Original article:

Conditions for the expansion of COVID-19 in the regions of the Northern part of Ukraine Conditions for the expansion of COVID-19 in Ukraine

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Abstract:

Background: The intensity of the COVID-19 epidemic process in the administrative territories of Ukraine differs. Risk factors for the spread of this infection have not been sufficiently studied, which prevents the development of adequate preventive and anti-epidemic measures at the local level. ***Objectives:*** Conduct an epidemiological analysis of the incidence of COVID-19 in the regions of the Northern part of Ukraine and identify the leading risk factors for spread. ***Material and Methods:*** The incidence of COVID-19 was analyzed for 73 weeks and 28 predictors. Fourier's spectral analysis, Feature Selection and Variable Filtering method of the Data mining module, Irwin's method, integral visual coefficient was used. ***Results.*** There were two rises in the incidence of COVID-19, the cyclicity was 18 - 24 weeks. The conditions for the spread of COVID-19 cases in the regions of the Northern part have been established, namely: the number of people and the elderly in the family, demographic and migration processes. Violation of regime-restrictive measures leads to abnormal rises in morbidity. ***Conclusions.*** The epidemic situation in the Northern part remains volatile, as there are conditions for the spread of COVID-19 that cannot be eliminated, as well as some, that need to be developed (tourism, demographic processes, financing, etc.). Therefore, compliance with restrictive measures and vaccination of the population of the region remain the main preventive measures .

Keywords: COVID-19; incidence dynamics; social and economic factors.

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Introduction: Coronary heart disease in 2019 (COVID-19), caused by SARS-CoV-2, has spread rapidly from sporadic cases, epidemics at the regional level to the pandemic officially recognized by the World Health Organization (WHO) on March 11, 2020[1]. Currently, in most countries, there are new epidemic rises in COVID-19 due to mutations in the virus[2, 3].

The spread of COVID-19 both within and outside the country is associated with migration, tourism, religious rites, etc.[4-7] It is reported that one patient

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with COVID-19 can infect 3-4 people in the cell[8], and human-to-human transmission of the virus occurs mainly among family members, including relatives and friends who are in close contact with the patient[9, 10]. At the same time, the spread of SARS-CoV-2 virus depends on the nature and speed of radical restrictive measures (observation, isolation, quarantine) at the national, regional and local levels, the use of personal protective equipment and social responsibility[11-14]. Timely and high-quality measures implemented in some countries at the beginning of the pandemic saved many lives and slowed the spread of COVID-19. But each administrative territory differs in the organizational capacity of restrictive measures, the level of training of health workers, culture and mentality of the population[15, 16].

In Ukraine, from March to April 2020, a strict quarantine regime and the use of personal protective equipment were introduced in all administrative territories. Despite the measures taken, the first fatalities were registered in March 2020. In a short time, COVID-19 spread throughout the country, leading to social and economic destabilization. On 25.11. In 2021, 3400340 confirmed cases were detected in Ukraine, and 84 149 people died. COVID-19 is expected to rise again in September, presumably due to the spread of new variants of SARS-CoV-2. At the same time, persistent social, natural and economic factors in a particular locality may contribute to the spread of these new strains of SARS-CoV-2 virus. Currently, the distribution of COVID-19 in the administrative territories of the country is uneven, which has led to a more detailed study of this issue in the regions of the Northern part of Ukraine, which differ slightly in socio-economic development.

Objectives: Conduct an epidemiological analysis of the incidence of COVID-19 in the regions of the Northern part (Poltava, Sumy, Kharkiv and Chernihiv regions)of Ukraine and identify the leading risk factors for spread.

Materials and research methods: In this study, we used data form the official site of, the Center for Public Health MH Ukraine[17], National Health Service of Ukraine (NHSU)[18], The State Statistics Service of Ukraine[19].

This study was conducted in the Northern part of Ukraine, which according to NHSU classification includes Poltava, Sumy, Kharkiv and Chernihiv regions for the period February 29, 2020 – July 23, 2021 (73 weeks). In general, the part is characterized by the specifics of historical and ethnic development and natural and climatic features.

The administrative territories of this part have slight differences in terms of migration processes, density, conditions and quality of life. Therefore, to determine the major factors that can contribute to the spread of infections via aspiration – aerosol transmission mechanism, we used 28 predictors (table 1).

Table 1 – Characteristics of the regions of the Northern part of Ukraine by social, economic and natural factors

Predictors	Poltava region	Sumy region	Kharkiv region	Chernihiv region
Women (persons)	742254	576668	1417308	535715
Men (persons)	636886	489387	1225517	447037
Age group 0-19 years (persons)	252464	182702	480851	172490
Age group 20-39 years (persons)	377327	290760	762702	264581
Age group 40-59 years (persons)	407963	315575	761171	276818
Age group 60 years and older (persons)	340816	277018	638101	268863
Average life expectancy (years)	71.9	72.43	71.84	70.68
Integral second index Assessment and partial human development	3.9103	3.7475	4.0564	3.7242
Integral index is an indicator of the natural environment	0.474	0.389	0.389	0.529
Block "population reproduction" of the integrated index of regional human development	0.7725	0.6957	0.6683	0.6895
Average household size (number of persons in a family)	2.36	2.43	2.43	2.30
Households with woman aged 30-58 years (%)	24.2	24.3	23.6	22.4
Households with people aged 30-59 years	22.0	21.5	23.4	21.5
Households with woman at the age of 59 years and older (%)	16.9	17.6	16.4	12.0
Households with people aged 60 and older (%)	8.8	9.3	12.0	9.4
Number of households (thousands)	586.50	439.0	1109.0	430.1
Households consisting of 3 persons (%)	24.3	34.00	28.0	23.1

Predictors	Poltava region	Sumy region	Kharkiv region	Chernihiv region
Households consisting of 4 people (%)	8.5	6.60	13.3	11.40
Households of 5 or more persons (%)	6.2	5.8	3.1	2.6
Households consisting people who have a job (%)	64.4	61.6	75.8	65.40
Total cash expenditures per month on average per household (UAH)	6775.25	7591.01	7754.70	8793.90
Total monthly income expenditures per month per household (UAH)	7773.35	8541.64	8259.98	9995.88
Total income per month per household (UAH)	10744.43	10238.66	10140.05	10883.33
Natural population growth (%)	-9.9	-10.2	-8.4	-12.5
Migration ("-" left, "+" arrived) (number of people)	+ 411	-2250	+ 5436	-1996
Population density (persons / km ^{2})	48.25	44.82	84.62	31.11
Migration rate per 10,000 population all flows (internal and external)	+3.8	-17.2	+10.7	-10.2
Coefficient of migration movement per 10,000 population interstate (external)	+4.8	-0.1	+2.7	-0.4

Analyzed the dynamics of multi-week morbidity (per 100 thousand population) on COVID-19. Verification of the normality of the distribution of indicators was performed using the Kolmagorov-Smirnov test. General time series theory and Fourier spectral analysis were used to determine the cyclicity of morbidity in the dynamics. The Feature Selection and Variable Filtering method of the Data mining module was used to assess the significance of predictors. Abnormal levels of time series (emissions, sharp declines or increases) were detected using the Irwin method[20].

Comprehensive evaluation of multi-week morbidity rates of COVID-19 was conducted with the use of integral indicators (II). Algorithm of calculating II was named by the authors as "the sum busy places"[21]. For the mean values of multi-week morbidity (M), standart deviation (σ) and multi-week growth rate (T), the rank (from minimum to maximum) for the period under study was determined. The obtained integral indices allowed calculating the integral visual coefficient (IVC, %) by the formula:

$$IVC = \left(1 - \frac{S_x - S_p}{S_x - S_y}\right) \times 100\%,$$

where Sx is the worst sum of places; Sp is the sum of the places of a specific object; Sy is the best sum of places.

The obtained IVC is an integrated assessment of the multi-week incidence rate, taking into account the main statistical characteristics that describe it. In our case, the value of IVC ∈ [0; 100 %] (Sx=12, Sy=3, Sp ∈ [3;12]).

Statistical calculations were performed using the computer program Statistica 10.0.

Ethical clearence: Not required

Results and discussion: Analysis of the multi-week incidence dynamics on COVID-19, taking into account the characteristics of the time series, showed two epidemic rises from October 2020 to January 2021 (peak rise in December) and from March to May 2021 (peak rise in April) (Fig. 1).

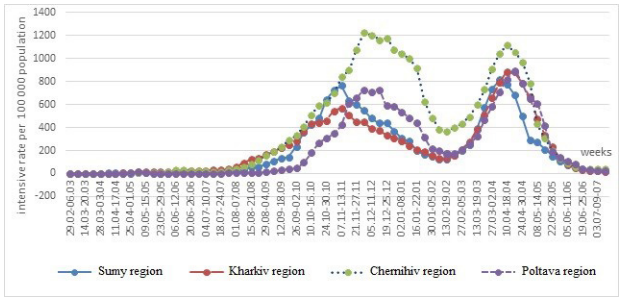

Figure 1. Dynamics of incidence of COVID-19 in the regions of the Northern part of Ukraine for 29.02.2020 – 23.07.2021

The regions of the Northern part of Ukraine joined the COVID-19 epidemic process almost simultaneously and had two epidemic outbreaks in 73 weeks, which may be related to migration processes, activation of the aerosol-aspiration mechanism of pathogen transmission. At the same time, the Kharkiv region showed an abnormal increase in the incidence of COVID-19 in the period from 15.05.2021 to 21.05.2021. It should be noted that the incidence increased mainly in Kharkiv, which is the educational and administrative center of the region. The reason for the complication of the epidemic situation with COVID-19 was the holding of cultural events in the city during the first ten days of May 2021, which contributed to the activation of the mechanism of transmission of COVID-19 and after 6-14 days of epidemic rise.

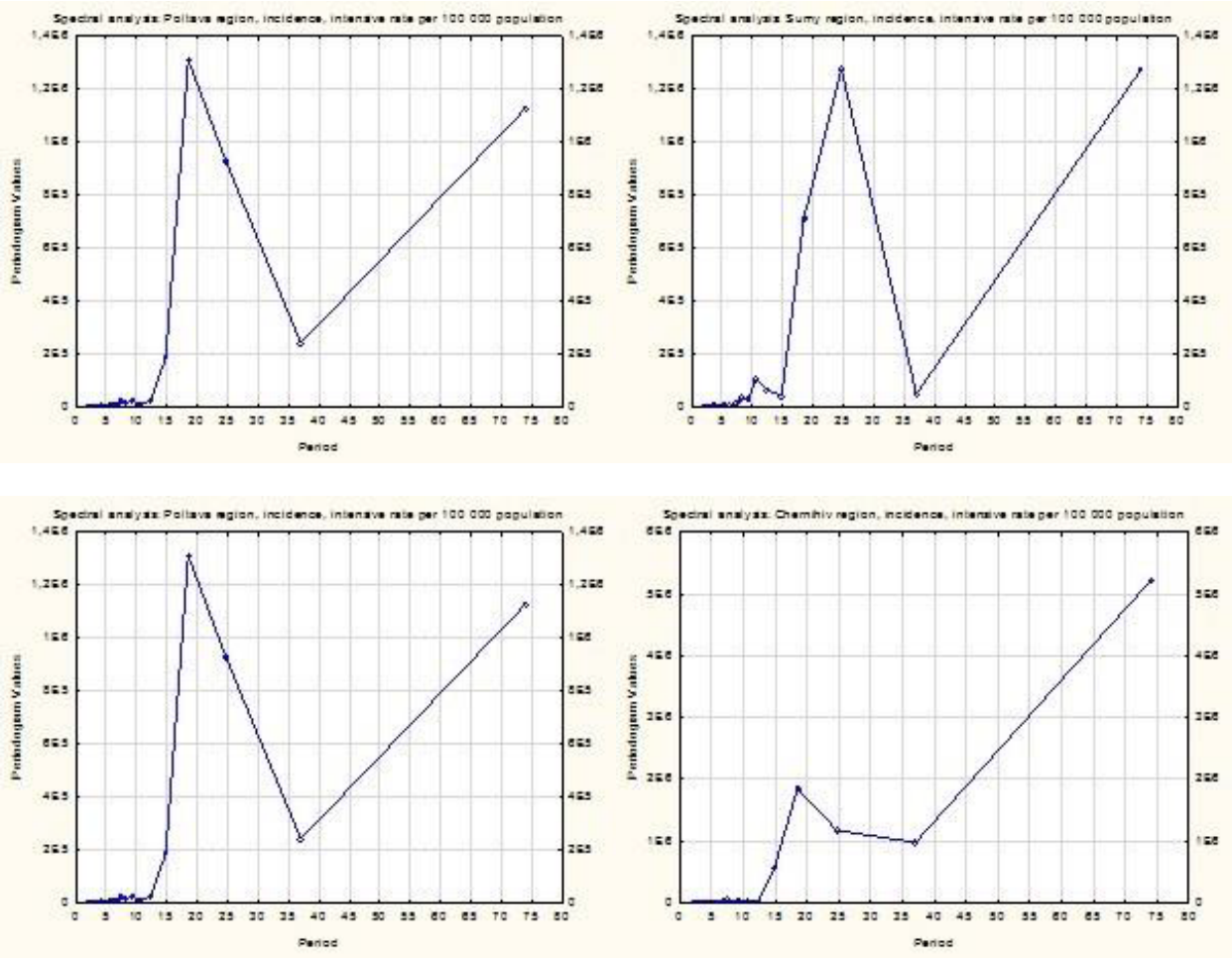

Figure 2. Periodogram of multi-week incidence of COVID-19 in the regions of the Northern part of Ukraine for 29.02.2020 – 23.07.2021

To identify the periodicity of the data, a Fourier spectral analysis was performed, which showed the presence of a seasonal component in time series with a period of 24 weeks (Sumy and Kharkiv regions) and 18 weeks (Poltava and Chernihiv regions) (Fig. 2). It indicates different rates of spread of this infection and may depend on the organization of anti-epidemic measures. But this question needs further research.

For the determination of the most affected area of the Northern part for COVID-19, IVC was used, which combined statistical indicators (M, σ, T) and acted as a generalized indicator (expressed as a percentage), which characterizes the average incidence over a multi-week period for territories studied. It was found that IVC in the Chernihiv region (88.89%) was significantly higher than in Poltava (55.56%), Kharkiv (44.44%) and Sumy (11.11%) regions (table 2).

Table 2 – Standard and summarized the incidence of COVID-19 in the regions of the Northern part of Ukraine on 29.02.2020 – 07.23.2021

Regions	Average SP		σ-		Average growth rate		The sum of ranks	Integral VC	
	M	rank M	σ	rank	T	rank T		IVC, %	rank IVC
Poltava	224.91	3	270.46	3	108.21	2	8	55.56	3
Sumy	214.47	1	245.50	2	103.22	1	4	11.11	1
Kharkiv	219.19	2	236.82	1	109.79	4	7	44.44	2
Chernihiv	384.61	4	413.26	4	109.035	3	11	88.89	4

Among the regions of the northern region, Chernihiv region had the highest incidence rates of COVID-19, which is confirmed by the ranking of regions by IVC (Table 2). It can be assumed that the effectiveness of preventive and anti-epidemic measures in this area was the lowest.

Using the Feature Selection and Variable Filtering method of the Data Mining Module, it was statistically proven that out of 28 predictors, 7 (25%) indicators are most likely to affect the incidence of COVID-19 in the northern region of Ukraine (table 3).

Table 3 – Social, economic and natural conditions that may contribute to the development of the COVID-19 epidemic process in the Northern part of Ukraine

Predictors	F-value	p-value
Age group 60 years and older (persons)	183.4	0.05
Integral index is an indicator of the natural environment	176.8	0.05
Average household size (number of persons in a family)	176.8	0.05
Distribution of households by age (%), women aged 59 and older	542982.1	0.0009
Total cash expenditures per month on average per household (UAH)	176.8	0.05
Total income per month per household (UAH)	176.8	0.05
Natural population growth (%)	183.4	0.05

The conditions established by us under which the epidemic situation with COVID-19 in the Northern part of Ukraine can be complicated confirm the conducted researches in other territories. Thus, more often the infection occurs in close communication with the patient, in families[7-9]. The most vulnerable risk group was the elderly[22, 23], which was confirmed by us. It has been proven that natural factors influence the spread of SARS-CoV-2 virus[24, 25], so the environmental indicator we studied confirmed this fact. Demographic processes are an important social condition that can contribute to the spread of infectious diseases[26, 27]. Thus, natural population growth (births and deaths) is included in the list of predictors on which the incidence of COVID-19 depends. International migration processes, including those related to tourism and family finances, are the main external driving force of the COVID-19 epidemic process[28-30]. International and domestic migration processes are not included in our list, but this important risk factor, which depends on the income and expenses, cannot be ruled out, as confirmed by our research.

In the regions of the Northern part of Ukraine implementation of the preventive and anti-epidemic measures are flawed, the low level of control in Chernihiv and Kharkiv regions has led to significant growth and abnormal emissions.

The epidemic situation with COVID-19 in the Northern region of Ukraine remains volatile, as there are social, natural and economic conditions affecting the spread of this infection, that cannot be urgently eliminated, and some need to be developed (tourism, demographics, finance, etc.). Therefore, the main most effective and cost-effective way to prevent the spread of COVID-19 is to vaccinate the entire population, which was introduced in Ukraine in early 2021. Along with specific prevention, it is necessary to control anti-epidemic measures in households, paying attention to large families and the elderly in them.

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Ethical approval: The work was carried out in accordance with the Code of Ethics of the World Medical Association (Helsinki Declaration). The work was approved by the Commission on Bioethics of the Kharkiv Medical Academy of Postgraduate Education, protocol №3 10/12/2022.

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Editing and approval of final draft: All authors

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