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DETERMINATION OF THE EPIDEMIC THRESHOLD OF AN INFECTIOUS DISEASE

OKREŚLENIE PROGU EPIDEMICZNEGO CHOROBY ZAKAŹNEJ

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Authors' contribution
Wkład autorów:
A. Study design/planning
zaplanowanie badań
B. Data collection/entry
zebranie danych
C. Data analysis/statistics
dane – analiza i statystyki
D. Data interpretation
interpretacja danych
E. Preparation of manuscript
przygotowanie artykułu
F. Literature analysis/search
wyszukiwanie i analiza literatury
G. Funds collection
zebranie funduszy

Summary

Background. The purpose of this work was to develop a program algorithm for calculating and graphically constructing the level of the epidemic threshold of an infectious disease.
Material and methods. To calculate the epidemic threshold of an infectious disease, a statistical method was applied. Microsoft Visual Basic was used (as a programming language and development environment) to write the program algorithm. MS Excel was used to enter the input data of the weekly incidence rate.
Results. The algorithm of the program is quite easy to use; it consists of 12 consecutive steps with the entry of relevant data in each field of the window that appears. Thus, weekly information on the level of morbidity in a certain region for any period of the year (maximum 52 weeks) is entered into the program. After entering the information, the program displays a graph with the epidemic threshold value for each week. Due to this, it is possible to compare the level of the epidemic threshold in different periods of the year.
Conclusions. The developed computer program makes it possible to determine the epidemic threshold of any infectious disease. It can be used to analyze and predict any infectious processes that are permanent, including COVID-19.

Keywords: epidemic threshold, SARS, COVID-19, pandemic

Streszczenie

Wprowadzenie. Celem niniejszego badania było opracowanie algorytmu programu do obliczania i konstrukcji graficznej poziomu progu epidemicznego choroby zakaźnej.
Materiał i metody. Do obliczenia progu epidemicznego choroby zakaźnej wykorzystano metodę statystyczną. Do napisania algorytmu programu zastosowano Microsoft Visual Basic (jako język programowania i środowisko programistyczne). Do wprowadzenia danych wejściowych tygodniowego współczynnika zachorowalności wykorzystano program MS Excel.
Wyniki. Algorytm działania programu jest dość łatwy w obsłudze; składa się z 12 kolejnych kroków obejmujących wpisywanie odpowiednich danych w każdym polu pojawiającego się okna. Tym samym do programu wprowadzane są cotygodniowe informacje o poziomie zachorowalności w danym regionie dla dowolnego okres roku (maksymalnie 52 tygodni). Po wprowadzeniu informacji program wyświetla wykres z wartością progu epidemicznego dla każdego tygodnia. Dzięki temu można dokonać porównania poziomu progu epidemicznego w różnych okresach roku.
Wnioski. Opracowany program komputerowy umożliwia wyznaczenie progu epidemicznego dowolnej choroby zakaźnej. Można go wykorzystać do analizy i przewidywania wszelkich trwałych procesów infekcyjnych, w tym COVID-19.

Słowa kluczowe: próg epidemiczny, SARS, COVID-19, pandemia

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Introduction

During the entire history of its existence, humanity has constantly faced many pandemics. Pandemics such as the plague in the 14th century, cholera in the 19th century, and the “Spanish flu” in 1918-1920 led to large demographic losses. In December 2019, a pandemic of the coronavirus disease (COVID-19) spread across the world, from which 6.72 million people have already died [1,2]. It is known that COVID-19 is a new virus related to the same family of Severe Acute Respiratory Syndrome (SARS) and some types of common cold [3,4]. The consequences of any pandemic lead not only to demographic, but also to significant economic losses, due to the external self-isolation of states and the introduction of internal quarantine regimes [5,6]. Therefore, the timely introduction of effective quarantine measures is extremely important to prevent the development of a pandemic.

To prevent an epidemic of any infectious disease, its timely prediction is important. Epidemic forecasting is based on long-term monitoring of the incidence rate, which is usually recorded weekly. The average value of such a weekly incidence is called the epidemic threshold, exceeding which may indicate the danger of an epidemic and is the basis for preventive anti-epidemic measures [7].

The epidemic threshold is the maximum value of the intensive incidence rate of influenza or SARS, which is the upper limit of fluctuations in the non-epidemic incidence rate, which is determined, according to multi-year data in each region every week, and indicates the beginning of an epidemic. This average indicator helps to determine the beginning of an epidemic rise in morbidity, which, under certain conditions can turn into an epidemic [8,9]. That is, to a certain extent, a signal to take measures to prevent an influenza epidemic.

There are a number of well-known statistical methods for calculating the epidemic threshold. The inconvenience in the calculations of the epidemic threshold lies in the repeated routine conduct of these calculations [10]. In addition, a large set of obtained calculation results, without their visualization, makes it difficult to perceive the patterns of the unfolding epidemic process. Therefore, the search for simpler and more convenient methods of calculating the epidemic threshold indicator is relevant.

The aim of this study was to develop a program algorithm for calculating and graphically constructing the level of the epidemic threshold of an infectious disease, including COVID-19.

Material and methods

In order to simplify the procedure for calculating the epidemic threshold of an infectious disease and to present them in a form convenient for analysis, a corresponding program in the Vista Basic software environment was developed [11]. The program is designed in such a way that it is possible to determine the epidemic threshold for any week of the year for any five-year time period or even more. The program works in dialogue mode, providing current information about the entered data, which allows you to avoid errors when entering data on morbidity and population in the studied region. The interface of the program is English, which makes it more convenient to use.

To calculate the epithreshold using a computer program, the following steps were used:

1) first, the arithmetic mean of the elements of the set (X) was calculated:

$$X = \frac{1}{N}\sum_{i=1}^{n} x_i \tag{1}$$

where

X – the average rate of morbidity for several weeks in which there was no epidemic of the disease;

N – the number of years in which no epidemic was recorded.

2) then the root mean square deviation (σ) and the upper tolerance limit of probable fluctuations of the average indicator (xσ) – the epidemic threshold were calculated:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{n} (x_i - X)2} \qquad (2)$$

3) calculation of the epidemic threshold indicator using the Student's table, for example:

$$x\sigma = x + Qp \qquad (3)$$

where Q – percentage point of the Student's distribution for the confidence probability *p* with N degrees of freedom.

Exceeding the epidemic threshold is considered to be a sign of the beginning of an epidemic.

Microsoft Visual Basic was used (as a programming language and development environment) to write the program algorithm. MS Excel was used to enter the input data of the weekly incidence rate. The program was approved at the meeting of the Committee on Bioethics for Research of the Ternopil National Medical University No. 14/22.

Results

The algorithm of the program for calculating the epidemic threshold of an infectious disease is as follows. When starting the program, certain parameters appear, which, within which the program, actually work. In particular, it indicates how many years it is necessary to enter data to obtain a statistically reliable value of the epidemic threshold for a particular week of the year (Figure 1).

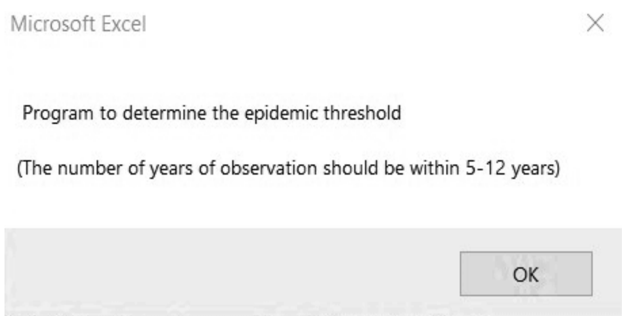

Figure 1. Information on the conditions of data entry

The next step is to choose the time period for which the epidemic threshold should be set. The program allows you to set an epithreshold, both for a separate weekly period of time and for all weeks of the year. In this example, the first week of the year has been entered (Figure 2).

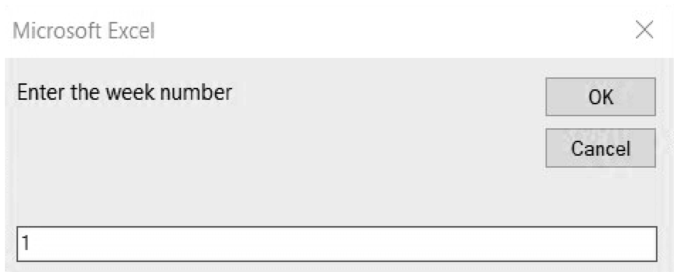

Figure 2. Given week of the year

In the next window, you are given the right to choose the number of years to be studied (within 5-12 years). In this case, it is planned to enter information on the incidence of SARS in the first week for five years. Thus, it is worth noting that the choice of years can be both a group of consecutive and different years, which can be dictated by the needs of the researcher.

If the number of selected years does not meet the conditions (requirements) of the program (for example, the data is entered incorrectly), the program displays the following message (Figure 3).

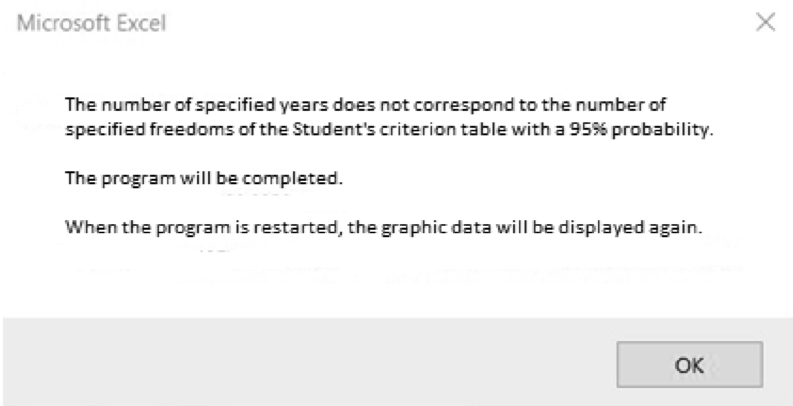

Figure 3. Information about violation of data entry conditions and program termination

The program also allows you to choose an algorithm for working with it (Figure 4). In the event that the performer admits the possibility of mechanical errors when entering data and therefore considers it necessary to check the entered data, he/she can select the "yes" option; in the opposite case: "no". This function allows you to increase the efficiency of working with the program.

Figure 4. Selection of information input algorithm

The next step of the program execution algorithm is to enter data on the incidence rate for the previously selected week of the year. In this example, it is the first week of each year (Figure 5). The number of years corresponds to the value entered earlier. This means that, in this example, it is necessary to enter information about morbidity for the first week of the year five time frame.

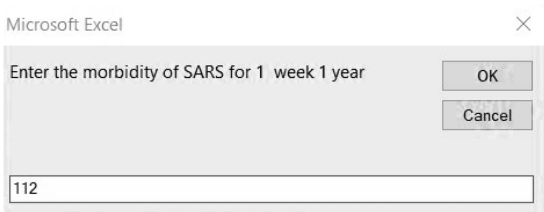

Figure 5. Data entry field

The entered information is stored in an MS Excel sheet and can be used for any analysis and processing after the program is finished.

Figure 6 shows that the program makes it possible to check the correctness of the entered information about the incidence rate.

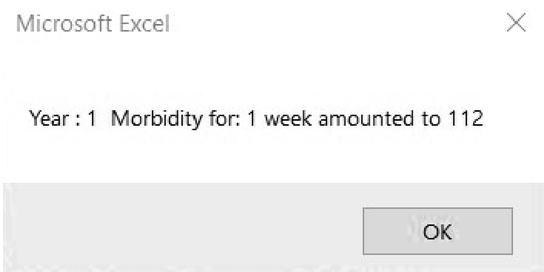

Figure 6. The window for checking data entry accuracy

Similarly, information is entered on the morbidity rate for a certain year. In addition, the total population in the studied territory in the specified year of observation should be entered into the program (Figure 7).

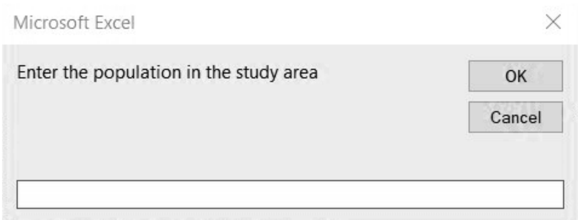

Figure 7. A field for entering information about the population in the studied territory in the given year

Upon completion of entering population morbidity data for the studied weekly period of time over a several-year interval, the program outputs the epithreshold value (Figure 8) and makes the following request (Figure 9).

Figure 8. The window for displaying information about the level of the epidemic threshold in the studied range of years for this week

After that, the program offers a choice – to continue entering data for the next week of the year, or to finish the work with saving the entered data (Figure 9).

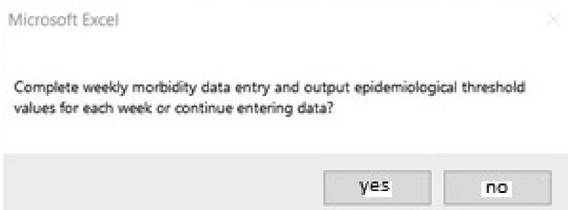

Figure 9. A window for making a decision on further information entry

In the case of confirmation "yes", the program will display a graph of the epithreshold value change for each of the entered values. In case of rejection "no", the program will provide access to enter the next data packet. In this way, weekly information for any period of the year is entered into the program (maximum – 52 weeks.) After entering the information, the program displays a graph (Figure 10) with the value of the epidemic threshold for each week.

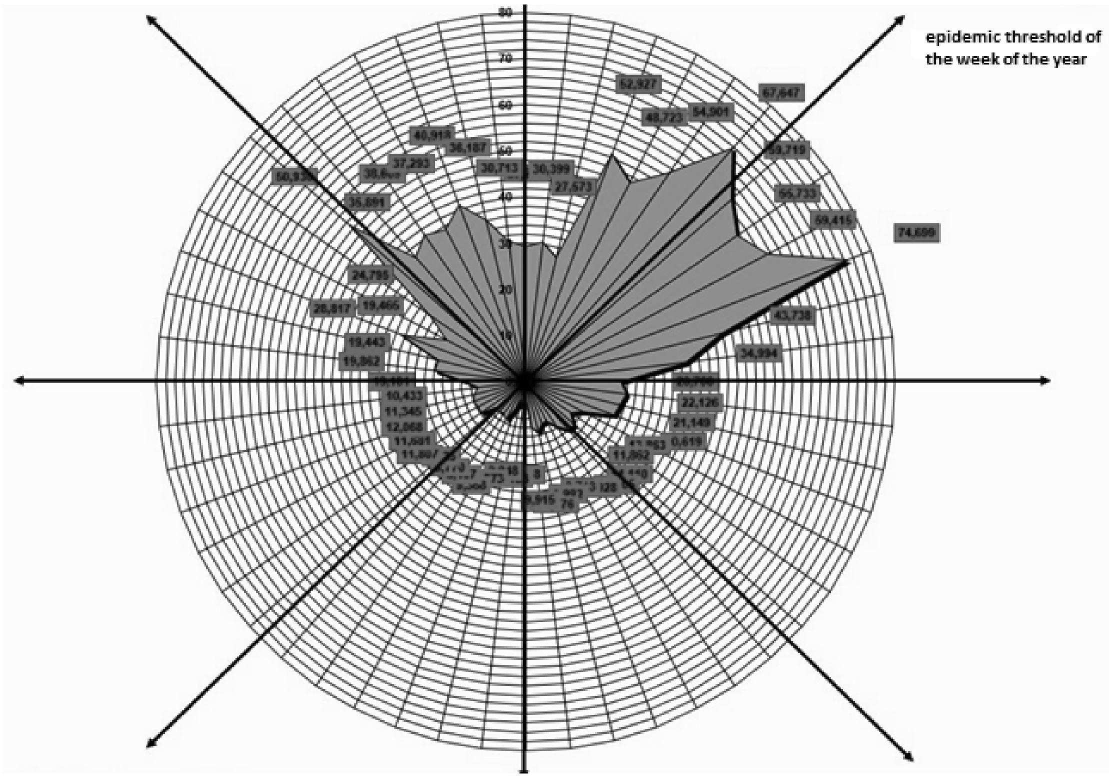

Figure 10. The graph that the program builds after entering data for all 52 weeks of the year

If you enter data for fewer weeks, the graph will display a field corresponding to the number of weeks entered. For example, in the Ternopil region of Ukraine with a population of 1,065,709 people, a large number of cases of COVID-19 were registered during 2020-2022. The weekly number of injured cases was entered into the program and a graph of the epidemic threshold was created (Figure 10). It is visible that the highest epidemic threshold was registered in October-November (the highest: 74,699 per 100,000 population). For a more accurate definition of the epidemic threshold of COVID-19 for a given region, weekly reporting is required for 5 years, but, in Ukraine, cases of COVID-19 began to be registered only in 2020. Therefore, looking at such an example, it is easy to understand the principle of operation of the program for determining the epidemic threshold of an infectious disease.

Discussion

It is known that influenza and other acute respiratory infections, and now also COVID-19, are the most widespread diseases that occur throughout the year, but most often in autumn and winter. According to the World Health Organization, SARS ranks first in the structure of infectious diseases and accounts for 80–90% of all infectious pathology [12]. The economic damage from the recent COVID-19 pandemic is huge, and it is a loss both for an individual (lost working days, medicine costs) and for society as a whole [13]. Therefore, timely determination of the epidemic threshold of seasonal infectious diseases (SARS) and the introduction of effective quarantine measures will help stop the spread of the epidemic.

The epidemic threshold is considered to be the maximum value of the acute SARS incidence rate, which is the upper limit of fluctuations in the non-epidemic incidence rate, determined according to long-term data in each region every week and indicating the beginning of an epidemic [14]. It is known that, in order to carry out an operational analysis of the incidence of influenza and SARS in certain weeks of the year, it is necessary to: number the weeks of the year (from week 1 to week 52 or 53); calculate the intensive indicators of influenza and SARS (total) per 100,000 population by age group and the entire population. When calculating the epidemic threshold in a routine way, many inaccuracies may occur, due to cumbersome calculations and the complexity of mathematical formulas [15]. The use of a computer program for automatic calculation of the epidemic threshold greatly facilitates the process of determining this indicator and also makes it possible to immediately visualize the epidemic picture of SARS in the region. Currently, there are programs for calculating the epidemic threshold of an infectious disease, but they are quite difficult to use in practice [16]. This prompted us to develop our own computer program for calculating and graphically constructing the level of the epidemic threshold of an infectious disease, including COVID-19.

The advantages of our program are that, after entering data on the level of morbidity by week, we see the display of the results in the form of a radar chart, unlike similar programs with a linear graph display. Due to a radar chart diagram, it is much easier to track the cyclicity of a certain disease. Furthermore, the program developed by us is relatively easy to use: as information is received (incidence rate weekly), the trend of changes is immediately displayed.

This program can be used to analyze and predict any infectious processes that are permanent, including COVID-19. In a broader sense, it can be used to obtain information about the dynamics of any population processes presented in any given time intervals (weeks, months, quarters) during the studied period.

Conclusions

The computer program developed by us makes it possible to determine the epidemic threshold of any infectious disease. It can be used to analyze and predict any infectious processes that are permanent, including COVID-19.

Disclosures and acknowledgments

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