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SHORT-TERM EFFECTS OF BLACK SMOKE ON CARDIOVASCULAR HOSPITALISATION IN ELDERLY IN NIŠ, SERBIA•

In the last few years, numerous epidemiological studies have brought new evidence on the effects of particle air pollution on cardiovascular hospitalisations. The aim of our study was to investigate the association between ambient concentrations of black smoke (BS) and daily total non-accidental cardiovascular hospitalisations in elderly in Niš. The daily mean number of all age cardiovascular hospitalisations was 12.46±6.26 (0 to 38) and 5.92±3.29 (0 to 20) among persons 65 years of age or older. Daily measurements for black smoke (BS) and SO_2, as well as the daily number of cardiovascular hospitalisations among persons 65 years of age or older, have been collected. BS (μg/m^3) was measured by the refractometry method and SO_2 (μg/m^3) was measured by spectrophotometry. A generalized linear model extending Poisson regression was applied. The effects of time trend, seasonal variations, day of week, temperature, relative humidity and barometric pressure were adjusted. Estimated OR of unipolutant regression model for person ≥65 yrs was 1.00135 (95% CI: 0.97835 to 1.02489), and the estimated OR of bipolutant model was 1.00975 (95% CI: 0.99457 to 1.02394) per 10 μg/m^3. The results do not support findings from previous studies that had shown an increase in the number of cardiovascular hospitalisation in the elderly in association with black smoke.

Keywords: elderly; cardiovascular hospitalization; hospital admission; black smoke; air pollution.

Exposure to air pollution contributes to the development of cardiovascular diseases, according to epidemiological evidence [1,2]. These scientific statements focus on cardiovascular hospitalisation and mortality.

Air pollution is composed of many environmental factors, such as sulphur dioxide, ozone, particulate matter, carbon monoxide and others. The potential biological mechanisms of influence air pollution on cardiovascular system have two possible interlinks - inflammatory response and abnormal autonomic control [3-6].

During the last decade, epidemiological studies conducted worldwide have shown that some sensitive groups of the population, such as the elderly, may be at particularly increased risk of cardiovascular disease of air pollution [7-10].

This is the first study providing quantitative estimates of the short-term effects of air pollution on cardiovascular hospitalisation in our country. This paper reports the results on the effects on daily black smoke (BS) on cardiovascular hospitalisation among persons 65 years of age or older in Niš, Serbia.

MATERIALS AND METHODS

Study area

The study area is the city of Niš, the second largest city in Serbia. The urban city area covers 32 km^2 with population of around 171,000 inhabitants. A major source of air pollution is fuel combustion including motor vehicle emissions and residential wood, coal and oil burning.

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Cardiovascular hospitalisations data

Daily cardiovascular hospitalisations data between 2001 and 2005 were obtained from the Republic Institute for Statistics in charge of coding the medical causes of death according to the International Classification of Diseases – 10th Revision (I00-I99), among persons 65 years of age or older.

Environmental data

Air pollution data were provided by the Public Health Institute of Niš. Daily concentrations of BS and SO_2 were monitored in the local monitoring network. BS (μg/m^3) was measured by the refractometry method and SO_2 (μg/m^3) was measured by spectrophotometry. Missing air pollution values for 6% days of the period were treated as being missing completely at random and were dropped from the analyses.

The concentrations of BS and SO_2 were measured for 24 h a day during the period from 2001 to 2005. The sampling protocol was carried out by well trained personnel. The laboratory experiments on black smoke were done according to the Regulation of Guideline Values of Imission (Official Register, Republic of Serbia).

The ambient level of black smoke was measured by the reflectance. The sampling was performed by the means of a pump operating with a flow rate of 1 L/min through Whatman No. 1 paper filters.

The air concentration of sulphur dioxide was determined simultaneously with that of black smoke. A measured volume of air was bubbled through solution of potassium mercury tetrachloride. The sulphur dioxide present in the air stream reacted with the solution to form a stable monochlorosulfonatomercurate. During the subsequent analysis, this complex was brought into reaction with acid-bleached pararosaniline dye and formaldehyde yielding intensely coloured pararosaniline methyl sulphuric acid. The optical density of this species was determined spectrophotometrically at 548 nm and was directly related to the collected amount of sulphur dioxide. The total volume of the air sample was determined from the flow rate and the sampling time. The concentration of sulphur dioxide in the ambient air was calculated and expressed in μg/m^3 and the lower limit of detection was 1.7 μg/m^3.

The daily mean temperature, the mean relative humidity and the mean barometric pressure values for the same period were obtained from the Republic Meteorological Department.

Modelling approach

Generalized linear model (GLM) extending Poisson regression was applied allowing over dispersion. This model used hospitalisation counts as the response variable, the natural cubic splines of the calendar time, temperature, relative humidity and barometric pressure, the day of week and season as indicator variables, and black smoke pollution as predictor variable.

The model fitting as well as the method to replace missing data selection was based on Akaike Information Criteria (AIC). To construct the model, the appropriate lag periods for weather variables and BS that gave the smallest AIC value were used. Individual lags from day 0 to day 7 were all examined, as well as the cumulative lags. In the same way the degrees of freedom for natural spline functions of time and weather variables influence approximation were selected. The pollutant was fitted as linear term. Analyses were done using S-PLUS 2000 software. The specific model formulation for cardiovascular hospitalisation is given below.

Persons of all ages:

$$\begin{aligned}E[\log(Yi)] = {} & a + ns(\text{calendar time}, df = 30) + \\ & + \text{indicator}(\text{season}) + \text{indicator}(\text{day of week}) + \\ & + ns(\text{mean temperature}_{lag=0}, df = 4) + \\ & + ns(\text{mean temperature}_{lag=0-3}, df = 4) + \\ & + ns(\text{mean relative humidity}_{lag=0}, df = 2) + \\ & + ns(\text{mean air pressure}_{lag=0}, df = 3) + \\ & + \text{air pollution}_{lag=0}\end{aligned}$$

Persons older than 65 years:

$$\begin{aligned}E[\log(Yi)] = {} & a + ns(\text{calendar time}, df = 30) + \\ & + \text{indicator}(\text{season}) + \text{indicator}(\text{day of week}) + \\ & + ns(\text{mean temperature}_{lag=0}, df = 4) + \\ & + ns(\text{mean temperature}_{lag=0-3}, df = 4) + \\ & + ns(\text{mean relative humidity}_{lag=0}, df = 2) + \\ & + ns(\text{mean air pressure}_{lag=0}, df = 2) + \\ & + \text{air pollution}_{lag=0}\end{aligned}$$

where *Yi* are daily hospitalization counts, *a* is the intercept, *ns* denotes a natural cubic functions of a covariates, and *df* represents the number of degrees of freedom.

RESULTS AND DISCUSSION

Table 1 shows the daily number of all age cardiovascular hospitalisations, cardiovascular hospitalisations among persons 65 years of age or older, pollutants concentrations and weather data. During the 5

Table 1. Daly values of cardiovascular hospitalisations, air pollutants and weather variables

Parameter	Mean	SD	Min	Median	Max
All age cardiovascular hospitalisations (n)	12.46	6.26	0	12	38
Cardiovascular hospitalisations among person ≥ 65 yrs (*n*)	5.92	3.29	0	6	20
BS / μg m^{-3}	22.83	21.82	1.00	17.00	225.00
SO_2 / μg m^{-3}	14.69	12.57	1.00	11.50	107.00
Temperature, °C	12.10	8.80	-11.60	12.80	30.50
Humidity, %	70.33	13.08	26.00	71.00	108.00
Air pressure, mbar	993.80	67.00	966.20	993.30	1014.80

years, there were 22,749 all age cardiovascular hospitalisations in the city of Niš, and 10,816 cardiovascular hospitalisations among persons 65 years of age or older. The daily mean number of all age cardiovascular hospitalisations was 12.46±6.26 (0 to 38) and 5.92±3.29 (0 to 20) among person ≥65 yrs. The daily mean level for BS was 22.83±21.82 μg/m^3, minimum 1.00 μg/m^3 and maximum 225.00 μg/m^3.

Low quality of the fuel and vehicles results in incomplete fossil burning during the heating and traffic in our country. Growing epidemiological evidence suggests that exposure to the particulate matter such as PM_{10} and $PM_{2.5}$ causes negative health effects. In shortage of the equipment for measuring this particulate matter, we use BS measurement data for calculation. However, WHO documents [11] indicate that BS could serve as a useful marker in epidemiological studies. The measured levels of BS are not very high, and they are generally below the national standard (50 μg/m^3).

Pearson's correlation coefficients between air pollutants and meteorological variables are presented in Table 2.

Figure 1 summarizes the results of BS influence on cardiovascular hospitalisations among persons 65 years of age or older. Estimated OR of unipolutant regression model per 10 μg/m^3 of BS persons 65 years of age or older was 1.00135 (95% CI: 0.97835 to 1.02489), and estimated OR of bipolutant model per 10 μg/m^3 of BS with adjustment for SO_2 was 1.00915 (95% CI: 0.99457 to 1.02394).

The majority of the published studies have found significant associations between a 10 μg/m^3 increase in air pollutants and increase in daily number of car-

*Table 2. Correlation between air pollutants and weather variables; * - significant at the 0.01 level*

Parameter	Humidity	Air pressure	Temperature	SO_2
BS	0.181*	0.197*	-0.305*	0.389*
SO_2	-0.007	0.344*	-0.556*	-
Temperature	-0.512*	-0.313*	-	-
Air pressure	0.020		-	-

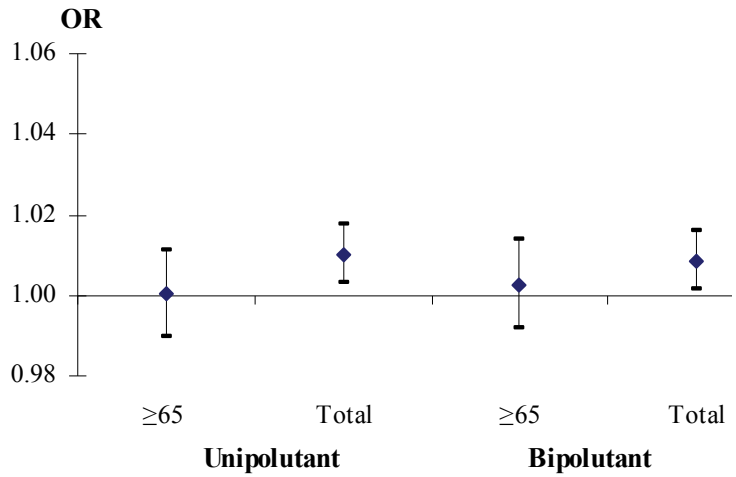

Figure 1. Association between black smoke concentration increase per 10 μg/m^3 and the number of all age cardiovascular hospitalisations and among persons 65 years of age or older.

diovascular hospitalisation [12-16]. There are lot of evidences of susceptibility that air pollution involves its effects on the elderly population. The results of the study of admissions to London hospitals [17] have showed that for cardiovascular admissions there is no evidence that particles (PM_{10} or BS) show stronger effects in the elderly. Chang *et al.* [18] found that on cool days (< 20 °C) all pollutants except O_3 and SO_2 were significantly associated with hospital admissions for cardiovascular diseases. The results from a study in Denver [19] suggest that no association was found between particulate matter and any of the health outcomes including cardiovascular admissions.

The present study is limited because it uses environmental monitoring data to represent ambient concentrations. Besides this, environmental monitoring data do not necessarily represent individual exposures. The associations which could be explained partially by the small number of pollution measures available for the period analyzed were not statistically significant. The results are also dependent on season and type of climates. In our country, the climate is moderate continental and higher air pollutants effects are found in warmer and drier climates.

CONCLUSION

The results of epidemiological studies indicate that ambient air pollution is a risk factor not only for respiratory diseases but also for cardiovascular diseases. This hospitalisations time series study have shown that all age cardiovascular hospitalisations are related to ambient air pollutants concentrations. There is a risk of cardiovascular hospitalisations among persons 65 years of age or older with increase of 10 $\mu g/m^3$ black smoke, but it is not statistically insignificant. However, in response to air pollution exposure, different age groups may respond differently. It will also be important to determine whether other groups of population are more susceptible to air pollution.

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NAUČNI RAD

KRATKOTRAJNI UTICAJ ČESTICA ČAĐI NA HOSPITALIZACIJU OD KARDIOVASKULARNIH BOLESTI KOD STARIH OSOBA U NIŠU,SRBIJA

U proteklih nekoliko godina brojne epidemiološke studije su donele nove dokaze o efektima čestica iz vazduha na hospitalizaciju od kardiovaskularnih bolesti. Cilj našeg rada je bio da se ispita povezanost ambijentalnih koncentracija čestica čađi i ukupnih dnevnih hospitalizacija od kardiovaskularnih bolesti kod starih osoba u Nišu.Srednja vrednost dnevnih hospitalizacija od kardiovaskularnih bolesti svih starosnih dobi bila je 12.46± ±6.26 (0 do 38) i 5.92±3.29 (0 do 20) kod osoba starijih od 65 godina. Prikupljeni su podaci dnevnih merenja koncentracija čestica čađi i sumpor dioksida kao i broj hospitalizacija od kardiovaskularnih bolesti kod osoba starijih od 65 godina u toku svakog dana. Koncentracija čestica čađi (μg/m^3) je merena metodom refractometrije i a koncentracija SO_2 (μg/m^3) je merena metodom spektrofotometrije. Primenjen je generalizovani linearni model Puazonove regresije. Efekti vremenskog trenda, sezonskih varijacija, dan u nedelji, temperatura, relativna vlažnost i barometarski pritisak su bili prilagođeni u modelu. Procenjeno je da je OR u unipolutantnom regresionom modelu za osobe starije od 65 godina bio 1,00135 (95% CI: 0,97835 do 1,02489), dok je OR bipolutantnom modelu iznosio 1,00975 (95% CI: 0,99457 do 1,02394) za svako povećanje koncentracija od po 10μg/m^3. Rezultati ne podržavaju zaključke prethodnih studija koje su dokazale da je porast broja hospitalizacije od kardiovaskularnih bolesti kod starijih osoba u vezi sa česticama čađi.

Ključne reči: stare osobe, kardiovaskularna hospitalizacija, čađ, aerozagađenje.