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Spatially Differentiated Impacts of Covid-19 on Selected Indicators of Mortality in Slovakia in 2020

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Abstract

Slovakia is a country with a specific development of the Covid-19 pandemic. While it was among the countries with the lowest number of cases and lowest mortality during the first wave, during the second and third waves Slovakia gradually became one of the countries with the worst development of the pandemic. The aim of this contribution is to summarise the situation in Slovakia during the first year of the pandemic and investigate its influence on selected indicators of mortality. An attempt was also made at determining its influence on the lethality rate of Covid-19, changes in mortality, and excess deaths. The research considered regionally differentiated levels and identification of risk districts from the aspect of the abovementioned phenomena.

Keywords: Covid-19; spatial analysis; mortality; lethality; excess deaths

Introduction

The influence of the Covid-19 pandemic on the population of given country is usually evaluated based on the number of cases and the number of deaths. These two statistics create a daily updated international panel of data which are managed by the World Health Organisation (WHO) and the John Hopkins University. Both metrics are distinctively influenced by the availability of testing and by various definitions of Covid-19-related deaths in individual countries (Riffe et al., 2021; in Karlinsky & Kobak, 2021). The influence of the pandemic among countries or over time is also conditioned by different levels of coverage and the reliability of data. An interregional comparison can be more demanding because the reported numbers of cases and deaths are distinctively influenced by the specific conditions of the regions. To analyse the influences and impacts of infection for longer, "closed" time periods is the best solution for monitoring and comparing infection rates at the regional level. This removes shortages in the statistics of regions and it also considers "running-down" data whose processing required a determined amount of time. In Slovakia, but also in the majority of advanced countries worldwide, the annual data are available on mortality, specific deaths according to basic structures of population, or death causes. These data, together with data on the course of infection on behalf of regions (of positivity of tests, prevalence, incidence, daily mortality growths) create a suitable basis for regional analyses. Further indicators and important information can be gained for monitoring the regionally differentiated impacts of Covid-19 on the population and selected demographic processes.

This contribution utilises the indicated databases to analyse the development of research into the pandemic in Slovakia and its regions. It is focused on the influence of one of the most important impact of the pandemic – increased mortality. By means of considering more indicators it follows the development, level, and alterations in mortality during the

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pandemic. The contribution also examines whether and to what extent the generally confirmed spatial concentration of coronavirus in Slovakia determines different levels of mortality in different regions. The aim of this contribution is to assess the state and development of the pandemic at a national level and to determine the differentiated mortality rate (of selected indicators) in different districts of Slovakia during the first year of the pandemic (2020). The direct effects of Covid-19 on three significant indicators of mortality are quantified, namely: lethality, specific, and excessive mortality. The results of the spatial analyses presented here identify implicitly the most affected regions from an aspect of selected indicators of mortality during the first and second waves of the pandemic in Slovakia.

Problems in evaluating lethality in times of a pandemic

The relatively broad and different definitions of lethality adopted by countries lead to various, often unsuitable or confusing interpretations. This ambiguity and common misunderstandings can result in an underestimation of the pandemic which is, according to a considerable part population, comparable to ordinary infection with low mortality. However, the high numbers of deceased persons evidence the relatively high risks and lethality associated with the infection.

Countries worldwide, however, have different definitions of cases of Covid-19 lethality. As a consequence, the numerator and denominator of each formula used for calculating lethality differ according to how it is defined. The WHO recommends the use of definitions of the cases of monitoring which are at a disposal in the temporary instructions of the WHO on the global monitoring for Covid-19 (WHO, 2020b). Lethality is defined for the purpose of monitoring deaths caused by clinically compatible illnesses in probable or confirmed cases of Covid-19. No period of full recovery should exist between the onset of the disease and the time of death (WHO, 2020c). The ratio of lethal cases is the quotient of the individuals with a diagnosed disease who will die of this disease. This ratio expresses the rate of gravity among found-out cases. Reliable data, which can be used for evaluating lethality, will usually be obtained at the end of a period after solving all cases (the affected persons have either died or they have recovered). During ongoing epidemics, the calculation of lethality provides only a conditioned estimation influenced by delays in the data of cases and deaths. This leads to great differences in estimations of lethality during the course of the epidemic. Restricting the analysis on solved cases is a simple solution for moderating distortion as a consequence of delays during the period in progress. However, this method does not fully eliminate all the problems connected with delayed reporting. Distortions and final estimations can be, for example, also influenced by differences in the time needed to solve cases. If people that are afflicted coronavirus are expected to die more rapidly than they would recover, the lethality can be overvalued; it can also be undervalued under the opposite circumstances. Therefore, statistical methods should be applied to forecast future results based on the probability of past results. For example, the modified version of Kaplan-Meier's analysis of surviving (Lipsitch et al., 2015) appears to be a very suitable method. It is generally stated that the lethality of Covid-19 is influenced by age, gender, ethnic membership (Pan et al., 2020), and by corresponding co-morbidities (Gold et al., 2020). Any attempt to assess only the rate of lethality in a population does not take into consideration the basic heterogenities among various risk groups. On the contrary, it leads to relevant distortions in the consequences of their different distributions in populations and among them (Angelopoulos et al., 2020). Therefore, estimations of death risk on individual risk groups should be focused on in order to better describe the real formulae of lethality occurring in populations. Potential distortions and inaccuracies are an accompanying sign of lethality estimation. These distortions can differ among various foci during the pandemic. At the beginning of infection, there is a greater probability of finding serious cases with a greater lethality. The patients with heavy illnesses will probably reach health service establishments and their illnesses will be confirmed by laboratory tests. However, the delays in producing death reports can lead to an underestimation of lethality. Cases of and deaths related to Covid-19, which occur in communities, often remain undetected or are reported late because they have been improperly ascribed to other causes. It is improbable that all deaths would be reported and properly assigned although death surveys can be the subject of smaller prejudices than cases survey.

The Covid-19 pandemic came accompanied by wide variations in the estimations of lethality, which can be, and often are, also misleading. It is hard to compare countries number of cases as they use various definitions of the word "case". They differ in their probabilities of revealing and registering all deaths related to Covid-19. Deviations in lethality can also be explained partially by time delays. The different quality of care or therapy during the various stages of illness can also play a part in these discrepancies. Finally, the different profiles of patients (age, gender, ethnic membership, and basic co-morbidities) in particular countries, especially in the case of big differences, influence the differentiated rates of lethality to a considerable degree.

The lethality of the Covid-19 illness was originally determined by the WHO as 3.4% (WHO 2020a, d). However, the values of lethality according to countries are considerably different. The lethality of Covid-19 has at times been reaching around 20% in countries with an explosive development of the epidemic and with insufficient testing of citizens. In contrast, statistics below 1% have also been reported in countries where the pandemic was under control and testing was extensive. Deaths were mainly recorded in older and attenuated patients, and persons suffering of other serious illnesses, chiefly of the heart and respiratory passages. Children are considered to be less threatened (Cennimo 2019). More epidemiological and regional studies exist in the present day which indicate different levels of lethality. Ioannidis (2020) stated the lowest lethality of Covid-19, indicating a value of 0.23%. This estimation, however, is distinctively lower than that established by other researchers until now. The majority of works, including the ones published by the WHO, have indicated a several-fold higher lethality, and the lethality rates in October 2020, for example, were at a level of 2.2% worldwide (ECDC, 2020). The study by Piroth et al. (2020) showed that in March and April 2020 approximately 16.9% of patients with Covid-19 had died in French hospitals, recording a three times greater lethality than the one registered for persons hospitalised with the flu. High lethality rates have also been recorded in the United Kingdom, where the values sometimes reached around 15%. Calculations of lethality were only made based on closed cases (the healed persons plus the dead persons) because the health outcomes of infected persons were unknown (Our World in Data, 2020)[1]. This means that in spite of the high values of lethality in France and the United Kingdom, the lethality rates had been undervalued in both countries.

Significance of monitoring and evaluation of excessive mortality during Covid-19

Excessive mortality is a term used in epidemiology and demography to designate the number of deaths from all causes beyond that which would be expected under "normal" conditions. Indeed, excessive mortality is a more complex criterion of the total influence of the pandemic on deaths than the confirmed number of deaths itself (lethality) related to Covid-19. In addition to the confirmed deaths, excessive mortality also includes deaths which have been incorrectly diagnosed and reported. The concept also encompasses deaths due to other causes which can be ascribed to total crisis conditions (Giattino et al., 2020). The excessive mortality can be measured several ways in times of a pandemic. The simplest way involves subtracting from the number of found-out des in given period during the pandemic the average number of deceases in the same period in previous years. Karlinsky and Kobak (2021) performed a linear extrapolation of the trend in the years 2015-2019 to calculate the excessive mortality during the pandemic in 2020. Chan et al. (2021) quantified the influence of the coronavirus on excessive mortality by estimating the number of deaths that would have occurred under "normal" conditions then if the pandemic had not taken place. Subsequently, they subtracted the gained value from the reported, total death number for all age groups and both genders. Llod-Sherlock et al. (2021) used quasi-Poisson models to estimate excessive mortality during the first wave of the Covid-19 pandemic. Equally, Woolf et al. (2020) estimated the expected deaths using a hierarchic Poisson regression model modified on the weekly numbers of deaths. Other authors (CDC, 2020) have used Farrington surveillance algorithms in analyses of excess deaths connected with Covid-19-related illnesses and compared these with historical trends of mortality. The P-score provides a useful means of estimating excessive mortality; it is a percentage difference between the number of deaths in a week in given year (e.g., in 2020) and the average number of deaths in equal weeks for determined years (most often over five-year periods). However, the P-score has some limitations. For example, the five-year average number of deaths can be perceived as a relative gross rate of "normal" deaths because it does not consider the trends in the size of populations or mortality. It is important to note that countries with older populations, which have a higher risk of mortality (including from illness related to Covid-19), will have as a standard a higher P-score in all age groups. The number of confirmed deaths caused by the coronavirus can differ from the total impact of the pandemic on deaths for several reasons. More countries have reported only Covid-19-related deaths which occurred in hospitals, omitting those people who died of Covid-19 complications at home. Other countries have, in turn, only reported deaths for which testing had confirmed that the patient had been infected by the virus. This registration, however, does not include the Covid-19-related deaths of untested individuals. Discrepancies in the numbers of deaths can also be caused by disunited systems of death reports which are not sufficiently precise (being valid especially for poorer countries). In fact, a pandemic can lead to an enhanced number of deaths

[1] The number of found-out cases depends on testing to a certain degree, but also on deaths and possibly on whether or not persons consider themselves victims of Covid-19. Since it is more tested, lethality is also decreasing in various countries worldwide (Our World in Data, 2020).

for other reasons also, including: attenuated systems of health care; a smaller number of people seeking therapy for other health risks; or less available financing and therapy for other diseases (e.g., AIDS, tuberculosis, and others). More deaths from other causes can thus be an implicit result of the pandemic. Secondary deaths do not result directly from infection with the virus[2], but rather from the lack of necessary healthcare during the epidemic. Indeed, states have had to eliminate health care or directed it in the first place to the therapy of patients with the coronavirus. On the other hand, mobility restrictions can lead to a smaller number of deaths resulting from traffic accidents during the pandemic. The interventions and measures put in place to stop the spread of Covid-19 can in turn reduce the number of deaths associated with the flu. The indicated realities show that the confirmed deaths related to Covid-19 often do not count on the total impact of the pandemic on the deaths, but in contrast to excessive mortality, they contain information on the cause of death. In turn, the advantage of monitoring excessive mortality is that it includes not only those who died of Covid-19-related complications but also those who died from all other causes. Both metrics are necessary for understanding the total influence of the pandemic on deaths.

In addition, Beaney et al. (2020) pointed out the irreplaceable role and meaning of monitoring excess deaths, consider the excessive mortality as a "gold standard" for measuring the impact of Covid-19 on mortality. They called to attention that the data monitored during the pandemic (cases and deaths), which quantify the total extent of illness in countries, have comparative restrictions according to the different sizes of populations as well as other differentiated demographic characteristics. The authors stated that age is strongly connected with mortality du to Covid-19 and the different age structure of populations has a distinctive influence on lethality as well as on total mortality. Even if these factors can be adapted or standardised, the comparisons of the mortality of Covid-19 remain restricted unless we understand how the definitions of mortality differ[3]. For example, the Russian definition of death cases of Covid-19, in contrast to the majority of European countries, relies only on the results of an autopsy. The recorded death had to be caused directly by Covid-19 meaning that it would not be counted if it was found-out that the patient had Covid-19 but it had not caused their death. This leads to insufficient reporting especially since Russia had one of highest numbers of Covid-19 cases in the world, and in spite of this, Russia reported very low rates of mortality due to the virus (only 1.7%) until July 31, 2020. In this context, Beaney et al. (2020) stated that with the proceeding development of the pandemic, the experts are focusing on excessive mortality as a more reliable metric for comparing countries more and more. Excessive mortality provides an estimation of the additional number of deaths over a given time period in comparison with the expected number of deaths. By the including all the causes, excessive mortality overcomes the differences among countries for reporting and testing for Covid-19, but also regarding incorrect classifications of the cause of death in death certificates. Given that the occurrence of further diseases will remain stable in the course of time, the excess deaths in cases which are directly or indirectly caused by Covid-19 can also be considered. Excessive mortality can also be standardised according to the age or size of a population, enabling mutual comparisons among countries. The excessive mortality is then a meaningful indicator which includes all causes of death and at the same time it is a metric of the overall influence of Covid-19 on mortality. Therefore, the timely and complex systems for collecting and reporting data on excessive mortality together with mortality caused by concrete causes (lethality) can be useful for monitoring trends within countries and among them.

Methods and data sources

The study utilises a relatively broad spectrum of data from relevant sources, especially from the WHO, Our World in Data, the European Centre for Disease Prevention and Control (ECDC), John Hopkins University, The Human Mortality Database, Statistical Office of the Slovak Republic (ŠÚ SR), Ministry of Health of SR, National Centre of Health Service Information (NCZI), the data of portal mapa.Covid.chat, and further sourc-

[2] Persons are considered for secondary victims of coronavirus who were not infected by virus but they died or yet will die because they did not get necessary health care in time of the epidemic.

[3] The World Health Organization (WHO) defines the decease of Covid-19 like a decease at which the Covid-19 is main cause of death, and it includes the confirmed also suspect cases. If Covid-19 is a factor which contributes to this but it is not the cause leading directly to death then it is not counted. Directing of the World Health Organization, however, has been introduced in April 2020 within which the countries could already introduce their own directing. In consequence of this considerable differences in the report of deceases of Covid-19 exist among countries.

es. An analysis focused on rating the level and development of prevalence[4] and incidence[5] is a starting point for evaluating situation in Slovakia during the first year of the pandemic and determining its position in the international context. The conceptual frame for rating the state and development of the pandemic situation in Slovakia was based on a range of relevant indicators. Selected indicators and characteristics such as cumulative calculi, rate of confirmed cases, sliding median, trend characteristics, and others, were monitored from the view of the infection level, development, changes, trends, but also from a spatial aspect. Their values for Slovakia were compared with those of selected countries, especially with the nearby Czech Republic. Research on the regionally differentiated impacts of the pandemic on lethality, mortality, and excessive mortality in districts was used to determine a coefficient of the spatial concentration and comparison of values of relative data. The P-score was utilised for comparing the rates of excessive mortality. Correlative analysis (concretely Spearman's correlative coefficient) was used to analyse the relationships between the monitored phenomena (share of old population and lethality of Covid-19). The information presented here provides a brief description of the situation in Slovakia in 2020 as well as in the context of its comparison with situations in other countries in Europe. The analyses proceed from certified data sources and from information from various relevant and reliable sources.

Evaluation of the development of the pandemic in Slovakia

The analysis focused on rating the level and development of Covid-19 prevalence and incidence is a conceptual starting point for evaluating the situation in Slovakia and determining its global position during the first year of the pandemic. The analysed data incorporate the most significant aspects of the pandemic – the level, seriousness, risks, and trends of its development and spreading. A detailed overview of the state and development of prevalence and incidence is a precursor for subsequent analyses focused on monitoring the influence and impacts of the pandemic at the level of lethality, mortality, and excessive mortality[6] in Slovakia in 2020 (Table 1). Data and indicators, which represent a necessary basis of information for important decisions, were also analysed. The cumulative number of confirmed positive cases and deaths includes daily increments and follows long-term developments. Changes in the rate of confirmed cases indicate continuous or turning trends of development. A seven-day sliding median is a basic criterion for regulations and the strictness of measures. Daily confirmed new cases demonstrate the ongoing development of the pandemic. Fourteen-day specific incidences reveal in detail the development of infections according to various structures and categories of the population.

Table 1. Descriptive statistics of basic data on Covid-19 in Slovakia (as of 31 December 2020)

The population	5,459,781
Number of tests performed	1,445,486
Rate of confirmed cases	184,508
Rate of confirmed deaths	225
Prevalence (seven-day sliding median)	2,095
Lethality of Covid-19	4,404
Excess deaths	402
Excess deaths (in %)	28.5
The share of lethality of Covid-19 in all deaths (in %)	6.8
The share of lethality of Covid-19 in excess deaths (in %)	72.0
The share of the old population (65 and over) on total lethality of Covid-19 (in %)	85.2

Source: mapa.Covid.chat (2021), Štatistický úrad SR (2021), Our World in Data (2021)

Evaluation of the lethality of Covid-19 in Slovakia

A precise understanding of the term lethality must be achieved to obtain the real picture on lethality during the Covid-19 pandemic. This work proceeds from the definition of lethality according to Maxdorf (2020). Lethality is a demographic indicator which is expressed as a rule in percentages as a quotient of the number of persons having died of a specific disease to the number of persons affected by this illness. The following formula can be used to express the formal record for calculating the such defined lethality:

$$m_t^c = \frac{M_t^c}{\bar{S}_t^c}$$

- m = lethality,
- c = cause,
- t = time (period),
- M = mortality,
- S = medium state of population

To evaluate the lethality of Covid-19 in Slovakia, one should bear in mind that it is impossible to gain a fully precise number of victims (deaths) of the vi-

[4] Prevalence is a statistical concept referring to the number of cases of a disease that are present in a particular population at a given time.
[5] Occurrence of new cases of disease over a specified time period.
[6] Excessive mortality designates the number of deaths relating to all causes beyond those that would be expected under „normal" conditions.

rus. Deviations in values of lethality in both directions (higher or lower) have been influenced by more factors. An overvaluation or undervaluation of lethality has been in part conditioned by testing, especially with a lack of registering positive cases. These have been connected either with "dual" registration or, on the contrary, by the non-recording of part of the tested persons and then by their non-inclusion in a registration system. Certain inaccuracies in the lethality values could also be caused by problems associated with ascribing the cause of death and by differences between the reported deaths and the total number of deaths.

Level of lethality differentiated by regions and age

Specific indicators of lethality have been used to obtain information regarding the various levels of lethality of Covid-19 in different regions as well as according to age. The regional indicator expresses the level of lethality in each district; the numerator expresses the mortality of Covid-19 in the district and the denominator expresses the medium state of the district's population. The level of lethality differentiated by age is expressed by a specific indicator of mortality according to age. The numerator expresses the mortality of Covid-19 of a monitored age category and the denominator expresses the medium state of the population of the monitored age category. This contribution analyses concretely seniors that are 65 in age and over.

Correlative analysis

The information revealing high rates of lethality of Covid-19 in seniors evokes questions regarding the extent to which values of lethality level are determined by age. In other words, it is unknown whether age represents a significant (predictive) factor of high mortality (lethality) due to Covid-19 in the senior population (a high share of the population in Slovakia has a post-productive age). The indicated relation was determined based on an examination of the dependence between the share of the old population (65 and older) and lethality. The relationships among the monitored phenomena were analysed using regional data on behalf of the districts. The data of the Statistical Office of the SR – "Balance of population according to age" and "The deceased persons according to cause of death, age, and gender" were utilised for the analysis. In the first step of the examination of dependence two assumptions were made regarding the relationships, namely: direct (1) and differentiated (2) effects of the influence of a high share of the senior population on lethality. The correlative analysis and the Spearman´s correlative coefficient values (below Skk) pointed to a medium-strong direct dependence (Skk = 0.387) and spatially relatively differentiated influence of the old population on the level of their lethality.

Changes in mortality and excessive mortality in districts during Covid-19

The analysis of the differentiated levels of the development of Covid-19-related deaths (their increase/decrease) in the districts proceeded from a standardised rate of mortality. Its average values for the last five years (2015-2019) were subtracted from the values for the year 2020. The results obtained for mortality were counted-over with regard to relatively low increments to 100 thousand inhabitants of mid-year population. The following procedure was chosen to measure excess deaths at the regional level during the Covid-19 pandemic. The number of expected deceases was estimated from the mortality data from the last five years (2015-2019). The indicated data on mortality were double-checked prior to this to eliminate "mortality shocks" which may distort long-term trends of mortality. Subsequently, the expected (estimated) deaths for the same year were subtracted from the registered deaths for the year 2020. Values of excess deaths were thus obtained for each district. A 95-percentage confidence interval was used due to the small size of the population and small number of deaths in most districts (the number of deaths is significantly influenced by processes of accidental nature).

Results

State and development of prevalence and incidence

Figure 1 shows a distinctive growth of the number of infected persons from October 2020. At the end of September, the number of infected was under the limit of 11,000, but at the end of October it had reached almost 60,000. On the last day of November, this number already exceeded 107,000, and at the end of the year, up to 184,508 persons had been infected.

Figure 2 also confirms the growing trend of the number of infected persons which includes changes in the rate of confirmed cases. The curve of positivity turned red over time, representing an unfavourable development with the rate of confirmed cases exceeding 10%.

The unfavourable development of prevalence is also displayed in Figure 3, which reveals the growth of values of the seven-day sliding median. It concerns a significant indicator on the basis of which the criteria for

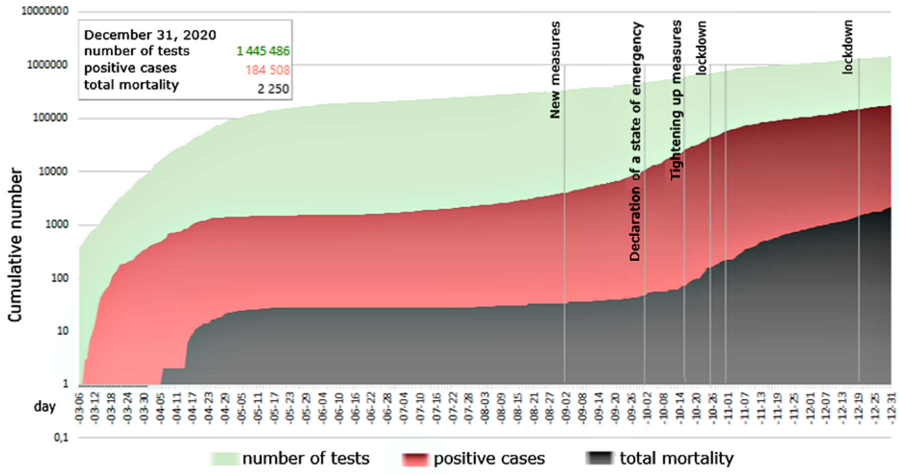

Figure 1. Cumulative number of tests, confirmed positive cases, and deaths up to 31/12/2020
Source: mapa.Covid.chat (2021), Our World in Data (2021)

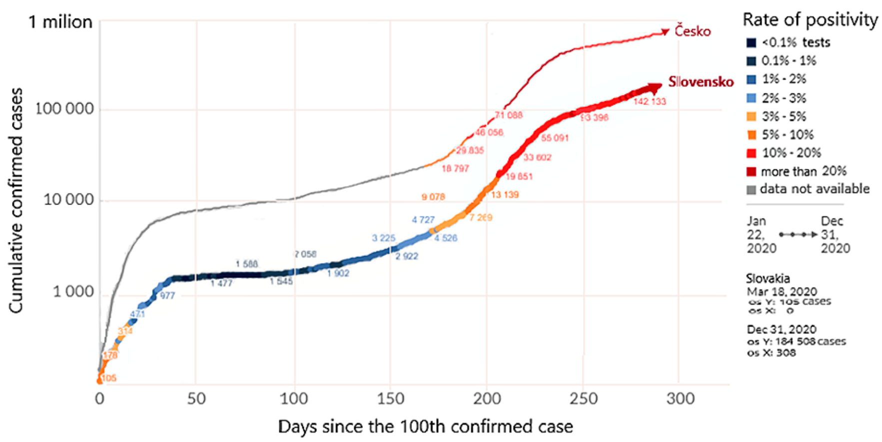

Figure 2. Changes in the rate of confirmed cases of Covid-19
Source: Johns Hopkins University (2021), Our World in Data (2021)

making stricter or looser measures are determined[7]. The limit for Slovakia was set to a value of 500 which was exceeded for the first time on 1/10/2020. Development in the following days, however, with relatively high values has never decreased under the indicated limit. On the contrary, shortly before Christmas, it reached maximum value of 3 045 cases.

Research on the specific incidence of lethality according to age groups (Figure 4) showed that while at the beginning of December most infected persons were in the age category of over 80-year-olds, the number of infected persons at the end of the month belonging to lower age categories (50-64; 25-49; 15-24) had distinctively increased. The steep growth of the curve of infected persons in the stated age categories indicates an insufficiency of adopted measures but also their non-observance by a considerable part of the population. It was manifested by the increased number of patients with a heavy course of illness, by the occupancy and exploitability of hospitals, as well as by the enhanced mortality of older persons.

Development and changes of lethality at a national level

In 2020 the Covid-19 pandemic caused the deaths of over four thousand people (4 404) in Slovakia and thereby became the third most frequent cause of death in the country (~6.8% of all recorded deaths). However, it became a massive cause of death only during the second wave of the pandemic. Over 97% of deaths ascribed to Covid-19-related illnesses happened in the last quarter of 2020 (ŠÚ SR, 2021). During December of that year, more than half (54%) of the annual deaths were related to Covid-19. According to the

7 One of decisive criteria for release of measures is so-called sliding median of number of infected persons during the last seven days which is daily evaluated. Approximately after 2 weeks in one phase it will be decided whether it passes to further phase. At the release of measures accepted in fight against the pandemic in Slovakia it is calculated the sliding median from daily number of new infected persons during the past week which is cleared from new infected persons in quarantine centres.

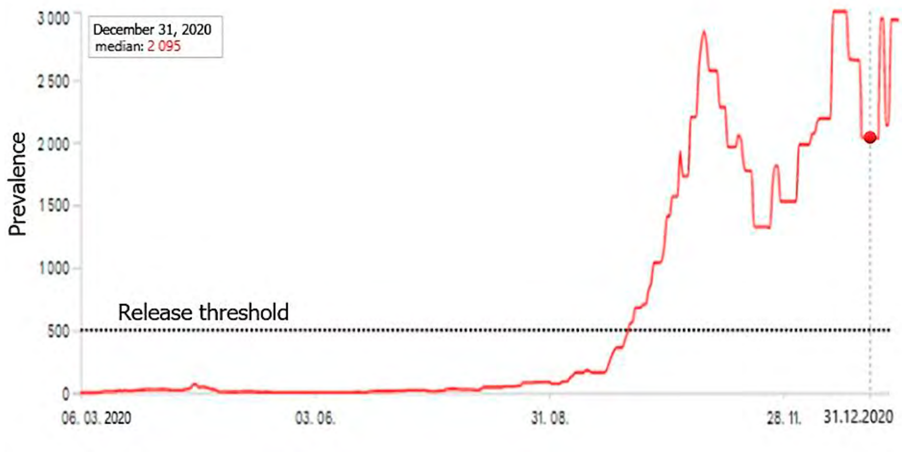

Figure 3. Seven-day sliding median
Source: mapa.Covid.chat

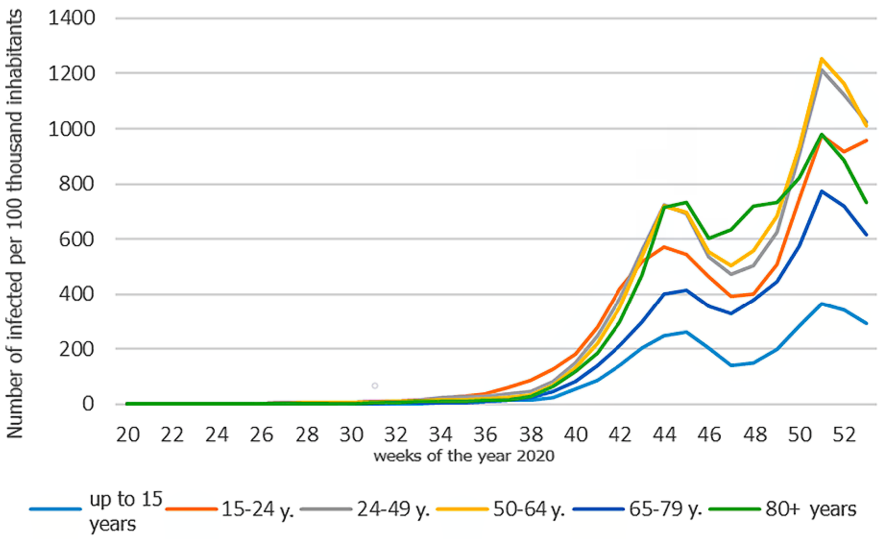

Figure 4. Fourteen-day specific incidence according to age groups
Source: ECDC (2021)

development of daily and average seven-day lethality in Slovakia (Figure 5), lethality values were low until the middle of December. However, in last days of the year the curve of new deaths was distinctively growing, as confirmed by the sliding average of new confirmed daily deaths from Covid-19 during seven days[8]. Until October 31st, Slovakia had recorded a total of 219 deaths related to Covid-19; a month later (30/11) 868 deaths had been registered and up to 2,250 at the end of the year (31/12) (mapa.Covid.chat 2021)[9]. The lethality values in Slovakia for the monitored period were considerably time differentiated. The highest value of 1.9% was recorded during the first wave, and on May 16th, it decreased distinctively before reaching a minimum value of 0.3% on October 16th. Following this date, the values began to grow again before reaching a value of 1.2% on December 31st. During the whole monitored period it had an average value of 1.19%. In comparison, Bulgaria experienced a lethality of 4%, Italy 3.5%, Hungary 3.2%, and Belgium 3% over the same period. Yemen had the highest lethality (29%) in the world (by 31/12/2020).

Figure 6 outlines the unfavourable development of the Covid-19 situation comparing the cumulative confirmed deaths in selected countries. The figure clearly shows that in in the last days of 2020 the cu-

8 At all sources of data on the pandemic the daily data have not to relate indispensably to the deceases just in that day but to the deceases reported in that day. Because the reporting can distinctively differ from day to day regardless to any real changes of deceases, therefore it is useful to display seven-day sliding average of the daily data.

9 The indicated numbers forced the government to accept a stricter lockdown which, however, began to be valid from the New Year (2021) and according to the majority it came late.

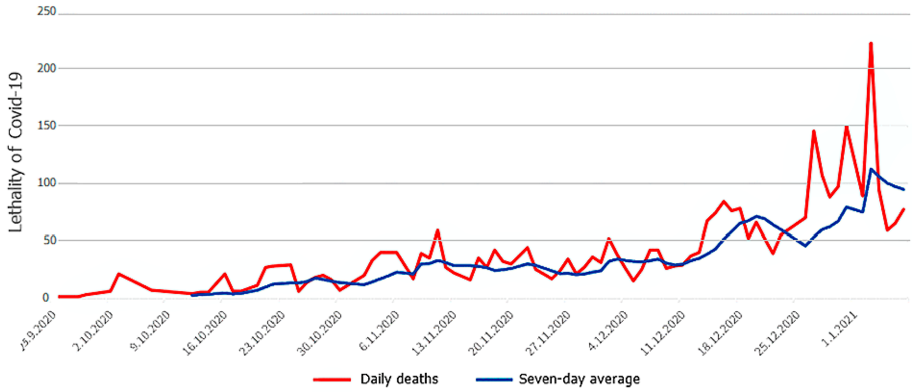

Figure 5. Development of the mortality of Covid-19
Source: Ministry of Health of the SR (2021a)

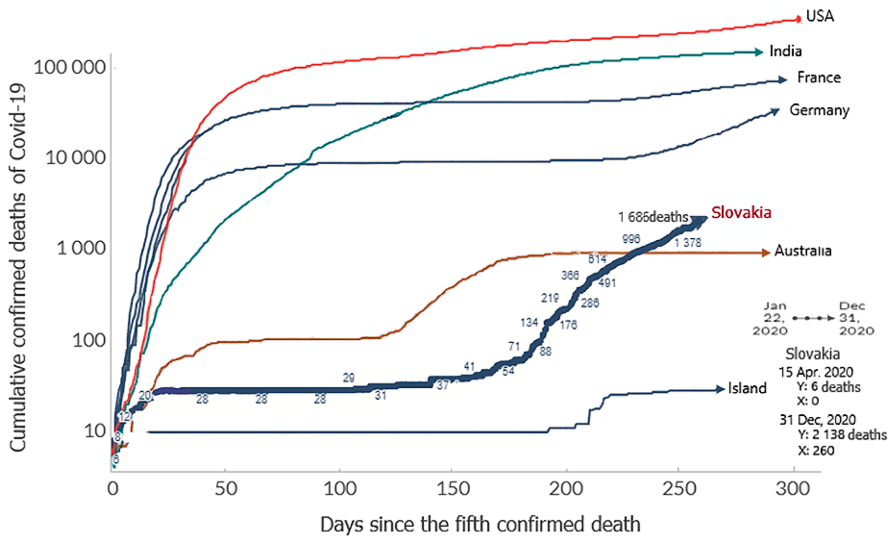

Figure 6. Cumulative confirmed deaths related to Covid-19 in selected countries
Source: Johns Hopkins University (2021), Our World in Data (2021)

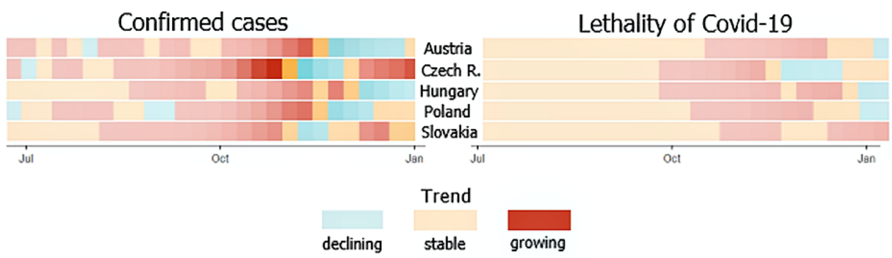

Figure 7. Developmental trends of 14-day confirmed cases and of lethality
Source: ECDC (2021)

mulative curve of deaths in Slovakia was disproportionately steep relative to that of other countries.

A worsened situation from the aspect of lethality (also of confirmed positive cases) can also be seen in Figure 7 which displays the developmental trends of 14-day confirmed cases and of lethality from July 2020. This visually dissimilar graphical representation enables not only a monitoring of different developmental trends but also a comparison of differentiated development and states in neighbouring countries at a certain time.

Regionally differentiated levels of lethality

The lethality in Slovakia was different from a time aspect as well as being distinctively differentiated spatially. The regional interval of confirmed deaths (lethality) from Covid-19 in the districts moved in intervals from 0.29% (Krupina district) up to 5.27%

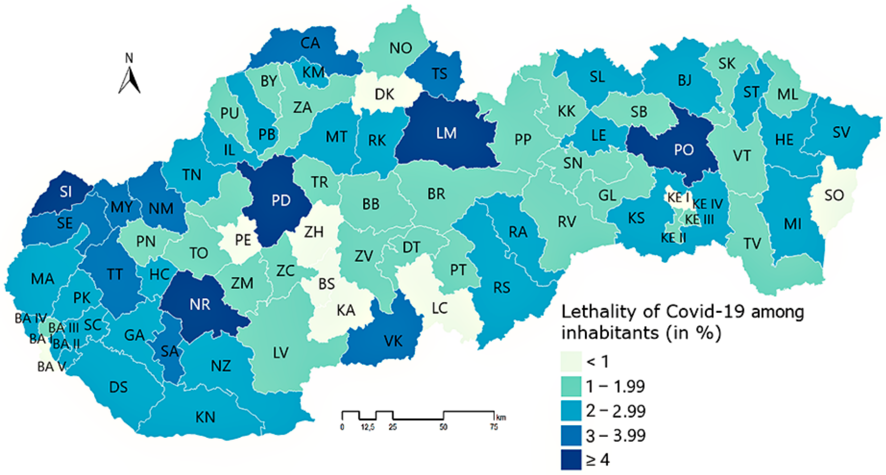

Figure 8. Lethality of Covid-19 among inhabitants in districts of Slovakia in 2020
Source: ŠÚ SR (2021), Institute of Health Analyses IZA (2021a, 2021b)

The abbreviations of districts: BB - Banská Bystrica, BS - Banská Štiavnica, BJ - Bardejov, BN - Bánovce nad Bebravou, BR - Brezno, BA - Bratislava, BY - Bytča, CA - Čadca, DT - Detva, DK - Dolný Kubín, DS - Dunajská Streda, GA - Galanta, GL - Gelnica, HC - Hlohovec, HE - Humenné, IL - Ilava, KK - Kežmarok, KN - Komárno, KE - Košice, KS - Košice-okolie, KA - Krupina, KM - Kysucké Nové Mesto, LV - Levice, LE - Levoča, LM - Liptovský Mikuláš, LC - Lučenec, MA - Malacky, MT - Martin, ML - Medzilaborce, MI - Michalovce, MY - Myjava, NO - Námestovo, NR - Nitra, NM - Nové Mesto nad Váhom, NZ - Nové Zámky, PE - Partizánske, PK - Pezinok, PN - Piešťany, PT - Poltár, PP - Poprad, PB - Považská Bystrica, PO - Prešov, PD - Prievidza, PU - Púchov, RA - Revúca, RS - Rimavská Sobota, RV - Rožňava, RK - Ružomberok, SB - Sabinov, SC - Senec, SE - Senica, SI - Skalica, SV - Snina, SO -Sobrance, SN - Spišská Nová Ves, SL - Stará Ľubovňa, ST - Stropkov, SK - Svidník, SA - Šaľa, TO - Topoľčany, TV - Trebišov, TN - Trenčín, TT - Trnava, TR - Turčianske Teplice, TS - Tvrdošín, VK - Veľký Krtíš, VT - Vranov nad Topľou, ZM - Zlaté Moravce, ZV - Zvolen, ZC - Žarnovica, ZH - Žiar nad Hronom, ZA - Žilina

(Presov district) of deaths. Thirteen districts had relatively high lethality values (more than 3%). A low lethality rate was exhibited by seven districts in which the values of lethality were under 1%.

The differentiated values of lethality of Covid-19 (Figure 8) indicate a considerable heterogeneity between the considered districts. Simultaneously, they show that the districts with very high lethality, but also with very low lethality, are situated evidently as isolated regions all over the country. Clusters (macroregions) are created only by the districts with middle and lower levels of lethality (the values of lethality lie in intervals from 2-3% or from 1-2 %) and with lower levels of lethality.

Regionally differentiated levels of the lethality of seniors

The different demographic characteristics of the districts must also be considered to postulate the considerable regional differentiability of lethality. The districts of Slovakia are differing considerably in the number of their populations, demographic compositions, levels of mobility of the population, and so on. To a large extent, the values of lethality are determined especially by the age structure of a region's inhabitants. The statistics show that the people over 65 years of age are most threatened by a heavy course of illness or by death relating to Covid-19 during the monitored year. This reality is connected with known facts and findings. Firstly, an older age diminishes the ability of the organism to produce immune reactions. An older age thus contributes to a higher occurrence of infections and virus illnesses. Secondly, older persons have a greater likelihood of having comorbidities (heart disease, diabetes, pulmonary illnesses, chronic illnesses with a decreased immunity…) which distinctively enhance the risk of mortality associated with the coronavirus. Indeed, the majority of the victims of Covid-19 (deaths) belonged to the senior age category (over 65 years). This population formed up to 85% of the total number of all persons deceased due to Covid-19. In Slovakia, this age category had a higher share of lethality in up to 45 districts (Figure 9). Moreover, the values of lethality of over 65-year-olds formed 100% of deaths in four Slovakian districts (Lucenec, Turcianske Teplice, Zarnovica, and Poltar). The share of Covid-19-related deaths of the indicated age group was under 80% in only ten districts, and the minimum value of 51.9% was registered in the Kezmarok district.

The detected correlation between an older age and lethality can be viewed as a straight line passing through measured points with a moderately ascending character (Figure 10). The graph in Figure 10 characterises the position of some districts as "buckling points". Their position points either to an "extremely" high share of lethality in some regions (red points) or to a very low share of lethality in the monitored age

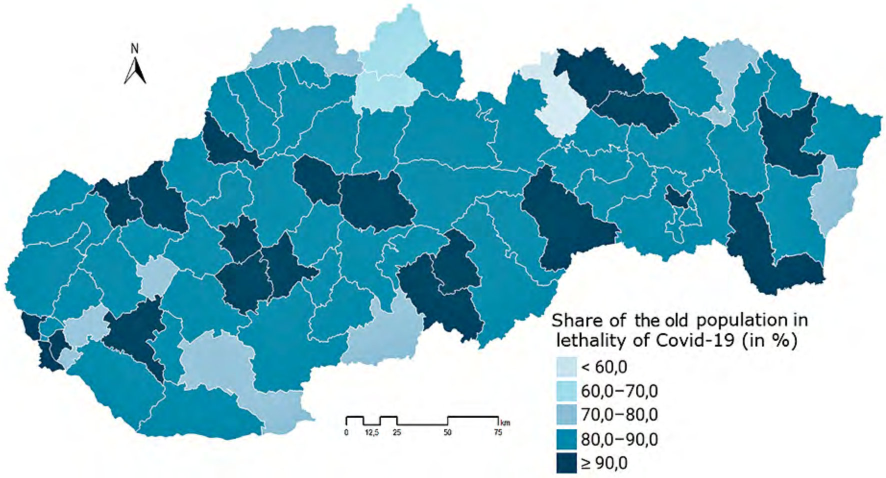

Figure 9. Lethality of Covid-19 of the population in the old (65 and over) age group in districts of Slovakia in 2020
Source: ŠÚ SR (2021)

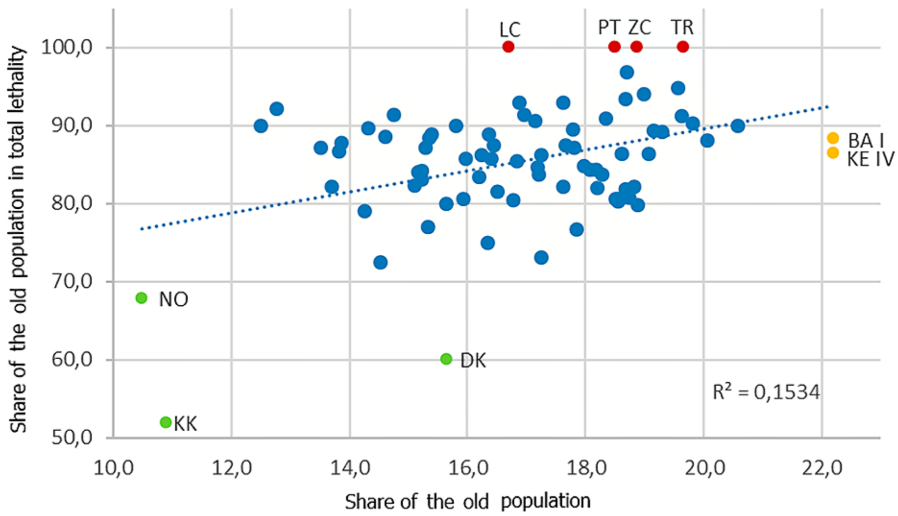

Figure 10. Share of the old population (65 and over) and lethality of Covid-19 in districts of Slovakia in 2020
Source: ŠÚ SR (2021)

group (green points). Other factors play a more intensive role than the virus itself in districts with a low lethality or mortality of seniors.

Changes in mortality

The coronavirus contributed to the number of deaths reaching more than 59,000 in Slovakia in 2020, representing a 10% growth in comparison with the average of the previous five years (2015-2019). The rate of mortality grew approximately by a hundred deaths to 100,000 inhabitants. Last year, the gross rate of mortality reached a value of 10.82 per mil in Slovakia. Out of 100,000 inhabitants, 1,082 people died during the year. The previous five-year average was lower by roughly a hundred persons (984) during 2015-2019. In 2020, the gross rate of mortality was the highest it has been over the last 70 years. Overall, Covid-19 caused 73 deaths per 100,000 inhabitants. Thus, the mortality represented a growth by 5,565 persons against the previous five years.

The results of regional mortality development showed that mortality grew in 71 districts (Figure 11). A total of 34 districts also showed a steep growth of mortality, representing areas with unfavourable and very unfavourable mortality ratios of men[10].

But at the same time only two of these districts registered a high share of deaths related to Covid-19. A relatively smaller growth of mortality was observed in

[10] At men only three from these districts and at women four districts from view of mortality intensity are distinguished by average mortality ratios expressed by life span at birth. In other words, life span at birth in none from identified districts with high growth of deceases does not exceed the average values.

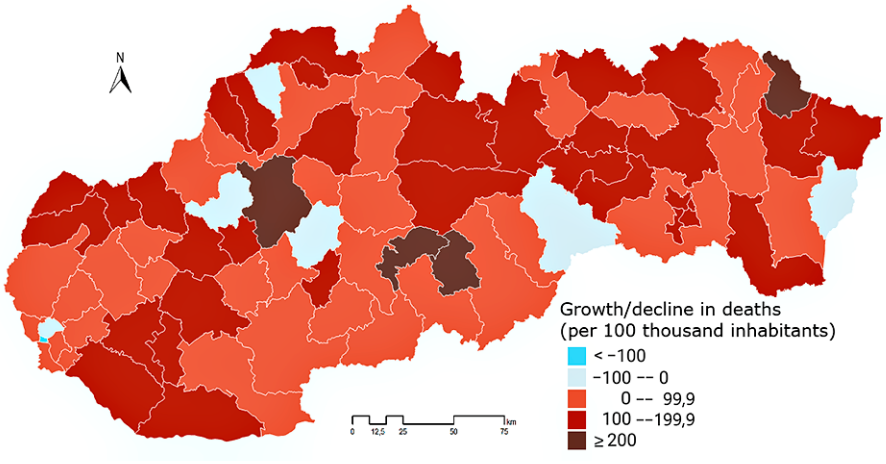

Figure 11. Growth (decline) of deaths in districts of Slovakia in 2020
Source: ŠÚ SR (2021)

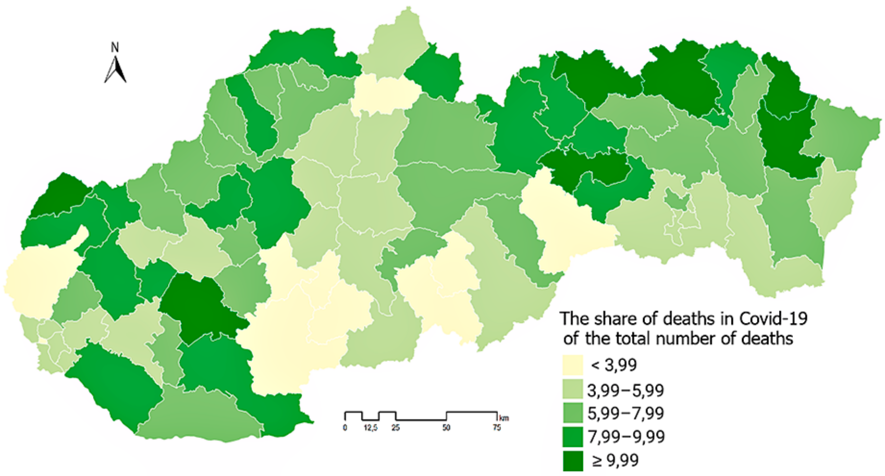

Figure 12. Share of deaths attributed to Covid-19 in districts of Slovakia in 2020
Source: ŠÚ SR (2021)

33 districts and eight districts even exhibited negative values of mortality (decline). This means that in 2020 they had a lower mortality than the average of the previous five monitored years. Two out of five districts of the capital and metropolis of Slovakia, i.e., of Bratislava, registered the highest decline.

Figure 12 shows the districts with the highest and lowest shares of "Covid-19 deaths". Shares exceeding 10% were found in seven districts, and up to five of these were found in the east of the republic. These districts (with a high share of Covid-19 mortality) had all been a regional focus of infection in the course of the year. Some of the indicated districts were foci several times, which caused their increased rates of mortality due to Covid-19. On the contrary, ten districts registered a very low share of Covid-19-related deaths (less than 4%).

Development and level of excess deaths

Altogether the deaths of which the coronavirus was the main cause covered 72% of excessive deceases. Deaths due to other causes accounted for the rest. Covid-19 became a new category of its own in the classification of death causes, which played a dominantly part in the growth of the number of deaths. Figure 13 present the excessive mortality visualised as the gross (raw) number of deaths. The number of raw deaths provides a gross overview of its range. Up to 1,409 deaths had been recorded in Slovakia by November 8th, 2020, or 402 more than recorded by the five-year average (2015-2019).

The values of excess deaths on behalf of individual districts are presented in Figure 14. Increased levels of overdeaths can be seen in the districts of southwestern and southeastern Slovakia and in the districts of the regional towns of Nitra, Zilina, and Presov. The majority of these districts were identified as regional and some even overregional foci of infection in 2020.

The calculated coefficient of spatial concentration showed that half of the registered excess deaths were concentrated in 21 districts; Covid-19 had a main share of excess deaths in thirteen of these. The wide

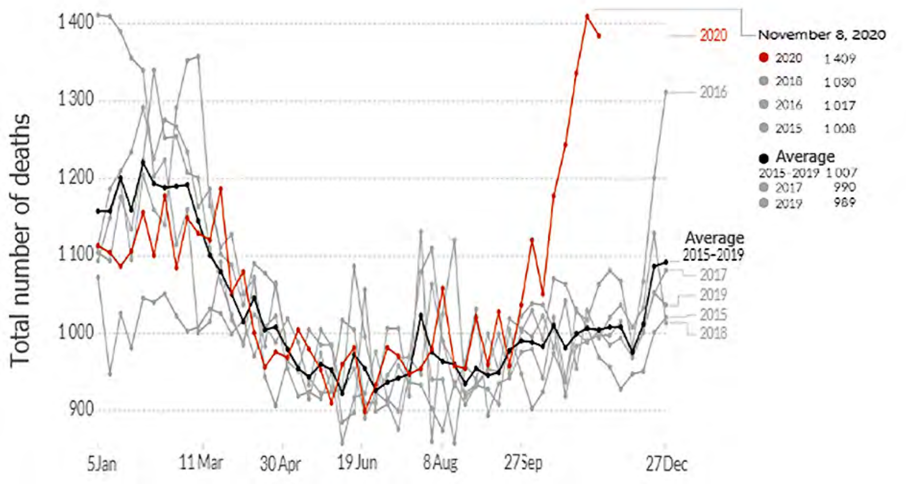

Figure 13. Excessive mortality in Slovakia during the Covid-19 pandemic ("raw" number of deaths)
Source: The Human Mortality Database (2021), Our World in Data (2021)

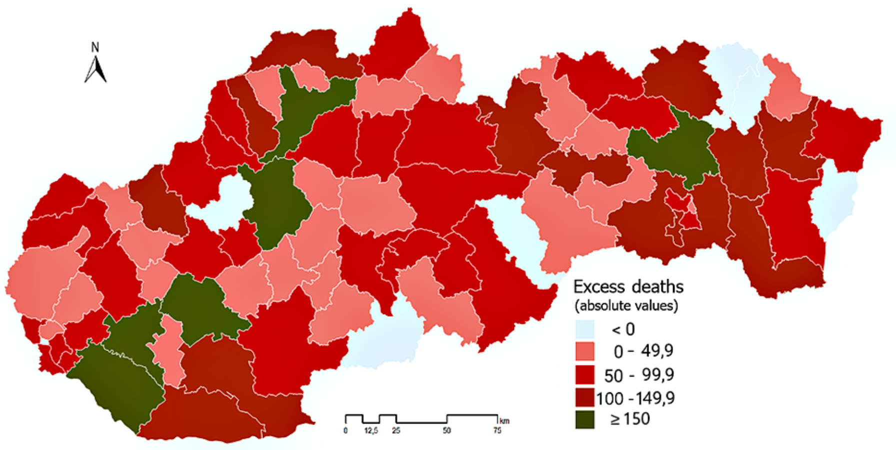

Figure 14. Excess deaths in districts of Slovakia in 2020
Source: ŠÚ SR (2021)

interval between the "district" values of overmortality due to Covid-19 (from 12% up to 77%) and the total number of overdeaths evidences the distinctively differentiated influence of infection in monitored spatial units.

Discussion and conclusion

The evaluation of the pandemic situation in Slovakia and its influence on selected indicators of mortality is complex. These were connected in the first place by definitions and by a relatively wide comprehension of monitored indicators. In case of lethality it is even connected with its different definition. Lethality is defined one way in some countries of Central Europe and in another in countries of Western Europe. A further problem was related to the registration of data from testing, especially of positivity cases. This factor was manifested mostly in lethality evaluation. The positivity rate is a factor (denominator) directly influencing the level of lethality. Overvalued lethality values of Covid-19 could partly be a consequence of antigen (Ag) testing, particularly related to a lack of registering positive cases. In fact, issues were associated with more persons testing positively at home (pensioners, economically active population, people without symptoms, and so on) and not reporting the result of the testing. Inaccuracies in the registration of positively tested persons could cause also an opposite effect, i.e., the undervaluation of lethality. Several cases have been registered when persons that had tested positive through Ag testing had subsequently undergone polymerase chain reaction (PCR) testing. In the case of positive results, the registration issues concerned double positivity and dual inclusion. Even if this error (duplicate registration) was relatively quickly removed, it influenced the accuracy of the results. Deviations of the lethality values in one or in the other direction (its overvaluation or undervaluation) could also be caused by problems in ascribing a cause of death, differences among the number of reported and overall deaths, and the way Covid-19 deaths are recorded (Ministry of Health of the SR, 2021a). In this context, it would be necessary and useful to determine whether or not the obtained results on the lethality of Covid-19 in Slovakia were deviated, and in which direction and to what extent. This, however, requires new and relatively complicated analyses, and detailed revaluations and arrangements (correction of indicated errors) for the registration of positively tested persons.

The evaluation of the pandemic in Slovakia was partly also influenced by the fact that the obtained data had been various and sometimes incorrectly explained or confusedly interpreted. In large measures, the correctness of the results depended on understanding the mechanisms by means of which Covid-19 influences various aspects of mortality. The dynamics of the development of the pandemic during the analysed period also had an influence on the evaluation. The whole first wave and the beginning of the intensive second wave belong to this period. During the first wave, Slovakia was among the countries with the lowest number of cases and the lowest associated mortality. The low values of cases and of monitored indicators of deaths during the first wave represented "isolated islands" in spatial terms. The low level of infected persons and of mortality did not enable a detailed evaluation, deeper interpretation, or more significant generalisation of mortality. The second wave (its beginning) was marked by distinctive increases of the "level" of cases but the monitored period only caught its initial phase. Comparative analyses at a national and regional level revealed the suitability of these reasons as a concept for interpreting the development of the pandemic and its impacts on mortality. The results allowed a comparison between the differences and differentiated impacts of the two waves on selected indicators of mortality. The closed annual time period enabled the analysis of the influences and differentiated impacts of the pandemic at a regional level. It was shown that the monitored indicators of mortality had been influenced not only by the pandemic (by the number of cases) but also by the different characteristics and specific conditions of the districts. The distinctive growth of the number of cases enhanced the level of infection and the values of monitored indicators in almost all districts. This area-wide increase was considerably spatially differentiated, and besides the levels of infection, the increase was conditioned particularly by the different demographic characteristics of the individual spatial units examined. The different profiles of the population (age, gender, ethnic membership, and basic comorbidities) in individual districts, especially in cases of great differences, had a significant influence on lethality determination and, to a large extent, they determined the levels of monitored indicators of mortality. However, until new mortality tables are made available, complex results can be achieved on the intensity of the influence and impacts of Covid-19 on further indicators of mortality in Slovakia. The comparison of mortality tables before and during the pandemic shows not only the growth of the total values of the probability of death among the population, but also mortality growth in various categories. The numbers of living persons will be diminished more quickly with age. Also, the medium life span, especially in age categories over 65 years, can be temporally and more distinctively reduced in risk regions affected intensively by the infection.

This study also confirmed that analyses focused on broader social and demographic indicators should be incorporated in future research to acquire a better understanding of the mechanisms through which Covid-19 influences various aspects of mortality. For example, Kim et al. (2021) tested the geographical differences of social and demographical indicators, mobility, and environmental factors in connection with the number of cases and with mortality related to Covid-19 in New York. Research has also focused on producing tools to identify superspreading places (SSP) which disproportionately spread the Covid-19 virus, i.e., foci, compounds, localities, and regions with a high intensity of cases. These are places with a high cumulation of the population or with a frequency of contacts distinguishing themselves by many further common social and demographical features. Huang et al. (2021) attempted to identify such SSP during four pandemic waves. Studies focusing on social and economic conditions, connections, and contexts of infected persons will provide a significant research direction for understanding the influence and impacts of the pandemic on mortality. Poor people, for whom the highest mortality rates have been recorded, have always bearded the greatest burden of large health crises and of the pandemic. Indeed, it is already evident that people with low social and economic statuses are much more exposed to Covid-19. From the point of view of mortality, older age categories associated comorbidities, which in the case of infection complicate the therapy of the virus itself, are the most affected. The excessive mortality rates connected with the coronavirus are also obvious among poor people in marginalised and socially dependent communities. The repeated phrase that "the Covid-19 does not discriminate" is a dangerous myth which excludes the greater vulnerability of those who are most socially and economically dependent (Patel et al., 2020).

The real contribution of this study lies in its relatively precise and detailed representation of the spatio-temporal aspects of the pandemic in Slovakia in 2020. Empirically, the study presented new information regarding mortality indicators and their differentiated levels in regions of Slovakia during the Covid-19 pandemic. The study provided a valuable research input, particularly in terms of the methodology used for understanding the relatively complicated problems associated with estimating and interpreting monitored indicators in times of an ongoing pandemic. The procedures and methods used here can also be applied to examine the impacts of the pandemic on the monitored demographic processes of other countries or their regions. This study can also serve in the comparative analyses of various aspects and indicators of mortality, and the examination of the spatially differentiated impacts of the pandemic in various spatial units and over distinctive periods (phases or waves) of the pandemic.

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