Modeling and Forecasting Trend of COVID-19 Epidemic in Iran

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Background: COVID-19 is an emerging disease and precise data on its epidemiological profile are not available in the world and Iran. In Iran, until March 17, 2020, approximately 14,991 COVID-19 patients were reported. Although modeling and predictions will be typically associated with random error, this study aimed to model and determine the epidemic trend and prediction of COVID-19 in Iran.

Methods: This study is a secondary data analysis and mathematical modeling. We used the daily reports of definitive COVID-19 patients released by Iran Ministry of Health and Medical Education. At the beginning of the outbreak, a delayed (stochastic) dynamic system model was used to calculate basic reproduction number (R_0). Epidemic Curve along with patient population growth, recovered and deceased individuals was used to predict the epidemic trend. Epidemic projection models of logistic growth differential equations, Gompertz growth, von Bertalanffy and Cubic Polynomial east squared error (LSE) method were used. Matlab software was used to predict the number of cases until April 3, 2020.

Results: In the first week of the epidemic, R_0 (the mean number of individuals directly infected by *an infectious COVID-19 case* through the total infectious period, when introduced to a susceptible population) in Iran was estimated to be 4.7 that has now fallen to below 2. The discovery process of COVID-19 cases in Iran is increasing and is based on public behavior and government interventions. Given the assumptions in Models, and three different scenarios, the prediction of the patients on April 3, 2020 using three growth models of Gompertz and von Bertalanffy and least squared error was estimated at 19,500, 27,000, and 48,830, respectively. The number of recovered individuals was estimated 6540 according to Von's model, 11800 according to the Gompertz model, and 21000 according to the curve fitting model with least squared error. The number of deceased COVID-19 patients was also estimated to be 1707 individuals using the logistic growth model, 3165 ones by Von's model and 6300 ones according to the LSE method.

Conclusion: The process of controlling the epidemic is tangible. The most ideal scenario is the Gompertz model, but it is hard to fulfill. If enforcement and public behavior interventions continue with current trends, the control and reduction of the COVID-19 epidemic in Iran will be flat from April 3, 2020 by Von's model and new cases are expected to decline from the following Iranian new year. This study suggests that government interventions and people's behaviors determine the persistence of the epidemic and should be addressed with greater responsibility, accountability, rigor, and quality.

Keywords: COVID-19, Coronavirus, Prediction, Modeling, Epidemiology

Introduction

Coronaviruses are a large family of viruses that have been identified since 1965 and so far 7 species of them have been discovered and reported to affect humans. These viruses have three genotypes of alpha, beta and gamma. The natural reservoirs of these diseases are mammals and birds, and therefore are considered as zoonotic diseases (1, 2). These viruses cause direct and indirect transmission of respiratory diseases with a wide range of cold symptoms from respiratory/fever symptoms, cough, shortness of breath to kidney failure and death, leading to more severe respiratory illness epidemic and pandemic in most countries of the world (3-5).

Severe acute respiratory syndrome (SARS) is caused by a species of coronavirus that infects humans, bats and certain other mammals, which has led to epidemics in 2002 and 2003 (2, 6, 7), Middle East Respiratory Syndrome (MERS) caused 2012 epidemic in Saudi Arabia (8), and more recently their newest variant COVID-19 has led to the recent epidemic in China and then across the world (9-11).

For these viruses, three genotypes were introduced and the COVID-19 genotype is betacoronavirus (9). COVID-19 is an emerging disease, with an incubation period of 1 to 14 (mostly 3 to 5) days. The mortality rate has been reported to be 2-3%. Approximately 80% of patients are classified as invisible infections (14–12).

As of the time of writing this article, March 11, 2020, COVID-19 pandemic was declared by the World Health Organization (WHO) in more than 100 countries

(most prevalent in China, Italy, Iran, France, Spain, Germany, and the United States) with 126369 cases, 4633 deaths and 68304 individuals recovered worldwide (15).

In Iran, the first case of COVID-19 was reported on February 19, 2020 (30 *Bahman*, 1398 in Iranian calendar) from Qom and until March 21, 2020. According to the Daily Reports in Iran, 14991 COVID-19, 853 deaths and a crude mortality ratio of 5.7% were reported (17). Universities, schools, public places and shrines were closed. People are referring to health centers and hospitals, and the public is almost alarmed by the epidemic of panic and inaccurate reporting in cyberspace. The recurring and important questions are: How is the size of the epidemic of COVID-19 in Iran and how long and when will the epidemic go down? We cannot answer these questions with certainty, but it can be investigated in terms of pathogenic behavior (coronavirus), host conditions, behavior (human) and environmental factors of coronavirus transmission, and the use of modeling given the assumptions and the percentage of error. Indeed, although the models are different, multiple, and changeable in nature and do not insist on the correctness of the forecasts, the decision-making conditions for health policy-makers and authorities are more transparent and helpful (18). This study aimed to model and determine the epidemic trend and predict COVID-19 patients in Iran using mathematical and statistical modeling.

Materials and methods

This study is a secondary data analysis and mathematical modeling based on a research proposal approved by Shahrekord University of Medical Sciences (Code of Ethics Committee on Biological Research IR.SKUMS.REC 1398.254) (19).

For the statistical analysis of definitive COVID-19 patients in Iran, daily reports of the Ministry of Health and Medical Education were used. The definitive diagnosis of COVID-19 was made using virus isolates from patients' biological samples and confirmed by the Reference Laboratory located in the Pasteur Institute of Iran were used. Patient population growth, epidemic curves, and recovered and deceased individuals were used to predict the COVID-19 epidemic trend. Different scenarios were designed and implemented for modeling and forecasting. First, based on a search for reliable sources of disease trends and epidemic curves across the world, the curve of Iran was also drawn. Focused and scientific group discussion sessions were held with experts on epidemiology, biostatistics, and mathematics, infectious diseases specialists as well as healthcare managers on the topic, the scenarios were discussed and agreement was reached on the application of the final scenarios. From different models and logistic growth differential equations, Gompertz growth, von Bertalanffy growth equation and curve fitting by Least Squared Error method with cubic polynomial for Epidemic forecasts were run in MATLAB

software until April 3, 2020 (the following Iranian new year). Models are presented as the following differential equations:

Logistic Differential Equation:

$$\frac{d}{dt}P(t) = aP(1 - bP)$$

Gompertz Differential Equation:

$$\frac{d}{dt}P(t) = aP\ ln(1/bP)$$

Von Bertalanffy's differential growth equation:

$$\frac{d}{dt}P(t) = aP\ ((bP)^c - 1)$$

Cubic Polynomial Polynomials:

$$P(t) = at^3 + bt^2 + ct + e.$$

Where P represents the number of individuals in each population, e, c, b, and a represent parameter and t time. $\frac{d}{dt}$ is a derivative of time (20,21). We used the MATLAB fminsearch function to calculate the unknown parameters in the differential equations, and also to solve the equations.

The basic reproduction number R_0R_0 was calculated by the following formula (21):

$$R_0 = 1 + r * T_c$$

where T_cT_c and rr are the mean generation interval of the infected and the growth rate, respectively.

Results

Frequency of daily statistics of COVID-19 (definite new cases), number of deaths and recovered cases) in Iran are shown in Table 1. The trend of epidemic spread in

Iran (daily linear and cumulative trend) are illustrated in Figure 1. According to data released on COVID-19 in Iran as of 26/12/98 (March 19, 2020), the following forecasts until 15/01/99 (May 5, 2020) were reported (Figures 2 and 3).

The most ideal scenario is the Gompertz model, but it is hard to fulfill. According to this model, in the most optimistic perspective, the maximum number of infected people until April 3, 2020 is 27,000. Based on Von Bertalanffy's Growth Model (the most realistic model), the maximum patients of COVID-19 are 19,500. According to the method of east squared error, this value was estimated to be 48830. For prediction of cumulative recovered cases of COVID-19 patients in Iran, three models of growth (Figure 2 a, b, c) were used.

The growth rate of Gompertz's model is $r = 0.1$

$r = 0.1$, so the number of $R_0 R_0$ is 1.75.

According to Figure 2 and the models of von and Gompertz for prediction of recovered patients, the model estimated the number of recovered individuals to be 6500 and 11800, respectively. Moreover, according to Figure 3, the maximum population of recovered individuals was estimated 21000 according to the method of east squared error. To predict and estimate the number of deaths due to COVID-19, two growth models (Figure 2) and the east squared error (Figure 3) were used to maximize logistic growth in the most optimistic manner. According to logistic, Von and east squared error method, the number of deaths will be 1707, 3165 and 6300 individuals, respectively.

Discussion

In this study, for the first time in Iran, to monitor the process of COVID-19 epidemic, prediction and estimation of the number of patients, R_0R_0, deaths and recovered individuals were performed and reported based on mathematical and statistical models. Although this prediction may be associated with random errors, it was made with assumptions about the past trends of the COVID-19 epidemic in Iran as well as the behavior of the people and government interventions.

One point that may change our estimates is that we are at the end of the solar year and are less than 10 days longer than the Iranian New Year (Nowruz 1399) and New Year's with long vacations may increase visits, travels, and other activities. It is a rigorous government and health care intervention that may be implemented more and more strictly on these days. Moreover, according to a valid scientific report, delay in the onset of symptoms until the isolation of patients plays an important role in controlling the epidemic. To achieve 90% control of the epidemic, 80% of the cases need to be tracked and isolated. The epidemic is controlled when a new infection does not occur 12 to 16 weeks after the initial cases of the disease (18). Therefore, it is recommended that efforts be made to control the epidemic with greater vigor and urgency and to conduct a daily risk assessment. In the current epidemiological situation in the world and Iran, fear control and avoidance of rumors are very important for the prevention and control of coronavirus.

There are three important points in this epidemic. The first point is to help calm down the atmosphere of society and to avoid tension in societies, and the second is to properly interpret the COVID-19 case fatality ratio (CFR) in Iran and calculate it tactfully. It should be taken into account in interpreting this index, since the denominator of the fraction is only positive, and the death rate is positive among the positive cases. This index should also be calculated until the end of the epidemic period, and if it is until the end of the epidemic and their outcome (death/recovery) is determined, this indicator will approach the real number. The third point is to recommend personal hygiene, in particular hand washing and avoiding contact with suspected patients, discovering unknown cases of infection and early detection and isolation of patients, which is emphasized by the healthcare system to overcome this disease. One article reported that up to 70% of the supply chain could be cut off and the epidemic could be controlled if contact and isolation, quarantine and isolation were appropriately accomplished (18).

The top priorities in Iran are now circular and comprehensive efforts to conduct epidemiological studies and identification of all aspects of the disease (source of disease, reservoir, pathways, infectivity, incubation period, incidence and prevalence, pathogenicity, immunogenicity, herd immunity, causes, epidemic and pandemic pattern, primary and secondary attack rates, response time, time needed for isolation and quarantine, treatment regimens, vaccines and other prevention

methods, disease surveillance and statistical reporting) and evidence-based interventions and epidemic control.

Application of experiences in China and Singapore epidemic shows the disease growth in the country to be logistically dispersed and the epidemic will be controlled in the near future, indicating that preventive activities in the two countries have been more useful among all East Asian countries. Obviously, cultural conditions are also effective. Given the prediction and modeling of the number of cases of coronavirus in Iran and because the virus is circulating in the country for at least a few weeks, we will have an ascending trend in the coming weeks. Application of the experiences of China, which took almost 70 days to complete the epidemic curve, has reached a flat level; it is recommended that the following epidemiological recommendations be implemented promptly and that interventions recommended by the World Health Organization be implemented.

Up-to-date and accurate data on definitions related to suspected, probable, and definitive people with coronavirus should be collected at all levels of the province's health care system. Percentage of completion and accuracy of their assessments and data should be monitored precisely and the epidemic curve should be drawn by rural, city, district, province, and other important sectors and be provided to the campus authorities in an updated dashboard format.

Access to the results of the analysis as well as data should be provided for researchers and experts on the basis of specific protocols available for this purpose

in the world and Iran, and a thorough critique and creative theories and ideas should be elicited from all university training and research groups.

Data should be carefully recorded and analyzed regarding the pathology, the time of onset of symptoms, natural course of the disease and the outcome of the disease to determine effective strategies to prevent and determine the necessity of intervention to control the spread of the disease at different levels.

At all levels of the health care system (governmental and nongovernmental), interventional care, diagnostic and therapeutic interventions, whether compliant or non-compliant, should be conducted for all cases since the beginning of the interventions based on the time of onset of symptoms and type of diagnosis and recorded, and their relationship to outcomes should be analyzed to evaluate the cost-effectiveness of various diagnostic therapeutic approaches. Health care system staff should be empowered to record and train data, especially the use of virtual, remote, and web-based networks. This will certainly improve the quality of data recording. All epidemiological indicators that determine the epidemic pattern, including baseline R zero, attack rate, incubation period, index case, primary cases, secondary cases, and GIS mapping should be determined in provinces, cities, and across the entire country, and epidemic trends should be monitored. The models used to predict the end of the epidemic and control it should be evaluated, as well.

Conclusion

The actual process of detecting COVID-19 cases in Iran has been increasing and is based on public behavior and government intervention. Complete reliance on any type of model will lead to systematic error, unless modeling provides a prediction with precise and clear assumptions and inputs and outputs. Given the assumptions in Iran, the prediction of the patients on 3 April (Farvardin 15), 2020 with the three growth models of Gompertz, von Bertalanffy and the least squared error were estimated at 27000, 19500, and 48830, respectively. The number of recovered individuals was estimated up to 6540 individuals according to von's model, 11800 ones according to Gompertz model, and 21000 ones according to least square method. The number of deceased COVID-19 patients was also estimated to be 1707 individuals using the logistic growth model, 3165 ones by von's model and 6300 ones according to the LSE method. If enforcement and public behavior interventions continue with current trends, the control and reduction of the COVID-19 epidemic in Iran will be felat from late May 2020, and new cases are expected to decline from mid-April of the following Iranian new year. This study suggests that government interventions and people's behaviors determine the persistence of the epidemic and should be addressed with greater responsibility, accountability, rigor, and quality.

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Conflicts of interest: None.

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Table1: The frequency of COVID-19 new cases, cumulative cases and deceased cases in Iran

Date	Number of new cases	Cumulative number of cases	New deceased cases	Cumulative number of deceased cases	Cumulative number of recovered cases
19-Feb-20	2	2	2	2	0
20-Feb-20	3	5	0	2	0
21-Feb-20	13	18	2	4	0
22-Feb-20	10	28	2	6	0
23-Feb-20	15	43	2	8	0
24-Feb-20	18	61	4	12	0
25-Feb-20	34	95	3	15	0
26-Feb-20	44	139	4	19	0
27-Feb-20	106	245	7	26	0
28-Feb-20	143	388	8	34	73
29-Feb-20	205	593	9	43	123
1-Mar-20	394	978	11	54	175
2-Mar-20	523	1501	11	66	291
3-Mar-20	835	2336	11	77	435
4-Mar-20	586	2922	15	92	552
5-Mar-20	591	3513	15	107	739
6-Mar-20	1234	4747	16	124	913
7-Mar-20	1076	5823	21	145	1669
8-Mar-20	743	6566	49	194	2134
9-Mar-20	595	7161	43	237	2394
10-Mar-20	881	8042	54	291	2731
11-Mar-20	958	9000	63	354	2959
12-Mar-20	1075	10075	75	429	3276
13-Mar-20	11364	1289	85	514	3529
14-Mar-20	12729	1365	97	611	4339
15-Mar-20	13938	1206	113	724	4790
16-Mar-20	14991	1053	129	853	4996

Fig. 1) The trend of new and cumulative cases of COVID-19 and R_0 curve in Iran

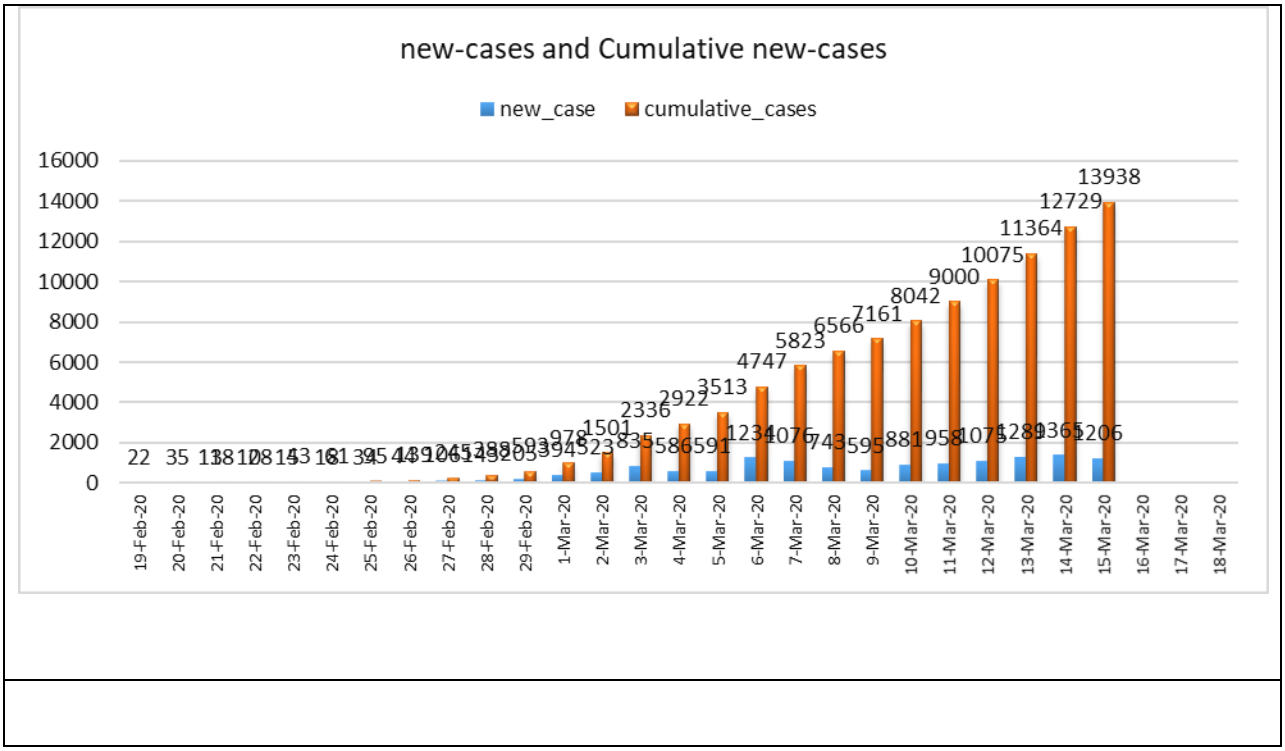


Fig 2. Prediction of COVID-19 by Gompertz and Von Bertalanffy models in Iran

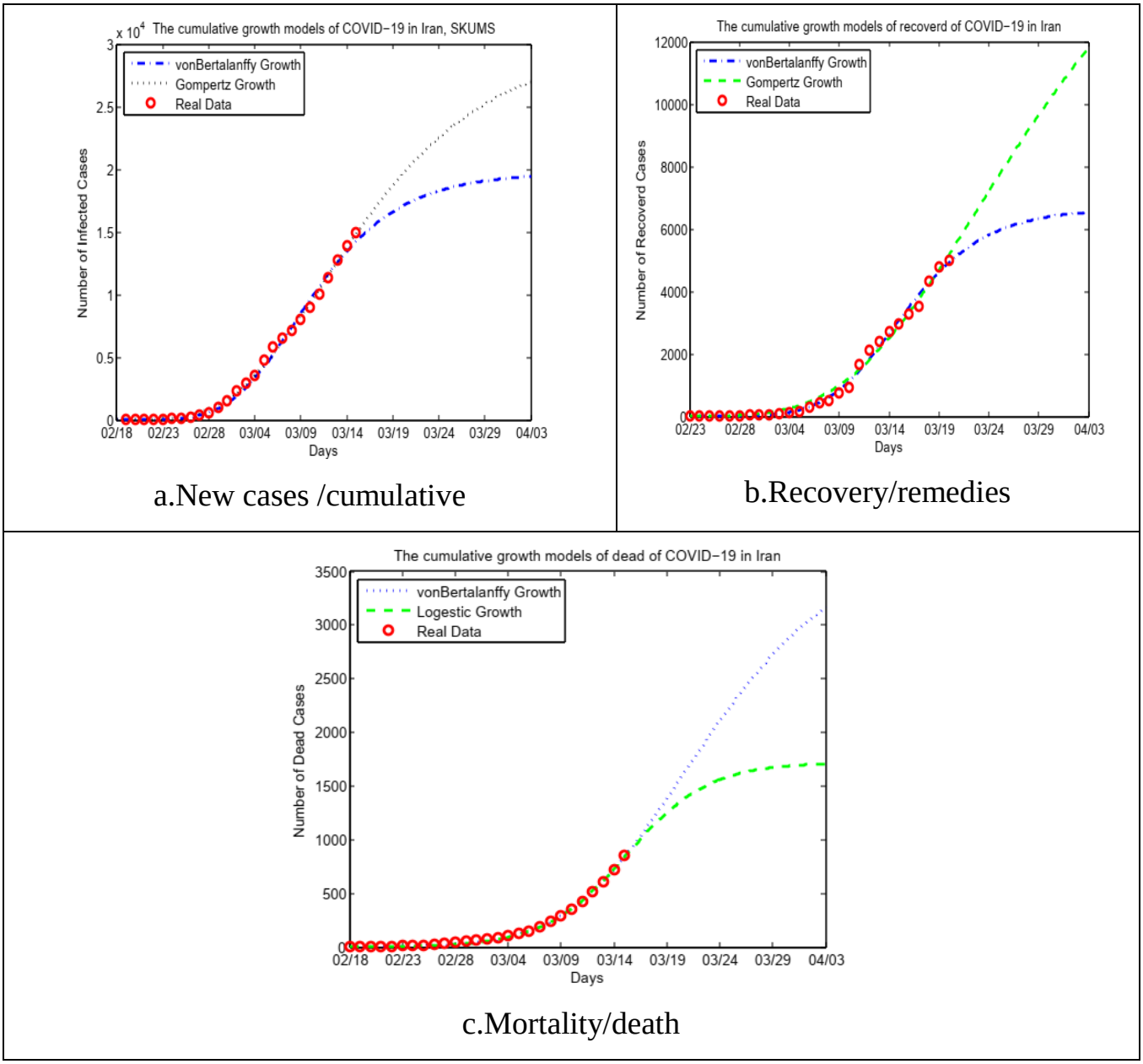
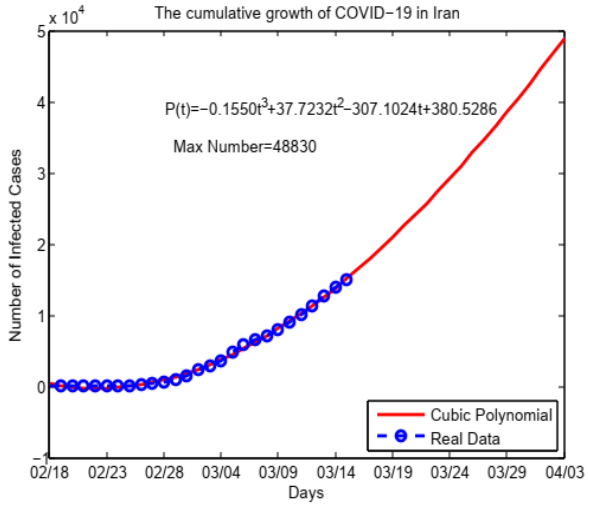
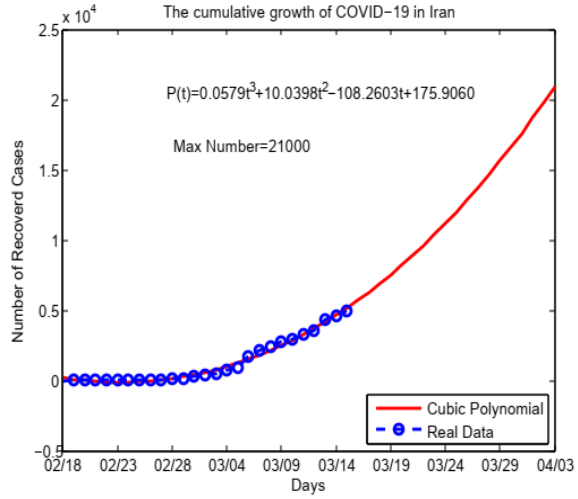


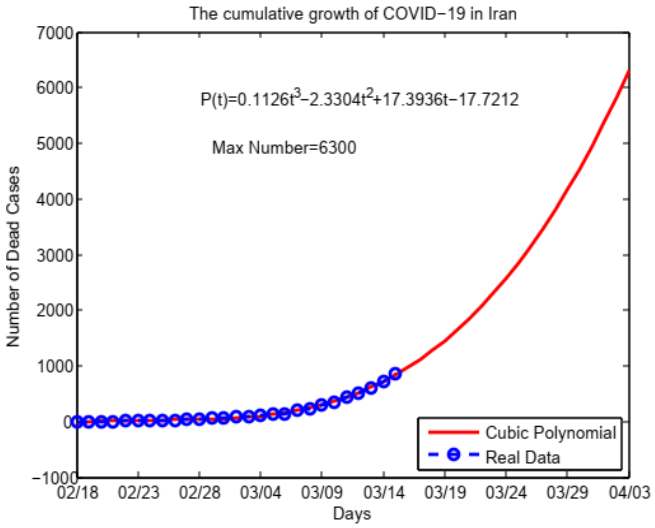
Fig 3. Prediction of COVID-19 by Cubic Polynomial model in Iran



a.New cases



b.Recovery



c.Mortality