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Association between ambient air pollution, meteorological conditions and exacerbations of asthma and chronic obstructive pulmonary disease in adult citizens of the town of Smederevo

Povezanost aerozagađenja i meteoroloških uslova sa pogoršanjima astme i hronične opstruktivne bolesti pluća kod odraslih stanovnika Smedereva

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Abstract

Introduction. Smederevo is the only town in Serbia with a steel factory, whose exhausts contribute to air pollution. Therefore, the city conducts continuous monitoring of air quality. In recent years, high levels of particulate matter (PM), including coarse (PM_{10}) and fine ($PM_{2.5}$) particles in the air have frequently been recorded. The aim of this study was to assess association between exacerbation of asthma or chronic obstructive pulmonary disease (COPD) in adults and air pollution or meteorological conditions. **Methods.** The study was conducted in the secondary care General Hospital in Smederevo covering approximately 81, 000 inhabitants living in the area of about 7 km around the automatic station for air quality monitoring from which the verified data were collected. Data on patients were obtained from medical records. The correlation between the incidence of diseases exacerbation and the number of days with exceedance of air pollutants limit level *per* month, as well as meteorological conditions, was tested with parametric Pearson bivariate correlation test in program SPSS. **Results.** The study population consisted of adults registered as asthma or COPD suffering patients (n = 1,624) with 570 episodes of remarkable exacerbations (moderate or severe) of the disease in 2011. Asthma exacerbation was significantly more frequent in women than in men. The number of days with high levels of $PM_{2.5}$ *per* month was statistically significantly associated with the total number of exacerbation (moderate and severe of both asthma and COPD) episodes among the female patients. There was also a statistically significant association between the number of days with $PM_{2.5}$ exceedance and the number of moderate exacerbations in the subgroups of non-smokers and obese patients. A significant correlation of the number of days with the exceedance of PM_{10} limit level was shown only for the subgroup of obese, non-smoking patients with moderate exacerbation. A significant negative association with the average ambient temperature was proven for the obese female patients and obese non-smoking patients with moderate asthma exacerbations. The number of COPD exacerbation was in positive correlation with the average air pressure for the subgroup of female smokers, but the connection with air pollution was not proven. **Conclusion.** Exposure to airborne particles in the town of Smederevo, mainly to $PM_{2.5}$, and to low temperature may trigger asthma exacerbation requiring emergency care. The most vulnerable may be women and obese patients.

Key words:
air pollution; particle size; weather; disease progression; risk factors; pulmonary disease, chronic obstructive; asthma.

Apstrakt

Uvod/Cilj. Smederevo je jedini grad u Srbiji u kome postoji železara čiji rad doprinosi aerozagađenju. Stoga se kontinuirano kontroliše kvalitet vazduha. Poslednjih godina beleže se visoke koncentracije suspendovanih čestica (*paticulate matter* – PM), grubih čestica PM_{10} i finih čestica ($PM_{2.5}$). Cilj rada bio je da se ispita da li postoji povezanost pogoršanja respiratornih oboljenja, hronične opstruktivne bolesti pluća (HOBP) i astme, sa aerozagađenjem i meteorološkim faktorima. **Metode.** Ispitivanje je obavljeno u Opštoj bolnici u Smederevu koja pokriva oko 81 000 stanovnika, nastanjenih u krugu od približno 7 kilometara oko automatske stanice za praćenje kvaliteta vazduha, sa koje su dobijeni verifikovani podaci o nivou aerozagađivača i o meteorološkim faktorima. Podaci o bolesnicima su dobijeni iz medicinske dokumentacije. Korelacija učestalosti pogoršanja bolesti sa brojem dana u mesecu tokom kojih je zabeleženo prekoračenje graničnih vrednosti aeropolutanata i prosečnim mesečnim vrednostima meteoroloških parametara određena je pomoću Pirsonovog testa u programu SPSS. **Rezultati.** Ispitivanu populaciju činile su 1 624 odrasle osobe obolele od astme ili HOBP koje su tokom perioda opservacije (2011. godina) imale ukupno 570 epizoda značajnog (umerenog ili teškog) pogor-

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šanja bolesti. Pogoršanje astme bilo je značajno češće kod žena nego kod muškaraca. Broj dana u mesecu sa visokim nivoima suspendovanih čestica $PM_{2.5}$ bio je u statistički značajnoj pozitivnoj korelaciji sa ukupnim brojem umerenih i teških epizoda pogoršanja obe bolesti (astme i HOBP) kod žena. Takođe, značajna povezanost utvrđena je sa brojem umerenih epizoda pogoršanja astme u podgrupama nepušača i gojaznih bolesnika. Pozitivna korelacija mesečnog broja dana sa prekoračenjem granične vrednosti za PM_{10} i pogoršanja bolesti utvrđena je samo za podgrupu gojaznih nepušača sa astmom. Nije nađena značajna povezanost aerozagađenja suspendovanim česticama i egzacerbacija HOBP. Analiza povezanosti sa ambijentalnom temperaturom pokazala je postojanje negativne korelacije sa brojem pogoršanja astme u kategorijama gojaznih žena i nepušača. Povišen atmosferski pritisak bio je u korelaciji sa porastom broja umerenog pogoršanja HOBP kod žena pušača. **Zaključak.** Izloženost suspendovanim česticama, posebno frakciji $PM_{2.5}$, i niskoj temperaturi vazduha može biti pokretač pogoršanja astme koja zahteva urgentno lečenje. Najosetljivije mogu biti žene i gojazni bolesnici.

Ključne reči:
vazduh, zagađenje; čestice, veličina; vreme (klima); bolest, progresija; faktori rizika; pluća, opstruktivne bolesti, hronične; astma.

Introduction

The adverse health effects of air pollution are widely acknowledged. Because the exhaust of steel plant operating in the town of Smederevo may contain a high concentration of pollutants, the quality of air was continuously monitored in recent years. Fossil fuel or coal combusting heating system in the city and aged vehicles also contribute to the pollution. Accordingly, high levels of particulate matter (PM) in the air have been measured there over the past six years.

Epidemiological studies during the last few decades have consistently shown that ambient air particles, even at moderate and low concentrations, can have both short- and long-term effects on health [1]. PM urban air pollution is associated with the increase of emergency visits and hospital admissions due to respiratory diseases like asthma and chronic obstructive pulmonary disease (COPD) [2].

Ambient PM is a mixture of particles generated from different processes, having variable sizes and chemical composition. Current ambient air quality monitoring in many countries, including Serbia, quantifies two different classes of airborne particles according their size – coarse, categorized as PM_{10} (with diameter from 2.5 μm to 10 μm) and fine, labelled as $PM_{2.5}$ (with diameter up to 2.5 μm). Ultrafine particles of nanoscale size (less than 100 nm in diameter) are not routinely monitored. In reality, all fractions are more or less present in the air, and it is still unclear which fraction of PM (coarse, fine or ultrafine) represents the highest risk for public health [3]. In studies of asthma and COPD hospital admissions, coarse PM has a stronger or as strong short-term effect as fine PM [4]. There are also studies indicating the relevance of ultrafine particles in terms of adverse respiratory health effects [5].

The aim of this study was to assess associations between airborne exposures to PM ($PM_{2.5}$ or PM_{10}) and exacerbation of asthma or COPD in adult citizens of Smederevo living in the area surrounding the steel factory.

Methods

This study was conducted in the secondary care General Hospital in Smederevo covering approximately 81,000 inhabitants living in the area of 7 km around the automatic station for air quality monitoring located in Radinac, nearby the steel factory. Data on meteorological conditions (average daily values of temperature, air pressure and wind speed) and air pollutants were collected from the same station, equipped with a Horiba analyser for SO_2 and NO_2, and a Grimm sampler for PM (all records on 2 m height).

The study population consisted of persons registered and followed up as asthma suffering patients (n = 1,100) and COPD patients (n = 524). The patients younger than 18 years were excluded from the study. Data were obtained from medical records. Criteria for moderate or severe exacerbation of the disease were requirements for additional therapy in Outpatients Emergency Room (orally or parenterally administered corticosteroid preparation for 2–12 days), or admittance to hospital, respectively.

For moderate exacerbations, correlations with air pollutants or with meteorological conditions were separately investigated for the subgroups made by the diagnosis (all the patients and separately asthma/COPD patients), by gender, by smoking status, and by body-mass index (BMI) (obese or non-obese). For the patients with severe exacerbations, data on smoking status and BMI were not available. The period of observation was one year (2011).

Independent samples Student's *t*-test was used to test the significance of the difference between the groups. χ^2 test was used to test the significance of the difference between frequencies of exacerbations. All variables were tested with Kolmogorov Smirov test in order to check the normality of their distribution. The correlation between the selected parameters was tested with parametric (Pearson's) bivariate correlation test in program SPSS (Statistical Package for the Social Sciences) software (version 10, SPSS Inc. Chicago, IL) with the complex sample module. A significance level of $p < 0.05$ was considered statistically significant based on two-tailed tests.

Results

The recorded values of air pollutants, meteorological conditions and number of days with air pollutants limit level exceedence are shown in Table 1.

According the recorded values, the average day concentrations of gasses SO_2 and NO_2 in Smederevo have been under 24 h-limit value during the whole year. Therefore, levels of SO_2 and NO_2 were not further considered in terms of association with diseases exacerbations.

Table 1

Meteorological conditions, air pollutants levels and the number of asthma or chronic obstructive pulmonary disease (COPD) exacerbation in Smederevo during 2011

Variable	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Meteorological conditions ($\bar{x} \pm SD$)												
temperature (°C)	0.31 ± 5.15	0.09 ± 3.55	7.33 ± 5.93	13.12 ± 5.53	17.34 ± 3.90	21.66 ± 2.37	23.12 ± 3.97	23.57 ± 2.57	21.56 ± 2.54	11.21 ± 4.40	3.28 ± 4.37	4.28 ± 4.10
Air pressure (mbar)	1009.28 ± 3.56	1008.28 ± 6.64	1010.80 ± 6.86	1004.22 ± 3.65	1006.42± 3.36	1002.48± 3.72	999.07 ± 3.86	1003.06± 2.78	1004.79± 4.46	1009.66± 5.10	1014.80± 4.68	1006.74 ± 8.85
wind speed (m/s)	1.43 ± 0.58	1.71 ± 1.13	1.84 ± 0.74	2.21 ± 1.09	1.53 ± 0.54	1.91 ± 0.74	1.47 ± 0.47	1.48 ± 0.67	1.37 ± 0.45	1.65 ± 0.76	1.20 ± 0.76	1.73 ± 0.72
Air pollutants ($\bar{x} \pm SD$)												
SO_2 (μg/m^3)	43.73 ± 24.25	46.16 ± 15.41	34.54 ± 19.09	17.47 ± 8.16	14.58 ± 8.72	10.23 ± 1.99	14.36 ± 8.28	13.59 ± 4.15	18.32 ± 12.98	19.09 ± 5.38	42.72 ± 18.65	39.51 ± 12.74
NO_2 (μg/m^3)	20.50 ± 8.78	20.82 ± 11.60	16.84 ± 7.87	13.34 ± 6.66	13.00 ± 4.55	10.03 ± 3.37	10.97 ± 3.20	12.70 ± 4.07	15.88 ± 4.86	16.31 ± 8.94	19.15 ± 8.96	16.54 ± 4.99
PM_{10} (μg/m^3)	112.84 ± 53.58	111.23 ± 56.46	98.56 ± 57.99	72.52 ± 38.19	54.37 ± 19.87	46.55 ± 16.64	49.69 ± 20.83	63.21 ± 28.77	67.04 ± 21.95	91.52 ± 58.03	170.13 ± 80.56	84.91 ± 38.51
$PM_{2.5}$ (μg/m^3)	98.82 ± 49.20	95.13 ± 41.37	61.33 ± 29.17	33.67 ± 16.96	28.54 ± 7.46	21.07 ± 7.62	22.10 ± 6.83	25.59 ± 8.57	31.01 ± 10.92	57.72 ± 32.33	130.77 ± 60.57	70.22 ± 33.02
Number of days with exceedance of maximal limit level												
PM_{10}*	31	24	25	18	13	9	16	21	23	20	29	26
$PM_{2.5}$†	31	26	27	10	3	2	1	5	9	20	29	25
Number of exacerbations												
Astma	34	27	30	22	8	24	29	16	27	20	27	36
COPD	20	26	33	21	11	28	27	17	24	20	20	23

***According to Serbian Law of air protection 24h-limit value for PM_{10} is 50 μg/L;**
†Serbia has no 24-h limit value for $PM_{2.5}$. Limit value of 35 μg/ L is set according to the United States Enviromental Protection Agency (EPA) recommendation (available at www.epa.gov/air/criteria.html);
PM – particulate matter; SD – standard deviation; $\bar{x}$ – mean value.

Of 1,624 recorded patients, there were 807 men (461 with asthma and 346 with COPD) and 817 women (639 with asthma and 178 with COPD). Diseases exacerbation happened to 420 patients (209 males and 211 females). The total number of exacerbations was 570, with a significantly higher incidence of worsening of COPD (270/524) than of asthma (300/1100), $\chi^2 = 90.59$, $p < 0.001$. The number of exacerbations *per* patient was 1–6 (moderate), and 1–4 (severe). There were significantly more moderate (442) than severe (128) exacerbations ($p < 0.01$). Table 2 shows the incidence of exacerbations *per* severity and *per* diagnosis. The maximal number of exacerbations (n = 63) was recorded in March, and minimal in May (n = 19).

The mean age of patients with exacerbations was 60.2 ± 15.4 years. There were no statistically significant differences between genders in terms of age (males 61.2 ± 16.8 years, females 59.1 ± 13.9 years). The COPD patients with the mean age of 66.0 ± 12.2 were significantly older than asthma patients with the mean age of 54.8 ± 16.1 years ($t = 9.28$, $p < 0.001$).

In both groups of patients, with asthma and with COPD, there were more moderate than severe episodes of exacerbations. The incidence of moderate exacerbations was significantly greater in the group of patients with asthma than in the group of COPD patients and reversely, severe exacerbations were more frequent in the group of COPD pa-

Table 2

Incidence of asthma and chronic obstructive pulmonary disease (COPD) exacerbations *per* month

Type of exacerbation	Number of exacerbation episodes *per* month				
	n	min	max	$\bar{x} \pm SD$	median
Total number	570	19	63	47.17 ± 12.28	51.5
asthma exacerbations	300	8	36	24.67 ± 7.71	26.0
COPD exacerbations	270	11	33	22.50 ± 5.71	22.0
Moderate exacerbations	442	9	55	36.50 ± 12.41	38.1
asthma moderate exacerbations	267	4	35	21.92 ± 8.21	24.0
COPD moderate exacerbations	175	5	21	14.58 ± 5.30	14.5
Severe exacerbations	128	4	16	10.67 ± 3.58	10.0
asthma severe exacerbations	33	1	5	2.75 ± 1.48	2.5
COPD severe exacerbations	95	3	12	7.92 ± 2.75	7.0

tients ($p < 0.001$). Among the patients with moderate exacerbations, the ratio between the smokers and non-smokers was 138/432, and the ratio between the obese and non-obese patients was 297/273.

Asthma exacerbations were significantly more frequent in women than in men ($f_{asthma\ male} = 97/461$; $f_{asthma\ female} = 203/639$; $\chi^2 = 15.0$, $p < 0.001$). There was no difference in the incidence of COPD exacerbations between genders ($f_{COPD\ male} = 181/346$; $f_{COPD\ female} = 89/178$; $\chi^2 = 0.16$, $p = 0.6$).

The total number of exacerbations *per* month (moderate and severe episodes of both COPD or asthma), was not associated with any of air pollution or weather parameters. However, when considering the subgroups of patients made by gender, a significant association ($p = 0.048$) was proved between the number of days with the exceedance of $PM_{2.5}$ limit level and the total number of exacerbations in the subgroup of female patients. For the subgroups created by the diagnosis (COPD or asthma), a borderline significant association ($p = 0.05$) was shown between the number of days with the excess of $PM_{2.5}$ limit level and exacerbation episodes in the patients with asthma. Further analysis revealed that this association became stronger when considering the following subgroups with moderate episodes of asthma exacerbations: non-smokers ($p = 0.029$), female non-smokers ($p = 0.028$), female patients ($p = 0.020$), obese patients ($p = 0.015$), obese females ($p = 0.011$), and obese non-smokers ($p = 0.010$). The correlations between the number of days with $PM_{2.5}$ exceedance and the number of asthma exacerbations *per* month in various subgroups of patients are shown in Figure 1.

The number of days *per* month with the excess levels of PM_{10} was in a positive correlation with asthma worsening only for a subgroup consisted of obese, non-smoking patients with moderate exacerbations ($p = 0.044$). The association between the number of days of PM_{10} exceedance and the total number of asthma exacerbations was close to, but did not achieve statistical significance ($p = 0.053$). A similar result was obtained when testing asthma exacerbations among females ($p = 0.054$).

Considering meteorological conditions, the average temperature was in a negative borderline significant correlation with the total number of asthma exacerbations in females. A statistically significant negative correlation of temperature and moderate asthma exacerbation was found for the subgroups of obese females ($p = 0.024$), and obese, non-smoking patients ($p = 0.039$).

The number of COPD exacerbations was not associated with air pollution or meteorological conditions. The exception was a positive correlation between the moderate exacerbations of COPD in the female smokers and the increase of the mean barometric pressure.

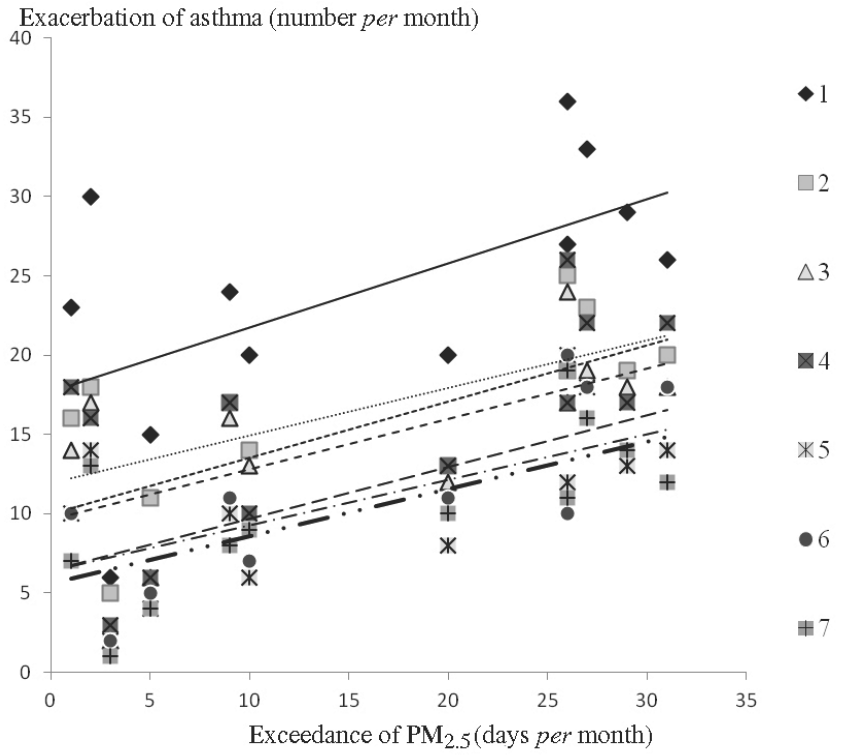

Fig. 1 – Correlations between the number of days with $PM_{2.5}$ exceedance and the number of asthma exacerbations *per* month in various subgroups of patients.

1. Asthma and chronic obstructive pulmonary disease (COPD) females with moderate and severe exacerbations; 2. Asthma females with moderate and severe exacerbations; 3. Asthma females with moderate exacerbations; 4. Asthma non-smokers with moderate exacerbations; 5. Asthma non-smoking females with moderate exacerbations; 6. Asthma obese non-smokers with moderate exacerbations; 7. Asthma obese females with moderate exacerbations.

PM – particulate matter.

The subgroups of patients in a statistically significant or borderline correlation with air pollution or meteorological parameters are listed in Table 3.

Because of limited observational period of just 12 months, reliable statistical analysis of season incidence was not possible.

For the two subgroups of patients (obese females and obese non-smokers with moderate asthma exacerbations) for which the significant association between both ambient temperature and air pollution was revealed, we compared the incidence of disease exacerbation between the coldest and the warmest 4 months of the year, as well as between the 4 months with the highest and the lowest number of days with the excessive levels of $PM_{2.5}$. The coldest months were January, February, November and December, and the warmest was a 4-month period from June to September (Table 1). The incidence of moderate asthma exacerbation was lower during the summer than the winter months, but there was no statistically significant difference. In obese females and obese non-smokers, average number of exacerbation *per* month was 8.0 ± 3.7 in the warmest months *vs* 14.0 ± 3.5 in the coldest months ($t = 2.32$, $p = 0.059$) and 9.7 ± 3.4 in the warmest months *vs* 15.5 ± 4.4 in the coldest months ($t = 2.05$, $p = 0.085$), respectively. The months with the highest number of days with over the limit concentration of $PM_{2.5}$ were January, February, March and November. Air pollution was lowest in the 4-month period from May to August (Table 1). The incidence of moderate asthma exacerbation was significantly lower during the period with the small number of days with the excess of $PM_{2.5}$ than in months with high number of days with a excessive air pollution, for both obese females (6.2 ± 5.1 *per* month *vs* 15.2 ± 2.3; $t = 3.03$, $p = 0.002$) and obese non-smokers (7.5 ± 4.9 *vs* 17.5 ± 2.5; $t = 3.61$, $p = 0.001$).

Discussion

Exacerbations of asthma and COPD are important clinical events, resulting in the decline of lung function, requirement of additional therapy, hospitalisation, or even death. For patients with asthma, exacerbations and poor control can be the result of exposure to environmental triggers, such as allergens and air particulates [6]. It is well-known that cigarette smoking is responsible for the vast majority of COPD. However, other sources of exposure, including working or living in polluted indoor and outdoor environments are recognized as significant contributors to the development, progression, and exacerbation of COPD [7].

In our study, asthma exacerbations were significantly more frequent in females than in males. These results are consistent with findings from many epidemiological studies suggesting that adult women suffer from more severe asthma than men. Gender differences appear to be the product of biological properties including body characteristics, hormonal, sociocultural and environmental differences [8]. Our analysis revealed that the number of days with excess levels of $PM_{2.5}$ *per* month was in positive correlation with the number of both moderate and severe exacerbation episodes among asthma patients (borderline significance, $p = 0.05$), and especially among females ($p = 0.02$). Other studies have also shown that PM of 10 μm or less seemed to affect primarily women with asthma, even at levels even below the national air quality standards [9].

Our further analysis has shown that there was the highest positive correlation between the number of days *per* month with exceedance of $PM_{2.5}$ and the number of moderate asthma exacerbations in obese patients. Other studies [10] suggested that BMI is a strong predictor of incident asthma among adult women. Furthermore, a meta-analysis of prospecti-

Table 3

Single correlation coefficients between the number of disease exacerbations *per* month and air characteristics in the selected subgroups of patients

Variables	Patients with exacerbations	*r*	*p*
Number of days with excess of $PM_{2.5}$	Female asthma and COPD patients, moderate and severe exacerbations	0.581	0.048
	Asthma patients, moderate and severe exacerbations	0.576	0.050
	Asthma females, moderate and severe exacerbations	0.657	0.020
	Asthma females, moderate exacerbations	0.631	0.028
	Asthma non-smokers, moderate exacerbations	0.628	0.029
	Asthma female non-smokers, moderate exacerbations	0.630	0.028
	Asthma obese patients, moderate exacerbations	0.677	0.015
	Asthma obese non-smokers, moderate exacerbations	0.708	0.010
	Asthma obese females, moderate exacerbations	0.700	0.011
Number of days with excess of PM_{10}	Asthma females, moderate and severe exacerbations	0.568	0.054
	Asthma obese non-smokers, moderate exacerbations	0.589	0.044
	Asthma patients, moderate and severe exacerbations	0.570	0.053
Mean temperature	Asthma females, moderate and severe exacerbations	-0.577	0.050
	Asthma females, moderate exacerbations	-0.576	0.050
	Asthma obese non-smokers, moderate exacerbations	-0.601	0.039
	Asthma obese females, moderate exacerbations	-0.645	0.024
Mean air preessure	COPD female smokers, moderate exacerbations	0.580	0.048

COPD – chronic abstructive pulmonary disease; PM – particulate matter.

ve epidemiologic studies revealed that overweight and obesity are associated with incident asthma in both women and men [11]. Association of obesity with asthma exacerbations is not well understood, as some co-factors like social status, smoking or gastroesophageal reflux disease (GERD) may be involved. After adjusting for demographics, smoking status, oral corticosteroid use, evidence of GERD, and inhaled corticosteroid use, Mosen et al. [12] suggested that obesity is associated with worse asthma outcomes, especially with an increased risk of asthma-related hospitalizations.

The mechanisms underlying the relationship between obesity and asthma have not been fully established, but adipose tissue-derived hormones have certain role in pathogenesis and control of asthma [13, 14]. A link between obesity, asthma and air pollution may be the finding that adults who are obese or even overweight, actually breathe in 7–50% percent more air *per* day than adults at healthier weights which makes them more vulnerable to air contaminants causing asthma and other pulmonary diseases [15].

Our analysis of the association between excess PM_{10} and asthma exacerbation revealed a positive correlation only in case of asthma obese non-smokers with moderate exacerbations.

The obese patients were also more vulnerable to the meteorological conditions, as ambient temperature drop was associated with the increase in the number of asthma attacks. The incidence of moderate exacerbations was higher during the coldest months than during the summer in the obese females and non-smokers, but there was no statistically significant difference. A low inverse correlation of ambient temperature with the attendance for asthma attacks during a year on similar number of patients (232) was reported by Rossi et al [16]. Their conclusions are that air pollen levels are not associated with asthma exacerbation, temperature among the meteorological factors had a small association, but increased levels of pollutants, especially NO_2, are associated with attacks of asthma. In our study of air pollution effects, air pollen levels were not available and NO_2 was not considered because it was within acceptable limits, but there was a significantly higher number of asthma exacerbations in months with excessive level of $PM_{2.5}$ than in the period when there has been little air pollution. Other studies on a much larger number of patients show that cold temperature is related to the increased risk of significant exacerbation of asthma in adults [17] and children [18].

In other studies indicate that acute exacerbations of COPD is associated with a short-term exposure to air pollution [19], and PM_{10} show a strong association with adverse respiratory health effects, even when adjusted for other major risk factors such as cigarette smoking [20]. However, in our study, though the total number of COPD exacerbations was not significantly lower than asthma exacerbations (270 and 300, respectively), a connection between high concentrations of PM ($PM_{2.5}$ or PM_{10}) and COPD exacerbation was not proven.

The number of COPD exacerbations was in a positive correlation only with the increased barometric pressure. Unfortunately, we had no validated data on air humidity. The association between barometric pressure and the increased number of COPD exacerbations has been shown by authors from different climate areas. Thus, a study from Taiwan [21] suggests higher barometric pressure, more hours of sunshine and lower humidity to be positively correlated with an increase in COPD consultations, while German authors [22] find barometric pressure to be in positive, but solar radiation in negative correlations with COPD exacerbations. Cold temperature is an important environmental factor for respiratory diseases exacerbations and COPD attacks are more frequent in winter [23]. However, it was not shown in our study.

The limitations of this study include the lack of some relevant information in the hospital database on severe exacerbations, such as smoking status and BMI, as well as short period of observation resulting in relatively small number of patients in certain subgroups. Nevertheless, this study demonstrated association of PM air pollution, especially $PM_{2.5}$, and asthma exacerbation. Females and obese patients were the most vulnerable subpopulations.

Conclusion

The results obtained in this study indicate that in the town of Smederevo, exposure to airborne particles, mainly to those with diameter up to 2.5 μm, and low temperature may trigger asthma exacerbations requiring emergency care. Reducing air pollution may lead to health benefits, especially among certain groups of asthmatic patients.

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