Estimation of the Size of Influenza Epidemic in the WHO European Region

DSÖ Avrupa Bölgesinde Grip Salgınının Büyüklüğünün Tahmin Edilmesi

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ABSTRACT

This study aims to estimate the magnitude of the influenza epidemic in WHO European countries and territories. The wavelengths of these countries were compared based on the number of influenza cases, including subtypes A and B. The epidemiological wavelength method was used to assess the outbreak's magnitude, considering factors like population density, human development index, case count, and the number of days since the first case was recorded. The UK, England, had the highest wavelength scores (W_e) in 2022, 2023, and 2024. Conversely, Azerbaijan had the lowest wavelength scores (W_e) in 2022 and 2023, respectively. The average wavelength score for WHO European countries and territories reached its peak in 2023, with the lowest score in 2022 at 13.44 W_e. The study suggests that the epidemiological wavelength method can be used to estimate outbreak size, providing a clearer and more reliable cross-sectional image of the epidemic.

Keywords: Influenza, WHO European Region, Epidemic, Epidemiological Wavelength method

ÖZ

Bu çalışma DSÖ Avrupa ülkeleri ve bölgelerindeki grip salgınının büyüklüğünü tahmin etmeyi amaçlamaktadır. Bu ülkelerin dalga boyları, A ve B alt tipleri de dahil olmak üzere influenza vakalarının sayısına göre karşılaştırılmıştır. Salgının büyüklüğünü değerlendirmek için nüfus yoğunluğu, insani gelişme endeksi, vaka sayısı ve ilk vakanın kaydedilmesinden bu yana geçen gün sayısı gibi faktörler göz önünde bulundurularak epidemiyolojik dalga boyu yöntemi kullanılmıştır. 2022 ve 2024 yıllarında Birleşik Krallık (İngiltere), en yüksek dalga boyu skorlarına (W_e) sahip ülke olarak öne çıkarken, Azerbaycan'da 2022 ve 2023 yıllarında en düşük dalga boyu skorları gözlemlenmiştir. DSÖ Avrupa ülkeleri ve bölgeleri için ortalama dalga boyu skoru 2023'te zirveye ulaşırken, en düşük skor 13,44 W_e ile 2022'de görülmüştür. Çalışma, epidemiyolojik dalga boyu yönteminin salgın büyüklüğünü tahmin etmek için kullanılabileceğini ve salgının daha net ve daha güvenilir bir kesitsel görüntüsünü sağlayabileceğini göstermektedir.

Anahtar Kelimeler: Grip, DSÖ Avrupa Bölgesi, Salgın, Epidemiyolojik dalga boyu yöntemi

Ethical approval has not been obtained as the data are public.

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INTRODUCTION

Each year, seasonal influenza accounts for approximately one billion cases, leading to 280,000 to 650,000 respiratory deaths, predominantly in developing countries, comprising 99% of cases.[1]

The upper respiratory tract, which includes the nose, throat, bronchi, and, less often, the lungs, is the main target of influenza, an acute viral illness. The illness is seen all throughout the globe and spreads swiftly among people, particularly in crowded areas. About 5–15% of people in the northern hemisphere are affected by the yearly influenza outbreaks that happen in the fall and winter. The upper respiratory tract, which includes the nose, throat, bronchi, and, less often, the lungs, is the main target of influenza, an acute viral illness. The illness is seen all throughout the globe and spreads swiftly among people, particularly in crowded areas. About 5–15% of people in the northern hemisphere are affected by the yearly influenza outbreaks that happen in the fall and winter.[2]

Annual influenza epidemics in the WHO European Region typically occur in the autumn and winter, potentially impacting up to 20% of the population.[3] The World Health Organization's May 2024 report indicates that the cumulative number of cases of influenza subtypes A and B recorded in the WHO European Region from September 1, 2023, to May 31, 2024, amounted to roughly 175,000.[4]

In the literature, modeling the COVID-19 outbreak and other epidemics by relying solely on case numbers as input and utilizing traditional epidemiological rates and methods poses a considerable challenge in accurately depicting the true progression of the outbreaks. Therefore, it is essential to model epidemics by considering the demographic and socioeconomic conditions of the countries or regions in which they occur.[5] This approach can enable a more accurate evaluation of outbreak magnitudes in countries or regions. The epidemiological wavelength approach functions as a tool to assess epidemic magnitude. Thus, decision-makers can transcend traditional epidemiological rates and methods that fail to effectively clarify pandemics or epidemics, facilitating a clearer and more reliable cross-sectional depiction of the epidemics.

This retrospective observational study aims to estimate the size of an influenza epidemic in countries and territories within the WHO European Region using the epidemiologic wavelength approach. Consequently, by using this method as an outbreak size estimation tool, decision-makers can more efficiently and swiftly control the epidemic process and enhance the resilience of health systems by making better informed public health decisions. The approach incorporates influenza cases from the FluNet database of the Global Influenza Surveillance and Response System as a parameter. The influenza cases dataset from the FluNet database encompasses cases from April 25, 2022, to October 21, 2024. The estimate of epidemic magnitude using the epidemiological wavelength approach incorporates additional parameters, including human development index and population density data sets.

MATERIAL AND METHODS

The study population comprised 55 territories and countries within the WHO-defined European Region, while the target population consisted of 50 countries and territories.

Data Sets

In order to estimate the size of the influenza pandemic in countries and territories in the WHO European Region using the epidemiological wave size method, It was first obtained data sets on the number of influenza cases by country and territory, population densities of countries and territories (people per square kilometer of land area), and human development index of countries and territories.

The study utilized the publicly available FluNet database from the WHO to monitor the number of cases of influenza in countries within the WHO European Region. Established in 1997, the Global Influenza Surveillance and Response System FluNet database functions as a web-based resource for the virological monitoring of influenza.[6] Influenza case counts include diagnoses of both type A and type B influenza. The surveillance system, comprising sentinel, non-sentinel, and additional unspecified types, supplied the influenza case numbers. Data on influenza cases were collected from April 25, 2022, to October 21, 2024. This is because the entry of influenza case numbers into the Global Influenza Surveillance and Response System (GISRS) FluNet began in April 2022. Bosnia and Herzegovina, Cyprus, and Turkmenistan were excluded from the dataset for year-by-year comparison due to missing data in the time series.

The current population density of the European region was obtained from https://ourworldindata.org.[7] Conversely, population density data for England, Wales, Scotland, and Ireland were acquired from the UK Office for National Statistics (ONS).[8]

The United Nations (UN) official website, https://hdr.undp.org/, provides the Human Development Index (HDI) dataset.[9] The latest published HDI data for 2022 were used. Since HDI data are not available separately for England, Wales, Scotland, and Northern Ireland, the HDI data for the United Kingdom were used as a proxy for these regions. Kosovo was excluded from the analysis due to a lack of available HDI data.

Ethical Approval

Ethical approval has not been obtained as the data are public.

Funding

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Confict of interest

The author declared no conflict of interest.

Statistical Analysis

The dependent t-test for paired samples, a parametric statistical test, was employed to assess whether the differences in the periodic wavelengths derived from the wavelength model were statistically significant from one another. The differences in the periodic wavelengths of WHO European countries or territories were analyzed in two groups: 2022-2023 and 2023-2024. Prior to the t-test for paired samples, the Shapiro-Wilk normality test was conducted to assess whether the test data met the assumption of normal distribution, which is one of the parametric assumptions. The Shapiro-Wilk test evaluates the null hypothesis, asserting that the data follows a normal distribution, in contrast to the alternative hypothesis that the data does not conform to a normal distribution. It is presumed that the data follows a normal distribution if the p-value for the Shapiro-Wilk test exceeds 0.05. The following hypotheses have been established within the scope of the dependent t-test for paired samples:

- H_0: There is no difference in mean between the difference in the number of influenza cases in 2022-2023 and the difference in the number of influenza cases in 2023-2024.
- H_A: There is a difference in mean between the difference in the number of influenza cases in 2022-2023 and the difference in the number of influenza cases in 2023-2024.

The study used Microsoft Excel[10] for data mining and data summarization, and the R programming language[11] for statistical tests.

Limitations of the study

Since the epidemiological wavelength method, which measures the size of epidemics, provides a snapshot of the epidemic, the findings obtained from the method should not be used as a means of predicting the future. However, future forecasting studies can use the method's findings as input. A further limitation is that the Human Development Index (HDI) published by the United Nations (UN) does not encompass certain regions within the WHO European Region, resulting in their exclusion from the study. Moreover, the likelihood of underreporting influenza cases in countries and territories within the WHO European Region can impact the outcomes of wavelength estimation.

Epidemiological Wavelength Method

The epidemiologic wavelength (W_e) method, as described by Bulut and Top[5], is employed in the WHO European Region to estimate the magnitude of influenza outbreaks at the country and territory level, as presented in equation (1).

$$W_e = ln(\sqrt{\frac{(c_c)^3 x p_d}{(1-t_r)^2 x h_i}} + 1) \quad (1)$$

The parameters used in Equation (1) are as follows: c_c number of confirmed cumulative cases, t_c number of days since the first case reported, $t_r = \frac{t_c}{365,25}$ the ratio of within the total day of the year of number of days since the first case reported, ln natural logarithm, p_d population density (people per square kilometer of land area), h_i human development index. The greater the positive value of W_e, the wider the wavelength and area of the epidemic's influence. If it is desired to estimate intra-country or intra-regional epidemic sizes with the method, the human development index (h_i) parameter in the denominator of the wavelength method is subtracted.[5] This is because the human development index is calculated by the United Nations at the country and regional level.[12]

RESULTS AND DISCUSSION

The epidemiologic wavelength of an influenza method was assessed within the framework of countries and territories in the WHO European Region. The results from the wavelength estimation method are organized in descending order based on wavelength size. The United Kingdom, England, exhibited the highest wavelength in 2022 at 20.1 W_e, whereas Azerbaijan recorded the lowest wavelength at 2.64 W_e (Figure 1). During the same period, Portugal and France ranked as the second and third countries with the highest wavelengths, respectively. The wavelengths of the three countries with the highest scores significantly surpass the average of 13.44 for the WHO European Region. In 2022, 26 countries and territories fell below the average of the WHO European Region.

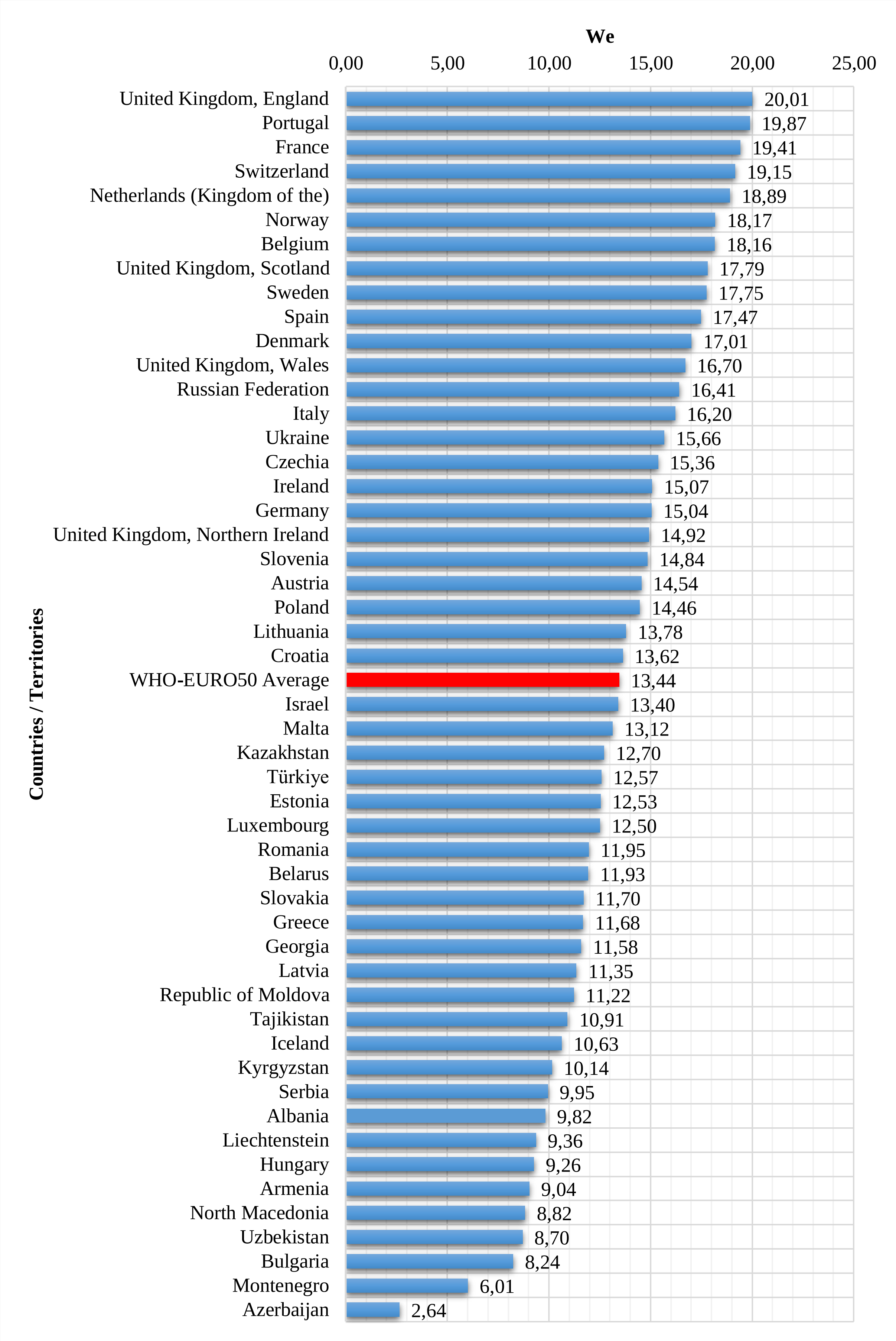

Figure 1. The Influenza Epidemiological Wavelengths in the WHO European Region, 2022

In 2023, the United Kingdom, England, exhibited the highest wavelength at 20.8 W_e, similar to the previous year, 2022 (Figure 2). Conversely, Azerbaijan recorded the lowest wavelength at 7.01 W_e. During the same period, Belgium and Italy ranked as the second and third countries with the highest wavelengths, respectively. The scores of the three countries with the highest wavelengths significantly surpass the average of 14.72 for the WHO European Region. In 2023, 23 countries and territories fell below the average of the WHO European Region.

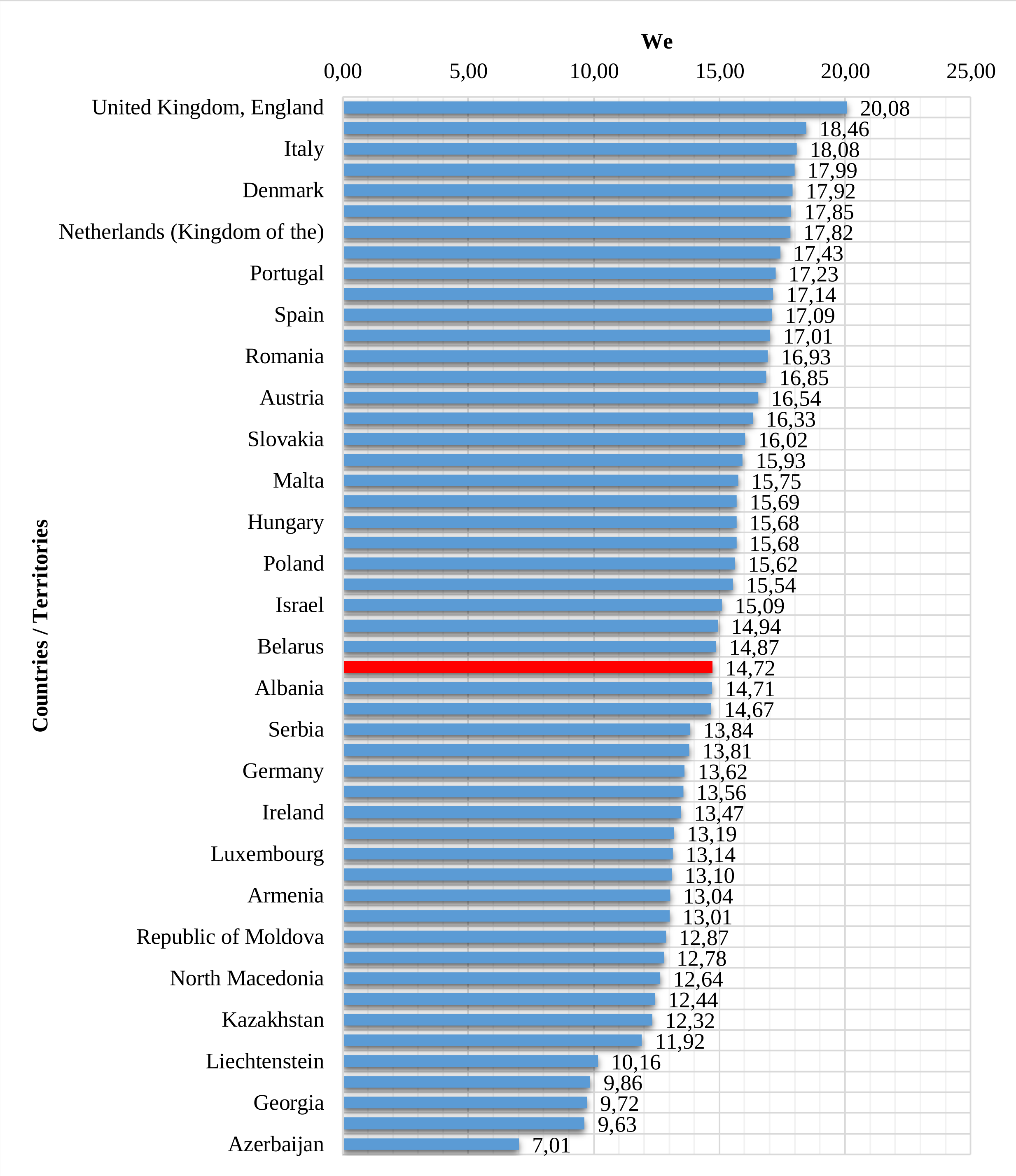

Figure 2. The Influenza Epidemiological Wavelengths in the WHO European Region, 2023

In 2024, the United Kingdom, specifically England, exhibited the highest wavelength at 21.17 W_e, whereas Kyrgyzstan recorded the lowest wavelength at 4.49 W_e, consistent with the data from 2022 and 2023 (Figure 3). In the same timeframe, France and Slovenia were listed as the second and third countries with the highest wavelength, respectively. The scores of the three countries with the highest wavelengths significantly exceed the average of 14.58 for the WHO European Region. In 2023, 27 countries and territories fell below the average of the WHO European Region

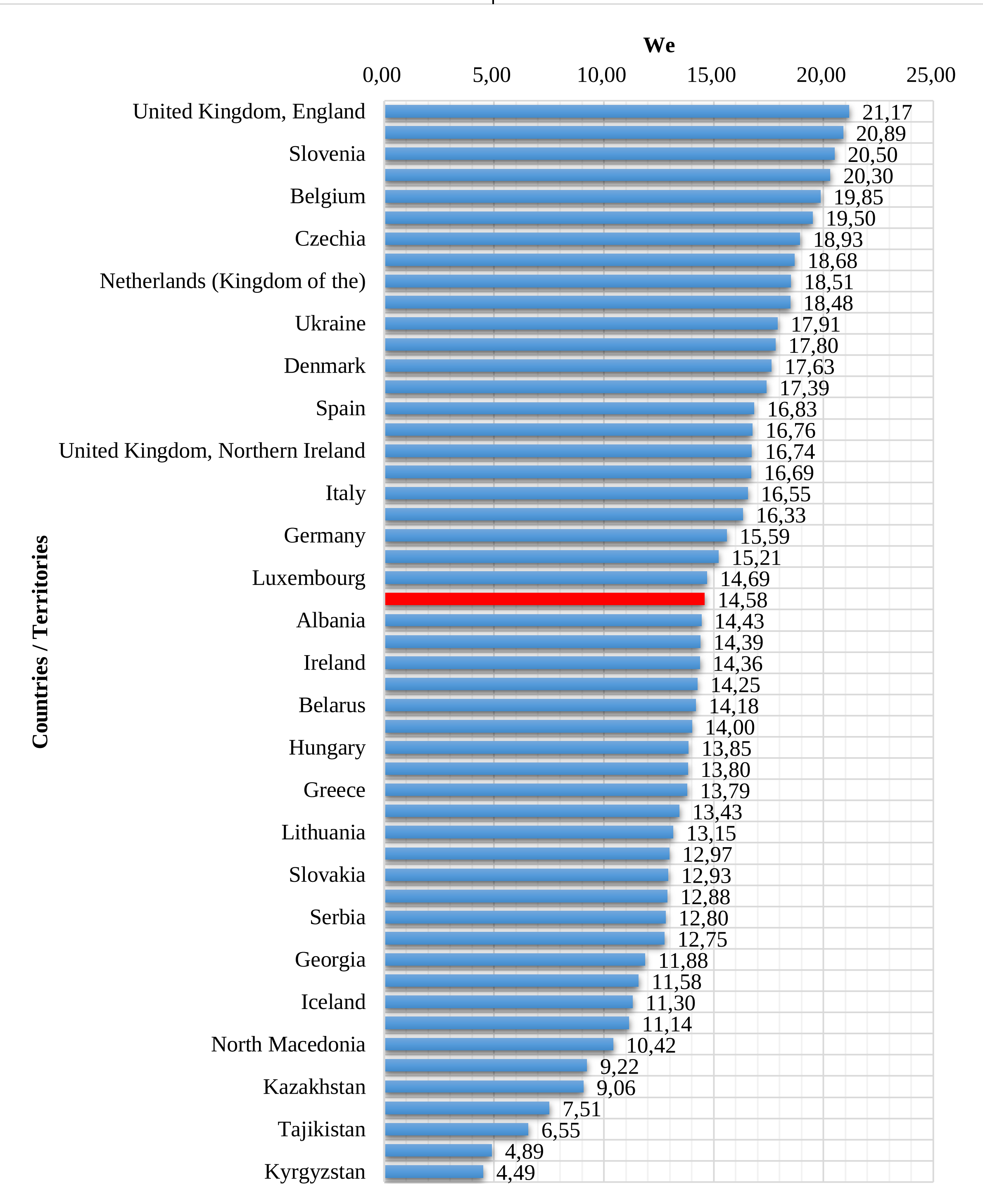

Figure 3. The Influenza Epidemiological Wavelengths in the WHO European Region, 2024

Shapiro-Wilk normality test was conducted to determine whether the assumption that the data required for t-test for paired samples is normally distributed was met. According to the findings, the data set used in the t-test for paired samples is normally distributed (W = 0.967, p = 0.1611). Then, the dependent t-test for paired samples was performed to determine whether the differences in the wavelengths of the 2022, 2023, and 2024 time periods, derived from the wavelength model, are statistically different from one another. The periodic wavelengths of countries or territories in the WHO European region were analyzed in two groups: 2022-2023 and 2023-2024. The dependent t-test for paired samples indicates a statistically significant difference in the differences in wavelengths between 2022-2023 and 2023-2024 (t(49) = -2.731, p < .009) (Table 1). Consequently, the alternative hypothesis was accepted. On the other hand, a weak and negative correlation was observed between the differences in wavelengths of the 2022-2023 and 2023-2024 time period pairs, which was statistically significant (r = -0.377, p<.007).

Table 1. Results of Statistical Analysis by Two Time Periods

Variable	Mean	N	Sd*	r**	t	df	p
2022-2023	-1.280	50	2.305	-0.377			0.007
2023-2024	0.142	50	2.133				
Pair 2022-2023&2023-2024	-1.423		3.684		-2.731	49	0.009

* **Sd:** Standard Deviation, ****r:** Pearson Correlation Coefficient

The findings from the epidemiological wavelength method showed that the epidemiological wavelengths of the influenza pandemic differed for the years 2022, 2023, and 2024. The variation in reported cases across countries or territories may be a significant factor in this context.

The coefficient of variation (CV) is a statistical measure that provides comparable results by dividing the standard deviation by the mean, allowing for analysis of the difference in data spread relative to the mean value, thereby enabling comparison of two random variables.[13] Accordingly, when the findings from the wavelength method are assessed by year, the notable results are as follows: In 2022, the WHO European Region exhibited a difference of 17.37 between the maximum and minimum wavelengths, accompanied by a population coefficient of variation (CV) of 0.28. The value exceeds that of 2023 (range = 13.06, population CV = 0.18) and 2024 (range = 16.67, population CV = 0.27). From these findings, it is observed that the variability in wavelengths is at its highest level in 2022. However, in 2023, the WHO European Region's countries and territories had the lowest population coefficient of variation (CV = 0.18) for wavelength. The low CV in 2023 is attributed to increased vaccination rates in countries affected by COVID-19, the implementation of public health measures reaching a certain threshold, and the internalization of these measures by countries.[14] The measures implemented for COVID-19 also aid in controlling the influenza epidemic due to analogous transmission pathways. For example, social distancing measures have become a key component of the public health response to the influenza pandemic, as in COVID-19, and have played an important role in mitigating outbreaks.[15-16]

In the evaluation of findings from the wavelength method by countries and territories, the United Kingdom, England, exhibited the highest wavelength of the epidemic across all periods within the WHO European Region. The following factors can account for this phenomenon: England consistently recorded the highest number of influenza cases among the countries and territories in the region across all time periods. The elevated population density of England, compared to most other countries or territories in the region, significantly contributed to the observed wavelengths. Research in this domain further corroborates these factors. The study assessing the relationship between COVID-19 and population density in Malaysia, utilizing the Pearson correlation coefficient, revealed a significant correlation between the two variables. The study indicated that areas with higher population density and crowding exhibited an increased risk of COVID-19 transmission.[17] A study conducted in the USA indicated that population density has a significant impact on the infectiousness of diseases such as COVID-19. The analysis showed that urban areas exhibit a higher vulnerability to respiratory diseases.[18] A study in Japan revealed a rising tendency in the overall number of infected individuals, which was correlated with higher population density due to human mobility during seasonal influenza epidemics.[19] Other studies also show that population density is an important factor in increasing the contagiousness of the outbreak.[20-21]

Conversely, in the WHO European Region, Azerbaijan has the lowest epidemic wavelength in 2022 and 2023 (W_e = 2.64 in 2022 and W_e = 7.01 in 2023). According to the estimation method, one of the main reasons for this is that Azerbaijan has the lowest number of reported influenza cases (c_c = 1) among the countries and territories in the European Region in these years. Similarly, in 2024, Kyrgyzstan experienced the lowest epidemic wavelength in the European region, with a value of 4.49. The most important reason for this is that Kyrgyzstan had the lowest number of reported influenza cases in 2024 (c_c = 5) among the countries and territories in the European Region. For both countries, these results may indicate the possibility of underreporting influenza cases. Underreporting of infectious diseases, including influenza, is a well-recognized challenge in surveillance systems, and various methods have been developed to quantify and address this issue.[22] This phenomenon has been observed in various settings, including aged care facilities,[23] and during the early stages of epidemics.[24] Further investigation is needed to confirm this hypothesis and to assess the extent of underreporting in these countries. Improving data quality and completeness, potentially through enhanced surveillance and reporting mechanisms in Azerbaijan and Kyrgyzstan, would be crucial for a more accurate understanding of influenza activity in the WHO European Region. This, in turn, would allow for more effective public health interventions and resource allocation

CONCLUSION AND RECOMMENDATIONS

This study highlights the importance of utilizing the epidemiological wavelength method to estimate the magnitude of influenza epidemics across the WHO European Region. The findings indicate significant variations in epidemic wavelengths over the years 2022, 2023, and 2024, with the highest variability observed in 2022. The analysis reveals that increased vaccination rates and public health measures implemented during the COVID-19 pandemic have positively influenced the control of influenza outbreaks, particularly in 2023. Additionally, the study underscores the impact of population density on the spread of influenza, with England exhibiting the highest epidemic wavelength due to its dense population and high case numbers. Conversely, Azerbaijan and Kyrgyzstan reported the lowest wavelengths, suggesting a possible underreporting of cases. This emphasizes the need for improved data transparency and sharing among countries to enhance public health responses and management of influenza epidemics. Overall, the study provides valuable insights for decision-makers to monitor and respond to influenza outbreaks more effectively.

Recommendations for Future Studies

The epidemiological wavelength method can be used as an estimation tool to reveal the size of epidemics. Thus, deeper insights can be obtained by comparing countries or regions within and among themselves by conducting studies both at the country level and within countries, especially in OECD countries.

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