ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH

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# Turkey in Between European Union Countries in the New Coronavirus (COVID-19) Outbreak; An Examination of the Doubling Times

## Yeni Koronavirüs (COVID-19) Salgınında Türkiye ve Avrupa Birliği Ülkelerinin Karşılaştırması; İki Katına Çıkma Sürelerinin İncelenmesi

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**ABSTRACT Objective:** In December 2019, the new coronavirus (COVID-19), which is identified as a new pneumonia factor, emerged in Wuhan, China's Hubei province. The new coronavirus is rapidly spreading all over the world and considered a pandemic. The first case in Turkey was confirmed on March 10, 2020, and on March 18, 2020, Turkey has reached the 100th case. **Material and Methods:** In this study, the doubling times of the outbreak in the European Union countries, especially Turkey, were investigated. Moreover, in this context, as South Korea has been extensively testing both symptomatic and asymptomatic patients and implementing effective strategies, the doubling times have increased steadily linearly without any decline. Therefore, the doubling times for European countries have been compared to South Korea. **Results:** The highest slope in doubling times was achieved in South Korea and Austria. Among the compared countries, Italy, despite its 51st day after its 100th case, has not yet experienced a rapid rise. In Turkey, the doubling time after the 100th case was calculated to be 1.04. Initially, Turkey was ranked as the country with the lowest doubling times between European Union countries, however, at the point reached today (the 34th day after than the 100th case); after Spain, Austria, Switzerland, and South Korea, Turkey ranks fourth by a doubling time of 13.14. **Conclusion:** Turkey on the 34th day after the 100th case of the outbreak, has made further successful progress more than major European countries. The prolongation of the doubling time in this wise is promising to combat the pandemic successfully.

**Keywords:** Coronavirus infections; COVID-19; severe acute respiratory syndrome coronavirus; Turkey; European Union

**ÖZET Amaç:** Aralık 2019'da, Çin'in Hubei eyaleti olan Wuhan'da, yeni bir pnömoni etkeni olarak tanımlanan yeni koronavirüs (COVID-19) ortaya çıktı. Yeni koronavirüs hızla tüm dünyaya yayıldı ve bir salgın olarak kabul edildi. Türkiye'de ilk vaka 10 Mart 2020'de doğrulanmış ve 18 Mart 2020'de 100'üncü vakaya ulaşılmıştır. **Gereç ve Yöntemler:** Bu çalışmada Avrupa Birliği ülkeleri, özellikle Türkiye'de, salgının iki katına çıkma süreleri incelenmiştir. Ayrıca bu bağlamda, Güney Kore, hem semptomatik hem de asemptomatik hastalara yoğun bir şekilde test yaptığı ve hasta takibi gibi etkili stratejiler uygulaması nedeniyle, iki katına çıkma süreleri herhangi bir düşüş yaşamadan, istikrarlı bir şekilde doğrusal olarak artmıştır. Bu nedenle Avrupa ülkeleri için iki katına çıkma süreleri Güney Kore ile karşılaştırılmıştır. **Bulgular:** İki katına çıkma sürelerinde en yüksek eğim Güney Kore ve Avusturya'da elde edilmiştir. Karşılaştırılan ülkeler arasında İtalya, 100'üncü vakasından sonra 51'inci gününde henüz hızlı bir yükselme yaşamamıştır. Türkiye ise sabit bir artış ile devam etmektedir. Türkiye'de 100'üncü vakadan sonra ilk iki katına çıkma süresi 1,04 olarak hesaplanmıştır. Başlangıçta Türkiye'de vakaların hızlı artışı ile iki katına çıkma süresi en düşük ülke konumundayken, bugün gelinen noktada (100'üncü vakasından sonra 34'üncü gün) İspanya, Avusturya, İsviçre, Güney Kore'den sonra, 13,14 iki katına çıkma süresi ile dördüncü sıradadır. **Sonuç:** Türkiye salgının 100'üncü vakasından sonra 34'üncü gününde beş büyük Avrupa ülkesinden daha başarılı ilerlemeler kaydetmiştir. İki katına çıkma sürelerini uzaması pandemi ile mücadelede başarı konusunda umut vaat edicidir.

**Anahtar Kelimeler:** Koronavirüs enfeksiyonları; COVID-19; şiddetli akut solunum sendromu koronavirüs; Türkiye; Avrupa Birliği

In December 2019, the new coronavirus, which is identified as a new pneumonia agent, emerged in Wuhan, China's Hubei province. The new coronavirus rapidly spreading all over the world and con-

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sidered as a pandemic. As of 21 April 2020, the new coronavirus caused a total of 2,397,216 confirmed cases and 162,956 deaths.[1] The new coronavirus disease is different from the previous epidemics such as SARS and MERS, with varying times of incubation, very rapid spread, and the severity of the clinical symptoms caused by it. The World Health Organization (WHO) called the infection COVID-19 on February 11, 2020, and declared this epidemic as a pandemic on March 11, 2020.[2,3]

It is thought that the epidemic is a zoonotic infection and spread from animal to human in the wet seafood market in Wuhan, and then spread human to human.[4,5] The most common symptoms in the clinical picture caused by COVID-19 are fever, cough, and shortness of breath. It has been determined that the virus is transmitted from person to person with droplets that usually occur with a cough. Touching the person's face or mucous after touching the contaminated surfaces also causes contamination.[6] While the disease progresses asymptomatically in some cases, mild upper respiratory tract infection or in progressed cases pneumonia, respiratory failure, multiple organ failure, and death may be observed.[7,8] With the spread of new coronavirus; public health precautions such as preventing close contact among people, encourage personal protection precautions (such as hand washing, wearing a mask to the crowd), travel restriction, and quarantine for the confirmed cases quickly came into effect.[9] Firstly, on 23-24 January 2020, the Chinese government closed the borders of Hubei. Italy, which is one of the countries most affected by the outbreak in the world, closed its borders on March 9 when they reached a total of 7375 confirmed cases and 366 deaths.[2,3,9] While India closed its borders on March 24, 2020, there were 434 confirmed cases and no deaths were reported.[9] Turkey is among the countries that act reasonably quickly on this issue. When the first case was seen on March 10, 2020, the borders had been already closed to China, Italy, South Korea, Iran, and Iraq.[10]

In Turkey, aiming to combat the outbreak which is considered an emergency in terms of public health, precautions are taken to prevent the spread of infection, while diagnostic and therapeutic implementations are carried out. On the other hand, by making an effort to understand the characteristics of the outbreak and how it spread, how it will end, it is tried to make predictions about the effect of control studies, efforts have been made to model the epidemic.

Modeling an outbreak contributes to the goal of evaluating alternative control precautions. In this context, the most critical parameter of the epidemic model is the rate of spread or reproduction. The rate of spread is the average number of secondary cases produced after the first infection in the absence of control precautions in a population and defines a threshold value that determines the probability of infection spread. The rate of spread also defines the level of intervention that should be used to control the outbreak. The spread rate is obtained from doubling times. As the infection slows, the doubling time increases. Therefore, it is essential to examine the doubling times in the outbreaks.[11,12] The change in doubling times between countries is probably due to the change in both spreading rates and control efforts.[12]

In this study, doubling times of the cases in Turkey were examined, and these times were compared to 10 countries in the European Region (Austria, Belgium, France, Germany, Italy, Netherlands, Spain, Sweden, Switzerland, England). Moreover, in this context, as South Korea has been extensively testing both symptomatic and asymptomatic patients and implementing effective strategies such as patient follow-up, the doubling times have increased steadily linearly without any decline.[12] Therefore, the doubling times for European countries have been compared to South Korea.

## MATERIAL AND METHODS

The spread rate is an indication of the infectiousness of a virus and represents the average number of new infections produced by an infected person in a population. The doubling times, known as another measure of spreading, are the time it takes to double the number of cases in the outbreak when there is no control effort. Therefore, doubling times are evaluated to examine the effect of the control effort required to reduce spreading. Similar to the SARS epidemic, the doubling times of the new Coronavirus are the pri-

mary step to examine the epidemiology of the outbreak and the potential public health impact.[12]

Typically, an infection that spreads from person to person will grow exponentially in the early phase of the outbreak. This exponential growth can be measured by growth rate(r), then infection prevalence is calculated as in Formula-1.[9]

$$N(t) = N_0 \exp(rt) + noise \quad (1)$$

The Poisson Generalized Linear model with Log link can be used as a mathematical model to derive the estimate of the spreading rate (r). In surveillance data, due to excessive noise, the quasi-Poisson distribution will be appropriate. Instant local growth rate when using a quasi -Poisson distribution with a log link is a time derivative as r(t), and is the instantaneous doubling time. Here, $N_0$ and $N$ are the total numbers of cases at time $t_0$ and $t$, and (r) is growth rate, respectively. By definition, for the total number of cases to be doubled, N = $2N_0$, and therefore the time-dependent doubling time is calculated as in Formula-2.[13,14]

$$\alpha(t) = \frac{t\ ln(2)}{\ln\ (N/N_0)} \quad (2)$$

In this study, doubling times were calculated for each day after the 100th case for each country. In this way, the countries have been made comparable to each other. The data of the study were analyzed in the R program.

## RESULTS

In this study, epidemiological data were obtained from official sources: national data were obtained from the official website of the Ministry of Health (www.saglik.gov.tr) and for the European Union region from the official WHO official site (situation reports) (21.04.2020). We compared the doubling time of Turkey and 10 European Union countries. In Turkey, the first case was confirmed on 10 March 2020 and crossed the 100th case on 18 March 2020 by reporting 198 cases.

A total of 90,980 cases were reported on April 20, 2020, for COVID-19 disease caused by the new coronavirus infection in Turkey. Doubling times in the days following the 100th case for Turkey are shown in Figure 1. The cumulative cases and their doubling times by days are shown in Table 1. In this table, for example, after the 100th case, to a number of 191 confirmed cumulative cases were reached in 1.04 days (doubling time). Likewise, to 5,698 cumulative cases seen on March 27, 2020, were achieved in 1.54 days. Finally, on the 34th day of the outbreak, April 20, 2020, 13.14 days were required to reach 90,980 cases. Daily new diagnosed cases are given in Figure 2.

Turkey and 10 European countries and South Korea's doubling time of the epidemic to the 21st

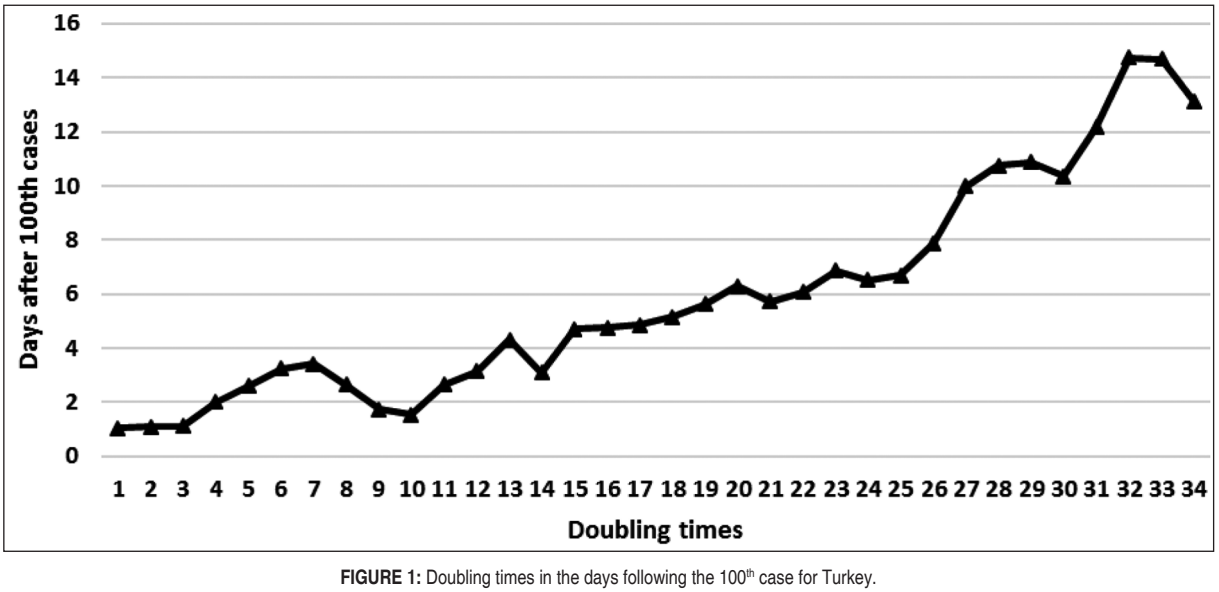


**FIGURE 1:** Doubling times in the days following the 100th case for Turkey.

**TABLE 1:** Doubling times (day) and cumulative cases after 100th case in Turkey.

| Days after 100th Case | Date | Cumulative Cases | Doubling times (Day) |
|---|---|---|---|
| 1 | 18 March 2020 | 191 | 1.04 |
| 2 | 19 March 2020 | 359 | 1.10 |
| 3 | 20 March 2020 | 670 | 1.11 |
| 4 | 21 March 2020 | 947 | 2.00 |
| 5 | 22 March 2020 | 1236 | 2.60 |
| 6 | 23 March 2020 | 1529 | 3.26 |
| 7 | 24 March 2020 | 1872 | 3.42 |
| 8 | 25 March 2020 | 2433 | 2.64 |
| 9 | 26 March 2020 | 3629 | 1.73 |
| 10 | 27 March 2020 | 5698 | 1.54 |
| 11 | 28 March 2020 | 7402 | 2.65 |
| 12 | 29 March 2020 | 9217 | 3.16 |
| 13 | 30 March 2020 | 10827 | 4.31 |
| 14 | 31 March 2020 | 13531 | 3.11 |
| 15 | 1 April 2020 | 15679 | 4.70 |
| 16 | 2 April 2020 | 18135 | 4.76 |
| 17 | 3 April 2020 | 20921 | 4.85 |
| 18 | 4 April 2020 | 23934 | 5.15 |
| 19 | 5 April 2020 | 27069 | 5.63 |
| 20 | 6 April 2020 | 30217 | 6.30 |
| 21 | 7 April 2020 | 34109 | 5.72 |
| 22 | 8 April 2020 | 38226 | 6.08 |
| 23 | 9 April 2020 | 42282 | 6.87 |
| 24 | 10 April 2020 | 47029 | 6.51 |
| 25 | 11 April 2020 | 52167 | 6.69 |
| 26 | 12 April 2020 | 56956 | 7.89 |
| 27 | 13 April 2020 | 61049 | 9.99 |
| 28 | 14 April 2020 | 65111 | 10.76 |
| 29 | 15 April 2020 | 69392 | 10.89 |
| 30 | 16 April 2020 | 74193 | 10.36 |
| 31 | 17 April 2020 | 78546 | 12.16 |
| 32 | 18 April 2020 | 82329 | 14.74 |
| 33 | 19 April 2020 | 86306 | 14.69 |
| 34 | 20 April 2020 | 90980 | 13.14 |

and 34th day are included in Table 2. According to the table, the longest doubling time belongs to South Korea. It is seen the doubling time of 21.86 days on the 21st day and 82.07 days on the 34th day. The shortest time is given for The United Kingdom (3.44 on the 21st day and 7.31 on the 34th day).

Figure 3 represents the time-varying doubling times for five major European countries and Turkey. According to Figure 3, Turkey's doubling times were located above the five major European countries. In Figure 4, South Korea's curve was added to the 5 European countries and Turkey's doubling times. As can be seen, the highest slope is achieved in South Korea. Among the compared countries, Italy has not experienced a rapid rise yet, despite being on its 51st days after its 100th case. However, Turkey continues with a constant upward slope. According to Figure 4, South Korea has managed to control the outbreak from the 21st day after its 100th case.

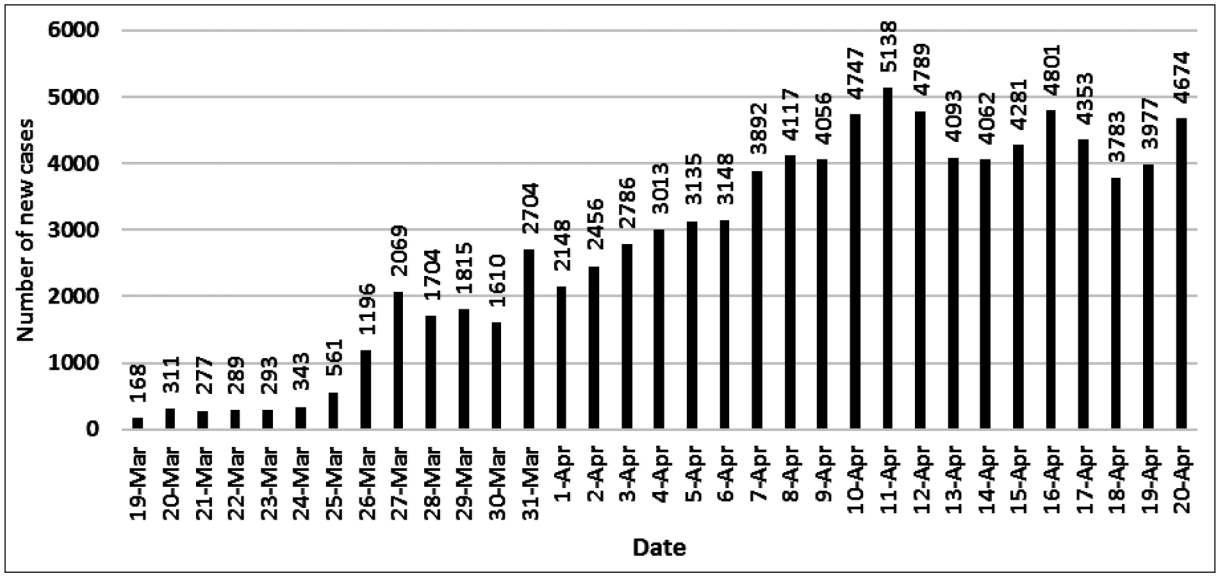


**FIGURE 2:** New daily cases of confirmed 2019 coronavirus disease (COVID-19) in Turkey as of 12 February 2020.

**TABLE 2:** New daily cases of confirmed 2019 coronavirus disease (COVID-19) in Turkey as of 12 February 2020.

| Europe Union countries | Doubling times in 21th day after 100th case | Doubling times in 34th day after 100th case |
|---|---|---|
| Austria | 9.32 | 29.78 |
| Belgium | 4.46 | 10.61 |
| France | 6.84 | 10.78 |
| Germany | 4.83 | 10.36 |
| Italy | 4.42 | 10.38 |
| Netherlands | 4.73 | 12.09 |
| Spain | 4.72 | 14.70 |
| Sweden | 8.45 | 8.42 |
| Switzerland | 5.68 | 20.40 |
| The United Kingdom | 3.44 | 7.31 |
| Turkey | 5.72 | 13.14 |
| South Korea | 21.86 | 82.07 |

## DISCUSSION

Risk prediction and modeling studies are critical in controlling outbreaks. In a review on COVID-19, 27 studies have been identified so far introduced 31 models. Most of these models were created for the determination of risk groups in terms of pneumonia in the community. The models are used for the prediction of diagnosis and prognosis. The studies carried out to predict the epidemiological features of COVID-19 have some limitations since they are carried out in the early stage of the epidemic, and their predictions can be considered as very optimistic.[15-20]

This study examines the doubling times of COVID-19 cases identified in Turkey until the date of April 21, 2020, and we aimed to estimate the spread rate of the outbreak and make predictions about the upcoming process. The doubling time of the cases calculates the periods required to double the cumulative incidence. The calculation of doubling times is with the cumulative cases; therefore, it is the calculation made directly from the raw data; which allows making predictions much earlier than other complex statistical models, and the estimates are quite consistent.[9]

After the first case reported in China on December 31, 2019, and the first death on January 11, 2020, all Turkey to Wuhan flights were stopped on January

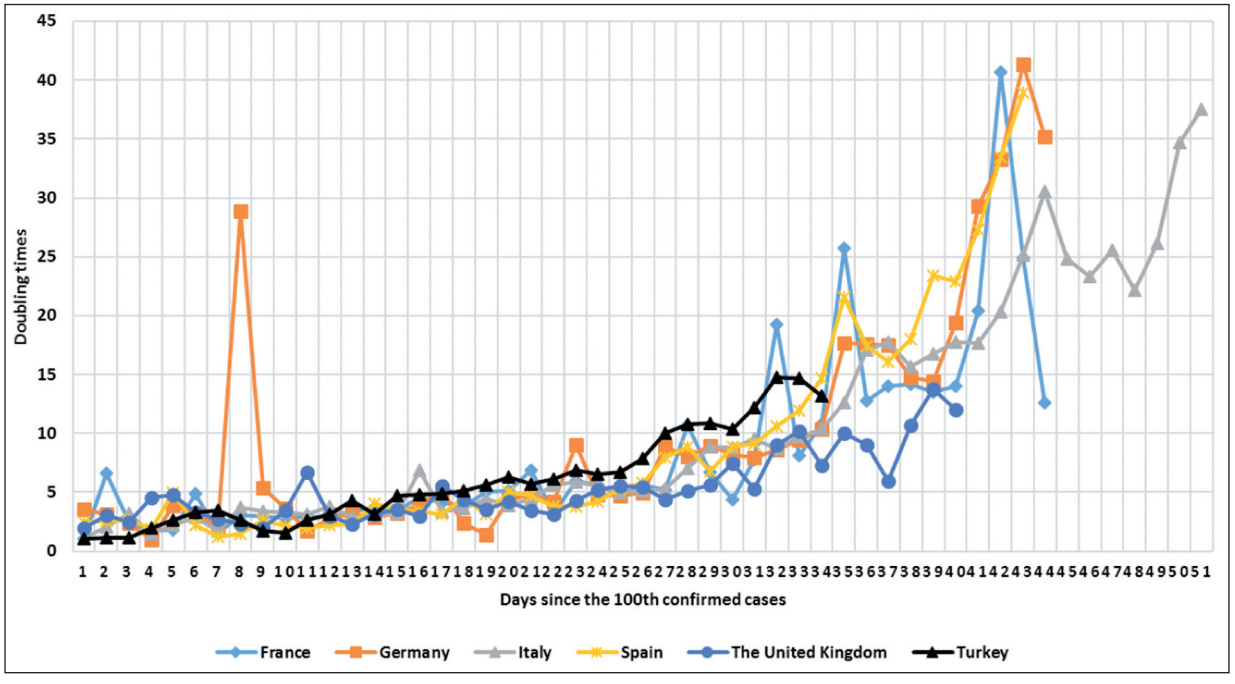


**FIGURE 3:** Doubling times (day) after the 100th case for 5 European countries.

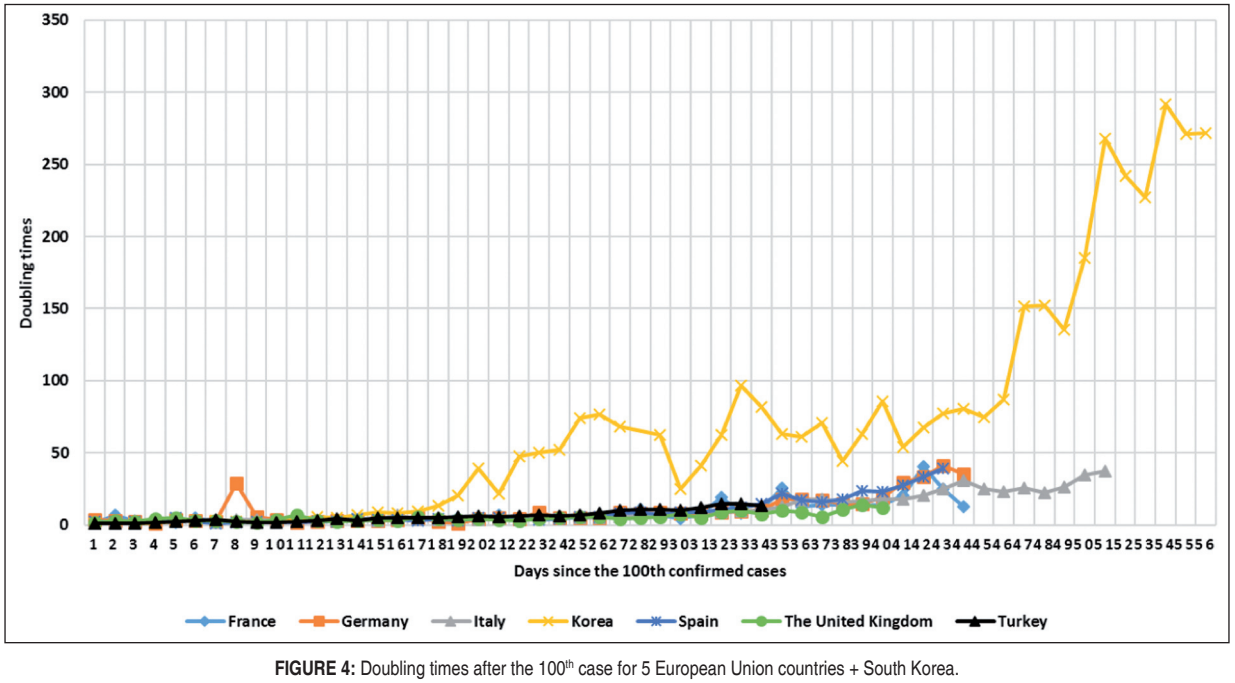


**FIGURE 4:** Doubling times after the 100th case for 5 European Union countries + South Korea.

22, 2020. Then all Turkey to China flights were stopped on February 5, 2020. Then, with the occurrence of the cases, all passenger round trips and cross-border transitions were stopped with Iran on February 23, 2020, and with Italy, South Korea, and Iraq on February 29, 2020. Following the reporting of the first case on March 10, 2020, in Turkey, all schools were closed on 12 March 2020. On March 13, 2020, public events are restricted.[10]

After the first case was seen, Turkey has reached the 100th case on 18 March 2020. The doubling time of the cases at this time stage was calculated as 1.04.

Peng et al., in the early stage of the epidemic in China, reported the doubling time as around two days. South Korea has been the only country that doubling times have risen steadily from the outset, with no decline. South Korea's success in controlling the outbreak was because of the strict control precautions has implemented early in the outbreak. In this way, the total number of cases graph has flattened in South Korea.[21] The comparisons between Turkey, European countries, and South Korea were made on the 21st day, and the 34th day after the reported 100th case in each country. The 21st day, which is the day when the doubling time of South Korea increased, and the case graph started drawing the plateau, was chosen as reference day.

Initially, because of the rapidly increasing number of cases, Turkey was ranked as the country with the lowest of doubling time between European Union countries, however, at the point reached today (the 34th day after than the 100th case); after Spain, Austria, Switzerland, and South Korea, Turkey ranks fourth by a doubling time of 13.14.

A small increase in the doubling times of the cases indicates that the number of cases continues to increase exponentially and that the combat should be continued. However, an increase of around 0.14 per day, as in China and South Korea, may suggest that the outbreak has been controlled. The success in the combat against COVID-19, as it is seen in South Korea, will be with steady increases in the doubling times that lead to flattened cumulative case curves.[21]

## CONCLUSION

Turkey on the 34th day after the 100th case of the outbreak, has made further successful progress more than major European countries. The prolongation of the doubling time in this wise is promising to combat the pandemic successfully.

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*During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.*

### *Conflict of Interest*

*No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.*

### *Authorship Contributions*

***Idea/Concept:*** *Robab Ahmadian;* ***Design:*** *Robab Ahmadian;* ***Control/Supervision:*** *Robab Ahmadian, İlker Ercan;* ***Analysis and/or Interpretation:*** *Robab Ahmadian;* ***Literature Review:*** *Yeşim Uncu, Robab Ahmadian;* ***Writing the Article:*** *Robab Ahmadian, Yeşim Uncu, İlker Ercan.*

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