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Finding the onset of COVID-19 - a correlation analysis with influenza epidemic around the world

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Abbreviations

COVID-19: Coronavirus Disease 2019;

CI: Confidence Interval;

ARIMA: Autoregressive Integrated Moving Average Model;

ILI: Influenza Like Illness;

NPIs: Non-pharmaceutical Interventions;

SARS-CoV: Severe Acute Respiratory Syndrome Coronavirus;

WMI: Weekly Morbidities of Influenza;

WMC: Weekly Morbidities of Coronavirus Disease 2019;

EVALI: electronic cigarette or vaping product use associated lung injury;

K-S: Kolmogorov-Smirnov.

Abstract

Background. COVID-19 showed similar and overlapping symptoms compared with seasonal influenza. It is difficult to distinguish them, especially in the early stage of the outbreak. The confluence of the two diseases might result in considerable morbidity, it is doubtful that whether COVID-19 had already affected the morbidity of influenza earlier than the first report.

Methods. We conducted Kolmogorov-Smirnov Test and Kruskal Wallis Test to discover seasonal and regional distributions of influenza and COVID-19. Cluster analysis was utilized to explore possible influence factors. Spearman Test was carried out for analyzing correlations between the two diseases. We employed Arima Model to predict time series of WMI. We proved differences between the forecasted and the original time series of influenza from 2019 to 2021 by Mann-Whitney U Test. Then we observed first abnormal peaks on the time series, tracing back to the onset of COVID-19 affecting influenza compared with the first-report time.

Results. WMI and WMC varied significantly in four seasons, five continents and the ten selected countries. Cluster analysis divided the data into two groups according to country, continent, population and morbidity. WMI of China, Israel, Honduras, Morocco and Nigeria were correlated with WMC. The forecasted and the original time series of influenza from 2019 to 2021 were significantly different. Compared with the forecasted one, some abnormal peaks firstly appeared on the original time series of influenza around Dec.31st, 2018 on Austria, Norway, Morocco and Nigeria, Jan.28th, 2019 on South Africa, Apr.8th, 2019 on Marshall Islands, Jul.7th, 2019 on America, Sep.30th, 2019 on China and Israel, Mar.11th, 2020 on Honduras.

Conclusions. Winter and autumn were the high incidence season for influenza and COVID-19, respectively. Oceania and Americas owned the highest incidence rate for these two diseases. Human immunity, continents, countries' policies and population were possible influence factors. Only in Honduras, the first reported COVID-19 case happened concurrently with the abnormal value of the ILI. And in the rest of the included countries, COVID-19 might happen earlier than its first reports. Among these regions, COVID-19 might firstly affect Africa in the first week of 2019.

Keywords: *COVID-19; influenza; time-series; ARIMA; onset*

1. Introduction

COVID-19 was firstly reported in the winter of 2019 accompanied with several symptoms including coughing, fever and so on^[1]. It has been being emergent to control this disease effectively for its readily communicable feature (higher transmissibility than seasonal influenza and SARS-CoV) as well as pandemic situation^[2-5].

Many countries have recommended or imposed various policies, and the effectiveness of implementation relied on people's awareness, knowledge and attitude towards COVID-19^[6-8]. This was one of the reasons that made the status of the epidemic control varied greatly in different countries around the world. Most respiratory infectious diseases were usually self-limiting^[9] except for a few serious consequences in specific populations^[10-16], making it difficult to detect and diagnose them in the early stage. At the same time, their symptoms were often partially similar and overlapping, for example, seasonal influenza and COVID-19 share the fever and respiratory symptoms^[17-19], making it difficult to distinguish them. What's more, COVID-19, as a new disease, lacked prior diagnostic experience and prompt awareness. These facts led us to explore whether COVID-19 has been misdiagnosed as seasonal influenza earlier than its first report around the world.

Recently, the traceability of COVID-19 attracts much of attention. It have been reported that COVID-19 cases might appear earlier than its first reports in some countries^[20-22]. A study confirmed that the confluence of COVID-19 and influenza might result in considerable morbidity^[23]. For tracing back to the earliest misdiagnosis and confluence, we conducted statistical analysis and time-series analysis. We explored the distribution characteristics of COVID-19 and influenza, the correlation between the two diseases, the possible influencing factors, and abnormal time series of seasonal influenza recent years. During these processes, we solved difficulties like stability transformation of time series and unification of data scale. To our best knowledge, the earliest incidence time of COVID-19 is still an open problem. We hope our results will provide guidance to find the possible sources of COVID-19 and to carry out the prevention and control measures well.

2. Materials and Methods

2.1. Collection of Data

To reflect the situation of all continents in the world, the number of countries and the total population in each continent were used as the references for sampling in this study. On the one hand, the number of countries included in each continent should be consistent with the proportion of countries among the five continents (Asia: Europe: Americas: Oceania: Africa = 48:48:51:21:58 $\approx$ 2:2:2:1:3). On the other hand, the relative size of the population included in each continent should be consistent with the relative size of the population among the five continents (Asia > Africa $\approx$ Americas > Europe > Oceania).

Besides, countries included should provide both the data of COVID-19 cases in 2020 and the data of influenza-like illness from 2011 to 2020. Countries missing too much of data were excluded.

According to the above criteria, China, Israel, Austria, Norway, America, Honduras, Marshall Islands, Morocco, Nigeria and South Africa were included in this study. Data of these ten countries was obtained from WHO^[24,25], Chines National Influenza Center^[26] and Country meters^[27] websites.

2.2. Data Processing

To address the missing ILI data according to the periodic features, if whole-year new cases data was missing, the data of the nearest year would be used to replace the missing one; if non-whole-year new cases data was missing, 0 would be used to replace the missing data. We used formulas listed below to calculate WMI and WMC.

$$WMI = a/c; WMC = b/c$$

(a: number of new influenza like illness per week; b: number of new COVID-19 cases per week; c: annual population)

2.3. Statistical Analysis

We conducted Kolmogorov-Smirnov Test and Kruskal Wallis Test to search for

season and area distribution characteristics of influenza and COVID-19. To find the high incidence seasons, we stipulated four seasons as Table 1. To find the high incidence region, we stipulated that different regions included Asia, Europe, Americas, Oceania and Africa. Kolmogorov-Smirnov Test was used to test normality. Then Kruskal Wallis Test was used to verify the significant differences amid four seasons as well as amid five regions.

We used cluster analysis to explore possible influence factors of the distribution differences of the two diseases. After operating Kolmogorov-Smirnov Test and Kruskal Wallis Test for verifying the differences amid ten countries included, we conducted K-means cluster analysis to look for the features of different clusters during the epidemics.

Spearman Test was carried out for correlations between WMI and WMC in the same country. As the correlations were confirmed, we continued to do time-series analysis for exploring the possible appearance of COVID-19.

IBM SPSS Statistics 24 was used to conduct statistical analysis. $P < 0.05$ was considered to be significant.

2.4. Time-series Analysis

In this study, Python 3 was used to conduct time-series Analysis. We used Dickey-Fuller Test to examine the stationarity of time series. Then we transformed non-stationary time series into stationary time series. Arima Model was used to build time series.

We used original WMI data to build ARMA Models of influenza from 2011 to 2018. Then we used the ARMA Models to forecast time series of influenza from 2019 to 2021 (named as the forecasted time series). At the same time, we used original WMI data (named as the original time series) to build ARMA Models of influenza from 2019 to 2021 and compared with the forecasted time series. Then we proved differences between the forecasted and the original time series of influenza from 2019 to 2021 by Mann-Whitney U Test. Finally, we observed abnormal peaks on the forecasted time series compared with the original one from 2019 to 2021. According

to the earliest abnormal peak, we judged the probably earliest time when COVID-19 affected influenza time series.

2.5. Quality Control

In this study, countries were randomly stratified sampling according to the inclusion and exclusion criteria. All the results were verified repeatedly by two investigators.

3. Results

3.1. Data and Study Population

The ratio of country numbers of Asia, Europe, Americas, Oceania and Africa was 48:48:51:21:58 (2:2:2:1:3). In addition, on Jan.1st, 2021, the population of Asia was about 4670867280, that of Europe was about 749874114, that of Americas was about 1028933407, that of Oceania was about 43061875, that of Africa was about 1358427180^[27], therefore the relationship of population was Asia > Africa $\approx$ Americas > Europe > Oceania in general.

Finally, we achieved new ILI cases per week in 2011-2021 (started from Jan.3rd; ended on Jan.17th, 2021) and daily COVID-19 new cases in 2020-2021 (started from Dec.30th, 2019; ended on Jan.17th, 2021) from 10 countries (Table 2), which we used to calculate weekly morbidity.

3.2. Distribution Features of Influenza and COVID-19

WMI of eight countries in northern hemisphere and of two countries in southern hemisphere looked different in four seasons in Figure 1. Then the K-S Test's result showed nonnormal distribution ($P < 0.001$, Figure 2, Table 3), thus we conducted Kruskal Wallis Test, proving that mean WMI of four seasons were significantly different ($P < 0.001$, Figure 2, Table 3) with the highest grade of season 4 (winter, grade=3211.77, Figure 2, Table 3).

In Figure 3, curves about WMC of eight countries in northern hemisphere and of two countries in southern hemisphere behaved different appearances in four seasons.

Then the K-S Test's result showed nonnormal distribution ($P < 0.001$, Figure 4, Table 3), thus we operated Kruskal Wallis Test, confirming that the mean of WMC for four seasons were significantly different ($P < 0.001$, Figure 4, Table 3) with the highest grade of season 3 (autumn, grade=334.91, Figure 4, Table 3).

Curves about WMI of ten countries trended differently in five continents in Figure 5. Then the K-S Test's result showed nonnormal distribution ($P < 0.001$, Figure 5, Table 3), thus we conducted Kruskal Wallis Test, gaining significant difference of mean WMI between five continents ($P < 0.001$, Figure 5, Table 3). Continent 4 had the highest grade (Oceania, grade= 4003.91, Figure 5, Table 3).

Figure 6 depicted different curves about WMC of ten countries in five continents. Then the K-S Test's result showed nonnormal distribution ($P < 0.001$, Figure 6, Table 3), thus we conducted Kruskal Wallis Test, testify that the mean of WMC for five continents were significantly different ($P < 0.001$, Figure 6, Table 3). Continent 3 (Americas) had the highest grade (grade= 356.23, Figure 6, Table 3).

3.3. Possible Influence Factors of Influenza and COVID-19

Kolmogorov-Smirnov Tests showed that WMI and WMC of the ten countries were all nonnormal ($P < 0.001$, Table 4), hence Kruskal Wallis Tests were choosed which proved significantly differences of the mean WMI ($P < 0.001$, Table 5) and the mean WMC ($P < 0.001$, Table 5) between ten countries. The highest grade of the two Kruskal Wallis Tests were country 7 (Marshall Islands, grade=4003.91, Table 5) and country 5 (America, grade=405.85, Table 5).

Cluster analysis for possible influencing factors of influenza divided the data into two clusters according to different cluster centers of country, continent, population and morbidity (cluster centers of cluster 1 including country 1, continent 1, population of 1406170204 and morbidity of 0.0000420151; cluster centers of cluster 2 including country 6, continent 3, population of 69267633 and morbidity of 0.0101980371; Table 5). And the same analysis for COVID-19 divided the data into two clusters according to different cluster centers of country, continent, population and morbidity (cluster centers of cluster 1 including country 6, continent 3, population of 73603300 and

morbidity of 0.0477510497; cluster centers of cluster 2 including country 1, continent 1, population of 1436838423 and morbidity of 0.0001248127; Table 6). As we could see, China was divided into different cluster from other countries.

3.4. Correlation between Influenza and COVID-19

WMI of China ($\rho = 0.412$, $P = 0.002$) and Honduras ($\rho = 0.527$, $P < 0.001$) were positive correlated with WMC in 2020-2021 (Table 7); WMI of Israel ($\rho = -0.402$, $P = 0.002$), Morocco ($\rho = -0.639$, $P < 0.001$) and Nigeria ($\rho = -0.449$, $P = 0.001$; Table 7) were negative correlated with WMC in 2020-2021 (Table 7); WMI of Austria ($\rho = -0.159$, $P = 0.245$), Norway ($\rho = -0.057$, $P = 0.678$), America ($\rho = -0.227$, $P = 0.095$), Marshall Islands ($\rho = 0.092$, $P = 0.503$) and South Africa ($\rho = -0.238$, $P = 0.080$) were uncorrelated with WMC in 2020-2021 (Table 7).

3.5. Time-series Analysis

We succeeded in building and plotting the original WMI series and the ARMA Models of influenza of ten countries from 2011 to 2018 (Figure 7), the original WMI series (the original time series) and the ARMA Models of influenza of ten countries from 2019 to 2021 (Figure 8), and the original time series and the forecasted time series of influenza from 2019 to 2021 (Figure 9). The AR(p), MA(q), d and RMSE value of each ARMA Model were listed in Table 8.

K-S Tests showed nonnormal distribution of the original time series and the forecasted time series of influenza from 2019 to 2021 ($P < 0.001$, Table 9) apart from the forecasted time series of Nigeria ($P = 0.2000$, Table 9), then we proved that the two time series of America ($P = 0.012$) and other nine countries ($P < 0.001$) were significantly different by Mann-Whitney U Test (Table 9). So far, the forecasted time series were proved to be significantly different from the original time series of influenza from 2019 to 2021.

Finally, because the ARMA Models from 2019 to 2021 didn't completely fitted the original time series, we still observed the original time series and the forecasted time series of influenza from 2019 to 2021 in a same picture (Figure 9), finding some

abnormal peaks and estimating the possible start time of COVID-19. In China, the first abnormal peak started from Sep.30th, 2019; In Israel, the first abnormal peak started from Sep.30th, 2019; In Austria, the first abnormal peak started from Dec.31st, 2018; In Norway, the first abnormal peak started from Dec.31st, 2018; In America, the first abnormal peak started from Jul.22nd, 2019; In Honduras, the first abnormal peak started from Mar.11th, 2020; In Marshall Islands, the first abnormal peak started from Apr.8th, 2019; In Morocco, the first abnormal peak started from Dec.31st, 2018; In Nigeria, the first abnormal peak started from Dec.31st, 2018; In South Africa, the first abnormal peak started from Jan.28th, 2019 (Table 10).

4. Discussion

WMI and WMC of the ten countries were significantly different in the four seasons. Since season 4 of WMI performed the highest grade, influenza would be more prevalent in winter. And season 3 of WMC performed the highest grade, COVID-19 would be more prevalent in autumn. A previous study had shown that high incidence of influenza appeared majorly in autumn and winter in temperate zone, and could occurred throughout the year in tropical zone^[28]. Among the countries involved in our study, most of China, Israel, Austria, Norway, America, Morocco and South Africa located in temperate zone, while the other three countries were tropical countries. This confirmed that our conclusions of high incidence season of influenza and COVID-19 were scientific to a certain extent. Besides, a study summarized that all over world respiratory virus would be more easier to spread in winter including influenza virus and human coronavirus^[29], which was consistent with our results. Nevertheless, we found that COVID-19 would be more prevalent in autumn than winter worldwide, which uncovered from the side that it might happen earlier in autumn than its first observation in winter.

In this study, WMI of ten countries were also proved to be significantly different in five continents as continent 4 performed the highest grade, presenting that influenza would be more prevalent in Oceania. A research speculated that new seasonal influenza A viruses might appear in Asia, then firstly spread to Oceania with

quick variation and reproduction^[30]. However, our study showed that COVID-19 would be more prevalent in Americas so far as continent 3 performed the highest grade in variance analysis of WMC of ten countries in five continents. The fact from WHO that as of Apr. 2021 the number of COVID-19 diagnoses in the Americas was the largest among the five continents seemed to confirm this as well^[25].

Then we explored influence factors of the two epidemics to try to explained all the differences to some extent. Firstly, the seasonal variations of the two epidemics might be attributed to seasonal human immunity. For example, it has been confirmed that seasonal solar radiation^[31] and vitamin D level^[32,33] could influence human immunity. As solar radiation was the lowest in winter in temperate zone, vitamin D would be deficient during this time^[34-37]. Secondly, we have found that the mean WMI of the ten countries were significantly different in the highest grade of country 7 (Marshall Islands), and the mean WMC of the ten countries were significantly different in the highest grade of country 5 (America), reminding us that different countries behaved divergent morbidity of the two diseases. Combined with the cluster analysis results which divided the data into two clusters according to different cluster centers of country and the country conditions including continent and population, different countries with different conditions might be one of the important influence factors of influenza and COVID-19. Besides, we noticed that China was divided into different cluster from other countries in both of the epidemics. Since China possesses the largest population^[27], the first reported COVID-19 case as well as rapid government actions, we also considered influence factors from aspect of country's policies and population. Several studies have shown that morbidity of influenza could be decreased after conduction of NPIs^[38,39]. And a study analyzed whether various governmental policies for addressing the COVID-19 pandemic in 177 countries were appropriate, finding different reaction degrees of these countries and suggesting that governments should promote their response facing COVID-19^[40]. Therefore, we speculated that country's policy was one of the influence factors. What's more, we noticed that WHO had informed influenza spreading easily in crowded places^[41]. And a paper reported that American population-level interest in telehealth was positively

correlated with increased COVID-19 cases, however, the present telehealth level might not satisfied their population demand^[42]. These studies supported our hypothesis about the impact of population on influenza and COVID-19. Therefore, we believed that different countries with different human immunity, continents, policies and population were possible influence factors of influenza and COVID-19.

Back to the doubt about whether COVID-19 happened earlier than its first observation, we conducted correlation analysis and time-series analysis. Figure 9 and Table 10 depicted that compared to the forecasted time series, the original time series of all the included countries from 2019 to 2021 behaved abnormal. There was a significant difference between the original and the forecasted time series of influenza from 2019 to 2021. We found reports about their first cases and compared the first reported time with the date of first abnormal peaks (Table 10). Shown that the most severe public affairs since 2019 was COVID-19, we had reasonable doubts about COVID-19 might impacting influenza epidemics early when the first abnormal peaks appeared in these ten countries. In a word, In Morocco, the COVID-19 might start from Dec.31th, 2018 though the first case was reported on Mar.2nd, 2020; the COVID-19 might make effects from Dec.31th, 2018 although the first case was reported on Feb.27th, 2020 in Nigeria; the COVID-19 might have an impact on influenza from Sep. 30th, 2019 while the first case was reported on Dec.31st, 2019 in China; and from Sep.30th, 2019 though the first case was reported on Feb.20th, 2020 in Israel. Please notice that Honduras is a mountainous country with excellent ecological environment, the trade and exchange with outsiders are relative limited, so the impact from outside is weak there. The abnormal value indicated that the COVID-19 might appear from Mar.11th, 2020 which was concurrent with the first reported case in Honduras, which illustrated that the number of ILI confirmed cases was effected by the COVID-19 to some extent. This result verifies the effectiveness of our method.

Considered that only the WMI of China, Israel, Honduras, Morocco and Nigeria were correlated with WMC in 2020-2021, we speculated that in these five countries, influenza might also impact COVID-19 itself except for the misdiagnosis led by

similar and overlapping symptoms between the two diseases^[17-19,43], thus the abnormal peaks of these five countries might come from the correlation between the two diseases as well as misdiagnosis. And the impact from COVID-19 on influenza in the other five countries Austria, Norway, America, Marshall Islands and South African were not that strong especially, but the misdiagnosis still exist according to the abnormal peak value. Among the five countries, abnormal peaks started earliest in Morocco and Nigeria from Dec.31st, 2018. These two countries were African countries, reminding us that perhaps Africa was affected earlier than other continents. We need more data from other continents and countries to verify.

There were still some deficiencies in our study. The original data of influenza on WHO website missed partly, and it didn't contain the data of different type of influenza. Nevertheless, given that we have handled the missing values, and we have included the data of ten years which was long enough, even if there is no typing in the original data, the overall trend of influenza would still show its seasonality, thus we believed that these data would be meaningful and significant.

5. Conclusion

High incidence season of influenza was winter, and Oceania owned the highest incidence rate. High incidence season of COVID-19 was autumn, and Americas owned the highest incidence rate. Human immunity in different countries, continents, countries' policies and population possibly influenced the distribution differences. Besides, COVID-19 might happen earlier than its first reports in China, Israel, Austria, Norway, America, Marshall Islands, Morocco, Nigeria and South Africa and affected ILI cases, while it happened concurrently when it was first reported in Honduras. In these regions, COVID-19 might made effects earliest in Africa in the first week in 2019.

Declarations

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Authors' contributions

Siyu Liu and Jiwei Jia designed the study and settled the method; Yixue Yang, Nan Yao, Yinpei Guo, Han Wang and Junwei Tian collected the data; Yixue Yang and Nan Yao analyzed the data; Yixue Yang drafted the first manuscript; Yixue Yang, Nan Yao, Yinpei Guo and Han Wang conducted the visualization; Yixue Yang, Ruirui Guo and Xuhan Wang validated the results; Bo Li, Siyu Liu and Jiwei Jia participated in amending the manuscript.

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Table 1 Months of Four Seasons

Spring/Season 1		Summer/Season 2		Autumn/Season 3		Winter/Season 4	
Northern hemisphere	Southern hemisphere	Northern hemisphere	Southern hemisphere	Northern hemisphere	Southern hemisphere	Northern hemisphere	Southern hemisphere
March	September	June	December	September	March	December	June
April	October	July	January	October	April	January	July
May	November	August	February	November	May	February	August

Table 2 Results of Study Population

Asia		Europe		Americas		Oceania		Africa	
Country	Population	Country	Population	Country	Population	Country	Population	Country	Population
China	1476592197	Austria	9015714	America	332716351	Marshall Islands	60147	Morocco	37232554
Israel	8741690	Norway	5473843	Honduras	9981560			Nigeria	209422421
								South Africa	59622023
Total	1485333887	Total	14489557	Total	342697911	Total	60147	Total	306276998

Figure 1 (a) Weekly Influenza Morbidity of Eight Countries in Northern Hemisphere during Four Seasons

Figure 1 (b) Weekly Influenza Morbidity of Two Countries in Southern Hemisphere during Four Seasons

Figure 1 Weekly Influenza Morbidity of Ten Countries during Four Seasons

Figure 2 High Incidence Season of Influenza

(country 1- China, 2- Israel, 3- Norway, 4- Austria, 5- America, 6- Honduras, 7- Marshall Islands, 8- Morocco, 9- Nigeria, 10- South Africa)

Figure 3 (a) Weekly COVID-19 Morbidity of Eight Countries in Northern Hemisphere during Four Seasons

Figure 3 (b) Weekly COVID-19 Morbidity of Two Countries in Southern Hemisphere during Four Seasons

Figure 3 Weekly COVID-19 Morbidity of Ten Countries during Four Seasons

Figure 4 High Incidence Season of COVID-19

Figure 5 High Incidence Region of Influenza
(continent 1- Asia, 2- Europe, 3- Americas, 4- Oceania, 5- Africa)

Figure 6 High Incidence Region of COVID-19
(continent 1- Asia, 2- Europe, 3- Americas, 4- Oceania, 5- Africa)

Table 3 Results of Variance Analysis for Distribution Features

Analysis Purpose	Grade	Season/Continent	P of K-S Test	P of Kruskal Wallis
High Incidence Season of Influenza	3211.77	season 4 (winter)	<0.001	<0.001
	2686.42	season 1 (spring)		
	2572.04	season 3 (autumn)		
	2000.92	season 2 (summer)		
High Incidence Season of COVID-19	334.91	season 3 (autumn)	<0.001	<0.001
	285.52	season 2 (summer)		
	257.55	season 1 (spring)		
	231.65	season 4 (winter)		
High Incidence Region of Influenza	4003.91	continent 4 (Oceania)	<0.001	<0.001
	3426.81	continent 3 (Americas)		
	2512.92	continent 2 (Europe)		
	2272.88	continent 1 (Asia)		
	1925.28	continent 5 (Africa)		
High Incidence Region of COVID-19	356.23	continent 3 (Americas)	<0.001	<0.001
	317.21	continent 2 (Europe)		
	268.48	continent 5 (Africa)		
	267.99	continent 1 (Asia)		
	66.69	continent 4 (Oceania)		

Table 4 Normality Test of Influenza Morbidity per Week and COVID-19 Morbidity per Week

Analysis Purpose	Country	P	Median	Interquartile Range
Normality Test of Influenza Morbidity per Week	China	<0.001	0.0000194939	0.0000471859
	Israel	<0.001	0.0010687180	0.0051945008
	Austria	<0.001	0.0001523000	0.0042965970
	Norway	<0.001	0.0052002475	0.0333135778
	America	<0.001	0.0039992415	0.0043208635
	Honduras	<0.001	0.0053472760	0.0055175492
	Marshall Islands	<0.001	0.0263977610	0.0489017460
	Morocco	<0.001	0.0034121485	0.0042637195
	Nigeria	<0.001	0.0000070821	0.0000189349
	South Africa	<0.001	0.0000211969	0.0001062515
Normality Test of COVID-19 Morbidity per Week	China	<0.001	0.0000186556	0.0000446202
	Israel	<0.001	0.0529703140	0.1325014740
	Austria	<0.001	0.0097429050	0.1066374900
	Norway	<0.001	0.0070738570	0.0291102170
	America	<0.001	0.0833752790	0.0949811780
	Honduras	<0.001	0.0254737660	0.0444137090
	Marshall Islands	<0.001	0.0000000000	0.0000000000
	Morocco	<0.001	0.0053008310	0.0409076970
	Nigeria	<0.001	0.0005924380	0.0015130247
	South Africa	<0.001	0.0190632040	0.0509404100

Table 5 Results of Variance Analysis for Different Country

Analysis Purpose	Grade	Country	P of Kruskal Wallis
Differences of Influenza Morbidity amid Different Countries	4003.91	country 7 (Marshall Islands)	<0.001
	3547.98	country 5 (America)	
	3305.65	country 6 (Honduras)	
	3164.49	country 8 (Morocco)	
	3023.02	country 4 (Norway)	
	2972.34	country 2 (Israel)	
	2002.83	country 3 (Austria)	
	1573.42	country 1 (China)	
	1446.56	country 10 (South Africa)	
	1164.81	country 9 (Nigeria)	
Differences of COVID-19 Morbidity amid Different Countries	405.85	country 5 (America)	<0.001
	376.16	country 2 (Israel)	
	339.85	country 3 (Austria)	
	320.35	country 10 (South Africa)	
	306.60	country 6 (Honduras)	
	294.56	country 4 (Norway)	
	293.65	country 8 (Morocco)	
	191.45	country 9 (Nigeria)	
	159.82	country 1 (China)	
	66.69	country 7 (Marshall Islands)	

Table 6 Results of Cluster Analysis for Possible Influencing Factors

Cluster	Number	Cluster Centers		Country
Possible Influencing Factors of Influenza	Cluster 1	524	Year	2016
			Week	27
			Country	1
			Continent	1
			Population	1406170204
	Cluster 2	4716	Morbidity	0.0000420151
			Year	2016
			Week	27
			Country	6
			Continent	3
Possible Influencing Factors of COVID-19	Cluster 1	495	Population	69267633
			Morbidity	0.0101980371
			Year	2020
			Week	26
			Country	6
	Cluster 2	55	Continent	3
			Population	73603300
			Morbidity	0.0477510497
			Year	2020
			Week	26
			Country	1
			Continent	1
			Population	1436838423
			Morbidity	0.0001248127

Table 7 Results of Correlation between Influenza and COVID-19

Country	Spearman's Rank Correlation Coefficient ρ	P of Spearman Test	Correlation
China	0.412	0.002	positive correlation
Israel	-0.402	0.002	negative correlation
Austria	-0.159	0.245	uncorrelation
Norway	-0.057	0.678	uncorrelation
America	-0.227	0.095	uncorrelation
Honduras	0.527	<0.001	positive correlation
Marshall Islands	0.092	0.503	uncorrelation
Morocco	-0.639	<0.001	negative correlation
Nigeria	-0.449	0.001	negative correlation
South Africa	-0.238	0.080	uncorrelation

Figure 7 ARMA Model of Influenza during 2011-2018

Figure 8 Time Series of Influenza during 2019-2021

Figure 9 The Original and The Forecasted Time Series of Influenza in 2019-2021
 (blue line- the forecasted time series; orange line- the original time series;
 abscissa- week counted from Jan. 1st, 2019; ordinate- morbidity)

Table 8 Parameter of ARMA Model
(a) ARMA Model of Influenza during 2011-2018

Country	AR(p)	MR(q)	d	RMSE
China	2	2	0	0.0000
Israel	2	2	0	0.0031
Austria	2	0	0	0.0012
Norway	3	2	0	0.0135
America	2	0	0	0.0007
Honduras	1	2	0	0.0017
Marshall Islands	1	4	0	0.0309
Morocco	1	0	0	0.0010
Nigeria	0	2	1	nan
South Africa	3	0	0	0.0001

(b) ARMA Model of Influenza during 2019-2021

Country	AR(p)	MR(q)	d	RMSE
China	1	0	1	nan
Israel	2	0	0	0.0023
Austria	1	0	1	nan
Norway	0	1	1	nan
America	1	1	0	0.0015
Honduras	0	3	1	nan
Marshall Islands	1	0	0	0.0320
Morocco	0	1	1	nan
Nigeria	2	0	1	nan
South Africa	1	0	1	nan

Table 9 Results of Variance Analysis for Difference between the Original and the Forecasted Time Series of Influenza in 2019-2021

Country	Grade	The Forecasted	P of K-S Test	P of Mann-Whitney U
China	126.83	The Original	<0.001	<0.001
	88.17	The Forecasted	<0.001	
Israel	138.58	The Original	<0.001	<0.001
	76.42	The Forecasted	<0.001	
Austria	124.91	The Original	<0.001	<0.001
	90.09	The Forecasted	<0.001	
Norway	124.34	The Original	<0.001	<0.001
	90.66	The Forecasted	<0.001	
America	96.82	The Original	<0.001	0.012
	118.18	The Forecasted	<0.001	
Honduras	151.43	The Original	<0.001	<0.001
	63.57	The Forecasted	<0.001	
Marshall Islands	146.12	The Original	<0.001	<0.001
	68.88	The Forecasted	<0.001	
Morocco	136.62	The Original	<0.001	<0.001
	78.38	The Forecasted	<0.001	
Nigeria	83.73	The Original	0.2000	<0.001
	131.27	The Forecasted	<0.001	
South Africa	151.83	The Original	<0.001	<0.001
	63.17	The Forecasted	<0.001	

Table 10 Comparison between the dates of the first abnormal peak and the first report of COVID-19

Countries	When the COVID-19 firstly reported*	When the first abnormal peak started on the original time series**
China	2019-12-31 ^a	2019-09-30 (40th week)
Israel	2020-02-20 ^b	2019-09-30 (40th week)
Austria	2020-02-25 ^c	2018-12-31 (1st week)
Norway	2020-02-26 ^d	2018-12-31 (1st week)
America	2020-01-20 ^e	2019-07-22 (30th week)
Honduras	2020-03-11 ^f	2020-03-11 (63rd week)
Marshall Islands	2020-10-27 ^g	2019-04-08 (15th week)
Morocco	2020-03-02 ^h	2018-12-31 (1st week)
Nigeria	2020-02-27 ⁱ	2018-12-31 (1st week)
South Africa	2020-03-05 ^j	2019-01-28 (5th week)

* These datas came from:

- a. <https://www.who.int/es/emergencies/diseases/novel-coronavirus-2019>
- b. https://www.sohu.com/a/374822696_162522
- c. <https://baijiahao.baidu.com/s?id=1659569615064840180&wfr=spider&for=pc>
- d. <https://baijiahao.baidu.com/s?id=1659648502481738968&wfr=spider&for=pc>
- e. <https://www.paho.org/en/covid-19-situation-reports?topic=All&d%5Bmin%5D=&d%5Bmax%5D=&>
- f. <https://www.paho.org/en/covid-19-global-and-regional-daily-update?topic=All&d%5Bmin%5D=&d%5Bmax%5D=&>
- g. <https://baijiahao.baidu.com/s?id=1681869314040782482&wfr=spider&for=pc>
- h. <https://baijiahao.baidu.com/s?id=1660105273178454266&wfr=spider&for=pc>
- i. <https://www.afro.who.int/countries/979/news>
- j. <https://covid19.who.int/region/afro/country/za>

**The numbers of weeks in brackets in this column represented the numbers of weeks counted from December 31, 2018.