Original article

Influence of Meteorological Factors on Covid-19 Incidence in the Conditions of Ukraine

Alla P. Podavalenko[1], Nina G. Malysh[2], Olga V. Kuzmenko[3], Viktoriya I. Zadorozhna[4], Svitlana V. Kolomiets[5], Oksana M. Chemych[6]

Abstract:

Objective: The coronavirus disease (COVID-19) is a problem for the health care systems of many countries around the world. Seasonal nature of influenza and other the respiratory viral diseases is commonly known. The nature of the relationship between the frequency of registration of cases of COVID-19 and natural factors is still being studied by researchers. The purpose is to determine the influence of air temperature, relative humidity, wind speed, and atmospheric pressure on the incidence of the coronavirus disease COVID-19 in the conditions of Ukraine. ***Materials and methods.*** Official reports of the Ministry of Health of Ukraine and data from daily monitoring of meteorological indicators conducted by the Sumy Regional Hydrometeorology Center were used in the paper. Descriptive and analytical ways of epidemiological method of investigation were applied. The search for parameters of interrelation between the frequency of registration of COVID-19 cases and meteorological cases took place using of program "Statistica", namely the relevant tools of this program: "Analysis"/ "Multiple regression". ***Results and Discussion*:** In the period under study from March 25, 2020 to December 31, 2021 in Sumy Oblast of Ukraine, three waves of rise in the incidence were registered. In the third wave of rise in the incidence, in autumn 2021 the frequency of registration of COVID-19 cases reached 1684.9 per 100 thousand of people, despite the fact that almost 70 % of the population had already recovered or were vaccinated. Meteorological factors in the conditions of Ukraine have little influence on the rate of spread of COVID-19. The value of multiple correlation coefficients was within those limits, which are considered moderate in terms of influence. A moderate inverse correlation was established between the frequency of registration of COVID-19 cases and indicators of air temperature, and a direct correlations - with indicators of relative air humidity. ***Conclusions:*** In the conditions of Ukraine, the studied meteorological factors (air temperature, relative humidity, wind speed, atmospheric pressure) indirectly influenced the intensity of the epidemic process of COVID-19. the strength of this influence was either weak or moderate.

Keywords: coronavirus infection; meteorological factors, correlation

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Introduction:

Climatic factors affect the dynamics of the incidence of acute respiratory diseases.[1,2] The incidence of respiratory infections is rising in the cold season. Influenza has a special place among acute respiratory viral infections, as it can lead to serious complications and cause death. Influenza epidemics that occur every year in many countries of the world have negative

1. Alla P. Podavale, Department of Hygiene, Epidemiology and Occupational Diseases, Kharkiv Medical Academy of Postgraduate Education, Amosova, 58, Kharkiv, Ukraine.
2. Nina G. Malysh, Department of Infectious Diseases with Epidemiology, Sumy State University, Rymskogo-Korsakova 2, Sumy, Ukraine.
3. Olga V. Kuzmenko, Department of Economic Cybernetics**,** Sumy State University, Rymskogo-Korsakova 2, Sumy, Ukraine.
4. Viktoriya I. Zadorozhna, SI «Institute of Epidemiology and Infectious Diseases named after L.V. Gromashevsky National Academy of Medical Sciences of Ukraine», M Amosova, 5, Kyiv, Ukraine.
5. Svitlana V. Kolomiets, Department of Economic Cybernetics**,** Sumy State University, Rymskogo-Korsakova 2, Sumy, Ukraine.
6. Oksana M. Chemych, Department of Infectious Diseases with Epidemiology, Sumy State University, Rymskogo-Korsakova 2, Sumy, Ukraine.

Correspondence: Nina G. Malysh, Doctor of Medical Sciences, Associate Professor. Department of Infectious Diseases with Epidemiology, Sumy State University, Sumy, Ukraine. E-mail: malysh.ng@gmail.com

social and economic consequences due to anti-epidemic measures. Scientists have been studying the mechanisms of seasonality in acute respiratory diseases for many years, but the results of their research are ambiguous.[2,3] Researchers concluded that the main reasons for increase in the incidence in the cold season are, firstly, better survival of viruses, and secondly, a decrease in immunity and an increase in the number of contacts of the population.[1,4-6]

SARSCoV-2 coronavirus unexpectedly rapidly spread from the Chinese city of Wuhan around the world and quickly became a problem on a global and national scale, had a negative impact on the life of society and the environment. The health care system experienced the greatest load and required the mobilization of all available resources.[7-9]

Researchers specify the impact of meteorological factors on dynamics of COVID-19 incidence. Some research findings are indicative of the observed expressed correlation between air temperature, humidity indices and COVID-19 incidence and in other investigations, on the contrary – scientists concluded that this influence is insignificant.[10-12]

The purpose of our study was to determine significance of meteorological factors in the epidemic process of COVID-19 in the conditions of Ukraine (for example, Sumy oblast).

Materials and methods:

Based on the reports of the Ministry of Healthcare of Ukraine, an analysis of the incidence of COVID-19 in Sumy oblast was conducted from March 25, 2020 to December 31, 2021.

The indicators of meteorological factors (air temperature (^{0}C), wind speed (m/s), relative air humidity (%), atmospheric pressure (mm Hg) was obtained from Sumy Oblast Center of Hydrometeorology.

Descriptive and analytical ways of epidemiological method of investigation were used in the paper. All quantitative research results obtained were subject to statistical processing using conventional methods of variable and correlation statistics. The search for parameters of interrelation between the frequency of registration of COVID-19 cases and meteorological cases took place using Statistica, namely the relevant tools of this program: "Analysis"/ "Multiple regression". The results of correlation analysis are presented as pair and multiple correlation coefficients. If the correlation coefficient was 0, it was considered that there is no connection between the phenomena, 0.1 to 0.29 the relationship was assessed as weak, 0.30 to 0.69 – moderate, 0.70 to 0.99 – strong, 1 is complete.

Characteristics of Sumy Oblast: located in the north-eastern part of Ukraine; the area is 23,832 km^2 and population 1 068 000 people (68% live in cities, 32% in villages); 17% of the territory is occupied by forests and shrubs; the climate is moderately continental.

Ethical clearance:

Ethical issues were ensured by the anonymity of the research being conducted and the compliance of its procedure with national and international ethical standards, the Declaration of Helsinki, 1975, revised in 2008, and other regulatory documents regulating the observance of bioethical principles of scientific research. The study was approved by the Ethics Committee of the Kharkiv Medical Academy of Postgraduate Education, Kharkiv, Ukraine, Protocol No. 9 pd of 15.06.2022.

Results:

The first case of COVID-19 in Sumy Oblast was registered on March 25, 2020. In the period under study from March 25, 2020 to December 31, 2021, three waves of rising incidence were observed, each of which lasted for about 3 months (Fig. 1).

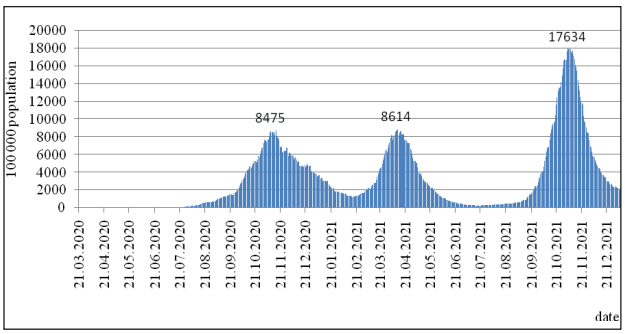

Figure 1. Incidence of COVID-19 in Sumy oblast from March 21, 2020 to January 06, 2022 (per 100 thousand of population).

The first onset of the increase in incidence began 6 months after the registration of the first cases of COVID-19 from October 01, 2020 to January 21, 2021. The second wave was observed from March 07, 2021 to May 22, 2021. The third wave was from September 24, 2021 to December 31, 2021. The highest incidence of coronavirus infection was registered during the third wave. On November 04, 2021, the incidence reached 1684.92 per 100 000

thousand of population. By that time, 118 972 people or 11.2% of the population had already been ill with COVID-19, completed the course of vaccination against coronavirus infection – 253 729 people or 23.8% of the population, 360 769 people or 33.9% received the first dose of the vaccine. 13.8% of those who received two doses of the vaccine were vaccinated with Astra Zeneca, 38.4% with Pfizer-BioNTech, 36.5% with Sinovac Biotech, 11.3% with Moderna.

Assuming that meteorological factors could influence the rate of spread of COVID-19, in order to study the level of this influence, we studied the data of monitoring carried out by Sumy Oblast Center of Hydrometeorology based on the indicators of air temperature, relative humidity, wind speed and atmospheric pressure in the period under study. It was established that the coldest month of the year was January (average monthly air temperature –3.9 ^{0}C), the hottest – July (average monthly temperature +23.4^0 C). Wind speed indicators ranged from 3 m/s to 21 m/s. Average wind speed was 9.3 m/s (Fig. 2).

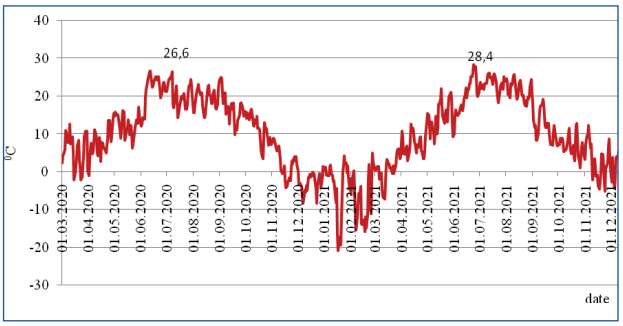

Figure 2. Daily indicators of air temperature (^{0}C) in Sumy Oblast from March 01, 2020 to December 31, 2021

Wind speed indicators ranged from 3 m/s to 21 m/s. Average wind speed was 9.3 m/s (Fig. 3).

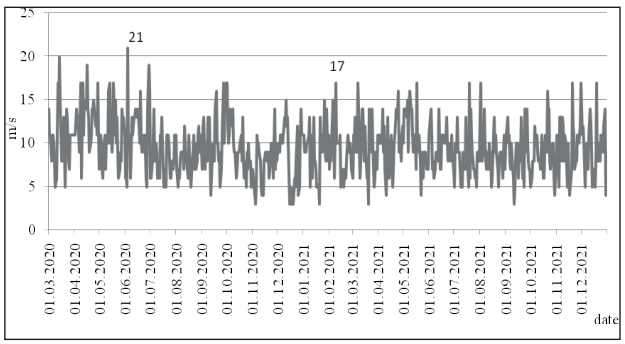

Figure 3. Daily indicators of wind speed (m/s) in Sumy Oblast from March 01, 2020 to December 31, 2021

Indicators of relative air humidity in the region ranged from 39 to 97 %. Average value was 75.4 % (Fig. 4).

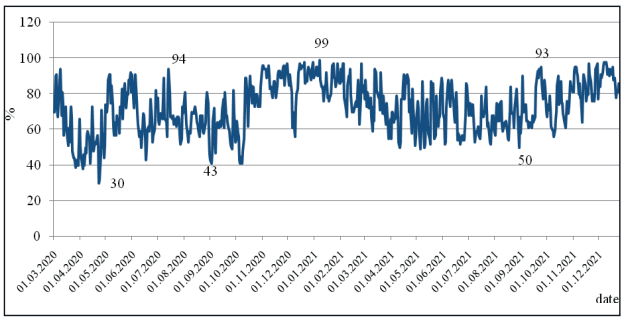

Figure 4. Daily indicators of relative humidity (%) in Sumy Oblast from March 01, 2020 to December 31, 2021

The value of atmospheric air pressure ranged from 730 to 762 mm Hg. Average value was 745 mm Hg (Fig. 5)

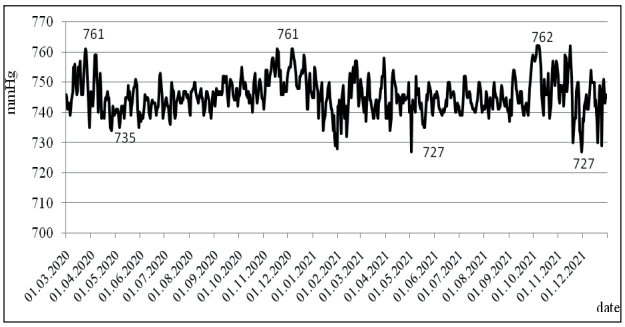

Figure 5. Daily indicators of atmospheric pressure (mm Hg) in Sumy Oblast from March 01, 2020 to December 31, 2021

Correlations between the frequency of registration of COVID-19 coronavirus infection cases and indicators of meteorological factors were identified by statistical methods of research taking into account probable incubation periods 3, 5 and 10 days.

As you know, the simplest way to represent a correlation is to calculate correlation coefficient r. Pair correlation coefficient reflects the nature of relationship between two features. At the same time, probable influence of other factors is not taken into account. Multiple correlation coefficient determines the relationship between three or more characteristics and shows the totality of influence of each of them.

We found that in Sumy Oblast there was an inverse moderate correlation between the frequency of registration of COVID-19 cases and air temperature indicators, i.e., by increasing the temperature of air,

there was a downward trend of the incidence, and vice versa, when the air temperature decreased – upward trend. The absolute values of pair correlation coefficients were within r= 0.30–0.6 (Table 1).

Table 1. Correlation coefficients between the frequency of registration of COVID-19 cases and indicators of meteorological factors

Probable incubation periods	Pair correlation coefficients (r)			
	air temperature (^{0}C)	wind speed (m/s)	relative air humidity (%)	atmospheric pressure (mm Hg)
3days	-0,394	-0,091	0,348	0,288
5 days	-0,379	-0,095	0,335	0,289
10 days	-0,354	-0,107	0,298	0,296

Direct moderate correlation relationships have been established between COVID-19 incidence and levels of relative air humidity. The value of pair correlation coefficients varied from r = 0.298 to r =0.348.

Indirect impact of atmospheric pressure and wind speed on the dynamics of Covid-19 incidence was even smaller. It was established that the values of pair correlation coefficients between the frequency of registration of COVID-19 cases and indicators of atmospheric pressure and wind speed ranged from r = 0.288 to r = 0.296 and from r = -0.091 to r = -0.107, respectively.

The value of multiple correlation coefficients between COVID-19 incidence and indicators of meteorological factors under the study at all values of incubation period (3, 5 and 10 days) did not differ materially. In terms of directionality of the relationship, they were direct, in terms of strength – moderate (from r= 0.472 to r= 0.512). The coefficients of determination R ranged from 22.3% to 26.3%. That is, variations in COVID-19 incidence during the entire period under study were caused by the influence of meteorological factors in only 26.3% of cases.

Separately, we investigated the likelihood of the influence of meteorological factors on the frequency of COVID-19 registration during periods of increased incidence in Sumy oblast.

Correlations between the incidence of COVID-19 and air temperature during all three outbreaks were found to be weak. The value of correlation coefficient ranged from r= 0.035–0.292 (Table 2).

Table 2. Correlation coefficients between the incidence in the periods of increased incidence and meteorological factors

Periods of increased incidence		Pair correlation coefficients (r)			
		air temperature (^{0}C)	wind speed (m/s)	relative air humidity (%)	atmospheric pressure (mm Hg)
01.10.2020-21.01.2021	3 дні	0,106	-0,331	0,265	0,368
	5 днів	0,079	-0,403	0,239	0,324
	10 днів	0,119	-0,295	0,185	0,079
07.03.2021-22.05.2021	3 дні	0,044	-0,254	-0,010	0,229
	5 днів	0,040	-0,296	-0,007	0,118
	10 днів	0,035	-0,320	-0,108	0,009
24.09.2021-31.12.2021	3 дні	0,285	0,015	-0,170	0,220
	5 днів	0,292	-0,006	-0,285	0,300
	10 днів	0,126	-0,013	-0,321	0,339

It was not possible to establish a reliable impact of relative air humidity on the frequency of registration of COVID-19 cases during all three outbreaks. The correlations were weak, the value of correlation coefficients ranged from r= - 0.321 to r= 0.265.

When studying the impact of wind on incidence, we observed a downward trend with increasing wind speed. This tendency was most pronounced during the first incidence growth from October 01, 2020 to January 21, 2021 and the second one from March 07, 2021 to May 22, 2021 (correlation index r depending on the incubation period ranged from r= -0.254 to r = -0.403). At the same time, it should be noted that these indicators were not statistically significant.

Correlations between the frequency of registration of COVID-19 cases and levels of atmospheric pressure were either weak or moderately expressed by strength. Correlation coefficient during all three incidence growth did not exceed the value r= 0.368.

In general, the influence of all four studied meteorological factors on the dynamics of COVID-19 incidence was moderate. The values of multiple correlation coefficients between the registration of COVID-19 cases and indicators of meteorological factors during the first rise in the incidence ranged from r= 0.482 to r= 0.619, during the second from r= 0.315 to r= 0.386, during the third r= from 0.362 to r= 0.436. The coefficients of determination R were the highest during the first rise in incidence from 23.2% to 38.3%. During the other two rises of incidence, the coefficients of determination R ranged from 9.9 % to 19.0 %.

Therefore, taking into account the above, it can be concluded that natural factors (air temperature, relative air humidity, wind speed, atmospheric pressure) in Sumy oblast of Ukraine indirectly influenced the level of COVID-19 incidence. This impact is not statistically significant ($p>0.05$). Probably, other factors, for example, social factors, which were not investigated in this work, had a more intense impact on the dynamics of the incidence of COVID-19 coronavirus infection.

Discussion:

Coronavirus disease (COVID-19) is an emergency both in the world in general and in Ukraine, in particular. In the period under study from March 25, 2020 to December 31, 2021 in Sumy Oblast of Ukraine, three waves of rise in the incidence were registered. In the third wave of rise in the incidence, in autumn 2021 the frequency of registration of COVID-19 cases reached 1684.9 per 100 thousand of people, despite the fact that almost 70 % of the population had already recovered or were vaccinated.

The researchers' findings in the study of the matter of COVID-19 assignment to "seasonal infections", in other words, associated with a certain season, are rather controversial.[10] It is impossible to say that the supposed connection between coronavirus infection and seasonal climate is cause-and-effect, despite of the fact that airborne transmission mechanism is dominant in the epidemiology of this disease.

The scientific and technological progress resulted in economic growth, development of science and technology, caused changes in living and working conditions of people. Progress provided an opportunity to work in comfortable conditions, to avoid severe climatic conditions. People spend a significant part of their lives indoors, where they live and work.[13] So, the transmission of virus from person to person most likely occurs indoors. Therefore, it can be assumed that the significance of indicators of outdoor air temperature, relative humidity, wind speed and other meteorological factors in activation of the epidemic process of respiratory infections will be insignificant.

Changing dynamics of incidence, seasonal growth of indicators are inherent in respiratory infections, which are caused by the most common pathogens.[14] Researchers call influenza viruses "winter viruses", and enteroviruses – "summer viruses", because the increasing incidence is observed in winter and summer, respectively.[15,16] The reasons for the above are different level of virus resistance to meteorological factors, as well as the competitive nature of interaction of viruses among themselves.[6]

At the same time, the state of local immunity of human respiratory tracts changes under the influence of natural factors. First of all, these factors include temperature and air humidity. Dry air contributes to the reduction of barrier function of the cells of mucous membranes of the respiratory tract, causes damage to the epithelium.[17] Short winter light days, vitamin D deficiency, low humidity and air temperature also cause disorders of the immune system of mucous membranes of the respiratory tract.[18]

Taking into account the research results obtained, we came to the conclusion that meteorological factors in the conditions of Ukraine have little influence on the rate of spread of COVID-19. This influence cannot be called strong, since the value of multiple correlation coefficients was within those limits, which are considered moderate in terms of influence. The above is confirmed by the values of R determination coefficients, which showed that only every fourth case of the disease of coronavirus infection COVID-19 can be considered related to the influence of meteorological factors.

Similar results were obtained by scientists from China, Italy and other countries. They established weak and moderately strong correlations between air temperature and the frequency of registration of COVID-19 cases.[19,20] Heat, high or low humidity and sunlight facilitate the destruction of coronavirus.[21]

We also found a moderate inverse correlation between the frequency of registration of COVID-19 cases and air temperature indicators. However, the above only partially confirms the well-known epidemiological hypothesis that low temperature of the environment contributes to the increase in incidence of acute respiratory viral infections, since the correlation coefficients calculated by us were not statistically significant.

Another generally accepted epidemiological hypothesis states that the higher air humidity, the lower ability of viruses to transmit and survive. The results of scientific research on the influence of relative humidity indicators on the dynamics of COVID-19 incidence are contradictory and ambiguous. Some scientists indicatethe negative impact of high air humidity on the viability of coronavirus, while others testify to the opposite in their publications.[22-25] We established direct moderate correlations between the

frequency of registration of COVID-19 cases and indicators of relative air humidity (p>0.05).

As for the correlation between the frequency of registration of COVID-19 cases and wind speed, according to the results of our study, no statistically significant relationship between the incidence and this factor was found (p>0.05). At the same time, there are scientific data on both negative and positive effects of wind speed on the spread of coronavirus infection.[24,25]

Air pressure on the planet can vary widely. It is common knowledge that air pressure greater than 760 mm Hg is considered increased, less - reduced. We found direct weak and moderate correlations between the incidence and atmospheric pressure parameters (p>0.05). Similar results were also obtained by other researchers.[26]

Conclusions:

The issue of correlations between the dynamics of COVID-19 incidence and indicators of meteorological factors is complex, controversial and not yet fully studied by scientists.

In the conditions of Ukraine, the studied meteorological factors (air temperature, relative humidity, wind speed, atmospheric pressure) indirectly influenced the intensity of the epidemic process of COVID-19. However, the strength of this influence was either weak or moderate (p>0.05).

We believe that an effective additional measure to fight respiratory infections would be to strengthen control over heating, ventilation and air conditioning systems in rooms where people stay for a long time, since this equipment, in case of improper use, can contribute to the spread of pathogens of respiratory infections.

It should be noted that this study has some limitations that should be taken into account when interpreting the results, namely, the level of incidence of COVID-19 could be influenced by restrictive anti-epidemic measures to prevent the spread of COVID-19 coronavirus, which were carried out in Ukraine and vaccination of the population. Socio-demographic factors were also not taken into account in this paper.

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Conflict of interest

Authors declare that they have no conflict of interests

Data availability

Data will be available on request

Authors's contribution

Data gathering and idea owner of this study: *Alla P. Podavalenko, Nina G. Malysh*

Study design: *Olga V. Kuzmenko, Svitlana V. Kolomiets*

Data gathering: *Alla P. Podavalenko, Nina G. Malysh, Viktoriya I. Zadorozhna, Oksana M. Chemych*

Writing and submitting manuscript: *Alla P. Podavalenko, Nina G. Malysh, Olga V. Kuzmenko, Viktoriya I. Zadorozhna*

Editing and approval of final draft: *Nina G. Malysh*

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