducted using the Medicare Surgical® Peak Flow Meter, a reliable device for assessing lung function [27,28]. To ensure hygiene and minimize the risk of communicable diseases, a clean disposable mouthpiece used for each participant to ensure hygiene. Measurements were conducted with participants in a standing position to facilitate optimal lung expansion and airflow. Each individual was guided to take a deep breath followed by a strong exhalation into the peak flow meter as rapidly and completely as possible. PEFR values were recorded in liters per minute (L/min). To ensure accuracy and consistency, three trials were performed by each participant, and the highest value obtained was used for analysis.

Measurement of Grip Strength

The assessment of HGS was carried out with the aid of a properly calibrated Camry Baseline Digital Hand Dynamometer (200 lbs / 90 kg capacity). Participants performed the test in a standing position, using their dominant hand to ensure consistency. Hand dominance was determined by self-report, with participants identifying the hand they predominantly use for writing and other daily activities. Before each measurement, the dynamometer handle was adjusted according to the participant's hand span, ensuring an optimal grip for both men and women. Each participant was instructed to squeeze the device with maximum effort for a few seconds without any additional body movement or support. Three trials were conducted, with 3 minutes rest between each attempt to prevent fatigue. The highest recorded value (in kilograms) from the three attempts was used for analysis.

Statistical Analysis

Arithmetic mean and standard deviation were applied as measure of central tendency and variability and used to summarize participants' demographic and clinical characteristics, body composition, hand grip strength, and peak expiratory flow results. To assess whether the data followed a normal distribution, the Kolmogorov – Smirnov and Shapiro–Wilk tests were applied. Multicollinearity among predictor variables was evaluated using Tolerance and Variance Inflation Factor (VIF) values, with tolerable thresholds indicating no significant multicollinearity. An independent sample t-test was conducted to compare selected variables between male and female participants. The association between PEFR and grip strength was examined separately for male and female using linear regression analysis, both unadjusted and adjusted for age, height, and weight. Zero-order, part, and partial correlations were calculated to evaluate the contribution of body composition variables to both the dependent and independent variables. A standard (enter method) multiple linear regression method was used, in which all independent variables were included in the model at once to evaluate both their combined and separate effects on predicting the dependent variable. All statistical analyses were conducted using SPSS (Version 26.0). Correlations between the variables of interest were illustrated using heat plot (See Figure 2), in which the degree of correlations were mapped using the colours of blue (negative correlation) to red (positive correlation).

Results

Table 1 Participants characteristics and body composition, hand grip strength and peak expiratory flow rate

Variables	Male (n = 57)		Female (n = 70)		Sig.
	Mean	SD	Mean	SD	
Height	173.24	5.77	159	5.33	.000
Weight	81.31	11.01	53.50	8.99	.000
BMI	23.97	3.83	20.52	3.25	.000
Fat%	23.54	6.15	25.43	6.45	.095
SMM	31.74	3.67	28.84	4.14	.000
HGS	47.67	7.37	29.45	4.51	.000
PEFR	521.49	101.35	341.21	68.65	.000

BMI = Body Mass Index, SMM = Skeletal Muscle Mass, HGS = Hand Grip Strength, PEFR = Peak Expiratory Flow Rate, SD = Standard Deviation

Table 1 presents the characteristics of the participants, showing significant differences between male and female in most variables. Male had significantly greater height, weight, and BMI ($p < 0.001$) compared to women. SMM was also higher in male ($p < 0.001$), while body fat percentage (Fat%) was slightly higher in female, though not statistically significant ($p = 0.095$). HGS was notably greater in male ($p < 0.001$), reflecting differences in muscle mass. Similarly, PEFR was significantly higher in male ($p < 0.001$), likely due to differences in lung capacity and respiratory muscle strength. These findings highlight sex-based variations in body composition, strength, and lung function.

Table 2 Regression analysis was conducted to examine the association between grip strength and peak expiratory flow rate, with adjustments made for anthropometric variables

Gender	Model	R	R^2	Adjusted R^2	SEE	Change Statistics				
						R^2 Change	F Change	df1	df2	Sig. F Change
Male	Unadjusted	.353	.125	.109	95.666	.125	7.85	1	55	.007
	Adjusted[a]	.366	.134	.067	97.883	.009	.179	3	52	.910
Female	Unadjusted	.245	.060	.046	67.042	.060	4.357	1	68	.041
	Adjusted[a]	.288	.083	.027	67.736	.023	.537	3	65	.658
Overall	Unadjusted	.729	.531	.527	84.897	.531	141.596	1	125	.000
	Adjusted[a]	.734	.539	.524	85.236	.008	.670	3	122	.572

SEE = Std. Error of the Estimate
Dependent = Peak Flow Expiratory Rate (PEFR)
Predictors: (Constant), Grip Strength
Note: [a]Adjusted Results for Height, Weight and BMI

Table 2 shown the changes into PEFR through HGS before and after adjusted the contribution of body composition variables i.e., height, weight and BMI for both sexes. The unadjusted values of R square for male participants were 0.125 (12.5%) indicating a small but significant ($P < 0.05$) variation into PEFR. The height, weight and body mass index have negligible impact with R square changes of 0.009 (0.09%) into PEFR. In female participants, the value of R square was 0.060 (6%) explaining very small but significant variation into PEFR by HGS as well. The body composition indices (height, weight and BMI) contribute 0.023 (2.3%) changes into R square value. The cumulative impact of body composition metrics was not significant at 0.05 level. Irrespective of gender, overall results were also showing similar outcomes where body composition metrics contribute 0.008 (0.08%) in R square indicating non-significant ($P > 0.05$) impact respectively.

Table 3 Beta coefficients explaining the variation into dependent variable including partial correlation for male participants

Model		U-Std.		Std.	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero order	Partial	Part
1	(Constant)	289.740	83.659		3.463	.001			
	Grip Strength	4.861	1.734	.353	2.803	.007	.353	.353	.353
2	(Constant)	518.479	433.874		1.195	.238			
	Grip Strength	5.291	2.109	.385	2.509	.015	.353	.329	.324
	Height	-1.337	2.654	-.076	-.504	.617	.096	-.070	-.065
	Weight	1.076	2.136	.117	.504	.617	.160	.070	.065
	BMI	-3.882	5.797	-.147	-.670	.506	.092	-.092	-.086

U-Std.= Unstandardized Beta Coefficient; Std. = Standardized Beta Coefficient
Dependent Variable: Peak Expiratory Flow Rate (PEFR)

Table 4 Beta coefficients explaining the variation into dependent variable including partial correlation in female participants

Model		U-Std.		Std.	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero order	Partial	Part
1	(Constant)	231.372	53.227		4.347	.000			
	Grip Strength	3.729	1.786	.245	2.087	.041	.245	.245	.245
2	(Constant)	478.821	277.513		1.725	.089			
	Grip Strength	4.458	2.071	.293	2.153	.035	.245	.258	.256
	Height	-1.494	1.891	-.116	-.790	.432	.054	-.098	-.094
	Weight	1.231	1.632	.161	.754	.453	.040	.093	.090
	BMI	-4.672	4.175	-.221	-1.119	.267	-.049	-.137	-.133

U-Std.= Unstandardized Beta Coefficient; Std. = Standardized Beta Coefficient
Dependent Variable: Peak Expiratory Flow Rate (PEFR)

Tables 3 and Table 4 present the regression analysis results for male and female participants, respectively, highlighting the association between HGS and PEFR while considering anthropometric variables. In both male and female, grip strength showed a moderate positive zero-order correlation with PEFR (r = 0.353 in men, r = 0.245 in women), indicating that stronger grip strength is generally associated with higher lung function. When controlling for height, weight, and BMI, the partial correlation of grip strength with PEFR remained significant in both male (r = 0.329) and female (r = 0.258), suggesting that grip strength contributes independently to lung function beyond the effects of body composition. The part correlation values (r = 0.324 in male, r = 0.256 in female) indicate that grip strength uniquely explains a notable proportion of the variance in PEFR.

Conversely, height, weight, and BMI exhibited weak or negligible correlations with PEFR in both sexes. In men, height and BMI had near-zero or negative partial and part correlations, with BMI showing the strongest negative partial correlation (r = -0.092), though it was not statistically significant (p = 0.506). In women, height and weight had small and non-significant partial correlations (r = -0.098 and r = 0.093, respectively), while BMI showed a slightly stronger negative partial correlation (r = -0.137) but remained non-significant (p = 0.267). These findings indicate that grip strength is a more meaningful predictor of PEFR compared to traditional body composition variables, reinforcing its potential role as a surrogate marker for respiratory function in both men and women.

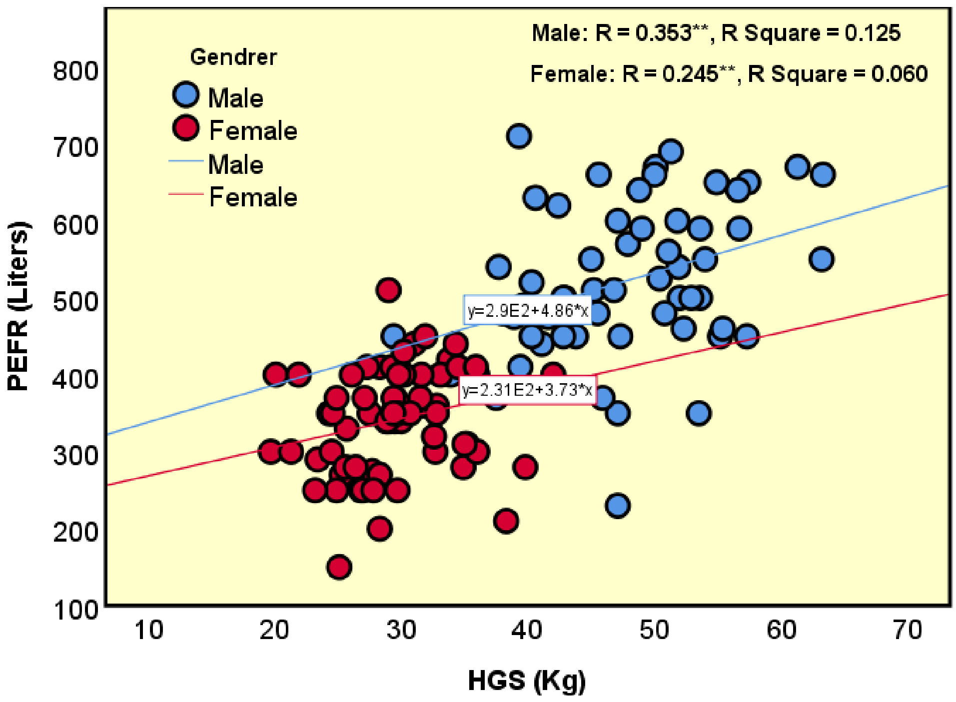

Figure 1 Scatter plot revealed relation between hand grip strength (HGS) and peak expiratory flow rate (PEFR) for both genders along with unadjusted R Square values

Discussion

The objective of the present study was to examine the relationship between HGS and PEFR, while adjusting for height, weight, and BMI. Additionally, an attempt has been also made to predict the PEFR using participants HGS, respectively. The prediction equations for both sexes have been mentioned in Figure 1, respectively. Various key findings have been observed in the present study, which need to be discussed accordingly.

First, a significant positive correlation (R = 0.729) was observed between handgrip strength (HGS) and peak expiratory flow rate (PEFR) when analysing all participants collectively (see Table 2). However, when examined separately by gender, the correlation coefficients decreased to R = 0.353 for males and R = 0.245 for females, indicating a moderate correlation in both groups. These findings suggest that while a notable relationship exists between HGS and PEFR, gender differences may influence the strength of this association. The observed significant correlation between HGS and PEFR corroborates previous studies done in similar population [29]. Another study conducted on Chinese population reported similar outcomes [30]. Significant association between HGS and PEFR were reported by the study including German adolescents aged 15.3 years (average) [31]. A study conducted in Denmark reported significant association between HGS and spirometry indices among health adolescents [32] adjusted for age, height, and weight. Lower HGS shown it relationship with air flow limitation (AFL) [33]. A significant association was also found between respiratory muscle strength and hand HGS in 61 national level elite Turkish athletes [34]. The present insights from the literature aligned with the current findings of this research in context of the general relationship between HGS and PEFR. No cultural and geographical variations have been identified in the literature.

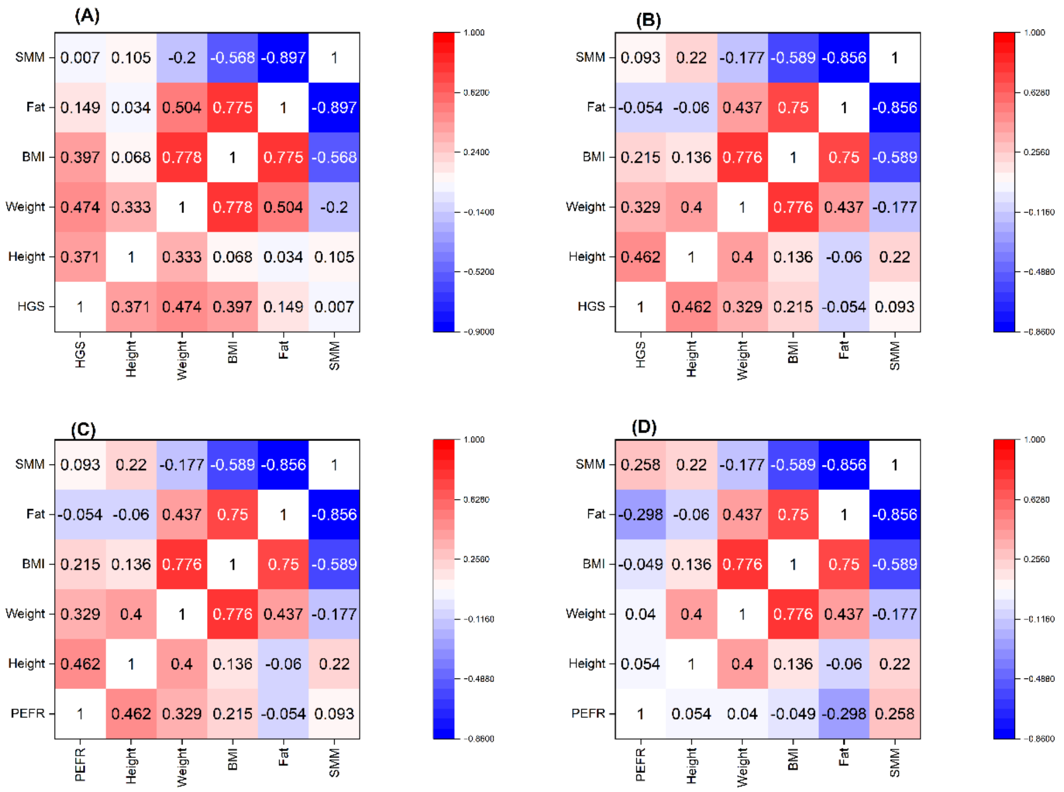

Figure 2 Heat map indicating relationship matrix (A) HGS and body composition of male (B), HGS and Body composition of female, (C) PEFR and body composition of male and (D) PEFR and body composition of female participants. The colour scale ranged blue (negative) to red (positive) indicating degree of relationship.

Second crucial point of discussion is the factors affecting or mediating the relationship of HGS and PEFR. As previously reported, enough literature available which confirm the strong relationship between HGS and PEFR. Simultaneously, several normative studies of HGS reporting significant relationship between HGS and body composition metrics (i.e., age, height, weight, and BMI). A normative study conducted on Indian adolescents reported high degree of correlation of HGS with Height and body mass (weight) [18,19]. Significant association between HGS and anthropometric measures were notified in literature [35–40]. There is lack of normative studies of HGS which create HGS standards in according to confounding factors of HGS. Specially, the body stature (standing height) is a crucial factor which is significantly reported as a confounder of HGS in the literature. While in another study weight is identified as significant factor which influence the individual difference of HGS [41]. Similarly, a report of HGS based on the participants of six countries also emphasize on adjusting HGS as per body size [42]. Therefore, the present study decided to use height, weight, and body mass index as the factors which effects was controlled during analysis.

Third, the mediating effects of anthropometric metrics between the relationship of PEFR and HGS were unclear in the literature. Therefore, the contribution of height, weight and BMI was computed using linear regression along with partial and part correlations for men and women participants. Whether the general relationship between height, weight, BMI is significant with both HGS and PEFR but, as provided in the Table 2 that changes in R^2 were not statistically significant. The height, weight and BMI contribute 0.9% (less than 1%) in male and 2.3% in female in the prediction of PEFR through HGS respectively. In simple terms, HGS predict PEFR even after controlling the effects of height weight and BMI metrics. The findings of the present study are consistent with research conducted on a Korean population over the age of 40, where various confounding factors such as age, height, weight, family income, education level, employment status, physical activity, tobacco and alcohol use, co-morbidities (including self-reported diabetes mellitus, angina or myocardial infarction, and stroke), as well as nutritional factors were considered. The following study reported significant associating between HGS and spirometry indices after adjusted for the above cited factors [43]. Another study involving COPD patients with an average age of 64.7 years reported that smokers with COPD often exhibit low hand grip strength, independent of their BMI [44].

While the present study identified a statistically significant association between hand grip strength (HGS) and peak expiratory flow rate (PEFR), the actual predictive capacity of HGS was modest. The change in explained variance (R^2) after adjusting for height, weight, and BMI ranged from only 0.9% in males to 2.3% in females, indicating that although HGS contributes to the model, it explains only a small portion of the variability in PEFR. These findings are consistent with earlier studies that reported modest but significant associations between muscle strength and pulmonary function [45,46]. Therefore, the results should be interpreted with caution. HGS may serve as a supplementary functional marker of respiratory performance rather than a standalone predictor [47].

This study was limited by its cross-sectional design, which prevents conclusions about cause and effect. The sample included only healthy young adults, so results may not apply to older or clinical populations. Additionally, factors like physical activity, nutrition, and smoking were not assessed. PEFR was the only lung function measure used; including other spirometry parameters in future studies could provide more depth. Future research should explore these findings in diverse groups, use longitudinal designs, and examine the effects of muscle-strengthening interventions on respiratory health.

Conclusion

The present study identifies hand grip strength as a significant and independent predictor of peak expiratory flow rate (PEFR) among healthy adults. While sex differences influenced the strength of this association, the relationship remained statistically significant in both male and female. The findings from regression analysis and partial correlation indicate that grip strength contributes uniquely to PEFR, even after adjusting for height, weight, and body mass index (BMI). Interestingly, traditional anthropometric measures like height, weight, and BMI demonstrated weak or non-significant correlations with PEFR, emphasizing the potential of grip strength as a more functional indicator of respiratory performance. These findings underscore the role of muscle strength in pulmonary health and suggest that hand grip strength could serve as a practical, non-invasive method for assessing respiratory function in clinical practice.

Funding Information: This study was conducted without any external funding.

Conflict of Interest: No potential conflict of interest was reported by the authors.

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