World Journal of Current Medical and Pharmaceutical Research
Content available at www.saap.org.in ISSN: 2582-0222

PEAK EXPIRATORY FLOW RATE AND ITS CORRELATION WITH ANTHROPOMETRIC, RESPIRATORY, AND POWER PARAMETERS IN HEALTHY ADULT NON-SMOKER MALES OF ALIGARH, NORTH INDIA: A CROSS-SECTIONAL STUDY

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DOI: https://doi.org/10.37022/wjcmpr.v8i3.472

ARTICLE HISTORY
Received on: 19-08-2026
Revised on: 02-11-2026
Accepted on: 14-11-2026

Keywords: *Peak expiratory flow rate; anthropometry; hand-grip strength; maximal expiratory pressure; pulmonary function tests; healthy adults; India.*

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ABSTRACT

Background: Peak expiratory flow rate (PEFR) is a simple, effort-dependent measure of ventilatory function influenced by anthropometric characteristics, ethnicity and environmental factors. Locally derived data are essential for establishing appropriate reference values. This study aimed to assess PEFR in healthy adult non-smoking males of Aligarh aged 18–40 years and determine its correlation with anthropometric, respiratory and muscular parameters.
Methods: This cross-sectional observational study included 150 healthy, non-smoking males divided into three age groups: 18–25, 26–32 and 33–40 years, with 50 participants in each group. PEFR was measured using a Wright-type peak flow meter. Anthropometric parameters included age, height, weight, arm span and body surface area (BSA). Respiratory parameters included maximal expiratory pressure (MEP), respiratory endurance time (RET) and breath-holding time (BHT), while hand-grip strength (HGS) assessed muscular power. Pearson's correlation coefficient was used for statistical analysis, with $p < 0.05$ considered significant.
Results: The mean PEFR was 500.93 ± 31.65 L/min (range: 420–620). Significant positive correlations were observed with height ($r = 0.703$), arm span ($r = 0.607$), BSA ($r = 0.280$) and MEP ($r = 0.300$), while age showed a significant negative correlation ($r = -0.306$). Weight showed no significant correlation. RET and HGS correlated significantly with PEFR only in the oldest age group, whereas BHT showed no significant association.
Conclusion: Height and arm span are the strongest anthropometric correlates of PEFR. These findings provide baseline regional data for developing and validating population-specific PEFR prediction equations for adult males in Aligarh.

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INTRODUCTION

Respiration comprises the coordinated processes by which oxygen is taken up from, and carbon dioxide released into, the external environment, and pulmonary function tests (PFTs) provide the principal objective means of evaluating this process in clinical and epidemiological practice [1]. Among the many indices derived from forced expiratory manoeuvres, peak expiratory flow rate (PEFR) - the maximal flow rate generated during a forced expiration starting from full inspiration - has retained particular popularity because it is simple, quick, inexpensive and effort-dependent only in its initial, large-airway-driven phase, making it comparatively robust to a poorly sustained terminal effort [2,3]. First introduced as an index of ventilatory function by Hadorn in 1942 and formally incorporated into spirometric practice in 1949, PEFR is now central to the diagnosis, severity grading and home-based monitoring of obstructive airway disease, particularly bronchial asthma and chronic obstructive pulmonary disease, and forms part of routine occupational and sports-medicine screening [3,4].

Because PEFR is powerfully influenced by body build, chest wall dimensions and respiratory muscle strength, a single reading is clinically meaningful only when compared against a reference value appropriate to the subject's age, sex, height and, ideally, ethnic and regional background [5]. Reference equations derived in European or North American populations systematically overestimate expected PEFR in Indian adults; a large multicentre Indian study using a European Union-scale peak flow meter found that Indian adults of average height and age had peak flows roughly 30% lower than the corresponding European prediction,

underscoring the need for population- and region-specific data rather than imported standards [6]. Multiple regional Indian studies - from Haryana, Punjab, Rajasthan, South India and elsewhere - have each reported somewhat different mean PEFR values and different relative contributions of height, weight, arm span and body surface area, reflecting genuine geographic, nutritional, socioeconomic and environmental heterogeneity within the country [6-9].

Beyond simple anthropometry, PEFR is ultimately generated by the coordinated action of the expiratory muscles, so indices of respiratory muscle strength and endurance - maximal expiratory pressure (MEP), respiratory endurance time (RET) and breath-holding time (BHT) - as well as generalised somatic and nutritional status, for which hand-grip strength (HGS) is a simple surrogate, might be expected to correlate with PEFR to a degree not captured by height or weight alone [10, 11]. Contemporary work outside India has confirmed a modest but consistent positive association between HGS and spirometric flow indices, including PEFR, in healthy young adults, reinforcing HGS as a plausible correlate of ventilatory performance rather than a purely orthopaedic measure [10].

Environmental air quality is a further factor relevant to the present study population. Ambient air pollution, including respirable suspended particulate matter and oxides of nitrogen and sulfur from vehicular and industrial sources, has been shown to adversely affect peak flow and its diurnal variability even in healthy, asymptomatic residents of polluted Indian cities [12]. Aligarh, historically a semi-urban centre in Uttar Pradesh, has in the past decade experienced a marked increase in automobile density, small-scale industry and general overcrowding, raising the possibility that locally measured PEFR values, and the strength of its anthropometric correlates, may differ from those recorded in less polluted settings or in earlier decades [6,12]. Despite this changing environmental profile, no data on PEFR and its correlates specific to the healthy adult male population of Aligarh existed prior to the present investigation.

The present study was therefore designed with two objectives: first, to establish contemporary PEFR values in healthy, non-smoking adult males of Aligarh across three decades of adult life (18-25, 26-32 and 33-40 years); and second, to quantify the correlation of PEFR with a panel of anthropometric (age, height, weight, arm span, body surface area), respiratory (MEP, RET, BHT) and power (HGS) parameters, both in the sample as a whole and within each age stratum, so as to identify which determinants of PEFR are most robust across the young-to-middle adult age range in this population. The regression-based prediction equations that can be derived from these correlations, together with their validation, are addressed separately in a companion analysis and are outside the scope of the present report.

MATERIALS AND METHODS

Study design and setting

This was a cross-sectional, observational study conducted in the Department of Physiology of a medical institution in Aligarh, Uttar Pradesh, India. Subjects were drawn from the general adult male population of Aligarh city.

Study population and sampling

A total of 150 healthy adult males aged 18-40 years were enrolled by purposive sampling after screening from the general population. Subjects were stratified a priori into three equal age groups of 50 subjects each: Group I (18-25 years), Group II (26-32 years) and Group III (33-40 years). All subjects belonged to Prasad's social class II or III, so as to minimize confounding by extremes of socioeconomic status [13].

Eligibility criteria

A subject was classified as normal, and eligible for inclusion, if he had no persistent morning cough or phlegm, no history of haemoptysis, breathlessness, wheezing or nasal catarrh at interview, and no history of cardiac disease or of bronchitis, pneumonia, pleurisy, pulmonary tuberculosis, bronchial asthma or bronchiectasis in the preceding three years. Current or former smokers and subjects with any acute or chronic respiratory illness at the time of testing were excluded. A detailed history and general physical examination were carried out for every subject using a structured proforma, and written informed consent was obtained prior to enrolment.

Anthropometric measurements

Age was recorded in completed years to the nearest birthday. Standing height was measured without footwear, in centimetres, with the subject standing erect against a wall-mounted stadiometer. Body weight was recorded in kilograms on a standard beam balance with the subject standing without footwear in light clothing. Arm span was measured, in centimetres, as the distance between the tips of the middle fingers of the two hands fully outstretched horizontally at shoulder level. Body surface area (BSA) was calculated using the Du Bois formula: BSA (m2) = W^0.425 x H^0.725 x 0.007184, where W is body weight in kilograms and H is standing height in centimetres [14].

Respiratory and power parameters

Peak expiratory flow rate (PEFR): PEFR was measured with a small, portable, pocket-sized Wright-type peak flow meter (graduated 90-700 L/min), which requires no battery or electrical power. With the subject standing and a nose clip applied, he was asked to inspire maximally and then expire as forcefully as possible into the mouthpiece with an airtight lip seal. After a practice trial, three readings were taken at 3-minute intervals and the highest of the three, expressed in litres per minute, was recorded as the subject's PEFR [3].

Maximal expiratory pressure (MEP): MEP, an index of expiratory muscle strength, was recorded 5 minutes after PEFR using a rubber-tube mouthpiece assembly connected to an aneroid sphygmomanometer dial graduated 0-300 mmHg. In the sitting position, with nose clip applied, the subject took a maximal inspiration and then expired as forcefully as possible into the tube, sustaining the peak deflection for at least 2 seconds; the highest sustained reading, in mmHg, was recorded [11].

Respiratory endurance time (RET): Using the same apparatus as for MEP, the subject was asked, after maximal inspiration, to expire forcefully so as to raise the manometer pointer to 40 mmHg and sustain it at that level for as long as possible; the time for which this pressure was maintained was recorded in seconds with a stopwatch [11].

Breath-holding time (BHT): With the subject sitting and nose clip applied, BHT was recorded, following a normal (tidal) expiration, as the duration for which the subject could voluntarily hold his breath while counting aloud at a steady pace; no verbal encouragement was given during the test, to avoid motivational bias [11].

Hand-grip strength (HGS): HGS, used here as a simple surrogate of generalised nutritional and muscular status relevant to effort-dependent respiratory testing, was measured in kilograms with a hand dynamometer, the subject gripping the instrument maximally with the dominant hand with the arm extended by the side [10].

Statistical analysis

Data were entered and analysed using R software. Descriptive statistics (minimum, maximum, mean and standard deviation) were computed for all anthropometric, respiratory and power parameters, for the sample as a whole and separately for each of the three age groups. The strength of association between PEFR and each of the other parameters was assessed using Pearson's product-moment correlation coefficient (r), calculated both for the total sample and within each age group. A p-value < 0.05 was considered statistically significant, p < 0.01 significant, and p < 0.001 highly significant.

Ethical considerations

The study protocol was approved by the Institutional Ethics Committee, and the study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from every participant prior to enrolment, and confidentiality of individual data was maintained throughout.

RESULTS

One hundred and fifty healthy, non-smoking adult males were enrolled and completed the study, 50 in each of the three predefined age groups (Table 1, Figure 1).

Table 01: Age-wise distribution of study subjects (n=150)

Group	Age range (years)	Number of subjects (n)
I	18-25	50
II	26-32	50
III	33-40	50
Total	18-40	150

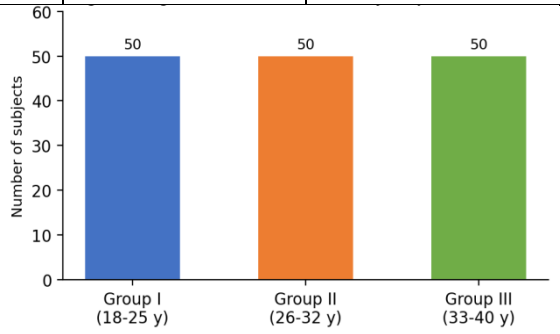


Figure 01: Age-wise distribution of study subjects (n=150)

Table 02: Anthropometric parameters of all subjects (n = 150)

Parameter	Minimum	Maximum	Mean +/- SD
Age (years)	18	40	28.55 +/- 6.33
Weight (kg)	44	81	61.61 +/- 7.72
Height (cm)	150	185	168.97 +/- 4.85
Arm span (cm)	158	182	170.87 +/- 4.80
Body surface area (m2)	1.45	1.99	1.70 +/- 0.11

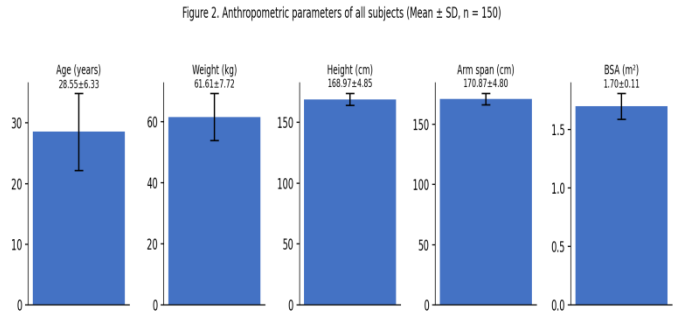


Figure 02: Anthropometric parameters of all subjects (n = 150)

The mean age of the study population was 28.55 +/- 6.33 years, mean height 168.97 +/- 4.85 cm, mean weight 61.61 +/- 7.72 kg, mean arm span 170.87 +/- 4.80 cm and mean body surface area 1.70 +/- 0.11 m2, confirming a reasonably homogeneous build typical of adult North Indian males.

Table 03: Anthropometric parameters by age group (Mean +/- SD)

Group	Age (years)	Weight (kg)	Height (cm)	Arm span (cm)	BSA (m2)
I (18-25 y)	21.48 +/- 1.85	58.00 +/- 8.17	169.00 +/- 6.77	171.16 +/- 6.50	1.67 +/- 0.12
II (26-32 y)	28.00 +/- 1.70	61.64 +/- 8.06	167.70 +/- 3.98	170.54 +/- 4.05	1.69 +/- 0.12
III (33-40 y)	36.18 +/- 2.18	65.18 +/- 4.80	169.30 +/- 2.86	170.90 +/- 3.33	1.75 +/- 0.62

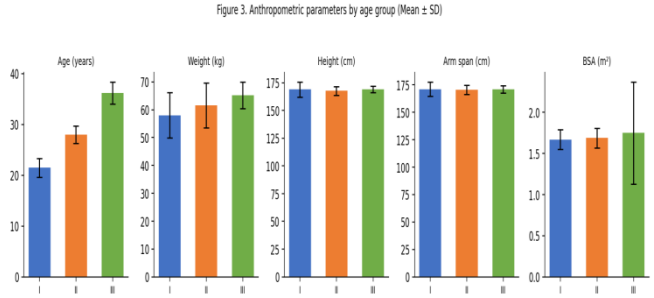


Figure 03: Anthropometric parameters by age group (Mean +/- SD)

Table 04: Respiratory and power parameters of all subjects (n = 150)

Parameter	Minimum	Maximum	Mean +/- SD
PEFR (L/min)	420	620	500.93 +/- 31.65
MEP (mmHg)	40	104	64.96 +/- 10.29
RET (sec)	3	53	28.25 +/- 6.26
BHT (sec)	2	45	26.21 +/- 7.72
HGS (kg)	28	75	53.85 +/- 7.68

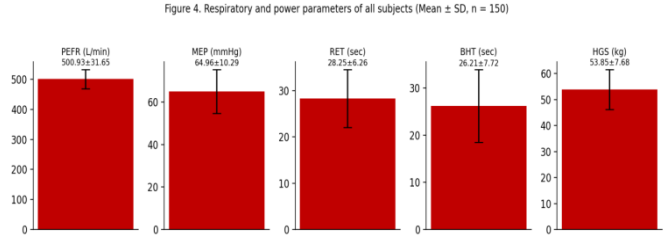


Figure 04: Respiratory and power parameters of all subjects (n = 150)

Table 05: Respiratory and power parameters by age group (Mean +/- SD)

Group	PEFR (L/min)	MEP (mmHg)	RET (sec)	BHT (sec)	HGS (kg)
I (18-25 y)	511.80 +/- 41.88	65.28 +/- 16.17	27.70 +/- 9.19	20.28 +/- 6.16	51.64 +/- 11.37
II (26-32 y)	498.60 +/- 21.29	66.88 +/- 5.76	29.32 +/- 4.72	31.22 +/- 7.58	55.64 +/- 3.99
III (33-40 y)	492.40 +/- 25.28	62.72 +/- 4.29	27.74 +/- 3.28	27.14 +/- 4.85	54.28 +/- 5.06

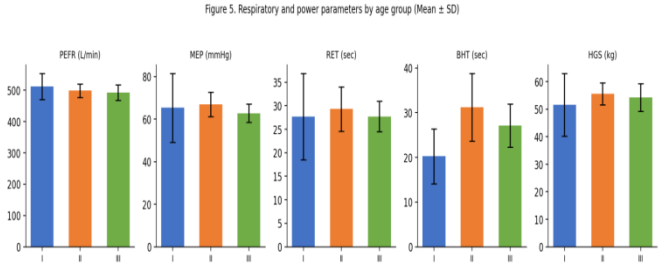


Figure 05: Respiratory and power parameters by age group (Mean +/- SD)

Mean PEFR declined progressively across the three age groups, from 511.80 +/- 41.88 L/min in Group I to 498.60 +/- 21.29 L/min in Group II and 492.40 +/- 25.28 L/min in Group III, while MEP, RET, BHT and HGS showed less consistent, non-monotonic trends across the age groups.

Table 06: Correlation of PEFR with anthropometric, respiratory and power parameters, total subjects (n = 150)

Parameter pair	Correlation coefficient (r)	P value
PEFR - Age	-0.306	< 0.001
PEFR - Weight	0.076	NS
PEFR - Height	0.703	< 0.001
PEFR - Arm span	0.607	< 0.001
PEFR - Body surface area	0.280	< 0.01
PEFR - MEP	0.300	< 0.001
PEFR - RET	0.142	NS
PEFR - BHT	-0.108	NS
PEFR - HGS	0.093	NS

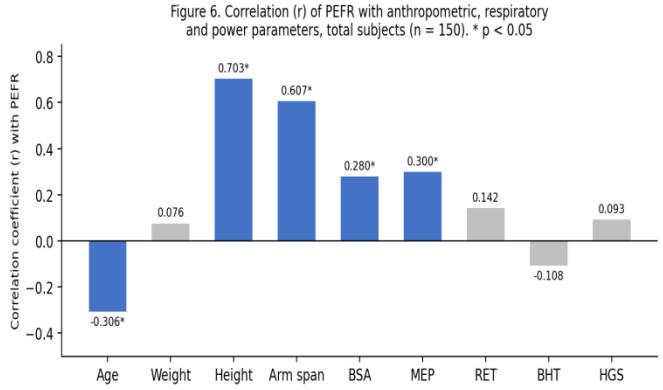


Figure 06: Correlation of PEFR with anthropometric, respiratory and power parameters, total subjects (n = 150)

In the sample as a whole, PEFR showed a highly significant negative correlation with age (r = -0.306, p < 0.001) and highly significant positive correlations with height (r = 0.703, p < 0.001), arm span (r = 0.607, p < 0.001) and MEP (r = 0.300, p < 0.001), and a significant positive correlation with body surface area (r = 0.280, p < 0.01). Weight showed no significant correlation with PEFR (r = 0.076). Among the remaining respiratory and power parameters, RET, BHT and HGS did not correlate significantly with PEFR when the total sample was considered together.

Table 07: Correlation coefficient (r) of PEFR with anthropometric, respiratory and power parameters by age group

Parameter pair	Group I (18-25 y)	Group II (26-32 y)	Group III (33-40 y)
PEFR - Age	-0.222 (NS)	0.028 (NS)	-0.487 (p<0.001)
PEFR - Weight	0.106 (NS)	0.370 (p<0.01)	0.231 (NS)
PEFR - Height	0.765 (p<0.001)	0.631 (p<0.001)	0.700 (p<0.001)
PEFR - Arm span	0.624 (p<0.001)	0.627 (p<0.001)	0.623 (p<0.001)
PEFR - BSA	0.377 (p<0.01)	0.435 (p<0.001)	0.433 (p<0.01)
PEFR - MEP	0.392 (p<0.01)	0.010 (NS)	0.112 (NS)
PEFR - RET	0.057 (NS)	0.222 (NS)	0.553 (p<0.001)
PEFR - BHT	0.060 (NS)	-0.169 (NS)	0.142 (NS)
PEFR - HGS	0.146 (NS)	-0.078 (NS)	0.298 (p<0.05)

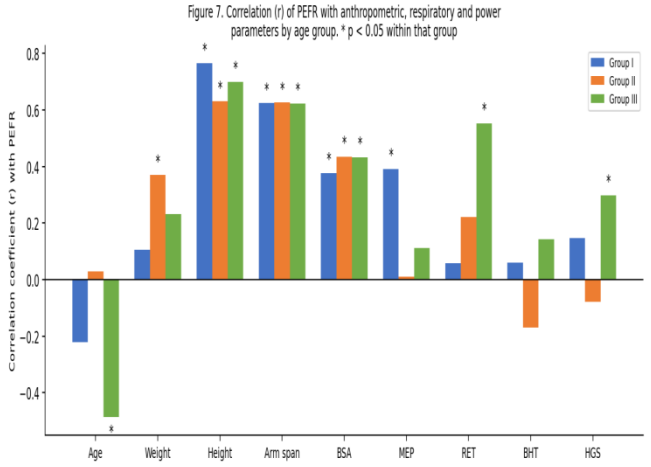


Figure 07: Correlation coefficient (r) of PEFR with anthropometric, respiratory and power parameters by age group

Height, arm span and body surface area retained a significant positive correlation with PEFR within each of the three age strata, confirming stature-related anthropometry as the most consistent determinant of PEFR across the adult age range studied. MEP correlated significantly with PEFR only in the youngest group (18-25 years; r = 0.392, p < 0.01); RET correlated significantly with PEFR only in the oldest group (33-40 years; r = 0.553, p < 0.001); and HGS correlated significantly with PEFR only in the oldest group (r = 0.298, p < 0.05). Age showed a significant negative correlation with PEFR only in the oldest group (r = -0.487, p < 0.001), while weight correlated significantly with PEFR

only in the middle group ($r = 0.370$, $p < 0.01$). BHT did not correlate significantly with PEFR in any age group.

DISCUSSION

This study provides, to our knowledge, the first locally derived correlational profile of PEFR in healthy adult non-smoking males of Aligarh, a North Indian city that has undergone substantial vehicular and industrial growth over the past decade, directly addressing both of the study's stated objectives - establishing contemporary PEFR values (Objective 1) and characterising their correlation with anthropometric, respiratory and power parameters (Objective 2). The observed mean PEFR of 500.93 +/- 31.65 L/min sits within the broad range reported from other Indian and South Asian populations but is appreciably lower than values reported from Western cohorts, a pattern consistent with the well-documented ethnic and regional variation in Indian peak flow norms.[6] Kodgule et al., in a large multicentric Indian study using a validated European Union-scale peak flow meter in over 6,000 healthy adults, similarly found that age and height were the principal determinants of peak expiratory flow, and that Indian adults recorded values roughly 30% lower than those predicted by Western (Nunn and Gregg) equations for an adult of equivalent height and age, reinforcing the argument that region-specific data are required for accurate clinical interpretation [6].

The strong positive correlation of PEFR with height observed in the present study ($r = 0.703$ in the total sample, and $r = 0.63$-0.77 within each age stratum) is consistent with the broader Indian literature. In a study of healthy adult males from Haryana, PEFR showed a statistically significant positive correlation with height, weight and chest circumference among younger subjects, with weaker and less consistent associations in older subjects, a pattern that parallels the present finding of a robust height correlation across all age groups but a weight correlation confined to the middle-aged group [7]. Aggarwal et al., in a North Indian spirometric cohort, demonstrated that arm span is closely related to standing height and can serve as a valid surrogate for height in the prediction of ventilatory indices including PEFR, particularly useful when standing height cannot be measured reliably - a relationship corroborated by the comparably strong height and arm-span correlations with PEFR found in the present sample ($r = 0.703$ and $r = 0.607$, respectively) [8].

The negative correlation of PEFR with age observed here, most pronounced in the oldest group ($r = -0.487$, $p < 0.001$), reflects the well-recognised decline in elastic recoil, chest wall compliance and respiratory muscle strength that accompanies advancing age even within a comparatively narrow young-to-middle-adult range, and is in keeping with the age-related decline in ventilatory function reported across the wider Indian PEFR literature [7,9]. The comparatively weak, non-significant correlation between PEFR and body weight in the total sample, despite weight's contribution to body surface area, suggests that in a population with a relatively narrow range of adiposity, stature-related linear dimensions (height, arm span) exert a considerably stronger influence on airway calibre and thoracic cage dimensions than does weight per se - a pattern also noted in some, though not all, regional Indian PEFR studies [7,9].

The significant, if modest, correlation between PEFR and MEP found in the youngest age group ($r = 0.392$, $p < 0.01$) is biologically plausible, since PEFR is generated by the same expiratory musculature that produces MEP, and supports the inclusion of simple respiratory muscle strength measures alongside anthropometry when characterising ventilatory performance in young adults. The significant correlation between PEFR and hand-grip strength observed only in the oldest group ($r = 0.298$, $p < 0.05$) is consistent with recent evidence, from a large cross-sectional analysis of nearly 20,000 adults, that hand-grip strength correlates positively with spirometric flow parameters including peak expiratory flow, an association attributed to shared determinants of generalised skeletal muscle mass and respiratory muscle function that may become more apparent with advancing age as muscle mass begins to decline.[10] The absence of a significant PEFR-HGS correlation in the two younger groups in the present study may reflect a ceiling effect, whereby respiratory muscle strength in younger, generally well-nourished subjects is not yet limited by overall muscular reserve to a degree that measurably constrains peak flow.

Given the documented deterioration in Aligarh's ambient air quality over the past decade, driven by increasing vehicular density and small-scale industry, it is plausible that environmental exposure contributes to the PEFR values observed in this cohort; studies from other polluted Indian cities have shown measurable reductions in peak flow and increased peak-flow variability even among healthy, asymptomatic residents exposed to elevated levels of respirable particulate matter and oxides of nitrogen, an effect that merits direct environmental monitoring alongside PEFR testing in future work from this region.[12] The present analysis was restricted to establishing which anthropometric, respiratory and power parameters correlate significantly with PEFR; translating these correlations into region-specific prediction (reference) equations, and validating their predictive accuracy, is addressed as a distinct objective in a companion analysis of the same dataset (see proposed title at the end of this document), consistent with standard practice of reporting correlational and reference-equation findings as separate, focused manuscripts.

LIMITATIONS

This study has some limitations. First, the cross-sectional design and modest sample size (50 per age group) limit generalisability and preclude longitudinal inference about individual decline in PEFR with age. Second, the study was confined to males; sex-specific data are needed before these findings can be extended to women. Third, ambient air pollution levels were not directly measured alongside PEFR, so the contribution of environmental exposure to the observed values remains inferential rather than directly demonstrated. Fourth, PEFR was measured with a mechanical Wright-type meter rather than a digital, electronically calibrated device; while adequate for the purposes of this study, calibration drift cannot be entirely excluded. Fifth, socioeconomic status was restricted to Prasad's classes II and III, so these findings may not be directly applicable to markedly different socioeconomic strata

CONCLUSION

In this cross-sectional study of 150 healthy, non-smoking adult males of Aligarh, PEFR was found to correlate most strongly and consistently with stature-related anthropometric parameters - height, arm span and body surface area - across the entire 18-40-year age range studied, with a significant negative correlation with age and more age-restricted associations with expiratory muscle strength (MEP), respiratory endurance (RET) and hand-grip strength (HGS). These findings directly fulfil both stated objectives of the study and provide a contemporary, locally relevant correlational basis for the clinical interpretation of peak flow readings in this population, as well as the empirical foundation for the region-specific PEFR prediction equations to be derived and validated in a subsequent, dedicated analysis.

ACKNOWLEDGEMENTS

Not Declared.

CONFLICT OF INTEREST

None

SOURCE OF FUNDING

Self-Funding

ETHICAL APPROVAL

This Study Was Approved By The Institutional Ethics Committee and Was Conducted in Accordance With The Declaration Of Helsinki.

AUTHOR CONTRIBUTIONS

All Authors Contributed Equally.

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