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Analysis of Global Influenza Outbreak Cycles and Patterns

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Abstract: History demonstrates that despite continuous advancements in modern medicine, the cyclical tendency of influenza to break out locally or globally remains largely unhindered. In 1918, the world experienced the most famous severe influenza pandemic in history—the "Spanish Flu". Following this pandemic, the average life expectancy in the United States dropped by 10 years. In 1957, the "Asian Flu" (virus type H2N2) emerged, sweeping through Asian countries within two weeks before spreading to Australia, the Americas, and Europe, affecting countless nations. Globally, over 2 million people were affected by this outbreak. Since April 2009, multiple countries and regions, including Mexico and the United States, have experienced outbreaks of H1N1 influenza. This paper aims to analyze the periodic patterns and rules of influenza outbreaks and transmission through climate influences by examining global influenza surveillance data from the World Health Organization, utilizing Python modeling techniques. Based on the research, this paper found that the spread of influenza will have different transmission cycles depending on the region and climate. Secondly, the spread of influenza will be affected by factors such as season, temperature, humidity and temperature difference between day and night. At the same time, through the study of the three proposed human activities, it was found that only school holidays significantly reduce the spread of the virus.

Keywords: influenza, region, outbreak

1. Introduction

The influenza, commonly known as the flu, is an acute respiratory infection caused by influenza viruses, characterized by high transmissibility and rapid spread. It primarily transmits through airborne droplets, direct human-to-human contact, or contact with contaminated objects. Typical clinical symptoms include sudden high fever, body aches, significant fatigue, and mild respiratory symptoms. Influenza viruses are classified into three types: A, B, and C. Type A viruses frequently undergo antigenic variations, possess high infectivity, spread rapidly, and are highly prone to widespread epidemics.

Currently, influenza vaccination is the most effective method of prevention. However, due to the rapid mutation of influenza viruses, the seed viruses used for vaccine production (known as influenza vaccine strains) need to be frequently updated. Therefore, obtaining influenza vaccine strains that best match circulating viruses is key to improving prevention and control effectiveness.

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Traditional influenza vaccine strain selection is primarily based on virological, serological, and epidemiological data. However, due to lengthy experimental cycles, this approach cannot timely reflect viral mutations, resulting in the World Health Organization's recommended vaccine strains having an accuracy rate of less than 50%.

Here's the English translation:

This paper analyzes WHO influenza surveillance data and utilizes Python modeling to summarize the periodic patterns and seasonal variations of influenza outbreaks across different global regions, aiming to establish more efficient influenza prevention mechanisms and improve vaccine effectiveness.

By examining these patterns and variations, it can better predict outbreak timing, optimize vaccine production schedules, improve strain selection accuracy, develop region-specific prevention strategies, and enhance global surveillance systems.

2. The Periodicity and Seasonality of Influenza

2.1. Analysis of Global Influenza Time Series

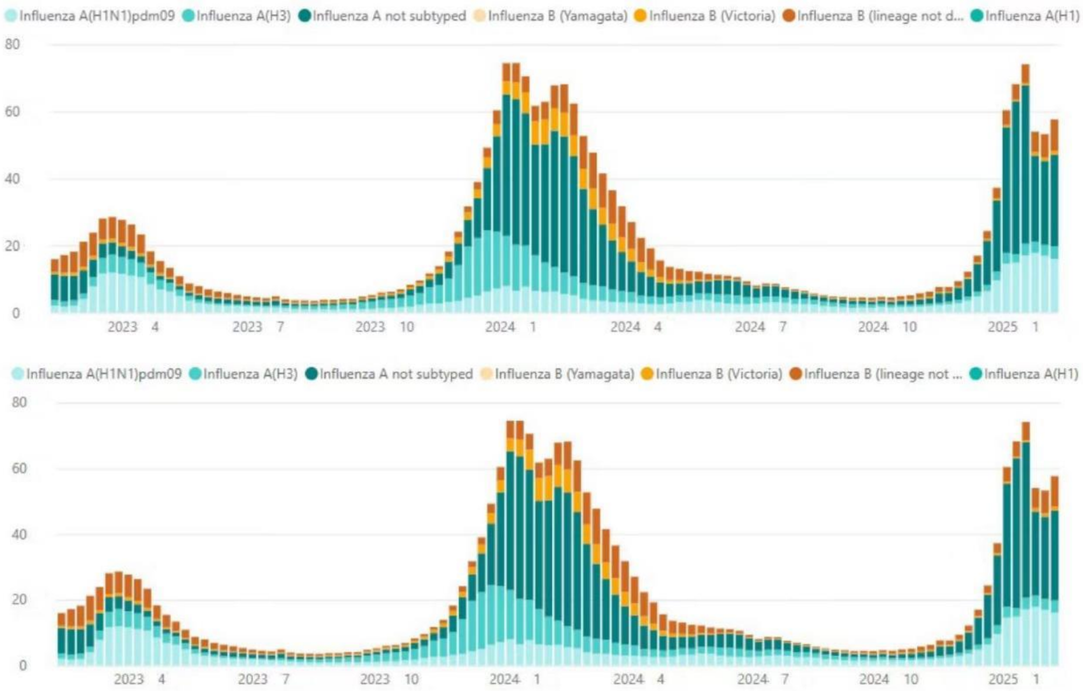

Figure 1: Picture of comparison of the number of influenza detections by subtype [1]

Figure 1 shows the temporal trends of different influenza subtypes (A(H1N1) pdm09, A(H3), A not subtyped, B (Yamagata), B (Victoria), B (lineage not determined), and A(H1) across various geographic regions. There are clear seasonal patterns, with annual peaks typically occurring during the winter months in temperate regions. Certain subtypes, such as A(H1N1)pdm09 and A(H3), show more pronounced spikes and variability over the years compared to the B strains.

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2.2. The Seasonal Differences and Patterns of Influenza Outbreaks in Different Regions

2.2.1. Seasonal Differences and Patterns of Influenza Outbreaks in Tropical Regions

Tropical regions exhibit more variable and less predictable seasonal patterns. A similar effort by Soebiyanto and others to link weather to respiratory syncytial virus (RSV) and rhinovirus found that the former was more active in lower temperatures and the latter followed an inverse U curve. It's not known why temperature seems to matter for RSV and rhinovirus but not influenza in these highly-seasonal temperature latitude [2]. In addition, numerous studies have found that the transmission rate and mortality rate of influenza are both related to humidity [3].

2.2.2. The Seasonal Differences and Patterns of Influenza Outbreaks in Temperate Regions

Taizhou City in Zhejiang Province is located in a subtropical monsoon climate zone, and according to the research conducted by Wang Ziyi, Shen Weiwei, and others, influenza incidence in the city shows clear seasonal patterns. Type A influenza viruses primarily circulate in the summer (July–August), with a second peak occurring in winter (January–February). Among them, the seasonal H3 subtype peaks mainly in July–August, while the novel H1 subtype peaks in January–February. Type B influenza viruses are prevalent in winter (December to February of the following year). This influenza pattern is consistent with other subtropical monsoon regions such as Jiangsu and Shanghai [4].

2.3. Analysis of the Cyclical Pattern of Influenza

In some areas, influenza is seasonal, usually occurring in winter and during high daytime mobility. The spread of influenza usually relies on crowd movement and mutual contact. Therefore, geospatial and temporal patterns are indispensable factors in influenza outbreak modelling. Traditional Susceptible-Infected-Recovered and susceptible-exposed-infective-removed models are commonly used to analyse the course of epidemics. However, more complex spatio-temporal models must be constructed if geospatial and population movement applications are to be considered. Influenza coexists with seasonal and temporal flows despite its stochastic and dynamic nature. The SARIMA (Seasonal ARIMA) model was used in the temporal outbreak modelling, and its equation is expressed as:

$$y_t = \emptyset_1 y_{t-1} + \emptyset_2 y_{t-2} + \cdots + \epsilon_t \tag{1}$$

In geospatial terms, it was chosen to use the SEIR model for the application of the application and to add quantitative and discrete rules to it in a uniform way:

$$\frac{dS}{dt} = -\beta\frac{SI}{N}\frac{dE}{dt} = \beta\frac{SI}{N} - \delta E\frac{dI}{dt} = \delta E - \gamma I\frac{dR}{dt} = \gamma I \tag{2}$$

3. The Impact of Climate and Human Activities on the Transmission of Influenza

3.1. The Impact of Climate on the Transmission of Influenza

The spread of influenza is closely related to factors such as season, temperature, humidity, and diurnal temperature variation [5].

3.1.1. Temperature

For low temperatures, cold conditions promote the survival of influenza viruses and help to explain the overwintering of the virus in the Northern and Southern Hemispheres. The airborne influenza A

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virus is more stable at low temperature and is more efficiently transmitted in cold weather. Furthermore, people are much more likely to be indoors during cold weather, thereby increasing the density of susceptible individuals in confined spaces that are necessary for efficient virus transmission. While the high temperature destroys influenza viruses, reducing the opportunity for transmission. But as it gets extremely hot, people's activity patterns can change and air-conditioning centers can become crowded, promoting the spread of the flu virus and other respiratory infections.

3.1.2. Humidity

When it is in low humidity, dry air does not absorb airborne influenza virus particles as readily as moist air does, facilitating airborne transmission. This is reflected in the micro-droplets that are generated and remain available for inhalation when people breathe, speak, cough, or sneeze in dry rather than wet conditions. Studies have shown that both laboratory-produced viruses and airborne influenza viruses collected during outbreaks are inactivated more rapidly in humid conditions than in dry conditions. Low humidity also leads to drying of the respiratory tract, reducing the body's innate immune defenses and increasing the likelihood of influenza infection. While it is in the high humidity. The water content in droplets are much higher, causing viruses to settle more quickly, reducing their ability to travel through the air. However, high humidity might also lead to increased secretion in the respiratory tract, indirectly promoting viral transmission.

3.1.3. Precipitation

The association between precipitation and the spread of the flu probably reflects correlations of this weather condition with lower temperature and higher humidity. Cooling and wetting of the environment facilitate the transmission of the virus: as noted just above, cooler, damper environments keep people indoors, enabling the airborne virus to spread.

Take Beijing as an example, Beijing is located in the northwestern of the North China Plain and has a typical warm temperate, semi-humid, continental monsoon climate. Beijing's summers are hot and rainy, winters are cold and dry, while spring and autumn are short. The annual average rainfall is 600 mm, with 75% of the precipitation concentrated in the summer.

Cao Zhidong, Zeng Dajun, and others conducted a study in 2009 on the relationship between the positivity rate of H1N1 influenza in Beijing and meteorological factors such as temperature and humidity. The study started on August 3, 2009, and ended on November 2, 2009, the H1N1 positivity rate in Beijing increased from 0.0086 to 0.7035. Using correlation statistical methods, they compared the H1N1 positivity rate during this period with four meteorological factors. The results showed that temperature and relative humidity were significantly negatively correlated with the H1N1 positivity rate, while precipitation and wind speed showed no significant correlation with the positivity rate. The spread of H1N1 in Beijing exhibited a notable synchronous pattern with cold and dry environmental conditions [6].

3.2. The Impact of Human Activities on the Transmission of Influenza

Wang et al. used monthly data from provincial administrative regions between 2004 and 2017 in China and influenza incidence data across different age groups nationwide to examine this question. The researchers found that school holidays can effectively inhibit the local transmission of influenza. In contrast, transportation and trade together can expedite the transmission of influenza both within a certain period and between periods within and between regions. The effects of school holidays and transportation on the transmission of influenza are especially pronounced during the winter and spring high-incidence seasons, whereas the effect of trade on the transmission of the disease is especially significant for summer and autumn (low-incidence) seasons. The researchers also found that

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compared with the other activities, railways and aviation have a greater impact on influenza transmission than highways (which was also found in the earlier study). In addition, they found that of the three economic activities—school holidays, transportation, and trade—school holidays alone have the effect of reducing the transmission of the disease [7].

4. Conclusion

This paper mainly studies the outbreak cycle of influenza in different climate regions, models and infers the outbreak cycle, and analyzes some of the main factors affecting the outbreak cycle of influenza. Finally, it analyzes how human activities affect the outbreak of influenza and provides some corresponding protective measures. The spread of influenza is closely related to factors such as season, temperature, humidity, and diurnal temperature variation. In highly urbanized areas, places with dense populations, such as shopping malls, schools, and factories, are prone to explosive outbreaks. Strengthening influenza surveillance, promptly understanding the epidemic characteristics and changes of the influenza virus, and summarizing regular patterns based on regional climate characteristics and outbreak periods are of significant guiding importance for future influenza prevention and control. This paper only analyzes the regional influenza outbreak in tropical and temperate climates, and does not analyze all climate regions in the world, so the data included may not represent the world. Secondly, the content of the human activity study of the influenza outbreak cycle is slightly insufficient, because no modeling and data calculation were performed, so the following content may focus more on the impact of human activities on influenza outbreaks and the study and analysis of preventive measures.

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