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Effects of meteorological conditions on mortality from chronic obstructive pulmonary disease

Утицај метеоролошких услова на смртност од хроничне опструктивне болести плућа

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SUMMARY
Introduction/Objective Previous studies have confirmed the effect of different meteorological parameters on patients suffering from lung diseases.
The aim of the study is to investigate the impact of meteorological phases on the death rate from chronic obstructive pulmonary disease (COPD).
Methods The data on the number of deaths caused by COPD and meteorological phases during the five-year period (2011–2015) in Šumadija district (Central Serbia) were obtained from the Republic Hydrometeorological Service and the Center for Biostatistics and Informatics in the Institute of Public Health Kragujevac.
Results A statistically significant correlation was determined between certain meteorological phases and COPD death rate. The highest death rate was determined during colder months, February and March. The lowest death rate was detected during the warm months (June-September). Although men died more often from COPD than women, the death rate of women showed a considerable increase during the five-year period.
Conclusion COPD death rate is highly dependent on the season of a year and might be associated with certain meteorological phases. There is a need for further research of the impact of meteorological phases on the morbidity and mortality from COPD.
Keywords: chronic obstructive pulmonary disease; meteorology; humidity; temperature

САЖЕТАК
Увод/Циљ Велики број студија је потврдио утицај различитих метеоролошких параметара на пацијенте са плућним болестима.
Циљ ове студије био је да се истражи утицај метеоролошких фаза на стопу смртности од хроничне опструктивне болести плућа (ХОБП).
Методе Подаци о учесталости метеоролошких фаза и броју умрлих од ХОБП-а током петогодишњег периода (2011–2015) у Шумадијском округу (Централна Србија), добијени су од Републичког хидрометеоролошког завода и Центра за биостатистику и информатику Института за јавно здравље у Крагујевцу.
Резултати Нађена је статистички значајна корелација између одређених метеоролошких фаза и стопе смртности од ХОБП-а. Највиша стопа смртности забележена је током хладних месеци (фебруар и март). Најнижа стопа смртности је уочена током топлих месеци (јун–септембар). Иако су мушкарци умирали чешће од ХОБП него жене, стопа смртности је код жена имала значајан пораст током овог петогодишњег периода.
Закључак Стопа смртности од ХОБП-а зависи од годишњих доба и може се повезати са одређеним метеоролошким фазама. Неопходно је даље истраживање утицаја метеоролошких фаза на морбидитет и морталитет од ХОБП-а.
Кључне речи: хронична опструктивне болест плућа; метеорологија; влажност; температура

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is one of the most important health problems [1, 2]. According to the data from the World Health Organization, almost three million people that suffer from COPD die yearly, and by the year 2020 this disease might become the world’s fourth most frequent cause of death [3]. Morbidity and mortality rates of COPD are increasing steadily, most likely due to exposure to cigarette smoke, air pollution, but also because of ageing of the population. Morbidity and mortality rate vary from country to countries and region to region [2, 4, 5].

Basic risk factors for COPD are: smoking, outdoor air pollution, poor quality of indoor air, genetic predisposition, age, sex, pneumonia, nutritional status, socioeconomic status, etc. [3, 6, 7]. Patients suffering from COPD have an increased risk of developing other pulmonary diseases – respiratory infections and primary lung cancer, cardiovascular disorders, osteoporosis, diabetes, and mental disorders such as neurosis and depression [3, 7, 8, 9].

Prevention of COPD includes healthy lifestyles, healthy nutrition and nutritional status, daily physical activity, and preserving a high quality of ambient air. COPD is characterized by a frequent changing of the phases of remission and the exacerbation of symptoms. Exacerbation of chronic respiratory and cardiovascular diseases can appear as a consequence of exposure to infectious agents, or noninfectious factors: an increase in concentration of sulfur dioxide and nitrogen oxides in the ambient air, and the impact of certain meteorological parameters such as wind speed and direction, air temperature, air pressure, humidity, and precipitation [10, 11, 12].

Meteoropathy is a group of symptoms and reactions related to a change in one or multiple meteorological factors. By the combination of meteorological and climate elements, 10 meteorological phases have been determined. Meteorological phases are a combination of the following factors: cyclone-anticyclone, air temperature, air humidity, the advance of the cold/warm front, dry/wet weather. Meteorological phases are as follows [13]:

1. Cyclone, warm, dry – CWD: an influx of warm or very warm air (warm sector). Sunny weather prevails, but the weather develops towards cloudiness and an increase in windiness from the southern quadrant (warm wind).

2. Cyclone, warm, wet – CWW: precipitation from compact, layered clouds. Relatively warm, wind blows from the southern quadrant, (southern tip), pressure drops, temperature rises or stagnates because of the precipitation, relative humidity increases.

3. Cyclone, warm front – CWF: A couple of hours before and after the warm front passes the weather is cloudy with precipitation, and during the actual transit of the front a sudden change in wind direction can be observed, temperature keeps rising, especially when precipitation in the back of the front weakens or stops. Relative humidity rises. Beside the precipitation, very low cloudiness occurs.

4. Cyclone, cold front – CCF: cloudiness develops followed by downpours, thunder and strong wind. Temperature drops rapidly, pressure rises significantly, relative humidity rises because of precipitation, but observed globally stagnates, and after the

precipitation stops it falls quickly. The wind keeps changing its direction and intensity suddenly.

5. Cyclone, cold, wet – CCW: Layered cloudiness (Ns) prevails paired with long-lasting precipitation, pressure rises, temperature drops or stagnates, humidity does not change much, but drops as precipitation stops. The wind is more intense and blows from the northern quadrant.

6. Cyclone, cold, dry – CCD: After precipitation ends, cold and windy weather persists. Precipitation can occur, but only for a short while and in a small quantity. The weather is cloudy, with a lack of precipitation, cold and with a tendency to change towards clear weather.

7. Anticyclone, cold, dry – ACD: Clear weather prevails. The wind comes from the northern quadrant, and its intensity is mostly weak. During the summer it is chilly, and during the winter half of the year it is cold. Pressure, temperature and humidity do not change much.

8. Anticyclone, cold, wet – ACW: Foggy, gloomy and cold weather in the area of the anticyclone.

9. Anticyclone, warm, dry – AWD: Clear and calm weather. The anticyclone is still dominant. Air temperature either basically does not change at all, or it has a slight increase on a daily basis. Transport of slightly warmer air from lower latitudes starts, weak winds from the southern quadrant start blowing.

10. Anticyclone, warm, wet – AWW: Cloudiness develops followed by precipitation and thunder. It manifests during the warm part of the year.

The impact of various meteorological phases on lung diseases has been intensively studied, but it still needs clarification.

The aim of this paper was to investigate the correlation between particular meteorological phases and the mortality rate from COPD.

METHODS

This study is a retrospective, descriptive study conducted during five-year period 2011-2015 in Šumadija district, Central Serbia. The Šumadija district is located at 185–220 m above sea level, between latitudes 43 and 44° N and longitudes of 20 and 21° E. The climate is temperate continental, with relatively cold winters, hot summers and the average annual temperature of 11.5°C.

Data on current meteorological phases used in this study were obtained from the Republic Hydrometeorological Service (RHMS). Information on mortality of COPD was obtained from the database of the Center for Biostatistics and Informatics in the Institute of Public Health Kragujevac.

This research was approved by the Ethics Committee of the Institute of Public Health Kragujevac, Serbia (no 01-2092). Spearman correlation analysis was conducted to investigate the relationship between meteorological phases and the mortality from COPD. SPSS 20.0 software for Windows was used.

RESULTS

COPD death rate in Šumadija district grew from 20.99 per 100,000 in the year 2011 to 24.14 in the year 2015. Table 1 presents the incidences of 10 meteorological phases (in percentages to total number of phases) and number of deaths by months, during the period 2011–2015. Phases 4 and 9 were dominant during the whole period. The incidence of the phase 9 was higher during the warm months (April-November) compared to the winter months (December-March). On the other hand, the phases 10 occurred only in spring and summer while the phase 8 was observed in autumn and winter.

Total number of deaths caused by COPD was 955 (617 men and 338 women). The highest number of deaths (114) was recorded in February and March while the risk of dying from COPD was significantly lower during the "warm" months (June-September). COPD death rate was 2–3 times higher for males than for females. However, an increase in the death rate was more prominent for women (from 13.4 to 16.2 per 100,000) while for men a slight decrease was observed (from 39.74 to 34.75 per 100,000).

The correlation of the death rate with the incidence of each meteorological phase (by months) was investigated using Spearman correlation analysis. The results are presented in Table 2.

DISCUSSION

Mortality rate detected in our study was higher than the values previously reported in Serbia [14]. The death rate from COPD grew by 15% during the five-year period. A particularly high increase of COPD prevalence and death rate observed in women were also reported by some other authors [1, 15].

The mortality rate from COPD is increased during a cold period of the year. This observation is in agreement with the results of some previous studies. For example, a large study in Taiwan reported a 0.8% increase in COPD exacerbations with 1°C decrease of the mean air temperature [16]. Cold weather usually contributes to lung diseases through bronchoconstriction, inflammation, mucous hypersecretion, as well as through modifying susceptibility to air pollution [10]. Although extremely hot temperatures and heatwaves have also been identified as a significant risk factor for patients suffering from lung diseases, cold temperatures and temperature changes have more pronounced effect [17–20].

COPD mortality rate was negatively related to the incidence of meteorological phases 1, 9 and 10 (Spearman's rho = -0.564, -0.816, and -0.480, respectively). All these three phases occur more often during the warm period of year. A strong negative correlation with the meteorological phase 9 indicates that clear and calm weather, which are typical for this phase, have particularly positive effects on patients with COPD. This result is rather understandable, considering the fact that sudden changes of certain meteorological parameters might aggravate symptoms of respiratory diseases. For example, some previous studies have suggested that sudden changes of inhaled air temperature could cause the release of inflammatory mediators produced by mast cells and more nasal inflammatory responses [21-25].

A positive correlation was found between the meteorological phase 3 and the mortality rate from HOPD (rho = 0.744). This phase is more typical for autumn and winter seasons. It is characterized by cloudy weather with precipitation, sudden change in wind direction, temperature rise, and increase in relative humidity. Our results are consistent with the studies reporting that COPD and cardiovascular mortality are higher during the cold season [26, 27].

Investigations have confirmed that a high content of water molecules in the air can cause dyspnea. High air humidity is related to the presence of allergens, pathogens, and noxious chemicals in the environment, consequently increasing the incidence of respiratory infections, allergies and exacerbation of COPD [21, 28, 29]. Research conducted in Novi Sad also points to the fact that an increase in relative air humidity leads to exarcebation of COPD [30].

CONCLUSION

An increasing trend of COPD death rate was observed in a five-year period. Of particular concern is a marked increase in mortality from COPD among women compared to men. There is a significant statistical correlation between certain meteorological phases and the mortality rate from COPD. There is a need for further research of the impact of meteorological phases on the morbidity and mortality from COPD. Special attention should be paid to warm and cold fronts, cyclones and anticyclones.

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REFERENCES

1. Vukoja M, Kopitovic I, Lazic Z, Milenkovic B, Stankovic I, Zvezdin B, et al. Diagnosis and management of chronic obstructive pulmonary disease in Serbia: an expert group position statement. Int J Chron Obstruct Pulmon Dis. 2019; 14:1993–2002. doi: 10.2147/COPD.S214690.
2. Adeloye D, Chua S, Lee C, Basquill C, Papana A, Theodoratou E, et al. Global and regional estimates of COPD prevalence: systematic review and meta-analysis. J Glob Health. 2015; 5:020415. doi: 10.7189/jogh.05.020415.
3. World Health Organization. Chronic Obstructive Pulmonary Disease (COPD). 2017. Available on URL: http://www.who.int/respiratory/copd/management/en/.
4. Yoon HK, Park YB, Rhee CK, Lee JH, Oh YM. Committee of the Korean COPD Guideline 2014. Summary of the Chronic Obstructive Pulmonary Disease Clinical Practice Guideline Revised in 2014 by the Korean Academy of Tuberculosis and Respiratory Disease. Tuberc Respir Dis (Seoul). 2017; 80(3):230–40. doi:10.4046/trd.2017.80.3.230.
5. Hillas G, Perlikos F, Tsiligianni I, Tzanakis N. Managing comorbidities in COPD. Int J Chron Obstruct Pulmon Dis. 2015; 10:95–109. doi:10.2147/COPD.S54473.
6. World Health Organization Chronic respiratory diseases, COPD management. 2017. Available on URL: http://www.who.int/respiratory/copd/management/en/.
7. Chronic Obstructive Pulmonary Disease (COPD). Centers for Disease Control and Prevention. 2016. Sep. Available on URL: https://www.cdc.gov/copd/index.html.
8. Sarkar M, Bhardwaj R, Madabhavi I, Khatana J. Osteoporosis in Chronic Obstructive Pulmonary Disease. Clin Med Insights Circ Respir Pulm Med. 2015; 9:5–2. doi: 10.4137/CCRPM.S22803.
9. Putcha N, Drummond MB, Wise RA, Hansel NN. Comorbidities and Chronic Obstructive Pulmonary Disease: Prevalence, Influence on Outcomes, and Management. Semin Respir Crit Care Med. 2015; 36(4):575–91. doi:10.1055/s-0035-1556063.
10. Hansel NN, McCormack MC, Kim V. The Effects of Air Pollution and Temperature on COPD. COPD. 2016; 13(3):372–9. doi: 10.3109/15412555.2015.1089846.
11. Jevtic M, Dragic N, Bijelovic S, Popovic M. Cardiovascular diseases and air pollution in Novi Sad, Serbia. Int J Occup Med Environ Health. 2014; 27(2):153–64. doi: https://doi.org/10.2478/s13382-014-0239-y.
12. Ilić M, Kopitović I, Vulin A, Zvezdin B, Hromiš S, Kolarov V, et al. Frequency and effects of seasonal flu vaccines on exacerbations of chronic obstructive pulmonary disease in Serbia. Vojnosanit Pregl. 2019. (in press) doi: https://doi.org/10.2298/VSP181214049I.
13. Gajić V, Milojević D, Rašković A, Smailagić J, Đonović N, Šijački A. Biometeorological phases influence pedestrian trauma. Srp Arh Celok Lek. 2011; 139(1-2):81–7 . doi: 10.2298/SARH1102081G.
14. Vukoja M, Rebić P, Lazić Z, Mitić-Milikić M, Milenković B, Zvezdin B. Early detection of asthma and chronic obstructive pulmonary disease in primary care patients. Med Pregl. 2013; 66(1-2):46–52. doi: https://doi.org/10.2298/MPNS1302046V.
15. Rossi A, Butorac-Petanjek B, Chilosi M, Cosío BG, Flezar M, Koulouris N, et al. Chronic obstructive pulmonary disease with mild airflow limitation: current knowledge and proposal for future research - a consensus document from six scientific societies. Int J Chron Obstruct Pulmon Dis. 2017;12:2593–610. doi: 10.2147/COPD.S132236.
16. Tseng CM, Chen YT, Ou SM, Hsiao YH, Li SY, Wang SJ, et al. The effect of cold temperature on increased exacerbation of chronic obstructive pulmonary disease: a nationwide study. PloS One. 2013; 8(3):e57066. doi: 10.1371/journal.pone.0057066.
17. Lin MT, Kor CT, Chang CC, Chai WH, Soon MS, Ciou YS, et al. Association of meteorological factors and air NO2 and O3 concentrations with acute exacerbation of elderly chronic obstructive pulmonary disease. Sci Rep. 2018; 8(1):10192. doi: 10.1038/s41598-018-28532-5.
18. Chiu PF, Chang CH, Wu CL, Chang TH, Tsai CC, Kor CT, et al. High particulate matter 2.5 levels and ambient temperature are associated with acute lung edema in patients with non-dialysis stage 5 chronic kidney disease. Nephrol Dial Transplant. 2019; 34(8): 1354–60. doi: https://doi.org/10.1093/ndt/gfy144.

19. Stankovic A, Nikc D, Nikolic M, Bogdanovic D. Shortterm effects of air pollution on cardiovascular mortality in elderly in Niš, Serbia. Cent Eur J Public Health. 2007; 15(3):95–8. doi: 10.2298/CICEQ120103107S.
20. Bogdanovic D, Milosevic Z, Lazarevic K, Dolicanin Z, Ranelovic D, Bogdanovic SD. The impact of the July 2007 heat wave on daily mortality in Belgrade, Serbia. Cent Eur J Public Health. 2013; 21(3):140–5. doi: 10.21101/cejph.a3840.
21. Cheng J, Xu Z, Zhu R, Wang X, Jin L, Song J, et al. Impact of diurnal temperature range on human health: a systematic review. Int J Biometeorol. 2014; 58(9):2011–24. doi: 10.1007/s00484-014-0797-5.
22. D'Amato M, Molino A, Calabrese G, Cecchi L, Annesi-Maesano I, D'Amato G. The impact of cold on the respiratory tract and its consequences to respiratory health. Clin Transl Allergy. 2018; 8:20. doi: 10.1186/s13601-018-0208-9.
23. Ehelepola NDB, Ariyaratne K, Jayaratne A. The association between local meteorological changes and exacerbation of acute wheezing in Kandy, Sri Lanka. Glob Health Action. 2018; 11(1):1482998. doi: 10.1080/16549716.2018.1482998.
24. Yang J, Zhou M, Li M, Liu X, Yin P, Sun Q, et al. Vulnerability to the impact of temperature variability on mortality in 31 major Chinese cities. Environ Pollut. 2018; 239:631–7. doi: 10.1016/j.envpol.2018.04.090.
25. Lin Z, Gu Y, Liu C, Song Y, Bai C, Chen R, et al. Effects of ambient temperature on lung function in patients with chronic obstructive pulmonary disease: A time-series panel study. Sci Total Environ. 2018; 619–620:360–65. doi: 10.1016/j.scitotenv.2017.11.035.
26. de Miguel-Díez J, Hernández-Vázquez J, López-de-Andrés A, Álvaro-Meca A, Hernández-Barrera V, Jiménez-García R. Analysis of environmental risk factors for chronic obstructive pulmonary disease exacerbation: A case-crossover study (2004-2013). PLoS One. 2019; 14(5):e0217143. doi: 10.1371/journal.pone.0217143.
27. Bijelovic S, Dragic N, Bijelovic M, Kovacevic M, Jevtic M, Ninkovic Mrdjenovacki O. The impact of climate conditions on hospital admissions for subcategories of cardiovascular diseases. Med Pr. 2017; 68(2):189–97. doi: 10.13075/mp.5893.00606.
28. Mu Z, Chen PL, Geng FH, Ren L, Gu WC, Ma JY et al. Synergistic effects of temperature and humidity on the symptoms of COPD patients. Int J Biometeorol. 2017; 61(11):1919–25. doi: 10.1007/s00484-017-1379-0.
29. Tian L, Yang C, Zhou Z, Wu Z, Pan X, Clements ACA. Spatial patterns and effects of air pollution and meteorological factors on hospitalization for chronic lung diseases in Beijing, China. Sci China Life Sci. 2019. (in press). doi: 10.1007/s11427-018-9413-y.
30. Jevtić M, Dragić N, Bijelović S, Popović M. Air pollution and hospital admissions for chronic obstructive pulmonary disease in Novi Sad. HealthMED. 2012; 6(4):1207–15.

Table 1. The incidence of meteorological phases and number of deaths from chronic obstructive pulmonary disease (COPD) by months during the 2011–2015 period

Month	Meteorological phase [%]										Number of deaths from COPD
	1	2	3	4	5	6	7	8	9	10	
January	5.8	1.9	11	21.3	15.5	6.5	18.1	8.4	11.6	0	89
February	8.5	2.1	9.2	22.5	14.1	11.3	14.1	1.4	16.9	0	114
March	9	2.6	11	25.2	14.2	9	12.3	0	16.8	0	114
April	8.7	4.7	4	26	13.3	9.3	6.7	0	26	1.3	99
May	9.7	5.2	1.3	29	12.9	4.5	7.7	0	27.1	2.6	88
June	8	3.3	2	22.7	17.3	6	5.3	0.7	32.7	2	56
July	9	4.5	1.3	22.6	14.8	8.4	7.1	0	30.3	1.9	67
August	11.6	3.2	1.9	22.6	9	7.7	6.5	0	36.1	1.3	50
September	10	2	1.3	18.7	14	10	14.7	0	28.7	0.7	52
October	9.7	2.6	3.9	18.1	9.7	9	12.9	0.6	33.5	0	68
November	9.3	2	6	23.3	12.7	8	10	2	26.7	0	70
December	7.7	4.5	9.7	20.6	14.8	7.7	11.6	15.5	7.7	0	88

Meteorological phases: 1 – cyclone, warm, dry; 2 – cyclone, warm, wet; 3 – cyclone, warm front; 4 – cyclone, cold front; 5 – cyclone, cold, wet; 6 – cyclone, cold, dry; 7 – anticyclone, cold, dry; 8 – anticyclone, cold, wet; 9 – anticyclone, warm, dry; 10 – anticyclone, warm, wet

Table 2. Spearman correlation coefficients (Spearman's rho) between meteorological phases and death rate of chronic obstructive pulmonary disease (COPD).

Meteorological phases	COPD death rate	p
Phase 1 (cyclone, warm, dry)	rho = -0.564	0.056
Phase 2 (cyclone, warm, wet)	rho =-0.016	0.961
Phase 3 (cyclone, warm front)	rho = 0.744	0.006
Phase 4 (cyclone, cold front)	rho = 0.274	0.389
Phase 5 (cyclone, cold, wet)	rho = 0.235	0.462
Phase 6 (cyclone, cold, dry)	rho = 0.265	0.404
Phase 7 (anticyclone, cold, dry)	rho = 0.371	0.235
Phase 8 (anticyclone, cold, wet)	rho = 0.260	0.415
Phase 9 (anticyclone, warm, dry)	rho = -0.816	0.001
Phase 10 (anticyclone, warm, wet)	rho = -0.480	0.115