ABS ACTA BIOLOGICA SLOVENICA
LJUBLJANA 2014 Vol. 57, Št. 1: 69–80

Methodological weaknesses regarding the use of PEF-meters when assessing physiological effects of air pollution risk factors

Metodološke pomanjkljivosti uporabe PEF-metrov za oceno fizioloških učinkov zračnih polutantov

Petra Golja

University of Ljubljana, Biotechnical Faculty, Večna pot 111, SI-1000 Ljubljana, Slovenia.
Correspondence: petra.golja@bf.uni-lj.si

Abstract: The manuscript discusses the applicability of self-administered monitoring of respiratory function in asthma patients in order to discern between negative health effects of different air pollutants on respiratory function. Thirteen asthma patients measured their respiratory function twice daily over a one month winter period. They used PEF-meters to monitor peak expiratory flow (PEF; L/min) and forced expiratory volume in the first second of expiration (FEV_1; L). Subjects' vital capacity (VC; L) was measured in a laboratory setting at the end of the measuring period. Respiratory data were evaluated in respect to the ambient concentrations of NO_2, NOx , SO_2 , O_3 , and PM_{10}, which were monitored during the same period. The concentrations of some air pollutants (PM_{10} and NO_x) exceeded the critical levels on several days during the study. PEF-meter data (PEF, FEV_1 and FEV_1/VC), however, did not respond significantly to the ambient conditions ($P>0.05$). The results speak against the use of self-administered PEF-meter monitoring for the recognition and investigation of air pollutant related negative health effects. Limitations and delimitations of the method are presented.

Keywords: respiratory function; asthma; self-administered respiratory monitoring; particulate matter; PM_{10}; PEF; FEV_1

Izvleček: Prispevek analizira uporabnost samo-apliciranega spremljanja dihalne funkcije pri astmatikih, uporabljenega z namenom razločiti med negativnimi zdravstvenimi učinki različnih zračnih onesnaževalcev na dihalno funkcijo. Trinajst astmatikov je dvakrat dnevno v obdobju enega meseca v zimskem času spremljalo svojo dihalno funkcijo. Maksimalni pretoka zraka ob izdihu (PEF; L/min) in prisiljen ekspiratorni volumen v prvi sekundi izdiha (FEV_1; L) so spremljali s PEF-metri. Vitalna kapaciteta preiskovancev (VC; L) je bila izmerjena v laboratoriju ob koncu raziskovalnega obdobja. Respiratorni podatki so bili analizirani glede na okoljske koncentracije onesnaževalcev NO_2, NOx, SO_2, O_3 in PM_{10}, ki so bili spremljani v istem časovnem obobju. Koncentracije nekaterih zračnih onesnaževalcev (PM_{10} in NO_x) so presegle kritično mejo v več dnevih raziskovalnega obdobja. Kljub temu, s podatki s PEF-metrov (PEF, FEV_1 in FEV_1/VC) ni bilo mogoče pokazati statistično značilnih odzivov dihalne funkcije na okoljske razmere ($P>0.05$). Rezultati raziskave izpostavljajo problematičnost uporabe samo-apliciranega spremljanja dihalne funkcije s PEF-metri za prepoznavo in raziskave negativnih zdravstvenih učinkov, povezanih z zračnimi onesnaževalci. V besedilu so podrobneje prikazane prednosti in slabosti predstavljene metodologije.

Ključne besede: respiratorna funkcija; astma; samo-aplicirano spremljanje dihalne funkcije; PM_{10}; PEF; FEV_1

Introduction

Respiratory tract is an organic system that is maximally exposed to air pollution. People with respiratory diseases are thus one of the most susceptible population groups to different air pollutants. Indeed, studies suggest that the quality of air in the environment can affect the respiratory function in humans (Rios et al. 2004), and that respiratory conditions, such as asthma, can be aggravated in a polluted environment (Heinrich et al. 1999).

Asthma is a chronic disease that severely affects the respiratory function. Asthma associated inflammation of the airways constricts the bronchia, which increases resistance and decreases the airflow through the respiratory system. It is generally accepted that the prevalence of asthma has increased significantly over the last years. It has been suggested that an increase in the number of asthmatic conditions is most likely related to environmental factors, as the period in which the changes have been observed is too short for genetic mutations to occur (Joseph et al. 1996). Epidemiological and controlled exposure studies of human volunteers have indeed demonstrated that exposure to a variety of pollutants induces asthma exacerbations (Peden 1996).

The intensity of asthma symptoms and signs varies in time and the aggravation of health status has been related to several factors, such as pollen, ambient temperature and viral infections (Gent et al. 2003). Furthermore, studies have demonstrated that the aggravation of disease is related to several air pollutants, although, the relation between asthma outbreaks and any particular air substance has not yet been determined unequivocally (Gent et al. 2003). Different studies suggest that particulate matter (PM) and NO_2 can be pointed out as air pollutants that cause the most negative health effects in individuals with already impaired respiratory function, namely, in COPD and asthma patients (Lagorio et al. 2006).

As air pollutants cause negative health effects worldwide, this topic has gained an increasing interest. Epidemiological approach has most often been used when the effects of air pollutants on health have been studied. In contrast, physiological data on this matter are rather scarce or even non-existent. Thus rather surprisingly, data on the effects of different air pollutants on a day to day respiratory function of both, healthy people and people with respiratory diseases, are limited, although they can provide vital information about the detection and consequent prevention against the environmental risk factors. In one of the few studies, for example, Linn and co-workers (Linn et al. 1996) reported that in healthy schoolchildren forced vital capacity measured in the morning decreases significantly with increase in particulate air pollution or NO_2 measured over the preceding 24 hours, and that morning-to-afternoon change in FEV_1 becomes significantly affected with increase in particulate matter, NO_2, or O_3 on the same day. Daily assessment of respiratory function can therefore serve as a fast and non-subjective tool, which is able to discern critical environmental factors.

It is likely that one of the reasons for the lack of data about the effects of different air pollutants on a day to day respiratory function is logistical, as daily ambulatory measurements of respiratory function are expensive and rather difficult to be organized. The availability and development of new techniques, which allow self-administered monitoring of respiratory function at home, thus provide promising new research opportunities and the use of peak expiratory flow meters (PEF-meters) has been suggested as a potentially useful methodological approach to address this issue (Bellia et al. 2003).

To monitor the respiratory state of asthma patients, pneumotachs or spirometers are usually used in ambulatory monitoring, and portable peak expiratory flow-meters (PEF-meters) by patients themselves. Peak expiratory flow (PEF, L/min) is the maximal flow of air during a forced expiration. PEF measurements are used in outpatient monitoring of asthma and in emergencies (Cross and Nelson 1991). PEF measurements, however, have been criticized for use with chronic obstructive pulmonary disease patients (COPD) due to unreliability, poor reproducibility, and unavailable reference values (Pauwels et al. 2001). To improve the monitoring, the measurements of forced expiratory volume in the first second of expiration (FEV_1, L) have therefore become regularly used and have also become available with newer portable PEF-meters. It has to be noted, that PEF and FEV_1 measurements provide different information, since PEF reflects flows in the large airways, and FEV_1 reflects obstruction in different parts of the airways (Paggiaro et al. 1997).

As data about the application of portable PEF-meters for a daily respiratory monitoring for the assessment of the effects of air pollutants on respiratory function are limited (Bellia et al. 2003), the present study aimed to assess the feasibility, sensitivity and applicability of self-administered monitoring of respiratory function by PEF-meters for the detection of environmental conditions that have previously been demonstrated to negatively affect respiratory function in humans. Should the negative effects of air pollutants be reflected in diminished respiratory function as self-assessed by PEF meters, asthma patients would gain a simple tool to recognize the environmental risk and consequently decrease it by modifying their behavior, i.e. by modifying the time or location of their outdoor exposure. We hypothesized that self-administered PEF-meter monitoring will be able to detect changes in respiratory function of asthma patients in relation to the concentrations of specific air pollutants in an urban area.

Methods

Asthma patients were selected for the study, because they, being respiratory disease patients, are one of the most sensitive groups to air pollution. Daily monitoring of the respiratory function of 13 asthma patients was performed over a period of one month. The study was performed in wintertime, as this is the period in which the likelihood for temperature inversion and thus the high concentrations of air pollutants in the selected urban area is the highest. Furthermore, the concentration of pollen, which can considerably worsen the respiratory function of asthmatic patients, and can thus interfere with the respiratory measurements, is smallest in winter. If the study was, for example, performed during seasons change, when the temperature fluctuation are highest and the pollen concentration increases, this two influential factors could severely interfere with the study results (Gent et al. 2003).

Ethical clearance

The study was conducted in accordance with the Declaration of Helsinki and the protocol of the study gained approval by the Ethics Committee of the Republic of Slovenia (approval number 110/12/04). Each subject provided written informed consent before participating.

Subjects

Asthma patients were asked to voluntarily participate in the study and were recruited by their attending pulmologist. The subjects with emphysema, chronic bronchitis, and heart failure could not participate in the study. Also, the subjects with acute upper respiratory infections could not be recruited. The main inclusion criteria for the subjects was a settled medical asthmatic condition, for which large alterations in regular medications were not expected to occur, as a substantial change in medication during the course of the study would likely interfere with the study results. Furthermore, as air pollution is affected by geographical features, the study aimed to minimize this effect by recruiting only the subjects living in an area within approximately 1.5 km of air radius around the measuring station of Environmental Agency of the Republic of Slovenia. Thus, only the subjects permanently living in the strict town area of Ljubljana were included in the study.

Protocol and instrumentation

The information about the daily concentrations of pollutants in the air of the town of Ljubljana was obtained from the Environmental Agency of the Republic of Slovenia, an official body that monitors air pollution in Slovenia. The data about the following pollutants were obtained: particulate matter of less than 10 micrometers in diameter (PM_{10}; $\mu g/m^3$); ozone (O_3; $\mu g/m^3$); sulphur dioxide (SO_2; $\mu g/m^3$); nitrogen dioxide (NO_2; $\mu g/m^3$), and nitrogen oxides (NO_x; $\mu g/m^3$).

Peak expiratory flow-meters (Piko-1 Ferraris Respiratory Europe Ltd., Great Britain) were used in the study to monitor the respiratory state of asthma patients. These PEF meters determine both, peak expiratory flow (PEF, L/min), thus the maximal flow of air during forced expiration, as well as the forced expiratory volume in the first second of expiration (FEV_1, L). According to manufacturers' recommendations, the PEF and FEV_1 values measured by PiKo-1 PEF meter correlate well at all flows with those measured by a pneumotach. The devices used correspond both, to the American Thoracic Society standards and to standards of the European Union.

Prior to the study, all subjects were given thorough instructions about the functioning of the PEF meters and aims of the study. A correct procedure of the measurement was demonstrated to them**.** To perform the measurement, the subjects were asked to stand up, hold a PEF-meter horizontally and be careful not to cover the expiratory outlets. They were instructed to blow as much air as they could through the mouthpiece of the PEF-meter after an audible signal. They were asked to perform the measurement three times at each occasion and to write down the obtained values of PEF and FEV_1 into the suitable tables after each measurement. The subjects performed the measurements in the morning, immediately when they got up, and in the evening, just prior they went to sleep. Apart from providing the values of PEF and FEV_1, all subjects were asked to daily fulfill the questionnaire with any remarks they thought might be relevant to the measurements, such as: their state of health, fever, cold, a change in measurement place (if they would be absent from home), and a change in medication. For each subject, the data acquisition tables were prepared in advance and were collected at the end of a one-month period.

Vital capacity (VC, L), i.e. the maximum volume of air that can be exhaled after a maximum inhalation, was also measured in a laboratory setting with a spirometer (Cosmed K4b2, Rome, Italy) at the end of the study period. The subjects' age was recorded and their height and weight were determined on a certified scale (Vita Libela Elsi, Celje, Slovenia). The spirometer was first calibrated with a 3-litre calibrating syringe (Cosmed, Rome, Italy), then the subjects were fitted with a nose clip. The standing subjects first breathed normally

Table 1: Subjects characteristics, including gender, with individual and average age, height, mass and smoking status presented

Tabela 1: Značilnost preiskovancev. Predstavljeni so spol ter posamezni in povprečni podatki za starost, višino, maso in kadilski status.

Subjects' characteristics
Lastnosti preiskovancev

Subject number Številka preiskovanca	Gender (male/female) Spol (moški/ženska)	Age (years) Starost (leta)	Height (cm) Višina (cm)	Mass (kg) Masa (kg)	Smoker (yes/ex/no) Kadilec (da/bivši/ne)
1	male / moški	56	177	84	Yes / Da
2	male / moški	58	189	97	Yes / Da
3	male / moški	31	186	81	Yes / Da
4	male / moški	70	164	52	No / Ne
5	male / moški	39	183	80	Ex / Bivši
6	female / ženska	26	166	54	Yes / Da
7	female / ženska	85	159	67	Ex / Bivši
8	female / ženska	41	175	60	No / Ne
9	female / ženska	40	166	61	No / Ne
10	female / ženska	64	163	76	Ex / Bivši
11	female / ženska	59	166	94	Yes / Da
12	female / ženska	59	155	92	Ex / Bivši
13	female / ženska	45	173	83	Ex / Bivši
AVG±SD	**/**	**52±17**	**171±11**	**75±15**	**/**

through a spirometer and then took a maximally deep breath, after which they blew through the mouthpiece as strongly and as for as long as they could. The whole procedure was repeated three times and the maximal measured volume of expired air was taken as representative for the subjects' vital capacity. No broncho-dilatators were used for the vital capacity determination.

Statistical analysis

For each pollutant, a day with its minimum and maximum measured concentration was selected. Then, PEF and FEV_1 values of all subjects measured for these two days were compared with a two tailed paired Student T-test. Both, the absolute and relative values of PEF and FEV_1 were analysed.

Table 2: The maximum hourly concentrations of fine particles (PM_{10}; µg/m^3) and nitrogen oxides (NOx; µg/m^3) in the air in the town of Ljubljana during the experimental period. The two experimental days with the maximum and minimum concentrations of the two air polutants are presented in bold. The shaded areas denote days in which the legislative boundary concentrations of PM_{10} or NOx were exceeded

Tabela 2: Največji urni koncentraciji finih delcev (PM_{10}; µg/m^3) in dušikovih oksidov (NOx; µg/m^3) v zraku v mestu Ljubljana med potekom raziskave. Dneva z največjima in najmanjšima koncentracijama obeh onesnaževalcev sta prikazana odebeljeno. Osenčena polja označujejo dneve, v katerih so bile zakonsko določene največje koncentracije PM_{10} ali NOx presežene

The maximum hourly concentrations of pollutants in the experimental days
Največja urna koncentracija onesnaževalcev v raziskovalnih dneh

Experimental Day Raziskovalni dan	PM_{10} (µg/m^3)	Experimental Day Raziskovalni dan	NO_x (µg/m^3)
4	**207.45**	**4**	**208.55**
3	181.47	5	200.55
5	155.19	6	170.30
25	133.18	25	162.35
6	126.29	12	138.90
2	121.15	3	136.80
27	115.01	11	132.35
28	102.92	18	119.35
1	95.42	27	112.75
12	90.02	1	102.85
24	88.35	17	94.10
26	84.01	13	93.50
11	75.33	8	92.30
17	70.00	26	91.25
13	69.75	28	91.15
18	67.60	2	90.70
19	59.27	22	87.05
16	55.49	24	86.70
14	52.45	23	78.65
23	52.14	16	75.15
20	50.90	19	75.10
21	46.38	9	57.70
8	44.08	20	48.75
15	42.22	10	40.80
10	39.70	15	31.65
22	38.32	7	30.10
9	37.32	14	22.70
7	**29.20**	**21**	**15.30**

To enable inter-individual comparisons, FEV_1/VC ratio was calculated for each subject and compared between the days with minimal and maximal concentrations of air pollutants. A P-value of less than 0.05 was adopted as statistically significant. All the following results are presented as average±SD.

Results

Subjects characteristics

The average age of the subjects was 52±17 years, height 171±11 cm and mass 75±15 kg. Eight of the subjects were females (two smokers, four ex-smokers, two non-smokers) and five of them males (three smokers, one ex-smoker, one non-smoker) (Table 1). During the study the subjects pursued their regular daily activities and reported no changes in their day-to-day medication. During the period of the study, none of the asthmatics required any emergency medical treatment, medicine alterations, or hospitalization.

Concentrations of pollutants

During the course of the study, the concentrations of PM_{10} and NO_x exceeded the legislatively determined critical values, i.e. the boundary daily value of 50 µg/m^3 for PM_{10} and the hourly boundary value of 200 µg/m^3 for NO_x, on several occasions (Table 2). The concentrations of ozone, SO_2 and NO_2 remained below the legislatively determined critical values for a particular substance throughout the course of the present study. The concentrations of air pollutants at the measuring location are presented on Figure 1.

Respiratory function measurements

Maximal evening values of PEF and FEV_1, both absolute and relative data, were used for the analysis.

On a day with maximal (207.5 µg/m^3) PM_{10} concentration, the PEF of the subjects was 342.5±146.7 L/min, and on a day with a minimal (29.2 µg/m^3) PM_{10} concentration 352.3±124.9 L/min (P=0.55). PEF, relative to the first day of measurements was 90±23 % on the day of the maximal, and 97±12 % on the day of the minimal PM_{10} concentration (P=0.26). The differences were thus not statistically significant (P>0.05).

FEV_1 of the subjects (Figure 2) was similar at 2.5± 0.9 L on a day with maximal and minimal PM_{10} concentration (P=0.67). FEV_1, relative to the first day of measurements was 90±22 % on the day of the maximal, and 94±21 % on the day of the minimal PM_{10} concentration (P=0.40). The differences were thus not statistically significant (P>0.05).

The ratio of FEV_1/VC of the subjects was 69±23 % on a day with maximal, and 71±19 % on a day with minimal PM_{10} concentration, with no significant differences (P=0.58>0.05) between the two days.

On a day with maximal (208.6 µg/m^3) NO_X concentration, the PEF of the subjects was 342.5±146.7 L/min, and on a day with minimal (15.3 µg/m^3) NO_X concentration 355.0±148.2 L/min (P=0.64). PEF, relative to the first day of measurements was 90±23 % on the day of the maximal, and 96±28 % on the day of the minimal NO_X concentration (P=0.41). The differences were thus not statistically significant (P>0.05).

FEV_1 of the subjects (Figure 2) was 2.5±0.9 L on a day with maximal NO_X concentration, and 2.9±1.0 L on a day with minimal NO_X concentration (P=0.18). FEV_1, relative to the first day of measurements was 90±22 % on the day of the maximal, and 105±28 % on the day of the minimal NO_X concentration (P=0.12). The differences were thus not statistically significant (P>0.05).

The ratio of FEV_1/VC of the subjects was 69±23 % on a day with maximal, and 78±26 % on a day with minimal NO_x concentration, with no significant differences (P=0.15>0.05) between the two days.

The concentrations of other air pollutants (ozone, NO_2, SO_2) did not exceed the legislatively determined critical levels during the course of the study. PEF, FEV_1 and PEF/FEV_1 were nevertheless compared with respect to the maximal and minimal concentrations of these pollutants and no significant differences between the conditions were observed (P>0.05).

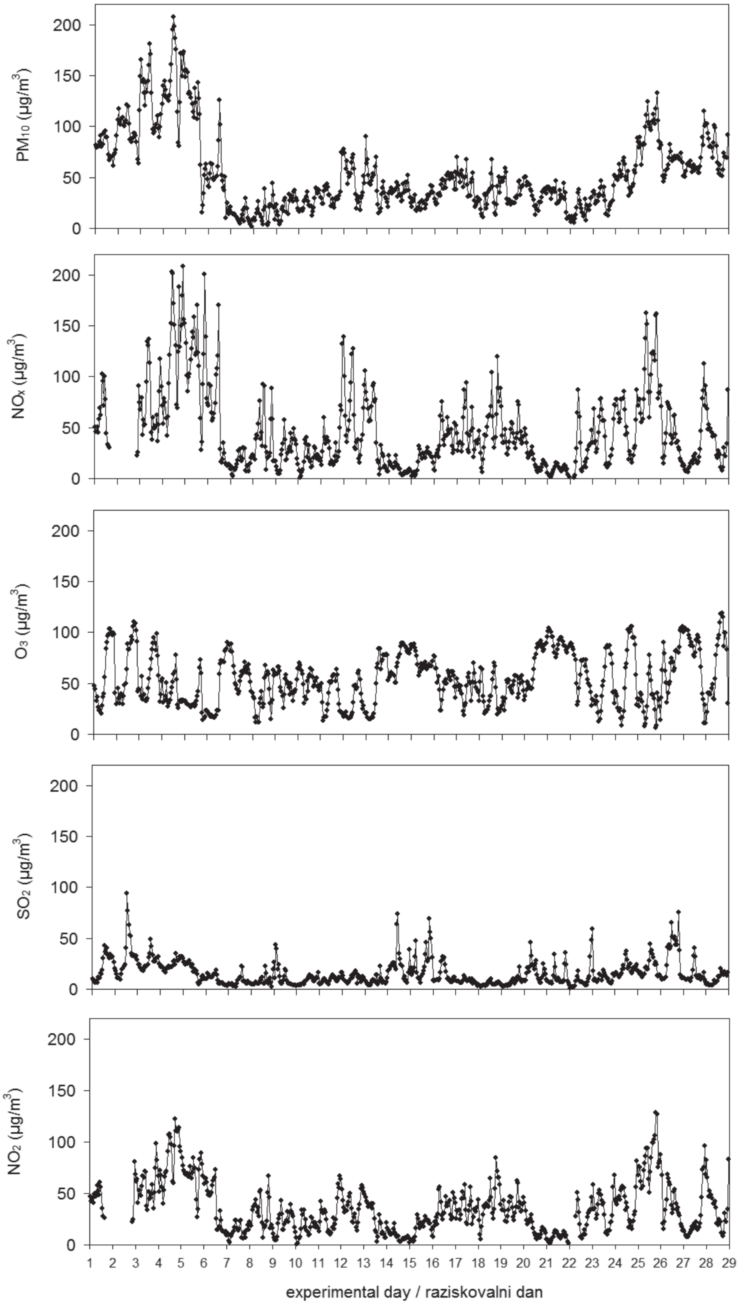

Figure 1: Measured concentrations of PM_{10}, NO_x, O_3, SO_2 and NO_2, all measured in µg/m^3 in ambient air, during the course of the study

Slika 1: Izmerjene koncentracije PM_{10}, NO_x, O_3, SO_2 in NO_2 v okoljskem zraku med potekom raziskave, vse izražene v µg/m^3

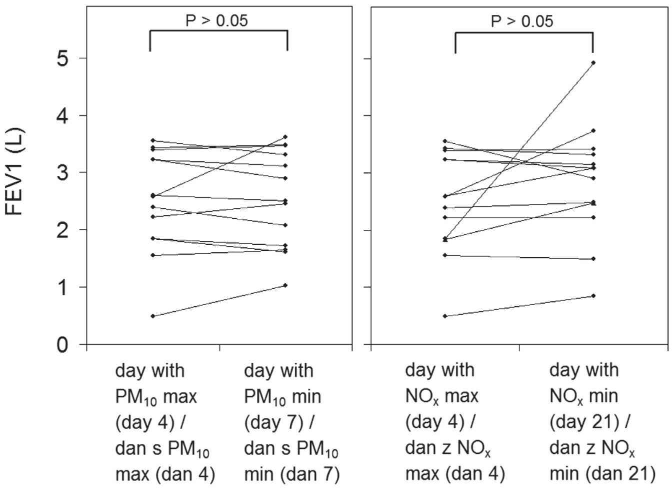

Figure 2: Individual values of forced expiratory volume in the first second of expiration (FEV_1, L) measured in the days with maximal and minimal ambient concentrations of PM_{10} (µg/m^3) and NOx (µg/m^3). For any of the pollutants, no significant differences in FEV_1, as assessed by self-administered PEF-meter monitoring, were found between the two days (P>0.05). The individual data also demonstrate that no consistent trend or pattern in the FEV_1 responses was evident

Slika 2: Posamezne vrednosti prisiljenega ekspiratornega volumna zraka v prvi sekundi izdiha (FEV_1, L), izmerjene v dneh z največjima in najmanjšima okoljskima koncentracijama PM_{10} (µg/m^3) in NOx (µg/m^3). Za nobenega od onesnaževalcev se FEV_1 vrednosti, izmerjene s samo-apliciranim spremljanjem dihalne funkcije s PEF-metrom, med obema dnevoma niso značilno (P>0.05) razlikovale. Posamezni podatki kažejo tudi na odsotnost kakršnegakoli trenda ali vzorca v izmerjenih FEV_1 vrednostih

Discussion

The present study investigated whether self-administered monitoring of respiratory function by PEF-meters can be used for the recognition of critical environmental conditions that have been demonstrated to aggravate the severity of asthma symptoms. Although the exact levels of air pollutants, as well as time of outdoor exposure cannot be standardised for a field study, both, the concentrations of PM_{10} and NO_x were elevated above the legislatively determined critical levels in several days during the selected study period, and were above the concentrations that have been proven to affect the respiratory function in asthmatics (Pope, III and Kanner 1993).

The respiratory values of PEF, FEV_1, and FEV_1/VC were investigated in the view of minimal and maximal concentrations of air pollutants detected in a one-month winter period. In contrast to the expectations, the elevated concentrations of the selected air pollutants were not significantly reflected in the monitored respiratory parameters of the subjects as self-assessed by PEF-meters. The lack of the observed effect might result either from the actual lack of a physiological effect, or from the inappropriateness of the used method to detect the effect – the two options are discussed below.

To a certain extent, the absence of effect can be explained by the fact that during the course of the present study, the concentrations of the majority of monitored air pollutants did not exceed the legislatively determined critical values. This might suggest that the actual respiratory function of asthma patients was indeed not affected by air pollutants. However, both, PM_{10} and nitrogen oxides did exceed the critical values for several days and therefore the absence of any significant effects of PM_{10} on the respiratory function as determined by PEF-meters should be seriously questioned.

The fact that exposure to particulate matter affects respiratory function in asthmatics has been demonstrated several times. In asthmatic children, an increase in particulate matter (PM_{10}) elevates the incidence of lower respiratory symptoms and cough (Aekplakorn et al. 2003). Similarly, small airway function significantly decreases, and oxidative stress significantly increases in relation to $PM_{2,5}$ (as well as to SO_2 and NO_2) concentrations in ambient air (Liu et al. 2009). Studies have also demonstrated that acute increases in PM_{10} result in a greater use of asthma medications and increased hospital admissions due to asthma (Lipsett et al. 1997). Even more, Pope and Dockery (Pope and Dockery 1999) noticed an average of 2 % increase in hospitalizations and related health care visits, and an approximate 3 % increase in asthma symptoms for each 10 μg/m^3 rise in PM_{10}.

Furthermore, Pope and Kanner (1993) reported that in smokers with mild to moderate chronic obstructive pulmonary disease PM_{10} of approximately 100 μg/m^3 was associated with a significant decline in FEV_1. The PM_{10} level of 100 μg/m^3 was exceeded in several days during the course of the present study, but nevertheless no significant diminishment in PEF or FEV_1 as self-assessed by PEF-meters has been detected. It therefore seems more reasonably to believe that the self-administered respiratory monitoring by PEF-meters failed to detect the actual physiological effect of air pollutants, rather than to believe in the absence of the actual physiological effect. The reasons for such conclusions are several and are presented in details below.

A potential difference between personal exposures and ambient pollution may be a source of variation. However, Janssen and co-workers (Janssen et al. 1998) demonstrated that personal PM_{10} concentrations are well correlated with ambient PM_{10} concentrations over time, which provided support for using fixed site outdoor measurements of air pollutants for studies aiming to link day-to-day variations in respiratory function with ambient conditions. In the present study, as PM_{10} concentrations were one of the crucial pollutants, the failure of self-administered PEF-meter monitoring to detect negative effects of air pollutants on respiratory function as being due to the difference between indoor and outdoor conditions, is therefore excluded.

One may also argue that the failure of self-administered PEF-meter monitoring to detect negative effects of air pollutants on respiratory function might be due to the number of subjects included in the study. However, as evident from the results, in the present study the calculated P values were far from statistical significance, although the inter-individual variability was accounted for by a repeated-measures design. Furthermore, no consistent changes were observed in the individual responses, thus no pattern or trend in the PEF or FEV_1 as related to the air pollutant concentrations was detected, rather the responses were chaotic (Figure 2). It is therefore rather unlikely that simply increasing the sample size would yield any significant response. Furthermore, the present study was designed on the basis of published studies, which used similar methodological approach, and found significant results with similar sample sizes (Chalmers et al. 2002; Kim et al. 2007; Fujimura et al. 2003). Kim et al. (2007), for example, investigated the effects of on-site ozone concentrations on peak expiratory flow in 17 asthmatics by the use of pocket PEF-meters. Kim et al. (2007) found that although the degree of asthma symptoms was influenced significantly by the ozone concentration, no significant correlation between PEF as self determined by pocket PEF-meters and ozone concentration was found. The results of Kim et al. (2007) provide further support to the present study, suggesting that it is highly unlikely to expect different performance assessment of PEF-meters, should indoor instead of outdoor measuring sites be used in the present study.

Furthermore, although the PEF-meters used to determine the respiratory function of the subjects in the present study have been assessed as reliable (Rodriguez-Pascual et al. 2006), self-administered PEF-meter monitoring still largely depends on the compliance of the subjects and should be therefore closely scrutinized. As usual with any self-administered monitoring, a certain percentage of the subjects will not follow the suggested protocol precisely, therefore, individual data have to be carefully examined. In the present study, for example, 20 subjects were enrolled, but data from 13 subjects satisfied the criteria for the final analysis, namely, three subjects did not perform the measurements regularly, as evident from the post-hoc memory recall of the PEF meters, one of the subjects experienced some problems with handling the PEF meter and therefore the respiratory data were not recorded, one of the subjects did not consent to vital capacity monitoring, and two of the PEF meters were broken due to misuse during the measuring period, which the subjects failed to report. It is therefore suggested that the subjects should be very thoroughly instructed about the proper use of PEF-meters. Ideally, a short test period of several days prior to the actual beginning of the study with repeated self-administered PEF-meter monitoring may prove beneficial in improving the reliability of measurements. During such a test period, subjects should follow a similar protocol as planned for the study, and data from the test period should be screened by the investigators. Subjects, who would fail to produce reliable self-administered PEF-meter measurements during the test period, should be further instructed, and, if no progress made, they should be excluded from the actual study. Finally, an insufficient compliance with long-term monitoring and falsified measurements will diminish the reliability of data; the option of automatic saving of the results provided by some PEF-meters, such as the one used in the present study, help to identify the falsified reports. In longer longitudinal studies, loss of PEF-meter accuracy over time (Irvin et al. 1997) should also be considered, as this will play a crucial role in the final success or failure of a study.

Povzetek

Kakovost zraka vpliva na dihalno funkcijo ljudi in zdravstveno stanje respiratornih bolnikov, denimo astmatikov, se v onesnaženem ozračju poslabša. Kljub temu obstaja znatno pomanjkanje podatkov o učinkih različnih onesnaževalcev na vsakodnevno dihalno funkcijo ljudi, saj, tudi zaradi različnih metodoloških pristopov, ustreznih rezultatov še nismo pridobili. Namen raziskave je bil zato oceniti uporabnost samo-apliciranega spremljanja dihalne funkcije pri astmatikih, uporabljenega z namenom razločiti med negativnimi zdravstvenimi učinki različnih zračnih onesnaževalcev na dihalno funkcijo.

Trinajst astmatikov je dvakrat dnevno v obdobju enega meseca v zimskem času spremljalo svojo dihalno funkcijo. Maksimalni pretoka zraka ob izdihu (PEF; L/min) in prisiljeni ekspiratorni volumen v prvi sekundi izdiha (FEV_1; L) smo spremljali s PEF-metri. Vitalna kapaciteta preiskovancev (VC; L) je bila izmerjena v laboratoriju ob koncu raziskovalnega obdobja. Respiratorni podatki so bili analizirani glede na okoljske koncentracije NO_2, NOx, SO_2 , O_3 , in PM_{10}, ki so bili spremljani v istem časovnem obdobju. Koncentracije nekaterih zračnih onesnaževalcev (PM_{10} in NO_x) so presegle kritično mejo v več dnevih raziskovalnega obdobja. Kljub temu s podatki s PEF-metrov (PEF, FEV_1 in FEV_1/VC), ni bilo mogoče pokazati statistično značilnih odzivov dihalne funkcije na okoljske razmere ($P>0.05$).

Rezultati pričujoče raziskave kažejo, da samo-aplicirana uporaba PEF-metrov ne omogoča razločevanja med negativnimi učinki različnih zračnih onesnaževalcev na dihalno funkcijo niti pri najbolj občutljivih skupinah ljudi, niti v okolju, v katerem so koncentracije zračnih onesnaževalcev dovolj velike, da po obstoječih podatkih povečajo število hospitalizacij, in niti ob tako povečanih koncentracijah zračnih onesnaževalcev (trdnih delcev), da dokazano negativno učinkujejo na dihalno funkcijo človeka. Nadalje, rezultati raziskave kažejo, da ostaja ambulantno spremljanje dihalne funkcije, čeprav je logistično zahtevno, eden redkih, če ne edini zanesljivi vir podatkov o negativnih učinkih zračnih onesnaževalcev na dihalno funkcijo, tako pri zdravih posameznikih, kot pri respiratornih bolnikih.

Conclusions

Quality of air affects respiratory function in humans, and respiratory conditions such as asthma are aggravated in a polluted environment. Nevertheless, data on the effects of different air pollutants on a day-to-day respiratory function are lacking, as due to different methodological approaches the issue in question has not been adequately addressed yet. The aim of this study was therefore to assess the applicability of self-administered monitoring of respiratory function in asthma patients in order to discern between negative health effects of different air pollutants on respiratory function. Thirteen asthma patients measured their respiratory function twice daily over a one month winter period. They used PEF-meters to monitor peak expiratory flow (PEF; L/min) and forced expiratory volume in the first second of expiration (FEV_1; L). Subjects' vital capacity (VC; L) was measured in a laboratory setting at the end of the measuring period. Respiratory data were evaluated in respect to the ambient concentrations of NO_2, NOx , SO_2 , O_3 , and PM_{10}, which were monitored during the same period. The concentrations of some air pollutants (PM_{10} and NO_x) exceeded the critical levels on several days during the study. PEF-meter data (PEF, FEV_1 and FEV_1/VC), however, did not respond significantly to the ambient conditions (P>0.05).

The novel findings of the present study are that the self-administered PEF-meter monitoring can not discern between the negative health effects of different air pollutants even in the most susceptible groups of population, even in the environments where the concentrations of air pollutants are high enough to induce increased level of hospitalizations, and even with increased levels of the air pollutant (particulate matter) that seems to cause the largest negative effects on human respiratory health. Furthermore, the results of the present study suggest that, although logistically demanding, ambulatory monitoring of respiratory function may be one of the few, if not the only reliable non-subjective source of information on the negative effects of air pollutants on respiratory function in both healthy individuals and respiratory patients.

Acknowledgement

I would like to express my gratitude to the subjects and acknowledge the work of Maja-Marija Rems, who assisted in data acquisition. I would also like to thank Mr. Anton Planinšek from the Environmental Agency of the Republic of Slovenia for his help with the environmental data, prof. dr. Igor Mekjavic from the Institute of Jozef Stefan for enabeling the vital capacity measurements, and Mr. Drago Zimic, MPhil, MD, for his kind cooperation.

References

Aekplakorn, W., Loomis, D., Vichit-Vadakan, N., Shy, C., Wongtim, S.,Vitayanon, P., 2003. Acute effect of sulphur dioxide from a power plant on pulmonary function of children, Thailand. Int J Epidemiol, 32 (5), 854-861.

Bellia, V., Pistelli, F., Giannini, D., Scichilone, N., Catalano, F., Spatafora, M., Hopps, R., Carrozzi, L., Baldacci, S., Di Pede, F., Paggiaro, P., Viegi, G., 2003. Questionnaires, spirometry and PEF monitoring in epidemiological studies on elderly respiratory patients. Eur Respir J Suppl, 40, 21s-27s.

Chalmers, G.W., MacLeod, K.J., Little, S.A., Thomson, L.J., McSharry, C.P., Thomson, N.C., 2002. Influence of cigarette smoking on inhaled corticosteroid treatment in mild asthma. Thorax, 57 (3), 226-230.

Cross, D. and Nelson, H.S., 1991. The role of the peak flow meter in the diagnosis and management of asthma. J Allergy Clin Immunol, 87 (1 Pt 1), 120-128.

Fujimura, M., Nishizawa, Y., Nishitsuji, M., Abo, M., Kita, T., Nomura, S., 2003. Longitudinal decline in pulmonary function in atopic cough and cough variant asthma. Clin Exp Allergy, 33 (5), 588-594.

Gent, J.F., Triche, E.W., Holford, T.R., Belanger, K., Bracken, M.B., Beckett, W.S., Leaderer, B.P., 2003. Association of low-level ozone and fine particles with respiratory symptoms in children with asthma. JAMA, 290 (14), 1859-1867.

Heinrich, J., Hoelscher, B., Wjst, M., Ritz, B., Cyrys, J., Wichmann, H., 1999. Respiratory diseases and allergies in two polluted areas in East Germany. Environ Health Perspect, 107 (1), 53-62.

Irvin, C.G., Martin, R.J., Chinchilli, V.M., Kunselman, S.J., Cherniack, R.M., 1997. Quality control of peak flow meters for multicenter clinical trials. The Asthma Clinical Research Network (ACRN). Am J Respir Crit Care Med, 156 (2 Pt 1), 396-402.

Janssen, N.A., Hoek, G., Brunekreef, B., Harssema, H., Mensink, I., Zuidhof, A., 1998. Personal sampling of particles in adults: relation among personal, indoor, and outdoor air concentrations. Am J Epidemiol, 147 (6), 537-547.

Joseph, C.L., Foxman, B., Leickly, F.E., Peterson, E., Ownby, D., 1996. Prevalence of possible undiagnosed asthma and associated morbidity among urban schoolchildren. J Pediatr, 129 (5), 735-742.

Kim, D.H., Kim, Y.S., Park, J.S., Kwon, H.J., Lee, K.Y., Lee, S.R., Jee, Y.K., 2007. The effects of on-site measured ozone concentration on pulmonary function and symptoms of asthmatics. J Korean Med Sci, 22 (1), 30-36.

Lagorio, S., Forastiere, F., Pistelli, R., Iavarone, I., Michelozzi, P., Fano, V., Marconi, A., Ziemacki, G.,Ostro, B.D., 2006. Air pollution and lung function among susceptible adult subjects: a panel study. Environ Health, 5 11.

Linn, W.S., Shamoo, D.A., Anderson, K.R., Peng, R.C., Avol, E.L., Hackney, J.D., Gong, H., Jr., 1996. Short-term air pollution exposures and responses in Los Angeles area schoolchildren. J Expo Anal Environ Epidemiol, 6 (4), 449-472.

Lipsett, M., Hurley, S., Ostro, B., 1997. Air pollution and emergency room visits for asthma in Santa Clara County, California. Environ Health Perspect, 105 (2), 216-222.

Liu, L., Poon, R., Chen, L., Frescura, A.M., Montuschi, P., Ciabattoni, G., Wheeler, A., Dales, R., 2009. Acute effects of air pollution on pulmonary function, airway inflammation, and oxidative stress in asthmatic children. Environ Health Perspect, 117 (4), 668-674.

Paggiaro, P.L., Moscato, G., Giannini, D., Di Franco, A., Gherson, G., 1997. Relationship between peak expiratory flow (PEF) and FEV1. Eur Respir J Suppl, 24 39S-41S.

Pauwels, R.A., Buist, A.S., Calverley, P.M., Jenkins, C.R., Hurd, S.S., 2001. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease. NHLBI/WHO Global Initiative for Chronic Obstructive Lung Disease (GOLD) Workshop summary. Am J Respir Crit Care Med, 163 (5), 1256-1276.

Peden, D.B., 1996. Effect of air pollution in asthma and respiratory allergy. Otolaryngol Head Neck Surg, 114 (2), 242-247.

Pope, C.A. and Dockery, B.D.W., 1999. Epidemiology of particle effects. In: Holgate, S.T., Samet, J.M., Koren, H.S., and Maynard, R.L. (Eds.): Air Pollution and Health, Academic Press, London, pp. 673-706.

Pope, C.A., III and Kanner, R.E., 1993. Acute effects of PM10 pollution on pulmonary function of smokers with mild to moderate chronic obstructive pulmonary disease. Am Rev Respir Dis, 147 (6 Pt 1), 1336-1340.

Rios, J.L., Boechat, J.L., Sant'Anna, C.C., Franca, A.T., 2004. Atmospheric pollution and the prevalence of asthma: study among schoolchildren of 2 areas in Rio de Janeiro, Brazil. Ann Allergy Asthma Immunol, 92 (6), 629-634.

Rodriguez-Pascual, L., Cordero-Guevara, J., Viejo-Banuelos, J.L., 2006. [Agreement between pneumotachograph and PiKo-1 measurements of PEF and FEV1]. Arch Bronconeumol, 42 (3), 144-147.