# Modeling Isolation Duration for COVID-19 Using Time Series Data of Confirmed Cases

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**Abstract** The novel coronavirus (COVID-19) has been estimated to have an incubation period of 2-14 days and a basic reproduction number of 2.24-3.58. The recommended isolation period for people in close contact with patients or suspected patients in various countries/regions is two weeks. Given the many uncertainties regarding the pathogen's transmissibility and virulence, the effectiveness of current infection prevention and control efforts is still unknown. With the data of confirmed cases of novel coronavirus pneumonia, released by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University.(Data cut-off time: 23:00 10/12/20), this paper revealed the diffusion plateau before the outbreak of COVID-19,which is also the outbreak period which can be provided a reference of the isolation period for countries/regions. It found the relationship between COVID-19 cases and time series follows a multi-fractal distribution and that the average outbreak period of COVID-19 is 28 days on the global. Various countries/regions' experiences with control measures show that, to completely prevent the spread of the novel coronavirus, borders must be closed, people must not gather in public in groups of more than two, masks must be worn in public, and the isolation period should be over 28 days. Absent any one of these measures, it is difficult to stop the virus from spreading.
**Additional keywords:** COVID-19, diffusion plateau, fractal analysis, infection

## Introduction

The epidemic process and the stage of COVID-19 pandemics should be explored and discussed since its outbreak at the end of 2019.[1]Given the dramatic increase in the number of confirmed cases globally, there is an urgent need for more in-depth analysis, by reported data resulted from countries/regions, to provide a basis for scientific decision-making in affected countries to fully control COVID-19. A necessary condition for preventing the spread of the novel coronavirus is to determine a reasonable incubation period and isolate people within days. It is critical to analyze and confirm COVID-19's incubation period.

It is very necessary to effectively curb the spread of COVID-19 that studying and revealing the number of infections and the mechanism of COVID-19 transmission will help scientists reasonably determine the optimal isolation period. While economic development and ensuring the normal life of humans, different scientific-based preventive and preventive measures are taken in different countries and regions.

This study, attribute the data as the "COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University"(https://github.com/CSSEGIS andData/COVID-19，Data cut-off time: 23:00 10/12/20)[2] and fractal statistics were used to analyze the cumulative number of confirmed cases and the corresponding time series. The number of confirmed COVID-19 cases in the world (excluding China), Asia (excluding China), Africa, Europe, America, and Oceania were analyzed. The analysis of the cumulative number of confirmed cases and the time series reveals that they follow a fractal distribution (power-law distribution), and shows that the coronavirus outbreak period is highly consistent with the actual isolation period by many countries. The purpose of the paper is to reveal the outbreak period of COVID-19 through data mining, and to try to reveal the regularity of the coronavirus outbreak from another level.

**1 The incubation period of COVID-19**

To determine the incubation period of infectious diseases is very important for the prevention of their spread. The incubation period in traditional epidemiology is usually obtained through investigation of infected individuals. There are various indications that the incubation period obtained by this individual method as a countries/regions isolation period is very limited in controlling the infection for the novel coronavirus. Therefore, the incubation period is defined the diffusion plateau phase based on the stage I of the three stages in the propagation model of COVID-19 pandemic in this paper. So, the isolation period for novel coronavirus is the diffusion plateau phase, whereas the isolation periods for most infectious diseases are usually determined based on incubation period. According to the relevant demographic analysis, the average incubation period of confirmed patients with Wuhan travel records was 6.4 days (ranging from 2.1 to 11.1 days[2]); other research has found the median incubation period to be 5.0 days (ranging from 2-14 days[4]).

Based on the current epidemiological survey in China, the incubation period of COVID-19 is 1-14 days.[5] Nevertheless, abnormal documented case with longer incubation of 42 days was even reported.[6] Incidents of SARS-CoV2 show great individual differences, and our current understanding of the virus' incubation period is actually very limited.[7] A 14-day quarantine period may not be optimal for effectively controlling coronavirus disease 2019 (COVID-19).[8]

As there is neither a complete epidemiological record of, nor any scientific determination regarding, the incubation period of SARS-CoV2, it is particularly challenging to contain this new kind of coronavirus. Now most countries/regions have adopted the 14-day isolation period recommended by the WHO for patients with novel coronavirus; however, this isolation period recommendation is anecdotal, based on general experience. The incubation period is strictly defined in the epidemiological sense, but so far, no organization or individual has been seen to conduct such an investigation. So, it may be a feasible method to infer the incubation period from the explosive period. Therefore, it is helpful completely blocking the spread of infectious diseases by studying the outbreak periods in various regions.

Although some models are established to represent propagation of the infectious diseases, they mainly use conventional methods to predict the number of coronavirus infections and transmissions in a certain area[9,10]. Meanwhile, the best way to make scientific prediction on trends is based on statistical analysis of existing big data, not just through modeling and making parameter assumptions. This paper is mainly to use fractal methods to study the form of virus transmission and whether the prevention and control measures of countries/regions are effective.

**2 Theoretical model and methods**

For an event that is occurred, scientists usually expect to find out various influencing factors, and by linear or nonlinear regression to fit, in order to be able to predict or analyze this event. There may be many factors affecting COVID-19 infection, such as climate, geography, and ethnicity, but it is difficult to find the correlation and the weight of influence from these factors in a short time. Even if the correlation between these factors is obtained through investigation and analysis, it is difficult to ensure whether these factors are complete and the accuracy of their values.

Traditional statistical methods require some assumptions such as normality, independence, and random sampling. However, each patient of an epidemic infectious disease is obviously not independent and random, and will not be infected without the source of infection. The source of the disease is the patient itself, which spreads to others through contact or non-contact. Obviously, at this point, it has been confirmed that the samples among covid-19 patients are not completely independent and random. Therefore, the limitations of using conventional traditional statistical methods to predict or establish a COVID-19 transmission and infection model are obvious.

Although the number of confirmed cases can be obtained for COVID-19, but the number of confirmed cases is still incomplete, because in reality it is impossible to detect all COVID-19 patients. If the data of COVID-19 confirmed cases follow the scaling law of fractal, we can infer the trend of COVID-19 infection through the fractal statistical method. Fractal geometry shows that the nature of objects (things) is interrelated, and local self-similarity shows the global characteristics of objects. It may be quite feasible to use fractal statistics to try to find out the transmission mechanism of COVID-19 virus and establish corresponding models. This is the characteristic of self-similarity of fractals.

It is difficult to apply COVID-19 virus by on traditional statistical methods. The reason is that each individual case of infectious disease is not completely independent, and a source of infection is needed. The cases are more or less naturally related. As a result, the obtained samples are not completely independent. We think that the best way to judge trends is to find patterns based on statistical analysis of existing data, not just by modeling and making parametric assumptions.

In general, a power–law (fractal) distribution is of the form [11]

$$p(t) = kt^d \qquad (1)$$

where $p(t)$ is the number of objects with size $t$, and $k$ and $d$ are constant. The scaling exponent $d$ could be a fraction and is usually called the fractal dimension. In many practical applications, as Newman pointed out[14], one of the methods to study the data is to calculate the cumulative distribution function. The cumulative distribution has an advantage in that it can reduce statistical fluctuations without losing any information.

According to a broad general idea, the power–law distribution is not restricted to the size of geometric shapes; $t$ in Eq. (1) may be an arbitrary measure of magnitude of an event or a variable of interest. In this study, as an extension to applications of the power–law (fractal) distribution, we attempt to examine the total confirmed cases of the COVID-19 as a function of the time series of Coronavirus infection to see if it obeys power–law distributions.

The fractal distribution law of the number of novel coronavirus infection cases in different countries can be drawn by double logarithmic figures. We call the bottom of the curve (and the last day of the total number of documented infection) as the case outbreak point (threshold), which is also called as the abnormal value, while the earlier time is the diffusion plateau phrase (background).

In formula (1), $p(t)$ denotes the total number of confirmed cases since the first documented infection of COVID-19, $k$ denotes the coefficient, $t$ denotes the number of days since the first confirmed case of novel coronavirus pneumonia.

If there is a relationship between $p(t)$ and $t$ as follows:

$$p(t) \propto kt^{d1};\ p(t) \propto kt^{d2};\ p(t) \propto kt^{d3} \quad (2)$$

Formula (2) shows that if the self-similarity of the total number of COVID-19 confirmed cases in space and time has local characteristics, i.e. multifractal characteristics. This shows that there are at least two different levels of distribution of COVID-19 pandemics in space and time. We define background distribution (i.e. the coronavirus latency)in the range of time scale $d > d_i$, the range of scale $d < d_i$ as abnormal distribution, and define $p(t)$ corresponding to $d_i$ as the lower limit of abnormal distribution, which is also called threshold.

Here we define the constant $d_2$ of $p(t) \propto kt^{d2}$ as the growth rate during the outbreak period of COVID-19. The higher the value is, the faster the coronavirus spreads and the more cases are infected. The incubation period in this paper refers to the time point from the outbreak of coronavirus as the starting point (i.e. the starting date of the curve in the scaling analysis chart), and the time period from the first documented to the first COVID-19 infection (days).

The infection and transmission of novel Coronavirus can be divided into three stages (Figure 1) by the statistical analysis of the number and time distribution of virus infection in the affected country. The first stage is the diffusion platform phase, this transmission stage is characterized by very slow increase in the number of infections, and the number of confirmed cases is really more less, because of most people don't care or no symptoms of the patients without self-knowledge, thus increases the chances of the spread of COVID-19, this period is usually in 3-4 weeks. The second stage is the outbreak phase, in which the total number of infected persons increases very rapidly and by a power exponential form with fractal dimension $D_f$($D_f$>1). The third stage is the control stage, in which the rate of infection is greatly reduced and tends to be flat. It should be pointed out that these three stages can be repeated. i.e., the third stage can also become the first stage, and it goes on in this way (see Oceania of figure 2).

At any one stage, COVID-19 is likely to repeat these three stages and can be recognized by different fractal dimensions obtained by fractal statistics. The model can also be used to assess the effectiveness of national or regional prevention and control measures. In the second stage, if the fractal dimension of the following curve is greater than the fractal dimension of the previous curve, the prevention and

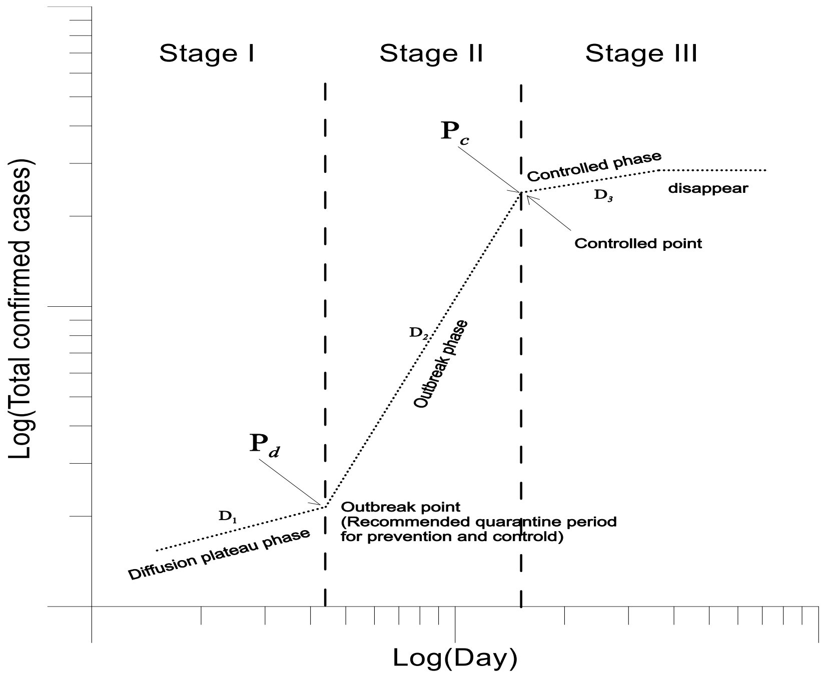


**Figure 1 the propagation model of COVID-19 pandemic**

control measures are not effective. In the third stage, if the fractal dimension of the following curve is less than 1, the COVID-19 has achieved critical control, preventing human-to-human transmission.

This feature can be used to analyze the looseness and tightness of epidemic prevention and control measures in various countries, which also indicates that the transmission power of the virus has been greatly reduced.

**3 Data analysis**

Data analysis shows that both the total number of confirmed cases and the total number of deaths from COVID-19 follow power law distribution[13], with the bottom of the curve (and the last day of the accumulated number of documented infections) being the case outbreak point or threshold (also called the abnormal value) and the earlier time being the incubation period (background). [14, 15]

Here we define the constant of $d_f$ (also called fractal dimension) as the growth rate during the COVID-19 outbreak period. The higher the value of, the faster the coronavirus spreads and the larger the number of infections. Log-log plots represent the relationships between the cumulative number of confirmed COVID-19 infections and the number of days since the first patient was documented in countries/regions that initially did not take any precautions.

Based on Formula (1), using global novel coronavirus diagnosis data and the corresponding timelines (Data cut-off time: 23:00 10/12/20), attribute the data as the "COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University"(https://github.com/CSSEGISandData/COVID-19).[2], Figure 2 shows that the average period from initial infection to epidemic outbreak was 28 days globally; 25 days in Asia; 39 days in America; 15 days in Africa; 28 days in Europe and 39 days in Oceania.

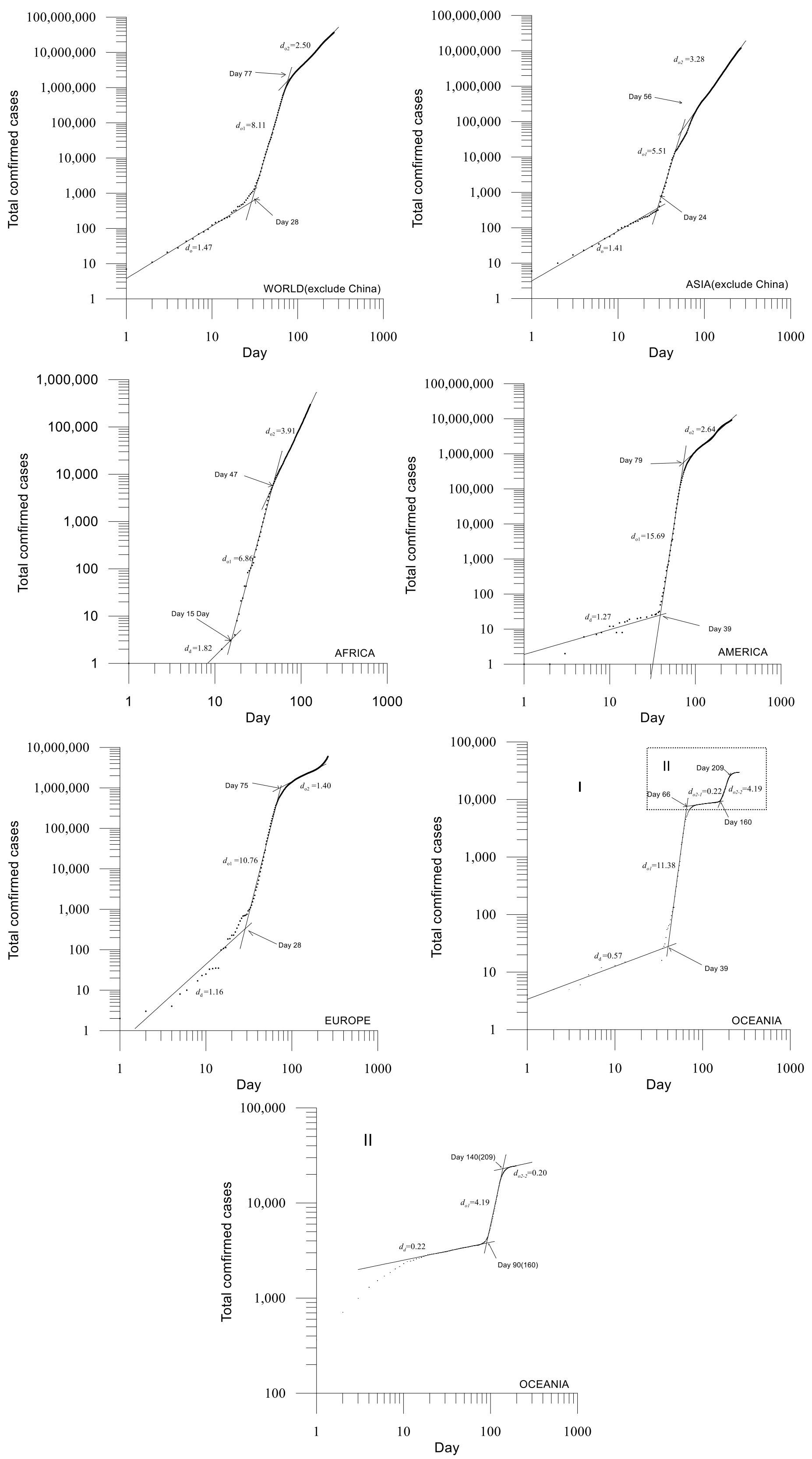


**Figure 2 Scaling analysis on the type of COVID-19 spreading in World, Asia, Europe, America, Africa, Oceania**

Australia and New Zealand adopted stricter isolation measures than other countries at the early stage of the novel coronavirus. For example, whereas passengers entering China must be isolated and observed at home for 14 days, but the border is not blocked (resulting in a surge of infections), New Zealand adopted a 28-day blockade and isolation policy. Figure 2 shows that the outbreak period of Oceania's novel coronavirus was 39 days (compared to 24 days in Asia), suggesting that if a country/region does not take measures to restrict domestic travel activities, simply blocking the border will not stop the proliferation of COVID-19 in its territory.

Due to various factors, it is not always possible to form, especially in the early stage of the COVID-19 outbreak, because people do not think they have been infected with the COVID-19 virus, and rarely go to the hospital for diagnosis. Therefore, there will be few cases and the data will be distorted, so that the statistical chart of the first stage is not formed. At this time, the number of confirmed rashes in the case closest to the curve was taken as the outbreak point. The tightening of countries' epidemic prevention measures is likely to result in more $d_2$ and $d_3$ curve repeats.

The Figure 2 shows that the global spread of the COVID-19 is still in the outbreak stage except Oceania. The world in Figure 2 shows that after 77 days of efforts by various countries, it has now entered a mild outbreak stage. And the speed of infection in Europe only accelerated during the outbreak stage, perhaps due to the introduction or mutation of new coronaviruses. The Oceania in Figure 2 shows that the fractal dimension $d$ is from 0.51 to 11.38 in the first outbreak stage, the second stage of outbreaks occurred 160 days later, then 209 days tend to be control phase, and the fractal dimension $d$ is from 0.22 to 4.16, and the period is 49 days.

Oceania (I) in Figure 2 shows that the Oceania has entered the late stage of the second wave of outbreak (see Oceania (II) in Figure 2). The diffusion plateau phase of the Stage I ( i.e. the controlled phase of the first wave of outbreaks of Stage III) of the second wave of the epidemic took 90 days (160th day in total) with a d value of 0.22, Stage II took 50 days (290th day in total days), and then the epidemic entered Stage III.

Oceania (I, II) in Figure 2 verifies the rationality of the model in Figure 1. We believe that as the epidemic progresses, this model will gain more and more evidence to justify it.

## 4 The diffusion plateau period of COVID-19 infection and preventive measures in

### Comparison by Continents/World

Since the outbreak of COVID-19 infection in mainland China and its continuous spread globally, different regions have adopted different attitudes to COVID-19 pandemics, introducing different response measures with different levels of severity. Dealing with this potentially catastrophic disease places different critical loads on medical resources and public health systems in different countries/regions. Moreover, the diffusion plateau period, outbreak period, and control period from COVID-19 infection following its silent intrusion differ between countries/regions. Table 1 summarizes the periods corresponding to COVID-19's spread on different continents (Table 1).

Table 1 Different stage in Continents and the world of COVID-19 spreading

| Continent | Stage I | | Stage II | | | | Stage III/ Stage I' | | Stage II' | | Stage III' | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $d_1$ | Diffusion plateau phase/ Outbreak Point/ Threshold[2] (day) | Fractal dimension $d_{2\text{-}1}$ | Fractal dimension $d_{2\text{-}2}$ | Outbreak phase 1 (2-1)(day) | Outbreak phase 2 (2-2)(day) Period[1] | $d_3/d'_1$ | Control period (day)/ Diffusion plateau phase/ Outbreak Point/ Threshold (day) | Fractal dimension $d'_2$ | Outbreak phase 1' (day) | $d'_3$ | Control period (day) |
| World* | 1.47 | 28 | 8.11 | 2.50 | 49 | 77 | - | - | | | | |
| Asia* | 1.41 | 24 | 5.51 | 3.28 | 32 | 56 | - | - | | | | |
| Africa | 1.82 | 15 | 6.68 | 3.91 | 32 | 47 | - | - | | | | |
| America | 1.27 | 39 | 15.69 | 2.64 | 40 | 79 | - | - | | | | |
| Europe | 1.16 | 28 | 10.76 | 1.40 | 47 | 75 | - | - | | | | |
| Oceania | 0.57 | 39 | 11.38 | - | 27[2] | - | 0.22 | 66/ 94 Diffusion plateau phase / 160 Outbreak Point | 4.16 | 49[3] | | 209 |

*Except for mainland China.

[1] The data is calculated by two cross-fitting curve equations, Outbreak phase 1 (2-1)(day)= Outbreak phase 2 (2-2)(day) Period -Diffusion plateau phase.

[2]The data = Control period(day) in stage III- Diffusion plateau phase.

[3]The data = Control period(day) in Stage III'- Outbreak Point in stage I'

We can be seen from Table 1, the diffusion plateau phase (Stage I)'s fractal dimension is $d_1$<2, the outbreak phase (Stage II) 's fractal dimension is $d_2$> 6, the control phase's fractal dimension (Stage III) is $d_3$ <1.

It can be seen from Table 1 that after the outbreak of COVID-19 epidemic in mainland China, the United States, Australia, and other countries/regions promptly took actions to prevent the entry of persons from countries/regions with COVID-19 pandemics; while these measures have not succeeded in blocking the spread of novel coronavirus within their countries/regions, they can delay, to a certain extent, the outbreak of coming COVID-19 pandemics. Comparisons of countries/regions experiencing COVID-19 pandemics reveal the most effective prevention and control measures are complete lockdowns, like those adopted in Australia and New Zealand. In America and Oceania, the maximum diffusion plateau phrase for novel coronavirus is 39 days. Figure 3 shows that the diffusion plateau phase of COVID-19 is less than 15 days 40% of the phase, 16-28 days 20% of the phase, and 29-39 days 40% of the phase.

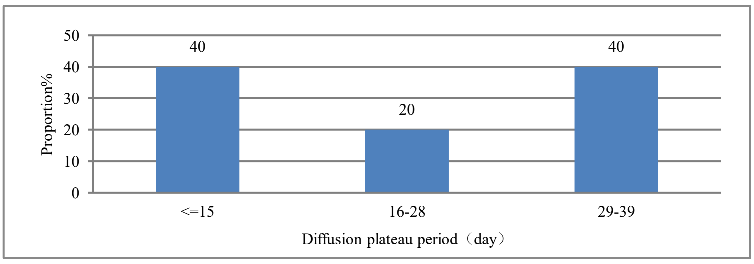


**Figure 3 Statistics of diffusion plateau periods of COVID-19 spreading in Continents/World**

The actual isolation period in many provinces of mainland China (except Hubei province) is about 14 days. The average incubation period of Oceania is 39 days, and most of the confirmed cases in these countries/regions were imported. Between the first sporadic documented COVID-19 cases to the final outbreak of national pandemics, now-confirmed patients were asymptomatic for many days while entering other countries/regions. Although Taiwan and Singapore took strict isolation measures in the early stage, they failed to prevent the pandemic's outbreak (shown in the double logarithm chart) by not initiating lockdown procedures; thus, the overall situation did not change.

The time needed for epidemic outbreak in different countries/regions differs with the global dissemination of COVID-19. At the same time, because there are still personnel exchanges and international intercourse between different countries/regions since the outbreaks began, and because there is no vaccine or special drugs at present, there is the possibility of a secondary outbreak (even in countries/regions with an alleviated situation) due to new inputs of COVID-19 carriers. Therefore, it is necessary to do a good job of COVID-19 epidemic prevention and pandemic control, including making targeted allocations of medical resources in advance.

**Conclusion**

As a public health intervention, containment was a non-starter; the virus had not only escaped, it was embedded both across the country and the globe.[16] Determining the incubation period of infectious diseases is especially important to completely blocking their spread. The general epidemiological incubation period refers to the medical investigation of the individual's onset period, while the statistical incubation period refers to the diffusion plateau phase of the epidemic infectious virus. There is no conflict between the two, but when considering the attributes of social security, perhaps the statistical incubation period is more useful. In order to distinguish the relationship between general epidemiological incubation period and the statistical incubation period, the statistical latency period is called the diffusion plateau period. The diffusion plateau phase is more appropriately called the incubation period in the statistical sense, and it may be more instructive to use this as the isolation period.

In comparing data from all continents/regions, we found that the maximum period between the first confirmed case of COVID-19 and the outbreak of a COVID-19 epidemic was 39 days. We think it is reasonable to define a 28-day of the diffusion plateau phase as a, based on fractal statistics of existing global data (rather than hypothesis modelling). Different continents have different diffusion plateau phase, reflecting the characteristics of fractal distribution. The reality is that a 14-day isolation period has not stopped the spread of novel coronavirus in various countries/regions. In most cases, effective contact tracking and case isolation are enough to control new outbreaks of COVID-19 epidemic within three months.[17] The longer the time from symptom onset to isolation, the lower the number of cases identified by contact tracking.

When many infected people in a country/region are asymptomatic, efforts at blocking of COVID-19 transmission will be incomplete, meaning the country/region will experience a longer incubation period and isolation period, and be less likely to control the epidemic. Washing hands, wearing masks, and paying attention to social distance are very important to control the spread of the epidemic. Large scale nucleic acid detection in epidemic areas, speeding up the development and application of safe vaccines, and establishing a closer global joint prevention and control cooperation relationship between countries are necessary for all mankind to win the victory of COVID-19 epidemic. While making no predictions, this paper attempts to reveal the laws behind the data through data mining. Its disadvantage is that it cannot predict the effectiveness of isolation measures, although we can test the effectiveness of isolation measures in a country/region through this model.

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