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DO WEATHER CONDITIONS INFLUENCE COVID-19 EPIDEMIC PROCESS?

Abstract. *We studied the influence of weather conditions (air temperature, absolute and relative air humidity, atmospheric pressure, wind speed and geomagnetic activity) on the epidemic process of COVID-19 in Sumy that is a city in north-eastern Ukraine for the period 4.05.2020-22.03.2021. The study was carried out using nonparametric Kruskal-Wallis dispersive analysis. The obtained results show that all meteorological factors affect the COVID-19 incidence rate. The air temperature, absolute humidity and atmospheric pressure are the most important meteorological factors influencing COVID-19 epidemic process.*

Introduction There are a lot of scientific researches proving relationship between fluctuations in epidemic process of infectious diseases and changes in weather conditions. Thus, acute respiratory viral infections, viral hepatitis A and E, shigellosis, leptospirosis, tularemia, malaria and many other infectious diseases have a pronounced seasonality. Meteorological factors, such as temperature, humidity, atmospheric pressure can affect the intensity of the epidemic process directly or indirectly. In some cases, this may be due to changes in the survival of pathogens in the environment [1,2], in others - with fluctuations in the susceptibility of the organism to the pathogen as a result of changes in physiological responses of the human body in response to weather factors [3,4].

However, the fundamental cause of seasonal fluctuations in the epidemic process of infectious diseases is considered to be seasonal changes in human behavior, which entail changes in the activity of the transmission mechanism [5].

The role of meteorological factors in the transmission of COVID-19 has not yet been studied. Establishing relationships between them could provide a stronger scientific basis for predicting future changes in the epidemiological process of this infection.

The objective is to study the relationship between the incidence of COVID-19 and meteorological factors in Sumy that is a *city* in north-eastern Ukraine.

Materials and methods To analyze the epidemiological situation, the data of daily monitoring of COVID-19 morbidity of the Sumy Regional Laboratory Center of the Ministry of Health Care of Ukraine [6] and results of daily monitoring of temperature, relative humidity, atmospheric pressure and wind speed of the Ukrainian Hydrometeorological Center for the period from 4.05.2020 to 22.03.2021 were used. [7].

Preparation of indicators for analysis. The average daily temperature (t), wind speed (w), relative humidity (rh) and atmospheric pressure (ap) were calculated for a given three-hour measurement interval. Absolute humidity (h) was calculated using the Clapeyron - Clausius equation [8]. We evaluated the average geomagnetic activity during the day (g) that is the arithmetic mean of the quasi-logarithmic three-hour index (K-index) characterizing the change in geomagnetic activity at a particular observatory in three-hour time intervals, starting from 00 a.m. The K-index is expressed in points and takes values from 0 to 9. The K = 0 corresponds to a calm geomagnetic field, K = 9 - to a very strong geomagnetic field perturbation.

Construction of variation series. We focused on the problem how weather conditions affect the mechanism of transmission of SARS CoV-2 virus, as well as the interaction of the virus with the body during the period preceding clinical manifestations. In this regard, the incidence rates were correlated with the average values of air temperature, wind speed, relative and absolute humidity, atmospheric pressure and geomagnetic activity in the 14-day period before the onset of clinical symptoms (incubation period). When constructing statistical series, it was also taken into account the period from the moment of the patient's application for medical care to the moment of receiving the results of the examination and making the final diagnosis was on average 3 days. Therefore, the variation series were formed in such a way that the meteorological indicators "lagged" behind the incidence rate, and each incidence was corresponded to the average values of temperature, relative and absolute humidity, wind speed, geomagnetic activity, and atmospheric pressure in the period from the 17th to the 3rd day before the final diagnosis.

The observation period was from 4.05.2020 to 22.03.2021. The number of observations of each indicator included in research n =307.

Statistical data analysis. To choose the method of statistical data processing, we studied the nature of the distribution of variables in variation series using the Shapiro-Wilk method. Then, it was determined whether the incidence of COVID-19 varies depending on the meteorological factor magnitude. To do this, we used a nonparametric Kruskal-Wallis analysis. The meteorological factor was an independent variable, the daily number of cases of coronavirus infection was dependent (response) variable. The numerical series of meteorological factors were converted into a categorical series. A quartile (Q) was used as a grouping feature. Separately for each compared group (Q), the mean values of the indicator and the corresponding incidence of COVID-19 - the median and the values of the 1st (q_1) and 3rd (q_3) quartiles - were calculated (Table 1).

The null hypothesis of the Kruskal-Wallis analysis was tested, H_0: the groups have the same distribution of median morbidity values. Quantitative assessment of differences in the distribution of values was performed using the criterion χ-square at the level of significance $\alpha = 0.05$. If the calculated significance level p was less than the critical value of α, hypothesis H_0 was rejected in favor of alternative hypothesis H_1: each group has a different distribution of median values of the dependent variable, i.e. morbidity.

Statistical data processing and visual presentation of the study results were performed using a software package Stata (Version 14.0).

Table1

Characteristic of COVID-19 morbidity in Sumy depending on the level of meteorological factors

Group (Q)	Meteorological index, Me (q_1; q_3)	Median daily incidence of COVID-19, Me (q_1; q_3)
1. Average daily temperature (t, °C)		
1	-3.6(-6.4; -2.2)	53 (36;90)
2	0.5 (-0.4; 8.9)	157 (94; 243)
3	16.1(14.0; 19.7)	43 (2;150)
4	21.9(21.2; 23.6)	5 (1;21)
2. Absolute humidity (h, g/m^3)		
1	3.3(2.9;3.6)	57(38;111)
2	5.0(4.2;7.1)	144(78;218)
3	8.7(7.9;10.5)	52(8;143)
4	12.1(11.3;13.0)	3(1;8)
3. Relative humidity (rh, %)		
1	58(56;60)	47(10;121)
2	65(62;68)	4(0;36)
3	77(75;79)	68(34;133)
4	87(85;89)	100(48;218)
4.Atmospheric pressure (ap, Hg mm)		
1	743 (742; 744)	32 (1;71)
2	745 (744; 744)	7 (2;42)
3	748 (747; 748,3)	58 (32;153)
4	752 (750; 753)	149 (68;221)
5. Geomagnetic activity		
1	1.404 (1.331; 1.478)	15 (1;93)
2	1.563 (1.522; 1.602)	8 (2;49)
3	1.794 (1.729; 1.861)	66 (35;130)
4	2.313 (2.085; 2.443)	117 (58;185)
6. Velocity of wind (w, m/s)		
1	2.6 (2.55; 2.7)	6 (2;92)
2	3.2 (2.9; 3.3)	44 (3; 148)
3	3.7 (3.6; 4)	49 (0;104)
4	4.7 (4.4; 4.9)	81 (38;165)

Results The first case of COVID-19 in Sumy was registered on 30.03.2020. During the next period, which lasted until 5.08.2020, the incidence of COVID-19 was sporadic: it did not exceed 9 cases per day and was almost stable, the absolute value of 1% of its increase was 0.01 cases.

The epidemic growth in the incidence of COVID-19 in Sumy began on August 6, 2020 and lasted 114 days (Fig1). The incidence of COVID-19 fell the peak on November 26. 2020 (501 cases per day). This growth was gradual. The first rise in morbidity was observed in the period from 6.08.2020 to 14.10.2020, the number of patients with the COVID-19 in this period increased with an increase of 0.16 cases by 1%. In the period from 15.10.2020 to 3.11.2020, the incidence of COVID-19 decreased slightly, the absolute value of 1% reduction in incidence was 2.01 cases. This decline in the epidemiological process coincided with the intensification of quarantine measures in the city, in particular with the transfer of the educational process in educational institutions to distance technologies, increasing requirements for boarding passengers in transport, visiting cultural institutions, catering and others. Anti-epidemic measures to disintegrate the population were officially introduced on 12.10.2020 and lasted until 16.11.2020. The expected effect of these measures was to appear from 16.10.2020 and continue until 20.11-3.12.2020 (from taking into account the incubation and diagnostic periods). However, the decline in morbidity lasted only 18 days, instead of the expected 35-48 days. From November 4, 2020, 12 days before the end of the intensified quarantine measures, the number of cases of coronavirus infection began to increase again. This second stage of the increase in morbidity was almost 20 times more intense than the first - the absolute value of 1% increase in morbidity was equal to 3.13 cases against 0.16.

From January 8, 2021 to January 25, 2021, the city was again introduced enhanced quarantine measures, the effect of which, according to estimates, was to appear from January 14. 2021 to 10.02.2021. However, the incidence of COVID-19 began to decline long before that - from 27.11.2020, and this second period of declining morbidity was observed until 22.03.2021, i.e. until the end of our observation. The intensity of the second decline in morbidity slightly exceeded the intensity of the previous decrease - the absolute value of 1% reduction in morbidity was 2.48 vs. 2.01. It should be noted that this reduction in the incidence of COVID-19 occurred when the immune layer of the population (as of 27.11.2020) was 20,589 people, i.e. 8% of the total population of the city, which is not enough to stop the epidemic.

Thus, changes in the intensity of the COVID-19 epidemic process did not always coincide in time with the periods of expected effects from enhanced quarantine measures. Why this is happening, and whether such a course of the epidemic process COVID-19 is affected by meteorological factors - in order to answer these questions, a dispersion analysis of Kruskal-Wallis was conducted.

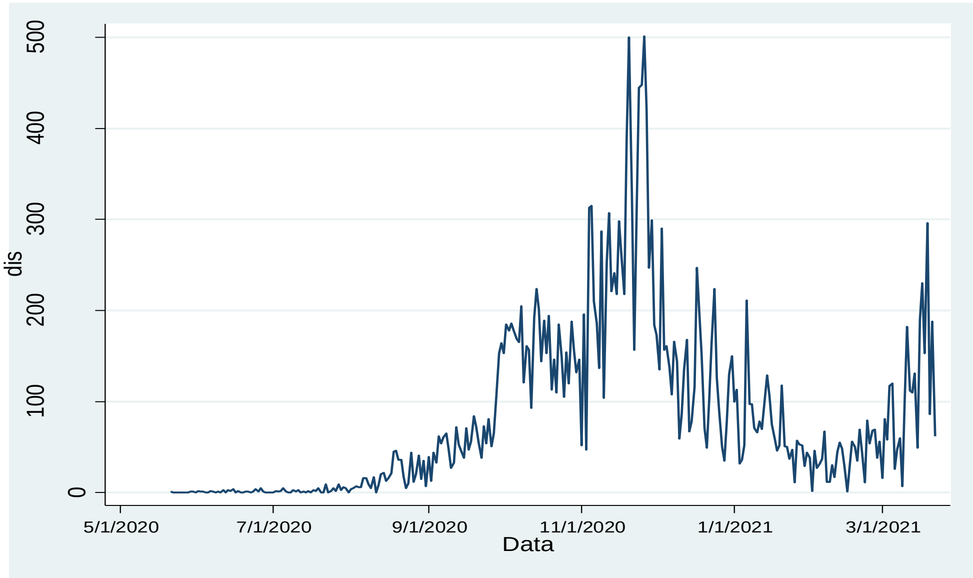

Fig. 1. **Dynamics of incidence of COVID-19 (dis) in Sumy in the period 21.05.2020-22.03.2021**

Kruskal-Wallis test. Kruskal-Wallis analysis of variance showed that the median values of the incidence of COVID-19 in the groups of factors influencing the incidence are statistically significantly different (Table 2). This means that the incidence of COVID-19 varies depending on the values of meteorological factors, and this pattern is pronounced, because p-value significantly exceeds the specified limits of significance.

Table 2

The results of testing the null hypothesis about the difference in the median values of the number of cases of COVID-19 in different groups of factors influencing the epidemic process COVID-19

Meteorological factors	χ^2 and degree of freedom (df)	p-value
t	106.219 (3 df)	0,0001
h	124.672 (3 df)	0,0001
rh	73.578 (3df)	0,0001
ap	184.426 (3df)	0,0001
w	20.756 (3df)	0,0001
g	63.857 (3df)	0,0001

Since the statistics of the Kruskal-Wallis test do not take into account the absolute values of indicators, but their average ranks, and the number of observations of different meteorological indicators is the same, it is possible to compare statistics of this test for different meteorological factors to compare their impact on COVID-19. As can be seen from table 2, the greatest influence on the epidemiological process of CIVID-19 have the average air temperature (χ^2 = 106.219), absolute humidity (χ^2 = 124.672) and atmospheric pressure (χ^2 = 184.426). Other factors (relative humidity, geomagnetic activity, and air velocity) appear to have less of an effect on the spread of the virus in the population.

Conclusion The results of the Kruskal-Wallis analysis of variance indicate the relationship between the incidence of COVID-19 and weather conditions in Sumy (Ukraine). The air temperature, absolute humidity and atmospheric pressure have a greatest influence on the COVID-19 morbidity. Other meteorological factors that are relative humidity, geomagnetic activity and wind speed have less importance in the spread of COVID-19 among the city's population.

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