

## Descriptive epidemiological analysis of the coronavirus disease 2019 (COVID-19) pandemic



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### ABSTRACT

At three months after the onset of the coronavirus disease 2019 (COVID-19) outbreak, the number of infected cases and deaths are significantly greater than expected. This drastic increase in the number of new cases has unveiled remarkable deficiencies in the public health systems of most of the countries in the world. This paper aims to provide a descriptive epidemiological analysis of COVID-19 as of February 18, 2020, by estimating the magnitude of this disease in terms of Case fatality rate, reproduction number ( $R_0$ ), and the pattern of mortality as a function of time and place. Moreover, we compare the burden of Covid-19 with the burden of a virus outbreak previously occurred. The main finding is that the estimated  $R_0$  for COVID-19 is 3.52, which is considerably higher than that reported for SARS (range, 2–3), MERS-COV ( $<1$ ), or Ebola (2.7) but a lower CFR. Globally, the CFR was stable during the study period, Feb 25–Apr 5, 2020, in the range of 3.43–4.92 with a mean value of 4.03. Both the USA and Europe have the highest number of cases and deaths. In contrast, in China, where the virus originated, great progress has been made with respect to disease control and lowering the caseload in a very short period. The number of cases and mortality due to COVID-19 has been hailed as one of the most remarkable public health deficiencies worldwide. Of course, CFR has its limitations as it tends to overestimate or underestimate the mortality risk of the disease. However, it can help us to better understand the severity of the disease as well as its progression and consequences on humans and healthcare resources. Hence, galvanize political support for ensuring adequate resources to overcome the consequences at the earliest possible.

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### 1. Introduction

Coronavirus disease 2019 (COVID-19) is an infectious disease caused by a newly identified coronavirus belonging to the Coronaviridae and Nidovirales families that can widely infect humans and animals. Human infection with novel influenza viruses of animal origin is a notifiable disease (Schicker et al., 2016). In December 2019, a novel coronavirus disease emerged in Wuhan City, Hubei Province, Central China. The initial source of the virus is believed to be the Huanan seafood market, with pangolins postulated as the potential animal host. The onset of the outbreak has been determined to be on February 28, 2020 (Baud et al., 2020), and

the disease has spread to neighboring countries, thereby fueling a severe, large-scale global outbreak. This epidemic has developed into a global pandemic by March 2020 and could no longer be contained by public health initiatives (Wilson et al., 2020).

Genome sequencing revealed that the virus, named 2019-nCoV, and later renamed COVID-19, is different from the beta coronaviruses associated with human Severe Acute Respiratory Syndrome (SARS) or the Middle East Respiratory Syndrome (MERS) (Wilson and Chen, 2020), and has been classified as a Class B infectious disease (Surveillances, 2020). The disease rapidly spread from Wuhan to other areas in China and then worldwide with considerable speed, which raised concerns about a global pandemic in the World Health Organization (WHO). Wuhan City is a major transport hub and center of industry and commerce and is home to the largest train station and the main airport in China. This situation facilitates worldwide connectivity and enables the rapid spread of the disease, both in China and in countries with high air

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passenger volumes from China, such as Singapore, Japan, and Thailand (Wu et al., 2020). The outbreak further progressed by infecting huge numbers of people around the world, including South Korea, Iran, and Italy. It has spread in a very short time due to airplane travel, which can carry both people and viruses (Wilson and Chen, 2020). By March 3, 2020, 80,151 cases have been detected and confirmed in Mainland China, while 10,566 cases were present in 72 countries (Chinazzi et al., 2020).

Several articles have reported that the virus infects individuals of all ages, including children. The common symptoms include fever, fatigue, dry cough, and breathing difficulty. The virus affects the immune system by invading multiple organs such as the heart, kidney, digestive system, blood, or nervous system (Naicker et al., 2020). The demographic groups most affected by COVID-19 are the elderly (>60 years of age) (MMWR, 2020) and those with comorbidities like diabetes mellitus, hypertension, and cardiovascular disease. Pregnant women and newborns also appear to be at higher risk for severe illness. Additionally, a patient's family members, medical and nursing staff, and escorts are at risk of being infected (Jin et al., 2020; Du et al., 2020). The virus is transmitted through human contact with a median incubation time of about 5–6 days and a mean serial interval of 3.96 days (95% confidence interval, 3.53–4.39 (Wilder et al., 2020). It is evident that respiratory droplets are the main mode of transmission (ECDC, 2020).

This pandemic has unveiled remarkable deficiencies in the public health systems of most of the countries in the world; therefore, determining medical needs and comparing the impact of various medical intervention strategies are important. Thus, this paper aims to provide a descriptive epidemiological analysis of coronavirus-associated pneumonia as of February 18, 2020, delineate the pattern of mortality due to COVID-19 in terms of time and place of its occurrence, and compare it with previous epidemics.

## 2. Materials and methods

### 2.1. Data sources and statistical metrics

Data on the number of confirmed cases and deaths due to COVID-19 were based on the European Centre for Disease Prevention and Control (Sanche et al., 2020). Descriptive epidemiological methods were used to describe the time, population, and regional distribution of both cases and deaths. An epidemic curve was constructed for the period February 25–April 6, 2020, for countries most affected by COVID-19, namely, China, Egypt, Iran, Italy, the Kingdom of Saudi Arabia (KSA), South Korea, Spain, and the United Kingdom (UK). Further, case fatality rate (CFR) and basic reproduction ratio (R0) were estimated for COVID-19 and compared with those for the SARS outbreak (2002), the MERS-COV (2012), and the Ebola epidemic (2013).

### 2.2. The basic reproduction ratio (R0)

R0 is a statistical parameter that is used to determine the transmission potential of an infection or disease and is defined as the average number of secondary infections produced by a typical infected individual in a completely susceptible population. When the R0 value is less than 1, the probability of an infection producing new cases is insufficient for an outbreak to be maintained. When R0 is greater than 1, the number of new secondary cases multiplies the infection, and the epidemic ensues until the proportion of susceptible individuals declines. Therefore, control measures are always targeted to reduce R0 to below 1, the state at which the outbreak cannot be sustained. Here, to estimate R0, several search engines were accessed to obtain data on "COVID-19." We capture the data, from reference (Li et al., 2020), of the early phase of the COVID-19. Some parameters of R0 are found from previous works (Read et al., 2020; Zhao et al., 2020; Zhou et al., 2020; Chen et al., 2020a; 2020b; Khan et al., 2014; Lau and Yip, 2008).

One way of R0 is the use of theoretical mathematical models with parameters. Most of them are educated guesses (Li et al., 2011). To estimate R0, we used the SIR model, which assumes that each individual in a population is either susceptible at first, infectious, or recovered from the disease with life-long immunity. This model is appropriate as a very simple model for Covid-19, ignoring features such as immunity from past infections. (Li et al., 2011; Hamid et al., 2020). Given the fact that R0 is a dimensionless number to help in calculating it (Jones, 2007), we have:

$$R0 = t \cdot \alpha \cdot d \quad (1)$$

where  $t$  denotes the transmissibility,  $\alpha$  denote the average rate of contact between susceptible and infected individuals, and  $d$  is the duration of infectiousness. To calculate R0, We used a SIR epidemic model, where SIR stands for "S, Susceptible-I, Infected- R, Removed."

Consider the following assumption: Constant (closed) population size  $N$ , Constant rates (e.g., transmission, removal rates), no demography (i.e., births and deaths); and well-mixed population, write  $s = S/N, i = I/N, r = R/N$  to denote the fraction in each component, the following ordinary differential equations describe the change rates of  $s(t), i(t),$  and  $r(t)$ . The SIR model is then:

$$ds/dt = -\beta si \quad (2)$$

$$di/dt = \beta si - vi \quad (3)$$

$$dr/dt = vi \quad (4)$$

where,  $\beta = t\alpha$  is known as the effective contact rate,  $v$  is the removal rate. Given that all rates are constant, the expected duration of infection is simply the inverse of the removal rate:  $d = v^{-1}$

Using  $\beta = t\alpha$  and  $d=v^{-1}$ , we have derived our expression for R0 given in Eq. 1. This R0 has been

computed for china, which developed the virus outbreak early. If  $R_0 < 1$ , the infection will be cleared, and in the case  $R_0 > 1$ , it will persist. Thus, the value of  $R_0$  is used to determine the intensity of control measures that need to be applied in order to contain the epidemic. We have compared this new basic  $R_0$  with that of a number of epidemics that have occurred in the previous years (Table 1).

## 2.3. Basic definitions

### 2.3.1. Case fatality rate (CFR)

CFR is the ratio of the number of confirmed cases and of associated deaths and is a measure of disease severity as a cause of death. CFR tends to evolve and represents variations in the degree of monitoring or directing an outbreak in a country.

The formula used to calculate CFR is:

$$\text{CFR}(\%) = \frac{\text{Total number of deaths due to disease at day X}}{\text{Total number of cases due to the same disease at day X}} (100\%)$$

This the resulting ratio is a probability that tells us how deadly the infection is and helps assess the performance of the healthcare system(s) of the country, compare action with health gain, and predict future health care needs.

### 2.3.2. Estimating the size of the epidemic

To predict how large an epidemic will be, understanding and measuring how individuals interact with each other within the community are necessary. Scientists solve these inherent difficulties by assuming a uniform mix of people (Ball et al., 2016), implying that the probability of contact with an infected person is equally likely for all individuals within a certain community. If a person moves from one subpopulation to another, the pathogen will be introduced to this new susceptible population, and the size of the outbreak will be determined by the behaviors of a relatively small number of infected people. Ultimately, the size and interval of an epidemic are determined equally by both population structure and  $R_0$  (Burrell et al., 2016). However, estimating epidemic size needs to identify a series of subpopulation structures through which an infected individual can travel (Burrell et al., 2016). Therefore, epidemics are often the outcome of smaller local outbreaks within subpopulations where most of the transmission occurs, followed by much more widespread dissemination by a small number of infected individuals (Shutt et al., 2017). The COVID-19 pandemic is the result of easy long-distance air travel.

## 2.4. Pandemic

Pandemic refers to a worldwide epidemic that is usually caused by an infectious pathogen that can transcend national boundaries and extend over

much of the entire world, affecting people everywhere.

## 3. Results

### 3.1. Descriptive analysis

Fig. 1 highlights some important numbers for the ongoing COVID-19 pandemic and reveals worldwide epicenters of the outbreak. Both the USA and Europe have the highest number of cases and deaths. In contrast, in China, where the virus originated, great progress has been made with respect to disease control and lowering the caseload in a very short period. The number of cases/deaths in Italy, Spain, and the USA were 53,000/15,363, 25,000/11,744, and 25,000/8501, respectively, on April 3, 2020. According to this analysis, the number of COVID-19 deaths rose strongly in countries with a high life expectancy, i.e., in Europe and the USA, where the elderly makes up a greater proportion of the population. Even though early studies postulated that COVID-19 could affect all age groups, the elderly have a higher risk of COVID-19 infection (Ma et al., 2020).

### 3.2. CFR and $R_0$

Fig. 2 presents the estimated CFR for the ongoing COVID-19 pandemic in nine countries during the study period of Feb 25–Apr 5, 2020. The CFR differs for each nation studied. CFRs for the disease in European countries, Italy, Spain, and the UK, were 7.3%, 5.17%, and 4.36%, respectively, at the confirmation of the onset of COVID-19, and gradually increased during the study period. This indicated that the infection starts with a low CFR and progresses to its peak value in week 7 after the first 100 cases. In Iran, one of the nations that were hit hard during the early stages of the pandemic, the CFR was 6.03% in the first week of confirmation with a mean value 6.5 for the entire study period. The result shows that the CFRs of the disease in the study period were 3.88%, 1.08%, and 0.63% for China, South Korea, and KSA, respectively. In Egypt, the disease spread late with an upward increase in CFR and an average value of 4.97, which is now 6 and is expected to increase for a period of time in the coming weeks. The CFR for the USA started at 5.85 for the first day but decreased gradually until it reached 2.5 during the last week of the study with a mean CFR value of 2.36.

Globally, the CFR was stable during the study period of Feb 25–Apr 5, 2020, in the range of 3.43–4.92 with a mean value of 4.03. Several studies (Baud et al., 2020) have shown that the CFR is significantly higher in the elderly (>over 60 years) and in those with underlying health conditions compared to young and healthy individuals (MMWR, 2020). Death probability from the COVID-19 infection also depends on the treatment provided to patients and

their own ability to recover from it, which can explain the high CFR for COVID-19.

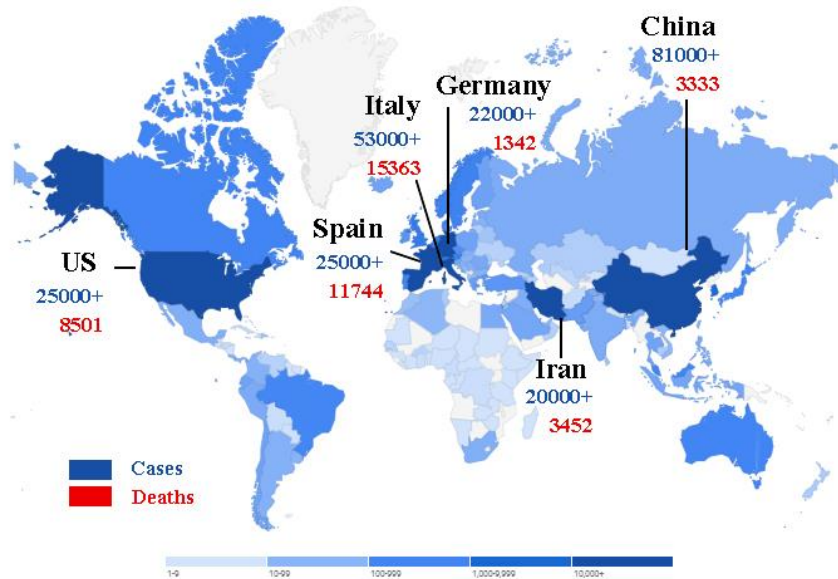


Fig. 1: Distribution of COVID-19 cases and deaths, worldwide, as of 3 March 2020

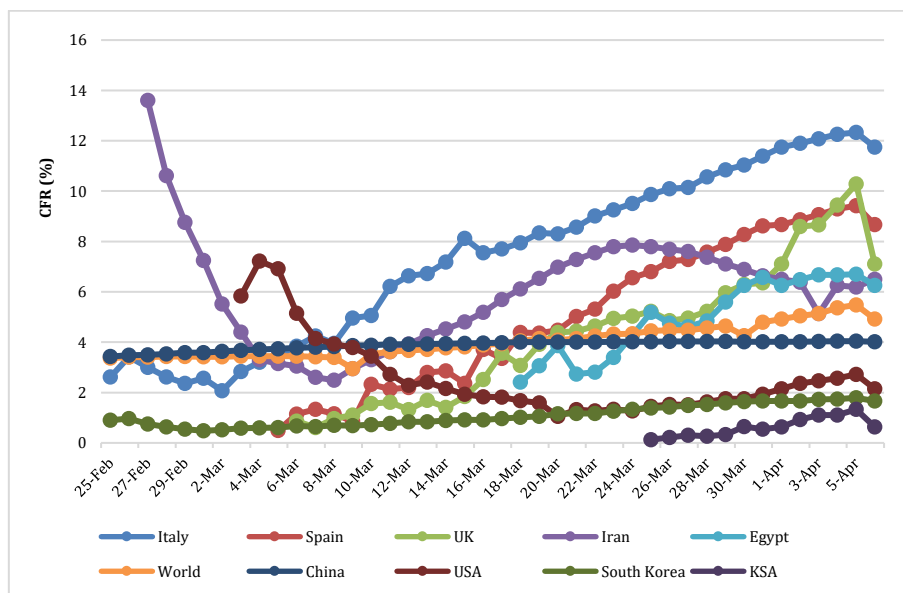


Fig. 2: Estimated case fatality rate for the ongoing COVID-19 pandemic in nine selected countries and the world

The time-series graphs (Fig. 3) show that the worldwide trend for the number of cases and deaths is to consistently grow upward, reach the first epidemic peak by week 6, and then slowly decline before accelerating by Epi week 9. Although the pandemic is not yet over, the overall curves show a pattern of worsening outbreak.

In the past 20 years, six comparable epidemics have been reported, SARS in 2002, the MERS-COV in 2012, Ebola in 2013, and the ongoing HIV/AIDS and malaria epidemics, in addition to the current COVID-19 pandemic. Table 1 shows a comparison between these epidemics with respect to the number of cases, deaths, CFR, and R0.

The SARS outbreak occurred in China in 2002 and led to 8098 cases and 774 deaths in multiple countries. Pregnant women with SARS appeared to have a higher mortality rate, and most of the cases were in Hong Kong, with a CFR of 9.6%. SARS also

spread to individuals in 37 countries in early 2003 with an R0 of 2–3 and CFR of 10% (Table 1).

MERS-COV first emerged in the KSA in 2012, and between September 2012 and March 2018, the disease spread to more than 26 countries worldwide with 2189 infected cases and 782 deaths, yielding a CFR of 37.3%. The estimated R0 for COVID-19 is 3.52, which is considerably higher than that reported for SARS (range, 2–3), MERS-COV (<1), or Ebola (2.7).

The 2014 Ebola epidemic in West Africa is considered as the largest and most severe Ebola virus disease outbreak ever reported as it led to 1133 deaths with a CFR of 50%. However, CFRs for the previous Ebola outbreaks varied from 25% to 90%.

The HIV/AIDS epidemic officially started in the USA in 1981 when several cases were reported among previously healthy, young gay men living in



New York and California (Keele et al., 2006; CPMA, 2020). As of 2018, over 37.9 million people are living with HIV worldwide, and about 62% have accessed antiretroviral therapy. Over 770,000 people with diagnosed HIV infection have died, resulting in a CFR

of 2%. The number of people living with HIV is greatest in sub-Saharan Africa and South and Southeast Asia; however, the prevalence of HIV as a percentage of the total population in a given region is highest in sub-Saharan Africa and in the Americas.

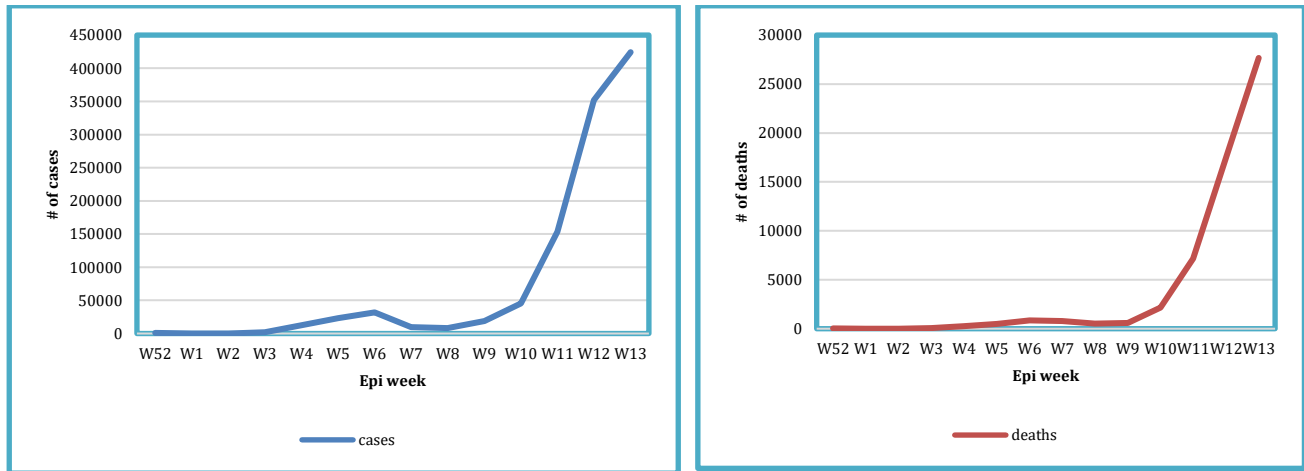


Fig. 3: The number of confirmed cases and deaths of COVID-19 worldwide as of Epi week 13, on 4 Apr 2020

Table 1: The number of cases, deaths, CFR, and R0 for different epidemics

Disease	Origin	Number of cases	Number of deaths	CFR	R0	References
COVID-19	China, 2019	>3500 × 10 <sup>3</sup>	>25000	3.5%	2-3 (3.52) **	(Wilson et al., 2020; Shutt et al., 2017; CPMA, 2020)
SARS	China, 2002	8098	774	10%	2-3	(Chowell et al., 2004; Zhou and Yan, 2003; Seto et al., 2003; Venkatesh and Memish, 2004)
MERS	Saudi Arabia, 2012	2519	866	34.3%	<1	(WHO, 2017; Munster et al., 2020)
Ebola	Guinea, 2013	28,646	11,323	50%	2.7	(WHO, 2014a; 2014b; Barbarossa et al., 2015)
HIV/AIDS	Congo, 1960	37.9 × 10 <sup>6</sup>	77 × 10 <sup>4</sup>	2%	-	(Ntsekhe and Hakim, 2005; Keele et al., 2006)
Malaria	Ancient disease	228 × 10 <sup>6</sup>	405 × 10 <sup>3</sup>	0.2%	-	(Ntsekhe and Hakim, 2005)

\*\* Estimated basic reproduction number (R0) for COVID-19

Malaria is an ancient disease with more than 80 countries worldwide reporting ongoing malaria transmission. In 2018, there were an estimated 228 million cases and 405,000 deaths due to malaria. African countries carry a high share of the global malaria burden as they account for 93% of all cases and 94% of all deaths, with most malaria cases and deaths occurring in sub-Saharan Africa.

#### 4. Discussion

This study aimed to shed light on the nature and magnitude of cases and deaths attributable to the COVID-19 epidemic. Over the past 30 years, outbreaks of deadly viruses that spread rapidly have increased, and the COVID-19 pandemic is the latest. It originated in China and spread rapidly to dozens of other countries, mainly due to easy means of transportation around the world. Another reason is the population density, which, according to the most recent United Nations estimates, is currently greater than ever at 7.8 billion, as of April 2020 (Weeks, 2020).

Although the spread of the disease cannot be stopped as long as R0 is greater than 1, previous SARS outbreaks have been successfully managed by isolating patients and following careful infection

control. We have estimated R0 for COVID-19 is 3.52, which exceeds WHO estimates of 1.4–2.5 and is higher than that of the SARS (2–3), MERS (<1), or Ebola (2.7) epidemics. However, it is notable that the CFR for COVID-19 is lower than that of the other previous epidemics. Together, this pattern reveals not only the risk of epidemic spread of the infectious agent for COVID-19 but also the difficulties that can be encountered during disease containment. The COVID-19 pandemic has led to substantial economic losses, psychological and social impacts. Furthermore, several studies show that despite its lower case fatality rate (3.5%), it has resulted in more deaths than SARS and MERS combined (Baud et al., 2020; Burrell et al., 2016; CPMA, 2020; Pathak et al., 2020).

SARS had a case fatality rate of approximately 10%, whereas Middle East respiratory syndrome (MERS) had a fatality rate of 34% between 2012 and 2019. With regard to the number of confirmed cases, the final population size of ongoing pandemic COVID-19 is not yet determined. Although the final population sizes of SARS, MERS, EBOLA, HIV/AIDS, and malaria were 8098, 2519, 28646, 37.9 million, and 228 million cases respectively, AIDS (HIV) and malaria are still ongoing diseases (Table 1).

Overall, the dramatic increase in the number of cases and mortality due to COVID-19 has been hailed as one of the most remarkable public health deficiencies worldwide, as healthcare facilities are being stretched thin by the disease in many countries. More than one million confirmed cases have occurred, and 3% of these individuals have died. Most of these deaths could be attributed to two factors: age greater than 60 years and the presence of underlying conditions such as hypertension, diabetes, cardiovascular disease, chronic respiratory disease, or cancer (Chen et al., 2020a; 2020b).

The estimated CFRs obtained for the ongoing COVID-19 pandemic for select countries, such as China, Egypt, Iran, Italy, KSA, South Korea, Spain, and the UK, increased gradually during the study period used here, which is a clear and characteristic feature of this epidemic. The disease has made a destructive historical impact worldwide. Compared to the Spanish flu pandemic in 1918 that killed about 50 million people (2.7% of the world population at that time (Chen et al., 2020a; 2020b), the COVID-19 pandemic is more widespread and more transmissible than the Spanish flu and any other epidemic ever reported. Therefore, measures that are more effective are needed to control its spread.

In general, most infections are in adults 60 years of age or older, and the number of confirmed deaths due to the disease is the maximum ever recorded due to a virus since the 1918 Spanish influenza outbreak. Our findings provide important parameters for further analyses as we have estimated an  $R_0$  value of approximately 3.52 for COVID-19, meaning that, on average, each infected individual has been spreading an infection to 3.43 other people. This rapid spreading has exposed insufficiencies in equipment available for adequate protection among healthcare workers, patients, and others during the outbreak. It is noteworthy that scientists have argued that quarantine and isolation can be successful and effective, and these measures have indeed reduced the spread of the COVID-19 pandemic, thus saving human lives (Zhou et al., 2020). Finally, the descriptive epidemiological analysis provided here can help understand the progression of the COVID-19 pandemic and its consequences on humans and healthcare resources and galvanize political support for ensuring adequate resources to overcome the consequences at the earliest possible.

#### 4.1. Limitation of CFR and $R_0$

Of course, CFR has its limitations. During an outbreak of a pandemic, the CFR would tend to overestimate or underestimate the mortality risk of the disease. If people have the disease but are not diagnosed, the CFR will overestimate the true risk of death. People who are sick are currently counted as a case, if they die of the disease, they will eventually be counted as death too. In this case, the CFR is an underestimate of what it will be when the disease has run its course. With COVID-19, I think there are

many undiagnosed people. Therefore, there is great doubt about the future of the COVID-19 pandemic as it takes a great deal of work to improve the forecasting tools as well as the descriptive measurement of the epidemic. Also,  $R_0$  has its limitations. Although  $R_0 < 1$  indicates the disease dies out, and  $R_0 > 1$  indicates the disease persists, sometimes  $R_0$  does not coincide with this persistence threshold. That is, the diseases can persist with  $R_0 < 1$ , and die out with  $R_0 > 1$ .  $R_0$  provides a clear, standardized measure of control effectiveness, but it is important to note that the use of  $R_0$ , for this reason, ignores other important concerns, such as the timing of secondary infections or the negative effect of control measures on the population (Ball et al., 2016).

#### 5. Conclusion

We have compared the course of multiple epidemic outbreaks that have occurred during the last 20 years. Our estimated mean  $R_0$  for COVID-19 is 3.43, which is considerably higher than that provided by the WHO (1.95) and is higher than that reported for SARS and MERS. However, the CFR for COVID-19 is less than that of SARS or MERS. COVID-19 has been spreading faster than other diseases because of human-to-human transmission. Strong measures and strict restrictions for curbing the spread of the coronavirus can prevent the disease for a while; however, the disease may reappear if restrictions are removed.

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#### Compliance with ethical standards

#### Conflict of interest

The authors declare that they have no conflict of interest.

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