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COUNTRIES' VULNERABILITY TO COVID-19 DEPENDING ON THE HEALTH BEHAVIOUR PATTERNS OF THE POPULATION

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Abstract: *The article analyses the factors determining the level of vulnerability of regions to the influence of pandemic threats. Statistical indicators for 2021-2022 regarding the course of the COVID-19 pandemic in Ukraine were taken for analysis, namely the number of infected persons and the number of deaths per thousand of the population. Indicators in the field of healthy behaviour of the population were adopted as variable determinants (namely, the amount of healthy food consumption, sugar consumption, the number of people engaged in physical culture and sports, the number of smoking people and the proportion of obese people), for which a quantitative statistical base is available exhaustively for all 24 regions of the country. The study aims to confirm or refute the hypothesis regarding the existence of a connection between the regional behavioural patterns of the population in the health field and the region's vulnerability to the impact of the COVID-19 pandemic. For the analysis, discriminant and canonical analyses were used, which were carried out in the STATISTICA software environment. Empirical indicators made it possible to confirm the hypothesis regarding a connection between regional behavioural patterns and the region's level in terms of the number of deaths from COVID-19. The hypothesis about a possible dependence between behavioural patterns and the number of infected with COVID-19 was not confirmed – the discrimination model was statistically insignificant. This suggests that establishing dependencies requires more input parameters to describe the model. It was determined that the consumption of healthy foods (milk, berries, fish) influences the mortality rate from COVID-19 (high, medium or low). Also, indicators with a high degree of influence include the number of people engaged in physical culture and sports, and the proportion of people with obesity. The results of the study will be useful in the development of regional and national strategies to promote the formation of the resilience of territories to pandemic threats and in the selection of tools for working with the population within the framework of informational and educational campaigns for prevention of severe courses of diseases caused by epidemic factors.*
Keywords: medical and social security of the population, pandemic, regional system stability, statistics of COVID-19, threats to public health.

JEL Classification: C12, I12, O18

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Introduction. The transformational processes in the social and economic, medical, financial and budgetary, institutional and political spheres of society caused in particular by the COVID-19 pandemic in 2020-2022 have various effects on the stability of countries and regions. In the context of COVID-19, the need to reorient the population's medical and social welfare models to face the challenges of the new pandemic more effectively has become urgent. For society, the introduction of such drastic and rapid changes is a challenging phenomenon. Innovations affect the sphere of life of individual people and the activities of business structures. Countries have experienced sharp economic issues (decrease in GDP, difficulties for local business (according to How COVID-19 is affecting companies around the world, 2021). One-quarter of companies saw their sales drop by around 50% due to COVID-19. Overall global sales fell by 27% between October 2020 and January 2021. There was a drop in investment attractiveness (according to data from the UN Conference on Trade and Development (Cristea, 2021). The volume of global foreign investment experienced a serious decline in 2020, with a decrease of 42%; in natural terms. The same level of investment was last observed in 1990, and is 30% lower than the 2008-2009 level during the global financial crisis. There were social challenges: living deterioration (before the pandemic, the largest number of Europeans rated their quality of life at 5 to 7 on the 0 to 10 scale; in the 2021 post-pandemic, more respondents rated their quality of life at 3 to 5 (Quality of life, 2021). We saw an increasing share of those who had rated their quality of life at the too low level – from 7% to 24% of Europeans. For the quality of medical and social population welfare (Moynihan et al., 2020), as a result of a systematic review of information sources, data from 81 sources on changes were summarized. Provision of medical services in the pre-pandemic and post-pandemic periods, of the 143 analysed cases, estimated an over 95% decrease of acquired aid. Additionally, the interquartile range was from -50.5% to -19.8% (if considered without outliers, certain of which, but to a very small extent, are positive values). Social activities fell as well (Giuntella et al., 2021). During the pandemic, the average number of steps taken by respondents per day decreased from 10,000 pre-pandemic to 4,600. Communication time decreased more than by half. On the other hand, the time before gadget screens has risen significantly. Other undesirable consequences occurred too (Quality of life, 2021).

Considering the real potential of territorial units to counter health challenges, it is possible to move to an effective (according to the possibilities) reactive strategy of transformation of national and regional policies in health. It becomes possible to develop an approach to minimize gaps for the planned changes in the system of providing medical care by the levels of integral potential to solve challenges in the field of health and, accordingly, increase the readiness of all stakeholders of this process to work in the conditions of transformations (Zolkover and Renkas, 2020). Assessing the integrated potential components to face challenges is particularly important, one of the essentials in which are the population's behavioural health patterns. An important issue is the dynamic measurement of each country's progress in implementing the Global Sustainable Development Goals adopted at the UN Summit. It can become an element of international cooperation in resisting global security and epidemiological threats.

Literature Review. Welfens (2020) argues that integrating the health sector into the macroeconomy is an important task. It emphasizes the role of health system quality and health insurance as indicators of endogenous time horizons and economic well-being, respectively. The potential of countries and regions in the health field was determined and calculated using different approaches. The analysis of scientific works made it possible to systematize the sources of author's identifying the potential components and interpreting the results. Lyeonov et al. (2021) used the centre of mass estimation method to model a country health profile. The authors identified relevant determinants characterizing society's social, economic, medical and behavioural models. Consequently, a sequence of health profiles was formed as a four-pole barycentric model of balanced composite dimensions (Klapkiv et al., 2020). It evaluated the competitiveness of three countries based on a comparative analysis of the indicator of the development of medical institutions. The methodological basis of the analysis was the ranking and generalization method. Markowicz and Rudawska (2021) developed conceptual frameworks for evaluating the effectiveness of national healthcare systems to combat of the SARS-CoV-2 pandemic. To achieve the research goal, scientists use a taxonomic indicator of development and conduct a correlation analysis. The components the authors propose to measure the health system performance include demographic, epidemiological, health-related, financial, infra-developmental and indicator-structural. They are described using 18 indicators. This approach can help track the performance of the healthcare system during pandemics. Sarabia et al. (2021) combined in one study such indicators as the Global Competitive Index, Health Systems in Transition and the System of Health Accounts and variables related to the environment of each region (competitiveness, security, infrastructure, population, healthcare system). They analysed the potential of 28 countries of the European Union, including Great Britain, to confront COVID-19. Descriptive analysis and binary logistic model (logit) became the methodical basis.

DonHee (2016) evaluated the efficiency of healthcare systems for 28 countries using the data envelopment analysis (DEA). Two output variables were used: life expectancy at birth and infant mortality rate. The following variables were selected as input variables: the number of doctors, hospital beds, radiation therapy devices per 1 million population, and total healthcare costs as a percentage of the country's GDP. Coccia (2022) proposed two indices for measuring effectiveness against pandemics: resilience (reducing the negative impact of a pandemic) and preventiveness (the ability to prevent the spread of a pandemic and restore the local socio-economic system). Alfano and Ercolano (2022) provide numerical justifications for their hypothesis that the ability to overcome pandemics is mainly determined by the quality of public administration, empirically examining the relationship between the effectiveness of quarantine measures and World Governance Indicators. Pereira and Marques (2022) suggest using a composite indicator to measure the sustainability of the national healthcare system based on 13 UN Sustainable Development Goals. The authors' calculations from 2016 to 2020 showed that less 28% of the World Health Organization member countries had effective national health systems. At the same time, the European region turned out to be the absolute leader in terms of the composite indicator level and evolution of individual components. Yelnikova and Kwilinski (2020) mainly focus their research on assessing the current state of implementation of public investment projects in the healthcare field. The authors' recommendations aim to improve Ukrainian society potential to face pandemic challenges. Koibichuk et al. (2021) define the essence of health as an economical category and its components. The authors provide a classification of quantitative determinants of health according to the content of their functioning, which makes it possible to determine the level of health of the territory. Shipko et al. (2020) include several indicators in the indicator of macroeconomic stability and calculate it using different methods. In Harust et al. (2019), different combinations of marketing, political and institutional determinants affecting the country's economic security level are highlighted. The 2SLS method was used to check the effectiveness of the calculations. Samoilikova et al. (2021) base their research on the analysis and assessment of cause-and-effect relationships and directions of mutual influence of individual indicators of tax incentives, innovative spending on macro-indicators. Chowdhury (2021) estimates the macroeconomic effects of changes in tax revenues and government expenditures that affect the national gross domestic product. They argue that economic growth depends on the real business cycle, in which fiscal policy plays a central role. The world scientific community has developed many economic and mathematical models for analysing the multidirectional impact of COVID-19 on different aspects of society. Modelling of factors that can affect the reduction of vulnerability of territories to the influence of epidemiological threats is a topical issue of research by scientists in the field of public health (Vasilyeva et al., 2020).

Methodology and research methods. The article aims to investigate the factors that determine the resilience of regional systems to the COVID-19 impact. Some studies on this issue are already available in scientific schools in different countries. In Assefa et al. (2022), the authors substantiated that the negative impact of pandemics, in particular COVID-19, is best neutralized by governments. They adequately respond to public health emergencies, timely update the national strategy, increase the health care potential, minimize national fragmentation in different regions, and overcome the internal socio-economic inequality. Lenton et al. (2022) analysed the resistance of over 150 countries to COVID-19. Among major factors determining the country's success in confronting pandemic challenges, the authors name the level of trust in authorities. Thus, the analysis of scientists' work makes us form a hypothesis regarding the existence of other important factors that determine society's resistance to the COVID-19 impact. To determine the factors in this factor set, a preliminary assessment of explicit and possible latent independent variables affecting the resulting indicators was carried out. In our case, the resulting indicators are two parameters – the number of COVID-19 cases per 1,000 population and the number of COVID-19 per 1,000 population. As part of the study, a hypothesis was put forward regarding a connection between the population's regional behavioural patterns in health care and ability challenges of territorial units. The discriminant analysis method was used to determine the significance of individual indicators of population behavioural patterns in Ukraine. It was performed in the STATISTICA 10 software environment.

Results. To study the impact of the population healthy behaviour patterns on the COVID-19 pandemic, a statistical research base was formed via indicators of 24 Ukrainian regions. The analysis of the regional vulnerability will be carried out in two stages. Firstly, dependence of COVID-19 cases will be examined. Secondly, medical aid for such cases will be studied. Indicators of healthy behaviour in the region include: consumption of milk and dairy products; consumption of fruits, berries and grapes; consumption of fish and fish products; sugar consumption; number of people engaged in physical culture and sports; number of people who smoke; number of obese population (Table 1).

Table 1. Data of population behavioural patterns of Ukrainian regions against health

Region	Consumption of milk and dairy products, person per year, kg	Consumption of fruits, berries and grapes, person per year, kg	Consumption of fish and fishery products, person per year, kg	Sugar consumption, person per year, kg	Number of people engaged in physical culture and sports, people per 1,000 people	Number of smokers, persons per 1,000 people	Share of the population of over 18 age years with obesity, %
Vinnytsia	198.9	63.5	15.4	30.6	201.2	155.5	15.2
Volyn	206.9	49.3	12.5	31.6	141.7	146.1	16.5
Dnipropetrovsk	197.5	68.1	13	28.5	184.5	218	16.4
Donetsk	170.4	45.6	12.9	28.5	53	225.7	15.6
Zhytomyr	209	54.6	15	26.8	80.3	166	18.2
Zakarpattia	230.8	55.8	8	29.4	149.2	190.4	17.9
Zaporizhzhia	171.4	53.8	13.6	28.8	137.8	221.4	16.8
Ivano-Frankivsk	276.7	54.7	9	32.5	72.1	133.1	14.4
Kyiv	211.2	81.4	16.8	24	114.1	106.9	19.4
Kirovohrad	213.8	53.5	13.5	32.7	60.8	199.3	18.9
Luhansk	147.4	45.3	9	29	22.8	81	16.4
Lviv	215.3	58.5	9.4	30.4	124.5	150.9	12.8
Mykolaiv	204.3	62.1	13.4	29.4	117.1	197.3	14
Odesa	185.8	64.3	16	27	280.9	167.2	16
Poltava	201.5	54.7	12	28.5	87.5	229.2	20.9
Rivne	191.7	44.8	10.5	28.3	84	160.8	12.5
Sumy	182.4	45.8	9.5	31	148.9	121.6	14.9
Ternopil	245.1	53.7	9.6	26.1	41.5	162.8	16.5
Kharkiv	203.9	55.6	9.2	25	111.3	176.7	14.8
Kherson	183.9	52.1	14	31.6	211.8	184.3	22.1
Khmelnytskyi	208.2	64.4	10.5	30	81.2	142.1	17.2
Cherkasy	216.6	62.7	13.9	35	93.1	185.5	19
Chernivtsi	226.6	70.1	10.5	31.2	116.1	165.2	18
Chernihiv	210.5	52.9	12.7	39.5	66.3	185.6	24.6

Sources: developed by the author on the basis of (Ukrstat, 2020; Ukrstat, 2018; Ukrstat, 2021).

At the following stage, data in Table 1 should be checked for multicollinearity. According to calculations (Table 2), the correlation value for all pair variables does not exceed 0.7, indicating the absence of multicollinearity. Therefore, all seven variables could be used for further analysis. The number of COVID-19 cases in for a thousand people is chosen as the target variable. Quantitative values of this indicator by region are presented in Figure 1. This quantitative indicator should be reformatted into a categorical one to divide the regions into groups based on the indicator's value of the number of infected people, which will be the target in the subsequent discriminant analysis. Regions with a value of this indicator below 7 are classified as a group with a low infection rate. Regions with a value 7-9 belong to the group with average infection rates. Regions with a value above 9 belong to the group with a high COVID-19 infection rate.

According to the discriminant analysis results, the Wilks Lambda value is 0.756. This value is closer to 1, indicating a low discrimination quality. In addition, the result of the discriminant analysis cannot be considered statistically significant, since the value of the p-criterion is significantly higher than 0.05 (0.98).

Discriminant analysis with the same set of independent variables will be performed. Still, the grouping will be defined via number of COVID-19 deaths (Figure 2). In this case, the value of Wilks' Lambda is 0.389, indicating a much higher distribution quality into groups (Table 3).

Table 2. The results of checking the input data for multicollinearity

Variables	Consumption of milk and dairy products	Consumption of fruits, berries, grapes	Consumption of fish and fish products	Sugar consumption	Number of people engaged in physical culture and sports	Number of people who smoke	Share of population with obesity
Consumption of milk and dairy products	1	0.297	-0.252	0.162	-0.169	-0.036	0.007
Consumption of fruits, berries, grapes	0.297	1	0.439	-0.211	0.334	-0.053	0.135
Consumption of fish and fish products	-0.252	0.439	1	-0.058	0.405	0.22	0.336
Sugar consumption	0.162	-0.211	-0.058	1	-0.108	0.104	0.419
Number of people engaged in physical culture and sports	-0.169	0.334	0.405	-0.108	1	0.125	-0.054
Number of people who smoke	-0.036	-0.053	0.22	0.104	0.125	1	0.231
Share of population with obesity	0.007	0.135	0.336	0.419	-0.054	0.231	1

Sources: developed by the author.

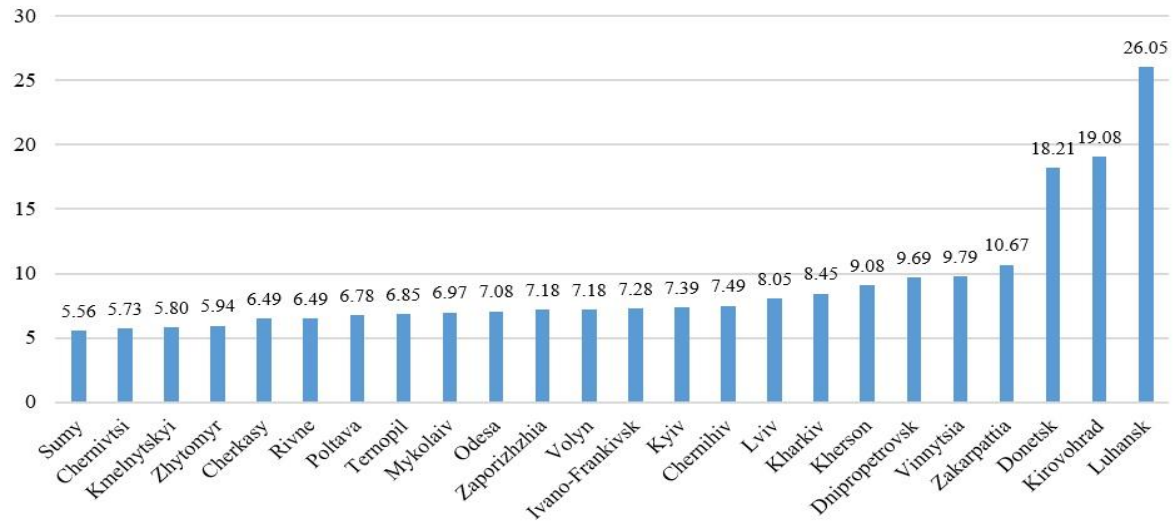

Figure 1. Number of people infected with COVID-19 per 1,000 persons in Ukraine (as of 18 September 2022)

Sources: developed by the author on the basis of (Minfin, 2023).

The value of Wilks Lambda varies slightly for all variables. It ranges from 0.392 to 0.529, which indicates a lower desirability of having the Sugar Consumption variable in the model. The most desirable is the presence of the variable «Consumption of milk and dairy products» in the discrimination procedure. The same findings confirm the value of partial Lambda, which ranges from 0.736 (for the variable «Consumption of milk and its products») to 0.993 (for the variable «Consumption of sugar»). The analysis of the values of Tolerance shows that the variables «Consumption of milk and its products», «Consumption of fruits, berries, grapes» and «Consumption of fish and fish products» are most related to other variables. The R^2 value also confirms this finding in the last column. It is the highest for these variables. Auxiliary table of calculated Mahalanobis distances (Table 4) is given below. Low and High groups have the most significant distance from each other. While the Low and Medium, Medium and High pairs are closer. It causes a certain probability of misclassification of observations between these groups.

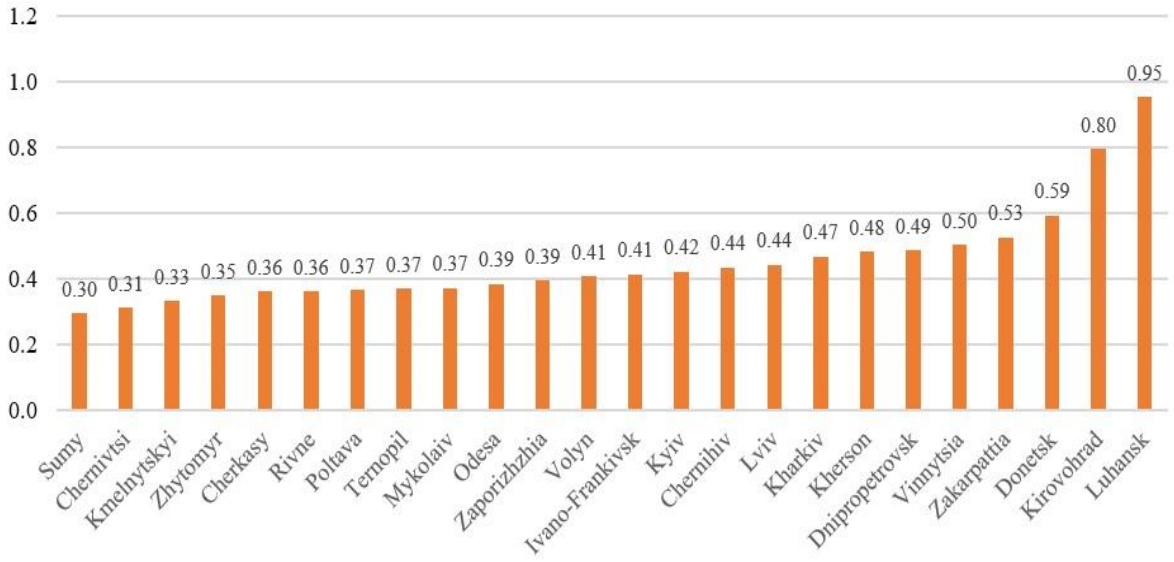

Figure 2. Number of deaths due to infection with COVID-19 per 1,000 persons in Ukraine (as of 31 December 2021)

Sources: developed by the author on the basis of (Minfin, 2023).

Table 3. Results of discriminant analysis of healthy behaviour indicators by the grouping variable of number of COVID-19 deaths

Variables	Wilkes Lambda	Partial Lambda	Tolerance	R^2
Consumption of milk and dairy products	0.529	0.736	0.565	0.435
Consumption of fruits, berries, grapes	0.445	0.875	0.566	0.434
Consumption of fish and fish products	0.411	0.948	0.546	0.454
Sugar consumption	0.392	0.993	0.676	0.324
Number of people engaged in physical culture and sports	0.456	0.853	0.718	0.282
Number of people who smoke	0.413	0.942	0.854	0.146
Share of population with obesity	0.468	0.831	0.664	0.336

Sources: developed by the author.

Table 4. Results of discriminant analysis of healthy behaviour indicators by the grouping variable of number of COVID-19 deaths

Mortality rate	High	Medium	Low
High	0.000	2.6	4.486
Medium	2.6	0.000	2.643
Low	4.486	2.643	0.000

Sources: developed by the author.

For quality analysis clarity of indicators grouping, it is advisable to carry out an additional study using a canonical investigation. As a result of the calculation, two canonical roots (constructable discriminant functions) were found. The eigenvalue (significance) is 0.74 and 0.48, respectively. Thus, the first discriminant function is more significant.

For further analysis, it is necessary to review the table of standardized coefficients (Table 5). As we can see from the standardized coefficients, the most significant contribution to the first discriminant function is made by the variable «Consumption of milk and dairy products» (1.047), and the most minor contribution is made by the variable «Consumption of sugar» (0.152). The cumulative fraction of the first canonical root is 0.609. The variable «Consumption of fruits, berries, grapes» makes the largest contribution to the second

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discriminant function (-0.722), and the smallest by «Number of smokers» (-0.023). The cumulative fraction of this canonical root is 1.000, which means that the second function thoroughly explains the discrimination variance. Next, for presentation clarity of classification results, we will construct a scatter diagram of the canonical values (Figure 3).

Table 5. Results of discriminant analysis of healthy behaviour indicators by the grouping variable of the number of COVID-19 deaths

Variable	Root 1	Root 2
Consumption of milk and dairy products	1.047	0.027
Consumption of fruits, berries, grapes	-0.351	-0.722
Consumption of fish and fish products	0.471	0.049
Sugar consumption	0.152	-0.037
Number of people engaged in physical culture and sports	0.628	-0.339
Number of people who smoke	-0.398	-0.023
Share of population with obesity	-0.594	-0.568
Eigenvalues	0.740	0.476
Cumulative share	0.609	1.000

Sources: developed by the author.

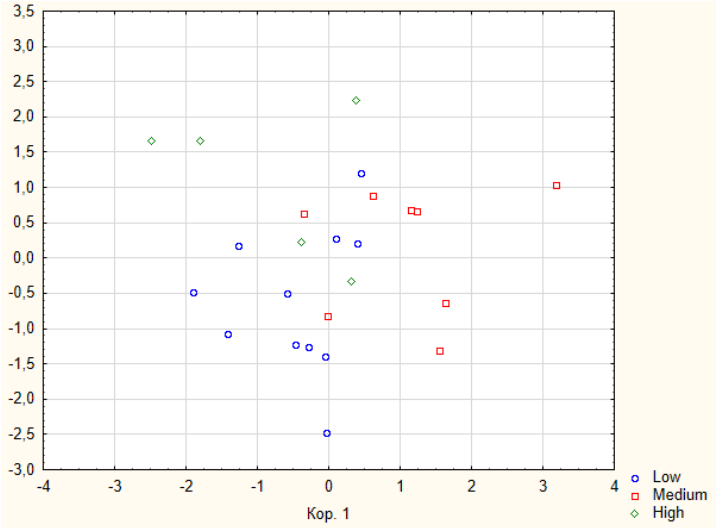

Figure 3. Diagram of distribution of canonical values

Sources: developed by the author.

Table 6 demonstrates classification functions. From Table 5, a priori classification probabilities were automatically generated proportional to group sizes. It is also possible to see features to classify groups by the rate of COVID-19 deaths. For example, to classify a group with a high mortality rate: High = 0.274 consumption of milk and dairy products + 0.632 consumption of fruits, berries, grapes + 1.784 consumption of fish and fish products + 2.763 consumption of sugar + 0.03 number of people engaged in physical culture and sports + 0.007. The number of smokers – 0.217, the proportion of the population with obesity – 114,981. In the next step, we will build a classification matrix (Table 7). According to the classification matrix, regions with a low mortality rate are grouped correctly in 81.82% of observations (9 observations were correctly classified, two observations were confused with a group with an average mortality rate). Medium-mortality regions are grouped correctly in 75% of observations (6 observations were correctly classified and two observations were confused with the low-mortality group). High-mortality regions are grouped correctly in 60% of observations (3 observations were correctly classified, but two observations were confused with the low-mortality group). Overall, the model correctly classified 75% of the observations, a reasonably high relevance rate.

Table 6. Results of discriminant analysis of healthy behaviour indicators by the grouping variable of number of COVID-19 deaths

Variable	Low	Medium	High
Consumption of milk and dairy products	0.287	0.354	0.274
Consumption of fruits, berries, grapes	0.769	0.634	0.632
Consumption of fish and fish products	1.814	2.129	1.784

Continued Table 6

Variable	Low	Medium	High
Sugar consumption	2.796	2.859	2.763
Number of people engaged in physical culture and sports	0.043	0.056	0.03
Number of people who smoke	0.064	0.047	0.007
Share of population with obesity	0,070	-0.444	-0.217
Constant	-114,981	-117,372	-98,741

Sources: developed by the author.

Table 7. Classification matrix of health behaviour variables by groups (as to the COVID-91 mortality rate)

Group	Percentage correct	Low	Medium	High
Low	81.818	9	2	0
Medium	75.000	2	6	0
High	60.000	2	0	3
Total	75.000	13	8	3

Sources: developed by the author.

According to the calculation results, regions with better population behaviour patterns against consumption of healthy food products are characterized by higher resistance to COVID-19 in terms of disease complications. At the same time, the amount of sugar consumption could be more decisive. It is noteworthy that such behavioural components as number of people engaged in physical culture and sports, as well as the proportion of obese people, are essential.

Conclusions. Thus, empirical calculations showed that number of people infected with COVID-19 is not a sign of discrimination, by which it would be possible to determine the predominant components of the population healthy behaviour. Instead, the hypothesis was confirmed about an existing connection between the regional population healthy behaviour patterns and the COVID-19 mortality rate. The discriminant analysis combined with the canonical analysis made it possible to single out the dominant features corresponding to classification of regions by the population's mortality level from coronavirus. We found out with a high probability that the population behaviour patterns against consumption of food products other than sugar (milk, berries, fish) determine to which classification group the region could be assigned according to the COVID-19 mortality rate (high, medium, low). Besides, the statistical significance of impact of such indicators was confirmed as number of people engaged in physical culture and sports and share of obese people. These results are helpful for future research to develop a strategy against pandemic threats; to plan work for preventing disease exacerbation caused by epidemic factors.

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Вразливість держав до COVID-19 залежно від патернів поведінки населення в сфері здоров'я

У статті здійснено аналіз факторів, що зумовлюють рівень вразливості регіонів до впливу пандемічних загроз. Для аналізу взяті статистичні показники за 2021-2022 рр. щодо перебігу пандемії COVID-19 в Україні, а саме кількість інфікованих осіб та кількість смертельних випадків у розрахунку на тисячу осіб населення. Змінними детермінантами прийняті показники в сфері здорової поведінки населення: обсяги споживання здорових продуктів, споживання цукру, кількість осіб, які займаються фізичною культурою та спортом, кількість осіб, які палять та частка осіб з ожирінням, за якими наявна кількісна статистична база вичерпно за всіма 24 регіонами країни. Ціллю дослідження є підтвердження чи спростування гіпотези щодо наявності зв'язку між регіональними поведінковими патернами населення в сфері здоров'я та вразливістю регіону до впливу пандемії COVID-19. Для аналізу використано дискримінантний та канонічний аналіз, які здійснені в програмному середовищі STATISTICA. Емпіричні показники дозволили підтвердити гіпотезу щодо наявності зв'язку між регіональними поведінковими патернами та рівнем регіону за кількістю смертельних випадків від COVID-19. Гіпотеза про можливу залежність між поведінковими патернами та кількістю інфікованих COVID-19 не підтвердилася – модель дискримінації виявилася статистично незначущою. Це свідчить про те, що для встановлення залежностей потрібно мати більше вхідних параметрів, які описуватимуть модель. Визначено, що споживання здорових продуктів (молоко, ягоди, риба) мають високий ступінь впливу на рівень смертності від COVID-19 (високий, середній чи низький). Також до показників, які мають високий ступінь впливу, відносяться кількість осіб, що займаються фізичною культурою та спортом, і частка осіб з ожирінням. Результати дослідження будуть корисними при розробленні регіональних та національних стратегій сприяння формування резильєнтності територій до пандемічних загроз та при виборі інструментів роботи з населенням у рамках інформаційно-просвітницьких кампаній з профілактики тяжких перебігів захворювань, зумовлених епідемічними чинниками.

Ключові слова: медико-соціальне забезпечення населення, пандемія, стійкість регіональної системи, статистика COVID-19, загрози громадському здоров'ю.