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Variations of Peak Expiratory Flow Rate Associated with Various Factors Among Healthy Adults in a City Setting

Abstract

Introduction. Peak Expiratory Flow Rate (PEFR) was first described by Hadorn as a measure of the lung function. The definition of PEFR established by the European Respiratory Society defines it as the maximal flow achieved during the phase of expiration, delivered with maximal force and starting from the maximal lung inflation level.

Aim. The authors of this study attempted at evaluating the variations of PEFR, taking into consideration the effects of one's age, height Body Mass Index (BMI), Body Surface Area (BSA), seasons of the year and air pollution. Healthy adults living in urban areas were subjects of the study.

Material and methods. The study group consisted of some 179 healthy subjects, 102 women and 77 men, aged 18 to 66. Every patient's medical history, including epidemiological, demographic data, as well as the information about the occurrence and symptoms of lung diseases, was taken from every patient. Only healthy subjects were selected for further analysis. Participants performed spirometry testing. Physical parameters were measured. Appropriate pollution data was obtained.

Results. The study group consisted of 179 patients (102 women and 77 men). There is a negative correlation between PEFR and age and a positive one between PEFR and height, as well as Body Surface Area and BMI (regarded as a quantitative, but not as a qualitative trait). There is a significant correlation between PEFR and PEFR adjusted by age, height and weight with seasons of the year. There is a statistically significant negative impact of NO_2, SO_2 and O_3 24 h mean and hourly NO_2 concentration on PEFR.

Conclusions. Peak Expiratory Flow Rate changes are also present in a healthy adult population. Prevalence of obesity is an important factor of the examined population.

Keywords: pollution, pulmonary function tests, spirometry, PEFR, BMI.

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INTRODUCTION

Pulmonary function tests (PFTs) are a valuable tool that may prove a significant aid in diagnosing and monitoring patients suffering from respiratory diseases. These tests may help obtain some important information concerning both large and small airways, parenchyma, the size and integrity of the pulmonary capillary bearing. Spirometry is commonly used to assess the functioning of lungs. The main assumption of forced expiration is clear: patients are asked to perform an inspiration to achieve maximum lung volume, and then to make a quick forceful exhalation in order to remove the maximum possible amount of air from the lungs [1].

In 1942, Hadorn described Peak Expiratory Flow Rate (PEFR), as a measure of the lung function for the first time. In 1949, it was accepted as a spirometry parameter. PEFR's definition by the European Respiratory Society states that it is the maximal flow achieved during the phase of expiration, delivered with maximum force, which starts from the maximum lung inflation level. It occurs about 100 ms after a forced expiration start and peaks for 10 ms. It is applied to monitor the disease progress and the treatment outcome upon it [2]. There are also significant correlations between PEFR and different measures of cognitive and physical function among the elderly. Moreover, it has been found to be a useful tool while attempting to predict the survival of older adults in selected populations or those with diabetes [3].

While PEFR is obviously related to factors like age, weight, height, race, gender, it is also affected by altitude, exercises, parental smoking, seasons and viral infections [4,5]. Findings of the authors investigating the pollution-related PEFR changes and the differences among healthy and asthmatic subjects seem to differ. Some of them have suggested that PEFR changes are more likely to happen to the latter group [6], while others either find no differences between the asthmatic and non-asthmatic [7], or no evidence of the relationship between PEFR and air pollution [8].

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AIM

The purpose of this study was to evaluate the variations of PEFR while taking into consideration various factors like age, height, Body Mass Index (BMI), Body Surface Area (BSA) and air pollution. The resesarch was done on healthy adults in a city setting.

MATERIAL AND METHODS

The study included 179 healthy subjects participating in free screening tests in Warsaw, Poland, between 2013 and 2014. The study group consisted of 102 women and 77 men. The subjects were aged 18 to 66. An epidemiological and demographic data was collected from every patient, as along with the information about the occurrence and symptoms of lung diseases. The exclusion criteria were: pre-existing chronic respiratory diseases, use of substances that can affect the respiratory system, symptoms that might indicate undiagnosed pulmonary disease, occurrence of relative or absolute contraindications for spirometry. The participants performed spirometry testing and physical parameters such as height and weight were measured. A written consent to become subject of a research study has been provided by every patient.

Subjects willing to participate in the study had been advised not to smoke, exercise or eat for at least two hours prior to the test. Drinking alcohol on the day of the test was also forbidden.

Gender, age, weight and height were obtained for each patient. All participants were of Caucasian ethnicity. Later, the following data were collected: an accurate intelligence on lung diseases, symptoms that may indicate an undiagnosed illness (such as breathlessness, swelling, chronic cough and its character, the presence of sputum and its nature, appetite and body weight changes during the last year), as well as any morbidities. Blood pressure and heart rate were measured afterwards.

Spirometry was performed along with the recommendations of the ATS/ERS and Polish Lung Disease Committee (PTChP) [1]. Initially, the patient took a few quiet breaths, being in an upright sitting position performed a maximum inspiration followed by a slow deep exhalation. In the next phase of the study the patient performed a dynamic, forceful exhalation after a maximum inspiration. According to the instructions of the measuring instrument, the patient performed an inspiration after a forced expiration lasting at least for six seconds and the signal of the spirometer. Individual breathing maneuvers have been carried out to obtain at least three reproducible, technically correct records, of which at least two forced expiratory curves differed in FVC and FEV1 of less than 150 ml. Spirometer also was used for controlling the correctness of the test by checking the exhalation phase start (time from the start of the maneuver to achieve 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 maneuvers were chosen, i.e. those receiving the highest scores.

The reproducibility was evaluated using a five-point scale A-F, only A and B grade tests were included in the analysis.

BMI was calculated from weight and height measurements obtained (to the nearest 10 grams and 1 cm) according to the formula:

$$[\text{weight in kg}]/[(\text{height in meters})^2]$$

Patients were divided into four groups of the BMI value. It was assumed as normal for values of 20-25 kg/m^2, of less than 20 kg/m^2 considered as underweight, 20-25 kg/m^2 as normal weight, 25-30 kg/m^2 as overweight, while 30-35, 35-40 and ≤ 40 kg/m^2 for obesity of the first, second and third degree respectively. BSA was calculated according to Du Bois formula:

$$0.007184 \times \text{Weight}^{0.425} \times \text{Height}^{0.725}$$

In order to evaluate the particulate matter concentrations in the air, the authors used the data provided by air quality monitoring stations supervised by Provincial Environmental Inspectorate (WIOS) in Warsaw. They were used to evaluate both the 24 h and hourly concentrations of particulate matter with less than 10 µm and 2.5 µm diameter (PM_{10} and PM_{25}), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO) and ozone (O_3).

The obtained material was analyzed using a number of statistical methods. This was due to the fact that a variety of factors had been taken into account (both qualitative and quantitative), as well as the assumptions of statistical tests.

In accordance with the principles of statistical tests selection, in order to verify the normality of the quantitative variables, Kolmogorov-Smirnov, Lillefors and Shapiro-Wilk test was performed. Levene's test was used to examine the homogeneity of variance. Analysis of variance with appropriate post-hoc Tukey tests were used, where available. To assess the differences between the average values of k independent samples, Kruskal-Wallis nonparametric tests with appropriate post-hoc modifications were performed, when needed. To evaluate the correlation between continuous variables, R Spearman, Kendall τ (tau) and Gamma tests were used. It was necessary to analyze the significance of differences between groups compared to the qualitative characteristics of the study population, hence the Pearson χ^2 test was used. Kendall's τ and coefficient of contingency tests were employed in order to understand the potential strength of this relationship.

RESULTS

Some 179 patients (102 women and 77 men) were subjects of the study. Some 88 patients were tested during the warm season and 87 patients were tested during the cold season. The mean age was 43±11 SD, mean height was 171±8 SD, mean weight was 75.5±15.7 SD. Mean BMI as a quantitative characteristic parameter was measured as 25.6±4.4 SD. Some 13 subjects were classified to be underweight, 77 had normal weight, while 60 people were included in the overweight group and 27 patients in the obesity group. Mean BSA was 1.87±0.21 SD. Mean PEFR was 7.40±2.16 SD.

During the tests, the mean 24 hour concentration of PM_{10}, SO_2, NO_2, CO, O_3 and hourly concentration of PM_{10}, PM_{25}, SO_2, NO_2, CO, O_3 remained below the maximum permitted concentration. More data is presented in Table 1 and Table 2 respectively.

TABLE 1. 24 hour concentrations of air pollution parameters in µg/m^3.

	Mean	Median	Mode	Frequency - of Mode	Minimum	Maximum	Std.Dev.
PM_{10}	41.3808	28.00	71.80	37	7.30	86.80	30.3637
SO_2	4.1633	4.30	2.70	37	2.70	6.00	1.0614
NO_2	46.4881	47.00	46.80	37	10.90	73.90	17.3520
CO	728.2373	708.00	932.00	37	243.00	1322.00	349.8886
O_3	28.4212	23.60	23.60	37	15.30	55.80	15.9268

TABLE 2. Hourly concentrations of air pollution parameters in µg/m³.

	Mean	Median	Mode	Frequency - of Mode	Minimum	Maximum	Std.Dev.
PM_{10}	45.6639	41.40	Multiple	6	6.00	107.30	26.7211
NO_2	56.6153	64.60	Multiple	6	5.90	117.50	32.4841
CO	772.9153	859.00	1000.00	8	125.00	1731.00	439.4260
PM_{25}	22.4983	24.10	25.00	6	10.90	32.30	5.9721
SO_2	4.6500	4.10	4.10	9	3.00	12.20	2.1814
O_3	44.3433	42.10	37.40	4	21.50	68.50	12.9763

As it might have been expected, some negative correlations between age and PEFR (R Spearman: – 0.323; Gamma: – 0.222; Kendall τ (tau): – 0.219; p = 0.00002) were found. Plus to that, a positive correlation between height and PEFR (R Spearman: 0.640; Gamma: 0.474; Kendall τ (tau): 0.463; p<0.00001) was found.

A positive correlation between BMI, as a quantitative characteristic, parameter and PEFR (R Spearman: 0.204; Gamma: 0.142; Kendall τ (tau): 0.141; p=0.006) was found but there was no statistically significant correlation between PEFR and BMI as a qualitative trait.

A positive correlation between BSA and PEFR (R Spearman: 0.562; Gamma: 0.374; Kendall τ (tau): 0.373; p<0.0001) was found.

There is a statistical significance (p<0.05) between PEFR values and the current season. It is the relation between PEFR values during the hottest season – summer (mean PEFR 6.96 µg/m³) – and the coldest season – winter (mean PEFR 7.75 µg/m³). A greater statistical significance (p<0.005) was found in relation between PEFR values and warm (mean PEFR 6,96 µg/m³) – cold (mean PEFR 7.84 µg/m³) seasons group – the data is presented in Figure 1. The mean PEFR values in both groups were lower in warm seasons than in cold seasons.

Using PEFR values adjusted by age, height and weight, statistical significance of these parameters, the relation between the hottest (mean adjusted PEFR 82.6%) and the coldest (mean adjusted PEFR 96.3%) season was found to be greater (p=0.000003). So was the relation between adjusted PEFR values and warm (mean adjusted PEFR 82.6%) – cold (mean adjusted PEFR 95.8%) seasons group (p=0.000001).

After examining the 24 hour concentration of air pollution group, only mean SO_2 values were shown to have a statistically significant impact on both absolute and adjusted PEFR values (p<0.05 and p<0.0177, respectively). The O_3 values had a statistically significant influence on adjusted PEFR values (p=0.0061) while the NO_2 had a statistically significant effect on PEFR's absolute values. (p=0.0019). However, it did not have such effect on the adjusted PEFR values (p>0.3).

After examining an hourly concentration of air pollution group, only mean NO_2 values had a statistically significant effect on the absolute values of PEFR (p=0.0056). It did not have such effect on the adjusted PEFR values (p>0.44).

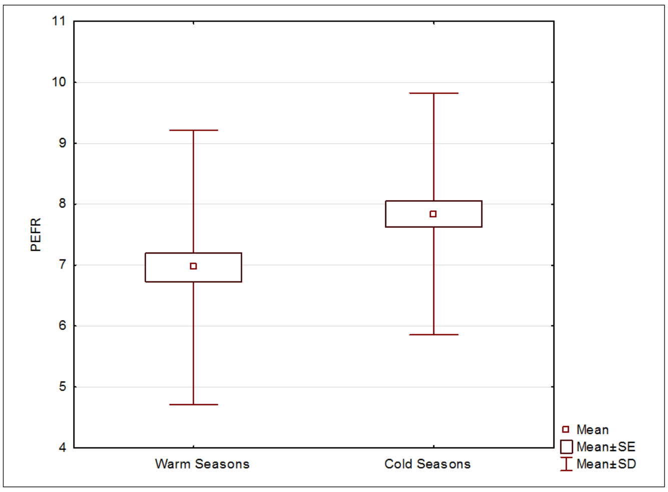

FIGURE 1. A relation between PEFR and Warm – Cold Seasons group.

DISCUSSION

The findings about negative correlations between PEFR values and one's age is consistent with the previous reports. Presumably, it may be supported by the fact that there is a relation between age and the effects that go along with it. Namely, the older the patient gets, the bigger increase in the rigidity of the chest wall and reduction of lungs elastic recoil. As a result, a reduction of spirometry values appears, and – by the action of "air trapping" and hyperinflation – to an increase in Residual Volume and Functional Residual Capacity. There is also a premature closing of the distal alveoli. With the increase of Residual Volume, a reduction of the diaphragm curvature emerges, which causes a diminution of this muscle strength and further impairment of airflow in the lungs. There is also a decrease of the intercostal muscles efficiency [9].

The positive correlation between PEFR values and height mirrors the findings of different authors. It can probably be explained by the presence of a bigger lung volume connected with a greater chest size in taller subjects, as well as by the size of airway passages or the increase of expiratory muscle effort, positively connected with an increase of participants height [10].

The authors found a positive correlation between one's BMI as a quantitative characteristic parameter and PEFR. Suresh et al. noticed a similar phenomenon. They confirmed that, after taking into account not only groups of normal, overweight and obese patients, but also the group of underweight people, which is the case in this study, increasing BMI as a quantitative trait results globally in improved spirometric parameters [11]. Nevertheless, there are some authors stating the opposite, for instance, referring patients who had undergone the bariatric surgery. There is one thing, however, that needs particular attention. A significant portion of the study groups were obese people, often described as even extremely obese. The cases describing an invasive weight reduction are mainly focused on people with an obesity much higher than the first degree obesity [12]. In this paper, 137 people were in the range of BMI 20-30 kg/m2 and the biggest group consisted of subjects in the range of 20-25 kg/m2. Thus, this study should be considered as a study of a population with a relatively low rate of obesity. This kind of population was investigated by Fukahori et al. Their work included a positive correlation between spirometric parameters, like Forced Expiratory Volume in first second (FEV1), and BMI as a quantitative trait, yet with p>0.05. At the same time, they presented a positive correlation of (pseudo) Tiffenau index and BMI as a quantitative trait [13]. Chakrabarti et.al., who also looked at underweight patients in their research confirmed the presence of the lowest values of spirometric parameters (PEFR with p=0.02) precisely in this group [14], which refers not only to our findings of quantitative BMI values vs. PEFR, but also remains consistent with our findings concerning the relation between PEFR and BMI tested as a qualitative trait. Hence, the lack of statistical significance between PEFR and BMI as a qualitative trait reflects previous findings by other authors. Schachter et al. confirmed, that peak expiratory flow (PEF), and mid forced expiratory flow (FEF(25-75)) were not statistically different among the BMI weight groups [15].

The authors reported a positive, statistically significant correlation between BSA and PEFR. This goes in keeping with the findings of other authors [10].

A statistical significance between PEFR values and seasons of the year, including the relation between PEFR values during the summer and winter, as well as even greater statistical significance between PEFR values and warm – cold seasons group was found. In both groups, the mean PEFR values were lower in warm seasons, than they were in cold seasons. Considering the fact that the study group consisted of healthy adults, the possible cause of this can be the effect of the mean temperature and humidity on human organism capacity. Increased temperature and humidity can affect the body in that way, as if it were constantly exercising. The central blood volume decreases up to 15% due to various factors, like distal blood vessels dilatation and sweating. This leads to further activation of sympathetic nerves and fatigue symptoms. Numerous works of different authors prove that exercises decrease PEFR which, in turn, confirms the findings of this paper [5].

There were no statistically significant differences between PEFR and particulate matter concentrations. Van der Zee et.al. confirmed that patients with asthma are more susceptible to particulate air matter than those without the symptoms [6]. However, Ward et al. contradicted this fact in his work [8]. Yet, Yamazaki et al. seems to confirm Van der Zee's thesis [16]. Nevertheless, the absence of statistically significant influence of particulate matter and CO concentration on healthy adults' PEFR, as shown in our work has been confirmed by numerous authors [17].

The statistically significant effects of hourly NO_2 mean values on PEFR were found both in our work and in Yamazaki's paper, where the rising of an hourly concentration of NO_2 was positively associated with PEFR declines. Furthermore, the NO_2 and PEFR associations also remained present, even when adjusted for $PM_{2.5}$ and Ox [16].

The presence of ome statistically significant effects that SO_2 and O_3 may have on PEFR as it was shown in our analysis, were confirmed by Higgins et al. According to their findings, the peak flow changes were modest, but occurred at air pollution levels oscillating below WHO's guide levels [18]. A statistically significant association between NO_2, O_3 and PEFR, as found in our study, was observed among the residents of Sao Paulo, Brazil. The observation was stated independently from their allergic sensitization status [7].

CONCLUSIONS

Peak Expiratory Flow Rate changes were also reported among the healthy adult population. It is negatively correlated with age and positively correlated with height, Body Surface Area, BMI as a quantitative, but not as a qualitative trait. Prevalence of obesity is an important factor of the studied population. There is a significant correlation between PEFR, PEFR adjusted by age, height and weight with seasons of the year, where mean PEFR values were lower in warm seasons than in cold seasons. There is no statistically significant effect of air particulate matter or CO on healthy adults' PEFR. NO_2, SO_2 and O_3 's influence is present in the 24 h mean concentration group, whereas only NO_2 presents a statistically significant effect on PEFR in an hourly air pollution concentration group.

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