

Clinical research

Comparing variations of peak expiratory flow among healthy adults from the Kuyavia-Pomeranian and Lublin districts of Poland

Maciej R. Składanowski¹, Paweł Jarosz², Barbara Mackiewicz²

¹Department of Psychiatric Nursing, Medical University of Lublin, Lublin, Poland

²Department of Pneumology, Oncology and Allergology, Medical University of Lublin, Lublin, Poland

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Corresponding author:

Maciej R. Składanowski MD

Department

of Psychiatric Nursing

Medical University

of Lublin

18 Szkolna St

20-124 Lublin, Poland

Phone: +48 693 331 020

E-mail: macsklad@wp.pl

Abstract

Introduction: Peak expiratory flow (PEF), a measure of lung function, was first described by Hadorn in 1942. The definition of PEF, written by the European Respiratory Society, states that it is the maximum flow achieved during the expiration phase, delivered with maximal force, starting from the maximum level of lung inflation. The aim of this study was to evaluate the variations of PEF associated with height, age, body surface area, place of residence and environmental factors among healthy adults in an urban setting in Poland.

Material and methods: The study comprised 88 healthy, non-smoking subjects: 30 females and 58 males, aged 20–80 years. Epidemiological and demographic data were collected from each participant, as well as information on symptoms and the occurrence of lung diseases. Only healthy subjects were selected for analysis. Participants completed spirometry testing; physical parameters were measured, and appropriate additional data obtained.

Results: Among the study group of 88 participants (30 females and 58 males), peak expiratory flow rate was negatively correlated with age ($p = 0.000001$), and positively correlated with height and body surface area (both $p < 0.000001$). There was a significant negative correlation between PEF and longitudinal environmental factors such as different particulate matter levels ($p = 0.0007$) present at the place of residence.

Conclusions: Peak expiratory flow changes are present in a healthy adult population. Place of residence and environmental factors influence the results of spirometry tests.

Key words: pollution, spirometry, environment, particulate matter.

Introduction

Spirometry testing is an important tool to aid the diagnosing and monitoring of respiratory diseases. It can assist in obtaining crucial information on the small and large airways, the parenchyma, as well as on pulmonary capillary bearing, its size and integrity. Pulmonary function tests (PFTs) are used to assess lung function. The main assumption of forceful expiration is clearly explained to each participant who performs an inspiration, which is required to acquire maximum lung volume; the participants then quickly and forcefully exhale to remove as much air from the lungs as possible [1, 2].

Peak expiratory flow rate (PEFR), which is a measure of lung function, was first described by Hadorn in 1942 and then accepted in 1949 as a parameter of spirometry [3]. The definition of PEFR written by the European Respiratory Society concludes that it is the maximum flow achieved during the expiration phase, delivered with maximal force, starting from the lung inflation level at its maximum. This occurs at approximately 100 ms from the start of a forced expiration and then peaks for 10 ms. It is commonly used to monitor the progress of the disease and outcome of the treatment applied [4, 5]. In the elderly, correlations are also found between peak expiratory flow (PEF) and different measures of physical and cognitive function [6]. The PEFR has also been known to predict the survival of older adults in selected populations [7–9] or participants with diabetes [10].

Peak expiratory flow is related to such factors as age, weight, height, race, and gender [11–13], and is also affected by altitude [14, 15], exercises [16, 17], parental smoking [18], the seasons and viral infections [19]. The purpose of this study was to evaluate the variations of PEF associated with such different factors as height, age, body surface area (BSA), place of residence and environmental factors among healthy adults in an urban setting.

Material and methods

The study comprised 88 healthy, non-smoking subjects, 30 females and 58 males, aged 20–80 years, resident in the Kuyavia-Pomeranian and Lublin districts of Poland, who participated in free screening tests in 2013–2015. Epidemiological and demographic data were collected from each participant, as well as information on symptoms and the occurrence of lung diseases. Exclusion criteria were: use of substances which could affect the respiratory system, chronic respiratory diseases, symptoms that could indicate undiagnosed pulmonary disease, and the occurrence of absolute or relative contraindications for spirometry. Participants completed spirometry tests; physical parameters such as weight and height were measured; additional data were obtained as required. All participants were Caucasians and written consent for participation in the tests was given individually by each participant. The approval of the competent Bioethics Committee for conducting the study was obtained.

Participants were told not to smoke, eat or exercise for at least 2 h prior to the test, as well as not to imbibe alcohol on the day of the test. Gender, age, height and weight were obtained from each participant. In addition, information about pulmonary diseases, symptoms that might indicate an undiagnosed illness (shortness of breath, chronic cough and its character, swelling, presence of

sputum and its nature, change of appetite or body weight in the last year), as well as information on any comorbidities, was collected. Heart rate and blood pressure were measured.

Spirometry tests were performed in accordance with the recommendations of the European Respiratory Society (ERS), the American Thoracic Society (ATS) and the Polish Lung Disease Committee (PTChP) [1, 2, 20]. First, each participant took a few quiet breaths while seated in an upright position, then performed a maximum inspiration, followed by a slow, deep exhalation. In the next phase of the study, each participant performed a dynamic, forceful exhalation after a maximum inspiration. According to the instructions of the measuring apparatus and on a signal from the spirometer, the participant performed an inspiration after a forced expiration lasting at least for 6 s. Individual breathing maneuvers were performed to obtain at least three reproducible, technically correct records, of which at least two forced expiratory curves differed in forced vital capacity (FVC) and forced expiratory volume (FEV₁) of less than 150 ml [21, 22]. The spirometer also controlled the correctness of the test by checking the start of the exhalation phase (time from the start of the manoeuvre to achieving peak flow (PEF) < 300 ms, back-extrapolated volume of FVC < 5% or 100 ml), and morphology of the respiratory curve. For further analysis, the best criteria meeting the maneuvers were chosen, i.e. those obtaining the highest scores. Reproducibility was evaluated with a five-point scale A–F, although only A and B grade tests were included in the analysis. Body surface area was calculated according to the Du Bois formula [23]: $0.007184 \times \text{weight}^{0.425} \times \text{height}^{0.725}$.

Statistical analysis

For analysis of the data obtained, a number of statistical methods were used due to the diversity of variables taken into account (both qualitative and quantitative), as well as the assumptions of the statistical tests. In accordance with the principles of selection of statistical tests, in order to verify the normality of the quantitative variables, the Kolmogorov-Smirnov, Lilliefors and Shapiro-Wilk tests were performed. Levene's test was used to examine the homogeneity of variance. Analyses of variance (ANOVA), with appropriate post-hoc Tukey tests, were used where available. To assess the differences between the average values of *k* independent samples, the Kruskal-Wallis non-parametric test with appropriate *post-hoc* modifications was performed, if needed.

To evaluate the correlation between continuous variables, Spearman's *R*, Kendall's τ and γ tests were used. For analysis of the significance of differences between groups, compared to the

qualitative characteristics of the study population, Pearson's χ^2 , and for understanding the potential strength of this relationship, Kendall's τ and coefficient of contingency tests were applied.

Results

In the study group of 88 participants (30 females, 58 males), 42 were tested in the Kuyavia-Pomeranian District and 46 in the Lublin District. Mean \pm standard deviation (SD) age was 49 ± 17.69 years, with the majority in the 20–30 age group, followed by the 60–70 age group; mean height was 172 ± 10.62 cm, with the majority in the 160–180 cm group; mean weight was 80 ± 16.17 kg, the majority in the 80–90 kg group. Mean BSA was 1.93 ± 0.23 m²; mean PEFR was 7.56 ± 2.39 l/min.

A negative correlation between PEFR and age (Spearman's $R = 0.494$; $\gamma = 0.348$; Kendall $\tau = 0.345$; $p = 0.000001$), as well as a positive correlation between PEFR and height (Spearman's $R = 0.662$; $\gamma = 0.500$; Kendall $\tau = 0.490$; $p < 0.000001$) was found, in line with expectations.

A positive correlation was found between PEFR and BSA (Spearman's $R = 0.593$; $\gamma = 0.421$; Kendall $\tau = 0.421$; $p < 0.000001$) (Figures 1–3).

There was also a major difference in spirometry test values between the populations studied in the Kuyavia-Pomeranian and Lublin districts. The population tested in the latter district had statistically significantly lower PEF values than those tested in the Kuyavia-Pomeranian District ($p = 0.0007$) (Figure 4).

In the Kuyavia-Pomeranian District, 24-hour and hourly concentrations of air pollution were obtained from a nearby air testing station. Unfortunately, no air testing stations were available in the proximity of the examination site in the Lublin District. Therefore, data were obtained for both districts from the General Inspectorate of Environmental Protection for the proper time of examination. It appeared that during the test dates there were differences concerning particulate matter volumes (Table I) [24, 25].

In the Lublin District, the amount of emitted dust particles increased by about 2.7% compared to the year 2014. At all measurement sites, the annual average permissible concentrations of PM₁₀, i.e. $40 \mu\text{g}/\text{m}^3$, were met. It was found, however, that the allowable limit for 24 h, i.e. $50 \mu\text{g}/\text{m}^3$, was exceeded. This means that each station had more than 35 days (up to 66 days) during which

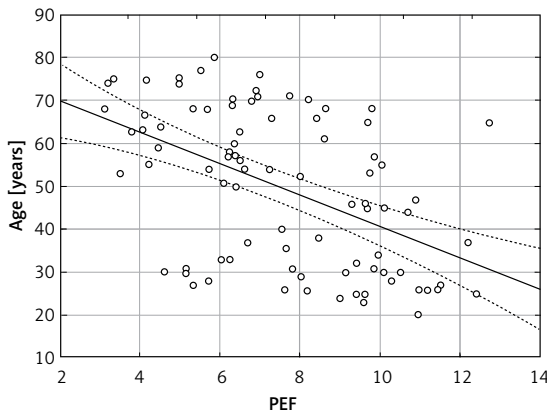


Figure 1. Peak expiratory flow (PEF) vs. age

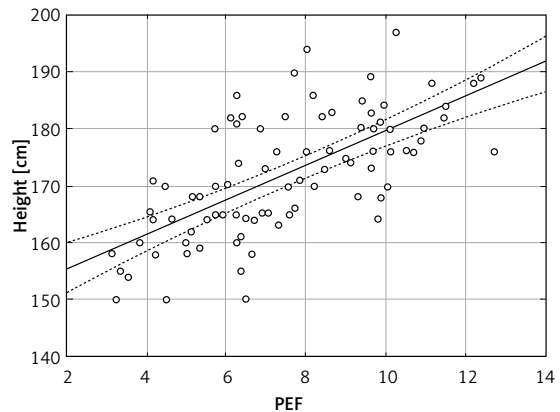


Figure 2. Peak expiratory flow (PEF) vs. height

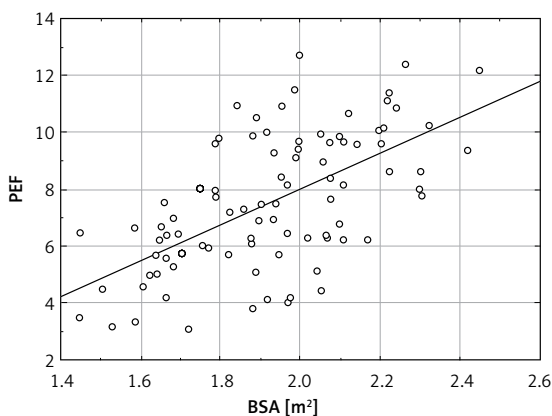
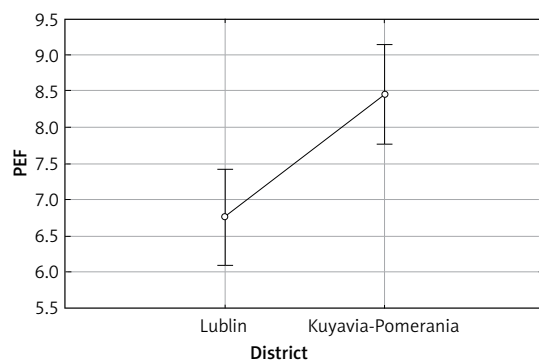


Figure 3. Peak expiratory flow (PEF) vs. body surface area (BSA)



Current effect: $F(1, 86) = 12.379, p = 0.0007$
 Effective hypothesis decomposition
 Vertical bars denote 0.95 confidence intervals

Figure 4. Peak expiratory flow (PEF) vs. districts

Table I. Mean daily particulate matter concentrations measured by air test stations closest to examination sites [24, 25]

Districts	Daily PM ₁₀ concentration		Daily PM _{2.5} concentration	
	First day	Second day	First day	Second day
Kuyavia-Pomerania	22.425	9.7	15.321	5.96
Lublin	81.229		65.375	

Table II. Zone classes for examined districts during spirometry tests (combined data from 2013 and 2015) [26, 27]

District	SO ₂	NO ₂	PM ₁₀	Pb	C ₆ h ₆	CO	O ₃	As	Cd	Ni	BaP	PM _{2.5}
Lublin	A	A	C	A	A	A	A	A	A	A	C	C
Kuyavia-Pomerania	A	A	C	A	A	A	A	A	A	A	C	A

A – zone class for pollutants with concentrations below permissible or target levels. C – zone class for pollutants with concentrations exceeding permissible or target levels.

concentrations were above 50 µg/m³. The mean concentrations for the year ranged from 29.2 to 36.4 µg/m³, achieving a mean value of 32.6 µg/m³. The highest 24-hour concentration was 187 µg/m³. High concentration values occurred during the heating period in each year.

PM_{2.5} air pollution was assessed on the basis of one criterion: the average concentration for the year. The mean concentrations for the year in the Lublin District ranged from 21.3–28.2 µg/m³ up to 141% of the target level of 20 µg/m³ and 112.8% of the permissible level of 25 µg/m³. Values exceeding the permissible level were recorded at more than half of the measurement stations. The percentage of PM_{2.5} dust in PM₁₀ varied from 70% to 81% [26].

In the Kuyavia-Pomeranian District, for annual mean concentrations, the PM_{2.5} dust content in PM₁₀ was 82.3%, as in the previous year. The annual average for PM₁₀ dust was lower than in the previous year and was 17.6 µg/m³, which constituted 44.0% of the permissible level. A lower frequency of PM₁₀ exceeding the allowable limit for 24 h (50 µg/m³) was observed 7 times. The annual average for PM_{2.5} was 14.5 µg/m³, which was 58.0% of the target volume. Maximum concentrations of PM₁₀ and PM_{2.5} were close to one another: PM₁₀ recorded level – 78.7 µg/m³; PM_{2.5} – 77.7 µg/m³ [27] (Table II).

Discussion

The occurrence of a negative correlation between PEF values and age is consistent with previous reports [28, 29] and can be explained by the rigidity of the chest wall increasing with age, as well as by reduction of the elastic recoil of the lungs. The outcome is a reduction of spirometry values. Air trapping and hyperinflation lead to further increase in functional residual capacity (FRC) and residual volume (RV) [30–33]; premature closing of

the distal alveoli takes place [32, 34]. With the increase of RV, a reduction of the diaphragm curvature occurs which, in turn, causes a diminution of strength of this muscle and further deterioration of airflow in the lungs. The efficiency of intercostal muscles also decreases [30, 32, 35].

A positive correlation between PEF values and height reflects the findings of different authors [36–38]. This can probably be explained by a greater chest size connected with greater lung volume in taller subjects, as well as the size of the airway passages or the increased expiratory muscle effort, positively related to an increase in participants' height [39, 40]. A statistically significant, positive correlation between PEF and BSA was found, which is consistent with the results of other studies [37, 39].

The participants tested in the Kuyavia-Pomeranian District had statistically significantly higher values of PEF than those tested in the Lublin District. According to the General Inspectorate of Environmental Protection, emissions from low emitters of combustion products from domestic furnaces and local coal-fired boilers during the heating season have a significant impact on air quality in the Lublin District. The PM₁₀ level has a decisive influence on air quality. This is due mainly to the use of hard coal for heating purposes, which results in an increase in the concentration of dust in the cold season. It is also worth bearing in mind that the share of PM_{2.5} dust in PM₁₀ varied from 70% to 81% [26, 41]; this is also in line with the data from the Lublin District study time – February. In the Kuyavia-Pomeranian District the study was conducted in late June. The mean PM₁₀ and PM_{2.5} volumes were substantially higher in the Lublin District compared to the Kuyavia-Pomeranian District, including hourly, daily and yearly means at the time of the study [26, 27, 41].

Regarding the influence of particulate matter concentrations on PEF, van der Zee *et al.* found

that participants with asthma were considerably more susceptible to particulate air matter [42]. This was in line with the work of Yamazaki *et al.* [43]. A decrease in spirometric values among healthy women living in areas with increased volumes of PM_{2.5} was confirmed by Kumar *et al.* [44]. Similar results were observed in the Lesser Poland region in a study undertaken by Mejza *et al.*, which concerned a random population of that region, where coal or wood is used for heating and cooking [45].

In conclusion, PEF changes are also present in the healthy adult population, and are negatively correlated with age, and positively correlated with height and BSA.

Places of residence and environmental factors influence the results of spirometry testing, such as PEF. Further analyses are needed for a better understanding of the longitudinal environmental factors' influence on human health.

Conflict of interest

The authors declare no conflict of interest.

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