ESTIMATING THE EFFECT OF GOVERNMENTAL PREVENTIVE ACTIONS ON CONTROL OF COVID-19 PANDEMIC IN SIX COUNTRIES

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ABSTRACT

Background: *In this study, we aimed to assess effectiveness of the major preventive measures to control of COVID-19 pandemic in six countries*

Methods: *Case numbers and intervention times of countries documented by the World Health Organization were used. A natural estimation plot (M0) was constructed for the initial period with no interventions. Estimation models (M1, 2, 3, etc.) to reach the threshold number of cases (5000 cases/day) were calculated for each intervention. The effectiveness of intervention was measured by the magnitude of displacement of its prediction plot to the right of the M0 plot.*

Results: *In the absence of interventions (M0 model), Turkey had the earliest threshold time (26.81 days), whereas France had the longest (58.72 days). Event-specific effect size was the largest for suspension of formal education in all countries, except for Italy (0.03). The effect size of closing the schools was the largest in Iran (16.52) and France (6.75) and the least in Spain (0.45) and Italy (0.03). Turkey (3.82) and the UK (6.07) had a medium effect size. The closure of workplaces had the largest effect size in the UK (4.27) and Italy (4.20). A recommendation to stay at home policy had the lowest impact in the UK (0.58). A second increase was noted in the case trend in Iran after lifting the containment measures.*

Conclusions: *Major interventions are effective and should be adopted early to achieve a higher health impact; however premature easing of restrictions can lead to a loss in controlling the spread of pandemic.*

Keywords: *COVID-19, pandemic, preventive measures, estimation model.*

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Introduction

In December 2019, the pandemic disease caused by severe acute respiratory syndrome-coronavirus 2 (SARS-CoV-2), which started in Wuhan, Hubei Province of China and rapidly spread worldwide, was named as novel coronavirus-2019 (COVID-19). The disease manifests itself in a wide spectrum, from mild upper respiratory tract infection to severe respiratory failure and even death. The main route of transmission of COVID-19 is respiratory droplets with a high fatality rate, particularly for those aged ≥65 years with comorbidities[(1)]. Decision-makers of countries (governments) affected by the COVID-19 outbreak have implemented a series of measures to protect their citizens from the pandemic[(2-4)]. Some major public measures include the closure of the schools, workplaces, and factories, cancellation of group events and meetings, international and domestic travel restrictions, and curfew to decrease the population density, while minor individual surveillance measures such as isolation, use of protective equipment (i.e., face masks), disinfection, promotion of hygiene, and social distancing are included in the pandemic guidelines[5]. The type, scope, and timing of these measures vary depending on countries due to their high economic and social impact. Effectiveness of the measures taken for COVID-19 is analyzed according to the demographic characteristics of the countries (i.e., the age distribution of the population), economic and sociocultural status, the enforcement power of the regulations, and the time of pandemic's entry into the country (i.e., public awareness is higher with late entry). Evaluation of the effectiveness of specific measures across different countries and comparison with each other may provide us valuable information on the timing, duration, and coverage of the various methods. This information may provide guidance on the implementation of such measures at the correct setting and time to provide the most effective results with minimal the cost, and also future planning and management of resources.

Epidemiological forecasting models are mathematical algorithms or parametric equations used to predict future trends by investigating the change in the number of cases over a period of time[6]. A future forecasting model can be formulated for each measure taken by a country by examining the trend of cases up to a specific point in time. Consequently, the effect of each measure can be objectively and mathematically calculated.

The matrix laboratory (MATLAB) is a complex programming language that helps us in function and data plotting, algorithm implementation, graphical multi-domain simulation, and model-based design development[7]. In the present study, we aimed to assess and compare the effectiveness of major governmental measures implemented for the control of the pandemic in six countries, including Turkey, Italy, Iran, Spain, France, and the United Kingdom (UK), with different geographical and socio-cultural communities using a MATLAB-based model design and to make a projection on how the process would proceed. This study aims to reveal the net contribution of each measure taken gradually at the beginning of the pandemic to the pandemic control. If this study had covered the later periods of the pandemic, it would be difficult to evaluate the independent contribution of each of them in pandemic control, as it would include many different measures together. In addition, it would not be possible to objectively evaluate the results due to the removal or loosening of some measures.

Methods

Data collection and definition of events

This study was conducted between 20.01.2020 and 29.04.2020. The COVID-19 data shared by six countries (Turkey, Italy, Iran, Spain, France, and UK) were retrieved from World Health Organization (WHO) online database[8]. These data included the date of the first recorded case, number of daily cases and cumulative cases, the daily number of deaths, and cumulative deaths through April 29th, 2020for each country, the peak number of cases, and duration of peak (peak time).

The major governmental actions taken in the countries were analyzed in the order of the date of the actions. Since the average incubation period of the disease is five to six days, the effect of each measure on the number of cases is expected to be apparent five or six days after its implementation[9]. Therefore, an event was defined as any occurrence seen after six days of each intervention.

Analysis of estimation models for events

The time from the start date of the pandemic in a country to the first event (E1) was coded as a non-event (E0) period with no event effects. During this period, based on daily actual case number trend, the M0 model plot (natural plot) was created as a case prediction model with a curve-fitting estimation method. The M0 shows how the pandemic would progress if not intervened. In the second step, the time from the start of the pandemic to the second event (E2) was coded as the E1 period, as it contained E1. The M1 model plot was created for the E1 period. The same steps were applied to create a model plot for each event. Thus, each model reflects the effect of all events up to that model event.

Finally, based on the daily actual case number trend for the entire pandemic period between the start and April 29, 2020, the case prediction model plot under the name of the Final Model (FM) for each country was extracted. It was assumed that the FM plot theoretically includes the combination of the effect of all events, including the last event. Then, to achieve standardization and to compare event effects objectively, the plot's time of each model to reach the same threshold number (threshold) was used. The threshold value was established as 5,000 cases per day since all countries in this study were close to the peak number of cases.

In the measurement of the effect of the events corresponding to a model, the temporal deviation time (days) between the point where the model plot cuts the threshold and the point where M0 cuts the threshold was used and named as the model effect size. The success of a model is assumed by the model plot's positioning to M0 plot; the more a model plot is right from the M0 plot, the more successful the results can be achieved. The specific effect of an event was measured by the time (event-specific effect size) between the model of that event and the points where the previous event model cut the threshold. The longer this period, the more successful that event is and the date (date) to reach the threshold is delayed. The models, which do not reach the threshold point (5,000 cases/day) and remain below this value, were accepted as the ideal model. In addition to the estimation models of daily case trends, cumulative case and death number model graphs of the whole pandemic period of each country were produced.

The MATLAB version R2019a software (MathWorks Inc., Nattick, MA, USA) was used to analyze the data. The duration (days) of the event periods and the number of cases pertaining to these periods were defined as the vector data in the software. In the extraction of all models, the MATLAB curve-fitting tools were used to calculate the subsequent trends based on daily actual case number trends. Multiple linear and non-linear models (such as power, polynomial, exponential, Gaussian, and trigonometric models) were analyzed using this method. Among these models, the model with the highest R-square (R2) value and the lowest root mean squared error (RMSE), and residual sum of squares (SSE) values were chosen as the best model with 95% confidence interval (CI). The results of the analyses were transferred to the tables and graphics.

Assessment of results

In the no-intervention model (M0), which normally does not include any events, the number of cases is expected to increase rapidly and reach the threshold (threshold number of cases, 5,000 cases/day) in a short time. The subsequent models which contain event effects should theoretically delay the date of reaching this threshold number of cases, that is, extend the time to reach this number of cases (effect size). In other words, the larger the model effect size of a model, the greater the effect of the events it contains.

The number of daily cases remains below 5,000. Indeed, since the increase in the natural model is power or polynomial, a higher number of new cases should be prevented by the event every day. Since a model plot that is very close to M0 would not change the course of the natural phenomenon, the event intervention of that plot should be interpreted as ineffective or insufficient execution in the country. In addition, the M0 plottrailing very close to the peak points of the FM indicates delay or failure in interventions.

In accordance with this information, the effectiveness of the events was briefly evaluated according to the following parameters:

- The sooner the M0 plot reaches the threshold, the faster the pandemic would progress without an intervention;
- The M0 plot trailing very close to the peak mean values of the FM indicates a delay or failure in interventions;
- The plot to the left of the M0 plot or adjacent to it indicates the intervention has failed;
- The distance of the model plots (M1, M2, M3, etc.) from the M0 plot at the threshold line gives the effect size in time and with more positive displacement on the X axis, the effect size and success of the model increase;
- The further clockwise rotation of a model plot on the right of the M0 plot (even exceeding its peak), the more successful it is;
- With more right positioning of the model plot with clockwise rotation,although it remains below the threshold number (5,000 cases/day) with respect to M0 plot, the model is considered ideal (very successful model).

Results

The pandemic preventive action, action date, event date, and event time for each country used in the model are summarized in Table 1.

Pandemic findings

According to WHO database, the first case of COVAccording to WHO database, the first case of COVID-19 was reported in France, and the latest onset was seen in Turkey among the countries included in this study.

Therefore, the period from the outset of the pandemic to the data collection date (April 29th, 2020) was the longest (95 days) for France and was the shortest (50 days) for Turkey (Table 2). The time to reach the peak numbers was 72 days, 67 days, 62 days, 41 days, 33 days, and 32 days for UK, France, Spain, Iran, Turkey, and Italy, respectively.

Country	Actions
Turkey	- 11.03.2020:Pandemic onset - 16.03.2020 (E1: 22.03.2020, Day 12):Formal education in all schools was suspended. - 21.03.2020 (E2: 27.03.2020, Day 17):Curfew for individuals aged ≥65 years and those with chronic illnesses - 28.03.2020 (E3: 03.04.2020, Day 24): İntercity bus transportation was banned. - 03.04.2020 (E4: 09.04.2020, Day 30):Entry-exit ban for 31 cities, curfew for individuals aged <20 years
Italy	- 20.02.2020: Pandemic onset - 30.01.2020 (E1: 05.01.2020):All direct flights to China were suspended (The action was started beforedocumented cases). - 31.01.2020 (E2: 06.02.2020): National emergency was declared (The action was started before documented cases). - 23.02.2020 (E3: 29.02.2020, Day 10: Entry-exit ban for 11 cities in the Northern Italy; Education in some schools was suspended; sports events were postponed; all collective events and meetings were cancelled. - 04.03.2020 (E4: 10.03.2020, Day 20: Formal education in all schools was suspended. - 07.03.2020 (E5: 13.03.2020, Day 23: Quarantine in the whole Lombardy, Northern Italy, where the epidemic broke out, and in 14 other cities (ban on entry-exit from cities); cancellation of all public activities - 09.03.2020 (E6: 15.03.2020, Day 25: Quarantine in all cities of Italy - 11.03.2020 (E7: 17.03.2020, Day 27: All shops were closed, except for pharmacies, markets, banks, etc. - 21.03.2020 (E8: 27.03.2020, Day 37: Parks and gardens were closed. - 22.03.2020 (E9: 28.03.2020; Day 38: All non-factories and businesses were closed.
Iran	- 20.02.2020: Pandemic onset - 05.03.2020 (E1: 11.03.2020, Day 21: Formal education in all schools was suspended. - 23.03.2020 (E2: 29.03.2020, Day 39: All shops were closed, except for pharmacies and markets. - 25.03.2020 (E3: 31.03.2020, Day 41: Intercity travel ban - 11.04.2020 (Stop Event) (sE1: 17.04.2020, Day 58: Opening of workplaces and lifting the intercity transportation ban - 22.04.2020 (Stop Event) (sE2: 28.04.2020, Day 69: curfew was partially ended, and parks and gardens were reopened.
Spain	- 31.01.2020: Pandemic onset - 11.03.2020 (E1: 17.03.2020, Day 47: Formal education in all schools was suspended; universities, museums, and nursing homes were closed (Only in the Basque Country). - 14.03.2020 (E2: 20.03.2020, Day 50: State of emergency was declared (curfew except for mandatory situations); formal education in all schools and universities was suspended.
France	- 26.01.2020: Pandemic onset - 14.03.2020 (E1: 20.03.2020, Day 55: All shops were closed, except for pharmacies and markets. - 16.03.2020 (E2: 22.03.2020, Day 57: Formal education in all schools was suspended. - 23.03.2020 (E3: 29.03.2020, Day 64: Curfew was declared for 37 cities across the country (until April 15th, 2020).
UK	- 01.02.2020: Pandemic onset - 16.03.2020 (E1: 22.03.2020, Day 51: Home stay was advised for individuals aged ≥ 65 years, those with chronic illnesses, and pregnant women (not a curfew). - 20.03.2020 (E2: 26.03.2020, Day 55: Formal education in all schools was suspended. - 24.03.2020 (E3: 30.03.2020, Day 59: All shops were closed, except for pharmacies and markets.

Table 1: Pandemic preventive action, action date, event date, and event time according to countries.

The peak daily number of cases for Spain, UK, France, Italy, Turkey, and Iran were 9,222, 8,719, 7,500, 6,557, 5,138, and 3,186, respectively. The cumulative number of cases was 210,773 for Spain, 201,505 for Italy, 161,149 for the UK, 114,653 for Turkey, and 92,584 for Iran.

The cumulative number of deaths was 27,359 for Italy, 28,822 for Spain, 23,627 for France, 21,678 for the UK, 5,857 for Iran, and 2,992 for Turkey. The cumulative case fatality ratios (death/ number of cases) were 18.83% for France, 13.37% for Italy, 13.45% for the UK, 10.68% for Spain, 6.34% for Iran, and 2.60% for Turkey.

Model findings

Forward, neutral plot estimation model was created using the daily number of cases (M0 plot) for each country, and specific formulas for every event model plot (Figure1) are given in Table 3.

For easy interpretation of the models obtained in the study, Turkey model has been detailed (Figures 2-3). The timeline of events and their effect on the actual number of cases is shown in Figure 2. Accordingly, a significant decrease was seen in the daily number of cases following each event. The relationship between the event time and the course of the actual death rate is shown in Figure 3.

Event-related estimation models	Countries					
	Turkey	Italy	Iran	Spain	France	UK
Start date	11.03.2020	20.02.2020	20.02.1970	31.01.2020	26.01.2020	1.02.2020
Last date	29.04.2020	29.04.2020	29.04.2020	29.04.2020	29.04.2020	29.04.2020
Time(day)	50	70	70	90	95	89
Number of cases peak time (day)	33	32	41	62	67	72
Peak number of cases	5138	6557	3186	9222	7500	8719
Model 0 (M0) time range (day)	0-12 (0-E1)	0-10 (E1,2-E3)	0-21 (0-E1)	0-47 (0-E1)	0-55 (0-E1)	0-51 (0-E1)
Model 0 (M0) Events	**No event**	**E1*,E2***	**No event**	**No event**	**No event**	**No event**
Model 0 (M0) Time (day) to 5000 case/day	**26.81**	Below limit	**40.82**	**51.94**	**58.72**	**58.54**
Model 0 (M0) Effect size(day)	**0**	Maximum	**0**	**0**	**0**	**0**
Model 1 (M1)time range (day)	0-17 (0-E2)	0-20 (0-E4)	0-39 (0-E2)	0-50 (0-E2)	0-57 (0-E2)	0-55 (0-E2)
Model 1 (M1)Events	**E1**	**E3**	**E1**	**E1**	**E1**	**E1**
Model 1 (M1) Time (day) to 5000 case/day	**30.63**	**29.84**	**57.34**	**52.39**	**61.14**	**59.12**
Model 1 (M1) Effect size(day)	**3,82**	**0**	**16.52**	**0,45**	**2,42**	**0,58**
Model 2(M2) time range (day)	0-24 (0-E3)	0-23 (0-E5,E6)	0-41 (0-E3)		0-64 (0-E3)	0-59 (0-E3)
Model 2 (M2) Events	**E2**	**E4**	**E2**		**E2**	**E2**
Model 2 (M2) Time (day) to 5000 case/day	**32.43**	**29.87**	**55.52**		**67.89**	**65.19**
Model 2 (M2) Effect size(day)	**5,62**	**0,03**	**14.70**		**9,17**	**6,65**
Model 3 (M3)time range (day)	0-30 (0-E4)	0-27 (0-E7)				
Model 3 (M3) Events	**E3**	**E5 E6**				
Model 3 (M3) Time (day) to 5000 case/day	**32.66**	**31.49**				
Model 3 (M3) Effect size(day)	**5,85**	**1,65**				
Model 4 (M4)time range (day)		0-37 (0-E8,E9)				
Model 4 (M4) Events		**E7**				
Model 4 (M4) Time (day) to 5000 case/day		**34.07**				
Model 4 (M4) Effect size(day)		**4,23**				
Final Model time range (day)	0-50	0-70	0-70	0-90	0-95	0-89
Final Model Events	**E4**	**E8,9**	**E3**	**E2**	**E3**	**E3**
Final Model (MF) Time (day) to 5000 case/day	**Below limit**	**37.03**	**Below lim.**	**53.20**	**Below lim.**	**70.04**
Final Model (MF) Effect size(day)	**Maximum**	**7,16**	**Maximum**	**2,26**	**Maximum**	**10,92**
Estimated pandemic duration (day)	81	109	100	112	126	135
Estimated pandemic termination	30.05.2020	27.06.2020	29.05.2020	30.06.2020	14.07.2020	23.07.2020

*In Italy, pandemic started with E1,2 events.

Table 2: COVID-19 properties of estimation models for countries.

Accordingly, there was a significant decrease in the number of daily deaths after each event. As seen in the daily case numbers graph (Figure 2), there were four major events and four event model graphics, as well as a threshold line showing 5,000 case/day. The time to reach the number of thresholds was calculated as 26.81 days in M0 model (red dots). The M1 model (red dot-dash) containing the E1 event effect was located just to the right of the M0 model at the point of intersection with the threshold line. The M1 effect size (bold green line) was the amount of time between M1 and M0 at the threshold level. The M1 effect size for Turkey was 3.82 days (E1). Accordingly, it indicated that the daily number of cases remained below 5,000 for at least 3.82 days. Indeed, as the M0 model power increased, more

Event-related estimation models	Turkey	Italy	Iran	Spain	France	U.Kingdom
M0 Model type/R²/SSE	Power 0.5764/1.099e+05	Power 0.690/3339	polynomial-LAR 0.918/2.135e+05	Power 0.9292/6.753e+05	Power 0.965/4.703e+04	Power 0.918/1.765e+04
M0 Equation	f(x) = a*x^b	f(x) = a*x^b	f(x) = p1*x^2 + p2*x + p3	f(x) = a*x^b	f(x) = a*x^b	f(x) = a*x^b
M0 coefficients (a,b, p1,2,3)	(0.112, 3.254)	(7.705, 1.241)	(3.481/-20.64/30.37)	(2.774e-13/9.476)	(2.222e-15/10.38)	(1.069e-15/10.56)
M1 Model type/R²/SSE	Polynomial 0.919/3.353e+05	Power 0,933/1.28e+05	polynomial-LAR 0.946/1.173e+06	Power 0.970/ 8.145e+05	Power 0.9752/6.363e+04	Power 0.929/7.682e+04
M1 Equation	f(x) = p1*x^2 + p2*x + p3	f(x) = a*x^b	f(x) = p1*x^2 + p2*x + p3	f(x) = a*x^b	f(x) = a*x^b	f(x) = a*x^b
M1 coefficients (a,b, p1,2,3)	(7.512,-72.43,149.7)	(0.3797/2.751)	(1.169/ 21.69/-90.05)	(8.275e-13/ 9.179)	(5.021e-13/8.956)	(6.842e-16/10.65)
M2 Model type/R²/SSE	Polynomial 0.970/5.426e+05	polynomial-LAR 0,972/3.259e+05	polynomial-LAR 0.959/1.228e+06		Power 0.851/2.004e+06	Power 0.931/2.329e+05
M2 Equation	f(x) = p1*x^2 + p2*x + p3	f(x) = p1*x^2 + p2*x + p3	f(x) = p1*x^2 + p2*x + p3		f(x) = a*x^b	f(x) = a*x^b
M2 coefficients (a,b, p1,2,3)	(6.235,-50.61,79.28)	(8.784/-107/354.6)	(1.347/ 15.99/-47.19)		(7.739e-09/ 6.447)	(7.4e-11/ 7.624)
M3 Model type/R²/SSE	Polynomial 0.989/5.211e+05	polynomial-LAR 0.988/1.732e				
M3 Equation	f(x) = p1*x^2 + p2*x + p3	f(x) = p1*x^2 + p2*x + p3				
M3 coefficients (a,b, p1,2,3)	(5.921, -42.45,64.21)	(6.608/-52.74/104.6)				
M4 Model type/R²/SSE		polynomial-LAR 0.978/4.354e+06				
M4 Equation		f(x) = p1*x^2 + p2*x + p3				
M4 coefficients (a,b, p1,2,3)		(3.72/25.55/-201.9)				
MF Model type/R²/SSE	Gaussian exp 0.966/4.046e+06	Gaussian exp 0.908/2.119e+077	Gaussian exp 0.9095/5.109e+06	Gaussian exp 0.9216/5.406e+07	Gaussian exp 0.7907/ 5.443e+07	Gaussian exp 0.9391/ 2.647e+07
MF Equation	f(x) = a1*exp(-((x-b1)/c1)^2)	f(x)=a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2)	f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) + a3*exp(-((x-b3)/c3)^2)	f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2)	f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2)	f(x) = f(x) = a1*exp(-((x-b1)/c1)^2)
MF coefficients (a1,2,3,b1,2,3,c1,2,3)	(4581, 35.9,16.03)	(-4726,11.93,15.51/ 5783 ,28.92 ,38.69)	(3692, 41.56, 8.522/ -1.129e+06 ,42.14 ,16.81/ 1.129e+06,42.14, 16.84)	1.596e+04,70.11,10.4/ 2.116e+04 ,68.72 , 13.95)	1671/65.32/5.342/3436/ 73.43/19.05)	(5592/76.12/19.89)

Table 3: COVID19 event-related pandemic case estimation model equations for countries.

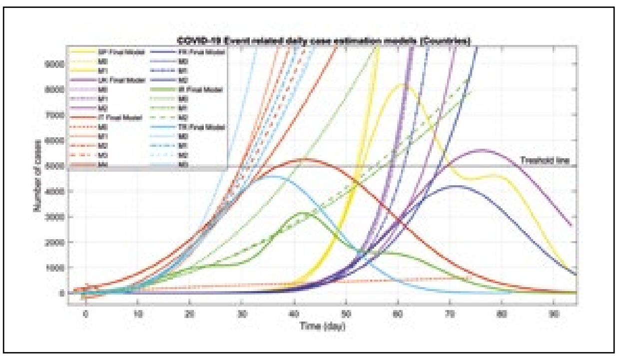

Figure 1: Event-related case estimation COVID-19 pandemic model of countries.

Looking at the M0 plots, which show the estimated course without intervention, except Italy, it is seen that Turkey will reach the treshold (5000case/day) value the fastest, while France and England will reach the slowest. In Italy, in the M0 model, which shows the effect of the initial local measures, it is predicted that the cases will successfully progress horizontally below the treshold value. After each intervention, the trend curve of the model (M1, 2, 3) shifted slightly to the right compared to M0, reflecting the success of the interventions corresponding to the models. When we look at the final models in terms of a total effect of major interventions, staying below the treshold value in the models in Turkey, Iran and France means that the interventions under pandemic control until that time were successful in these countries.

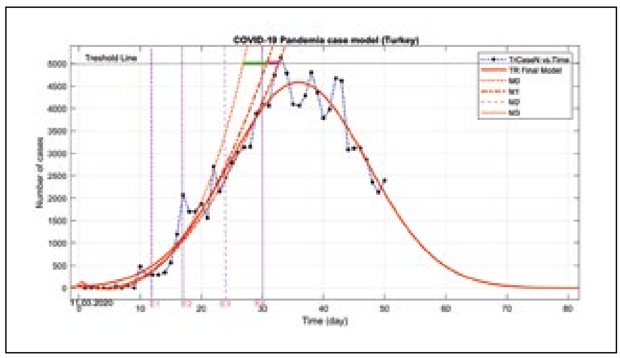

Figure 2: Turkey's event-related case COVID-19 pandemic model.

In the real case course, it is seen that the number of cases per day has clearly decreased after each intervention (blue dotted line) in Turkey. In addition, it is seen that the estimated case plot after each intervention slows down the time to find the treshold value a little more and moves to the right of the M0 estimated course plot, and the total effect of all interventions falls completely below the treshold value in the final model that predicts. The difference between the times to reach the treshold value between the two models shows the net effect of the added intervention as an effect size.

new cases were prevented. The M2 model (red dash) included both E1 and E2 event effects with a total of 5.62 effect size. The M2-M1 effect size difference was a specific effect size for E2 (bold pink line) and measured as 1.80 days. After each event, the model curve approached the peak point, leading the M0 model curve to evolve to the right as seen in the FM. As the FM of Turkey did not exceed the threshold, the effect size for that model was unable to be calculated. In our study, this model was interpreted as a successful and ideal model, similar to any other models which were successful enough to be below the threshold line. Chronologically, Italy and Turkey responded early with the implementation of major interventions (i.e., school closures, workplace

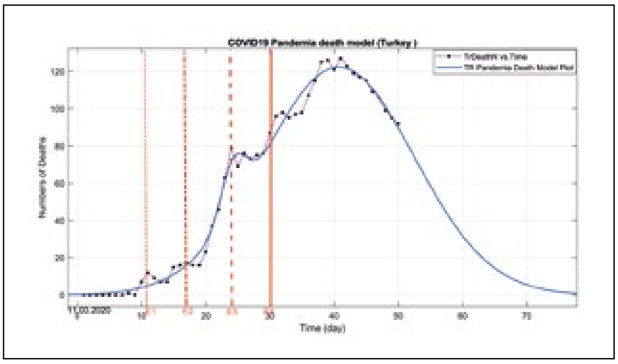

Figure 3: Turkey's event-related death COVID-19 pandemic model.

This real case plot shows the decrease in the number of deaths after each intervention in Turkey.

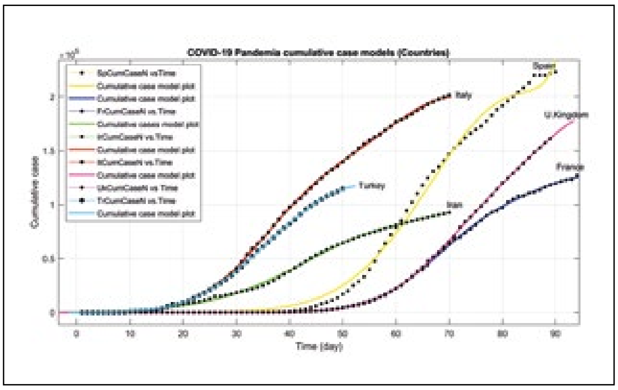

Figure 4: Cumulative case COVID-19 pandemic model of countries.

Estimated cumulative case course graph overlapping the actual cumulative case course in countries (Cumulative Case Model Rsquare>0.99 for all countries).

closures, quarantine, and curfew) after the outset of the pandemic: Italy (E1 and E2 at outset) and Turkey (E1: Day 10), followed by France (E1: Day 55) and the UK (E1: Day 51) (Table 2).

In country models (Figure 1), the M0 model plots (natural plots) showed an eventless period for all countries, except for Italy where regional measures implemented before the first documented case contained E1 and E2. The M0 plot curve remained below the threshold number (5,000 cases/day) in the Italy model, and the clockwise rotation (ideal model) was nearly close to the X (time) axis, which was interpreted in favor of a very successful effect. The duration of the M0 plot reaching 5,000 cases was found to be the shortest in Turkey (26.81 days) and the longest in France (58.72 days). The M0, the number of cases reaching in the natural plot curve of 5,000 case/day was 26.8 days for Turkey, 29.84 for Italy, 40.82 days for Iran, 52.00 days for Spain, 58.68 days for France, and 58.69 days for the UK. The M1 plot was used for the natural plot where the case numbers climbed in Italy for a second time.

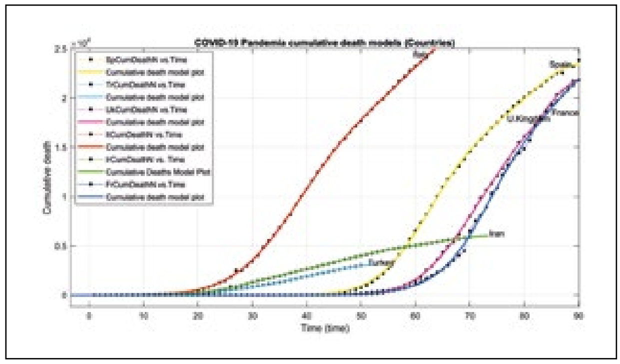

Figure 5: Cumulative death COVID-19 pandemic model of countries.

Estimated cumulative death course graph overlapping the actual cumulative death course in countries (Cumulative Death Model Rsquare>0.99 for all countries).

The comparison of M1 and M0 revealed the highest effect size for Iran (16.52) and Turkey (3.82), while the effect size was the lowest for Italy (model failed, left of the M0plot), Spain (0.45), and the UK (0.58). Although Italy initially started with an ideal effect size using the M0 model (despite the E1, E2, E3 interventions), the M1 model was first to exceed the threshold with 29.4 days ahead of Turkey.

In the M2 models, the effect size was found to be highest for Iran (14.70) and France (9.17), the lowest for Italy (0.03), and moderate for the UK(6.65) and Turkey(3.82) In the M3 model, Turkey (5.82) had the highest effect size, while Italy (1.56) has the lowest effect size. Considering the FMs, the estimated event trend remained below the threshold for Turkey, Iran, and France and, therefore, their models were found to be successful (ideal model). In the remaining countries, the effect size was the highest in the UK (10.92) and the lowest in Spain (2.26). Italy had a moderate effect size (7.16). Different interventions had variable effect sizes in specific countries. Closure of schools had the largest effect size in all countries, except for Italy (0.03). The highest values were seen in Iran (16.52) and France (6.75), while the lowest values were seen in Spain (0.45) and Italy (0.03). These values were averaged for the UK (6.07) and Turkey (3.82). The highest values of the effects of workplace closures were seen in the UK (4.27) and Italy (4.20), while the lowest values were seen in Iran (-1.82; the negative value in Iran might be due to ineffective E2 or reduced E1 effect) and Turkey (1.80). The effects of lockdown/curfew were the lowest (0.58) in the UK, where this practice was applied as a recommendation, but not a legal restriction, while France and Italy (initial local practice) had ideal values. The decision of quarantine for cities yielded an ideal value for Turkey, whereas this value was 1.63 for Italy.

	Cumulative Number of Cases	Cumulative Number of Deaths	Daily Numbers of Cases	Daily Number of Deaths
Turkey	General model Gauss2: f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) Coefficients (with 95% confidence bounds): a1 = 8.584e+04 (-3498, 1.752e+05) b1 = 57.87 (55.16, 60.58) c1 = 14.21 (3.941, 24.48) a2 = 6.632e+04 (-7112, 1.398e+05) b2 = 42.04 (31.42, 52.66) c2 = 15.67 (12.06, 19.27) Goodness of fit: SSE: 2.145e+07 R^2: 0.9999 Adjusted R^2: 0.9998 RMSE: 698.2	General model Gauss1: f(x) = a1*exp(-((x-b1)/c1)^2) Coefficients (with 95% confidence bounds): a1 = 3141 (3068, 3214) b1 = 55.18 (54.36, 56.01) c1 = 21.4 (20.8, 22) Goodness of fit: SSE: 8.904e+04 R^2: 0.9991 Adjusted R^2: 0.9991 RMSE: 43.52	General model Gauss1: f(x) = a1*exp(-((x-b1)/c1)^2) Coefficients (with 95% confidence bounds): a1 = 4576 (4393, 4760) b1 = 35.89 (35.28, 36.5) c1 = 16.1 (14.97, 17.24) Goodness of fit: SSE: 1.709e+07 R^2: 0.8823 Adjusted R^2: 0.8773 RMSE: 603	f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) Coefficients (with 95% confidence bounds): a1 = 122.4 (120.1, 124.7) b1 = 40.73 (40.36, 41.11) c1 = 16.6 (15.68, 17.51) a2 = 27.48 (20.51, 34.44) b2 = 24.33 (23.81, 24.84) c2 = 2.804 (1.905, 3.703) Goodness of fit: SSE: 2252 R^2: 0.9806 Adjusted R^2: 0.9784 RMSE: 7.155
Italy	General model Gauss2: f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) Coefficients (with 95% confidence bounds): a1 = 1.982e+05 (1.951e+05, 2.014e+05) b1 = 71.71 (71.02, 72.41) c1 = 25.35 (21.49, 29.21) a2 = 5.7e+04 (3.461e+04, 7.94e+04) b2 = 42.67 (41.39, 43.94) c2 = 15.19 (13.57, 16.81) Goodness of fit: SSE: 5.317e+07 R^2: 0.9999 Adjusted R^2: 0.9998 RMSE: 911.5	General model Gauss2: f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) Coefficients (with 95% confidence bounds): a1 = 2.703e+04 (2.65e+04, 2.756e+04) b1 = 72.53 (72.01, 73.06) c1 = 23.33 (19.53, 27.13) a2 = 7910 (4745, 1.107e+04) b2 = 45.39 (44.06, 46.72) c2 = 14.53 (13.14, 15.92) Goodness of fit: SSE: 4.487e+05 R^2: 0.9999 Adjusted R^2: 0.9999 RMSE: 83.73	General model Gauss2: f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) Coefficients (with 95% confidence bounds): a1 = -4726 (-1.337e+04, 3918) b1 = 11.93 (5.121, 18.74) c1 = 15.51 (2.785, 28.23) a2 = 5783 (1858, 9707) b2 = 28.92 (-9.645, 67.49) c2 = 38.69 (11.39, 65.99) Goodness of fit: SSE: 2.119e+07 R^2: 0.9147 Adjusted R^2: 0.908 RMSE: 575.4	General model Gauss2: f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) Coefficients (with 95% confidence bounds): a1 = 502.3 (343, 661.5) b1 = 36.53 (35.46, 37.61) c1 = 10.61 (8.221, 13) a2 = 522.5 (451.4, 593.6) b2 = 54.68 (49.8, 59.57) c2 = 23.34 (18.9, 27.78) Goodness of fit: SSE: 2.284e+05 R^2: 0.9594 Adjusted R^2: 0.9562 RMSE: 59.74
Iran	General model Gauss2: f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) Coefficients (with 95% confidence bounds): a1 = 2.305e+04 (690.6, 4.541e+04) b1 = 74.05 (65.31, 82.78) c1 = 8.718 (2.163, 15.27) a2 = 7.984e+04 (7.565e+04, 8.403e+04) b2 = 62.48 (60.45, 64.51) c2 = 26.57 (25.25, 27.9) Goodness of fit: SSE: 8.457e+07 R^2: 0.9989 Adjusted R^2: 0.9988 RMSE: 1150	General model Gauss2: f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) Coefficients (with 95% confidence bounds): a1 = 5753 (5218, 6288) b1 = 73.12 (71.33, 74.9) c1 = 25.66 (9.299, 42.02) a2 = 1651 (-1127, 4430) b2 = 43.47 (36.75, 50.18) c2 = 16.76 (10.95, 22.56) Goodness of fit: SSE: 1.521e+05 R^2: 0.9995 Adjusted R^2: 0.9995 RMSE: 48.75	General model Gauss3: f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) + a3*exp(-((x-b3)/c3)^2) Coefficients (with 95% confidence bounds): a1 = 3692 (-1.29e+04, 2.028e+04) b1 = 41.56 (40.57, 42.54) c1 = 8.522 (0.2777, 16.77) a2 = -1.129e+06 (-5.273e+11, 5.273e+11) b2 = 42.14 (-1186, 1270) c2 = 16.81 (-6831, 6865) a3 = 1.129e+06 (-5.273e+11, 5.273e+11) b3 = 42.14 (-1189, 1274) c3 = 16.84 (-6820, 6854) Goodness of fit: SSE: 5.109e+06 R^2: 0.9095 Adjusted R^2: 0.8976 RMSE: 289.4	General model Gauss2: f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) Coefficients (with 95% confidence bounds): a1 = 68.7 (22.4, 115) b1 = 29.76 (27.33, 32.18) c1 = 9.031 (3.504, 14.56) a2 = 127.5 (109.3, 145.7) b2 = 48.64 (43.12, 54.15) c2 = 23.55 (17.58, 29.53) Goodness of fit: SSE: 4.195e+04 R^2: 0.806 Adjusted R^2: 0.7909 RMSE: 25.6
UK	General model Gauss1: f(x) = a1*exp(-((x-b1)/c1)^2) Coefficients (with 95% confidence bounds): a1 = 1.595e+05 (1.567e+05, 1.623e+05) b1 = 92.12 (91.38, 92.86) c1 = 23.19 (22.63, 23.76) Goodness of fit: SSE: 1.91e+08 R^2: 0.9991 Adjusted R^2: 0.9991 RMSE: 1490	General model Gauss1: f(x) = a1*exp(-((x-b1)/c1)^2) Coefficients (with 95% confidence bounds): a1 = 2.098e+04 (2.061e+04, 2.134e+04) b1 = 89.73 (89.04, 90.43) c1 = 19.5 (18.91, 20.08) Goodness of fit: SSE: 6.268e+06 R^2: 0.9984 Adjusted R^2: 0.9983 RMSE: 270	General model Gauss1: f(x) = a1*exp(-((x-b1)/c1)^2) Coefficients (with 95% confidence bounds): a1 = 5592 (5309, 5876) b1 = 76.12 (74.96, 77.29) c1 = 19.89 (18.12, 21.65) Goodness of fit: SSE: 2.647e+07 R^2: 0.9405 Adjusted R^2: 0.9391 RMSE: 554.8	General model Gauss1: f(x) = a1*exp(-((x-b1)/c1)^2) Coefficients (with 95% confidence bounds): a1 = 821.2 (756.9, 885.5) b1 = 76.15 (74.83, 77.46) c1 = 16.75 (14.69, 18.81) Goodness of fit: SSE: 1.153e+06 R^2: 0.8805 Adjusted R^2: 0.8777 RMSE: 115.8
France	General model Gauss2: f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) Coefficients (with 95% confidence bounds): a1 = 1.244e+05 (1.215e+05, 1.273e+05) b1 = 99.05 (96.41, 101.7) c1 = 24.09 (21.8, 26.37) a2 = 3.658e+04 (2.108e+04, 5.209e+04) b2 = 74.51 (72.98, 76.04) c2 = 14.59 (12.77, 16.42) Goodness of fit: SSE: 4.72e+07 R^2: 0.9998 Adjusted R^2: 0.9997 RMSE: 728.2	General model Gauss2: f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) Coefficients (with 95% confidence bounds): a1 = 2.332e+04 (2.302e+04, 2.361e+04) b1 = 95.65 (94.46, 96.84) c1 = 19.87 (19.2, 20.54) a2 = 3262 (2445, 4078) b2 = 77.14 (76.33, 77.95) c2 = 8.787 (7.402, 10.17) Goodness of fit: SSE: 2.968e+06 R^2: 0.9995 Adjusted R^2: 0.9994 RMSE: 182.6	General model Gauss2: f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) Coefficients (with 95% confidence bounds): a1 = 1671 (660.5, 2682) b1 = 65.32 (63.14, 67.51) c1 = 5.342 (1.44, 9.245) a2 = 3436 (2670, 4202) b2 = 73.43 (70.44, 76.41) c2 = 19.05 (15.76, 22.35) Goodness of fit: SSE: 5.443e+07 R^2: 0.8018 Adjusted R^2: 0.7907 RMSE: 782	General model Gauss1: f(x) = a1*exp(-((x-b1)/c1)^2) Coefficients (with 95% confidence bounds): a1 = 959.5 (848.6, 1070) b1 = 76.86 (75.49, 78.23) c1 = 14.38 (12.33, 16.43) Goodness of fit: SSE: 3.339e+06 R^2: 0.7617 Adjusted R^2: 0.7565 RMSE: 190.5
Spain	General model Gauss3: f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) + a3*exp(-((x-b3)/c3)^2) Coefficients (with 95% confidence bounds): a1 = 5.664e+06 (-1.695e+11, 1.695e+11) b1 = 87.84 (-760.2, 935.9) c1 = 11.47 (-1588, 1611) a2 = -5.457e+06 (-1.695e+11, 1.695e+11) b2 = 87.79 (-779.2, 954.7) c2 = 11.36 (-1588, 1611) a3 = 1.159e+05 (-5.641e+04, 2.883e+05) b3 = 68.57 (56.54, 80.6) c3 = 13.32 (9.47, 17.17) Goodness of fit: SSE: 4.628e+07 R^2: 0.9999 Adjusted R^2: 0.9999 RMSE: 755.9	General model Gauss3: f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) + a3*exp(-((x-b3)/c3)^2) Coefficients (with 95% confidence bounds): a1 = 1.54e+07 (-1.383e+13, 1.383e+13) b1 = 89.48 (-1070, 1249) c1 = 15.98 (-4780, 4812) a2 = -1.538e+07 (-1.383e+13, 1.383e+13) b2 = 89.48 (-1080, 1259) c2 = 15.97 (-4802, 4834) a3 = 4714 (-5168, 1.46e+04) b3 = 64.98 (60.76, 69.2) c3 = 9.949 (6.897, 13) Goodness of fit: SSE: 2.418e+05 R^2: 1 Adjusted R^2: 1 RMSE: 54.63	General model Gauss2: f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) Coefficients (with 95% confidence bounds): a1 = -1.596e+04 (-5.843e+04, 2.652e+04) b1 = 70.11 (68.37, 71.86) c1 = 10.4 (5.572, 15.22) a2 = 2.116e+04 (-2.149e+04, 6.381e+04) b2 = 68.72 (66.7, 70.74) c2 = 13.95 (10.09, 17.82) Goodness of fit: SSE: 5.406e+07 R^2: 0.926 Adjusted R^2: 0.9216 RMSE: 802.3	General model Gauss2: f(x) = a1*exp(-((x-b1)/c1)^2) + a2*exp(-((x-b2)/c2)^2) Coefficients (with 95% confidence bounds): a1 = -1.594e+06 (-3.321e+12, 3.321e+12) b1 = 71.78 (-1943, 2087) c1 = 12.74 (-4199, 4224) a2 = 1.594e+06 (-3.321e+12, 3.321e+12) b2 = 71.78 (-1944, 2088) c2 = 12.75 (-4197, 4222) Goodness of fit: SSE: 6.382e+05 R^2: 0.9294 Adjusted R^2: 0.9252 RMSE: 87.16

Table 4: COVID-19 daily/cumulative case and death model equations for countries.

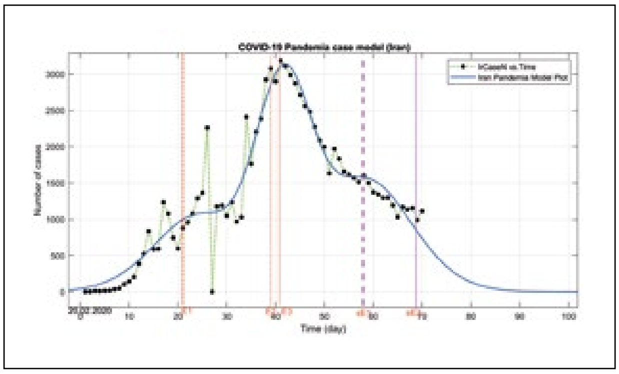

Figure 6: Iran's event-related case COVID-19 pandemic model.
After the interventions were terminated (stop events 1 and 2), the real case number course (dotted line) in Iran deviation from the expected course plot (solid line) to rise above it.

Discussion

In the present study, we assessed the effectiveness of major governmental measures implemented for the control of the pandemic in six countries worldwide. Our study results showed that the results of the estimation models we used were compatible with the actual course of the pandemic in the prespecified countries. We objectively demonstrated that the effects of prevention measures varied depending on each country

The M0 model (epidemic trend without a major intervention) analysis estimated that the country to reach the threshold (5,000 cases/day) number earliest was Turkey with 27. The spread of the epidemic in Turkey for the first two weeks was more rapid than any country, including Italy. The demographic structure of the country with a high youth rate, crowded family life, and traditional sociocultural practices with abundant interactions may be possible contributing factors. Countries which followed Turkey in the epidemic spread rate were Italy and Iran, where social interactions were considered to be more excessive in Italy among other European countries and similar between Iran and Turkey. This course was the slowest in France and the UK.

In the current study, Turkey ranked the first which took necessary measures against the COVID-19 outbreak. While the pandemic spread rate was higher than the other countries at the beginning of the outbreak, early action timings provided early pandemic control, although the event effect size values were average. In Turkey, daily case numbers increased rapidly by power at the outset of the pandemic, the trend turned into a polynomial increase later and, then, into a Gaussian trend (Figures 2-3), resulting in a lower peak and cumulative case numbers, compared to the other countries. Although Italy, similar to Turkey, took early measures, the same effect could not be achieved, possibly due to the fact that major intervention coverage was regional initially and generalized at a later stage, when the pandemic achieved a considerable momentum or due to low compliance and enforcement. Other European countries experienced a low outbreak activity during the first month, which might be due to several minor preemptive actions taken by the governments or to the lifestyles of the individuals with less social interaction across generations, compared to the Eastern countries or elderly. Of note, Chinese and Italian experience may have increased awareness and adoption of personal protective measures. Cumulative trends showed that Spain, with similar social interaction practices to Italy, had an earlier and rapid increase in the case numbers, compared to the UK and France (Figures 4-5). The cumulative case and cumulative death curves of Italy after Day 21 and Spain after Day 49 were quite similar (Figures 4-5). Close placement of the M0 (natural plot) curve to the actual peak point in Spain implies a delay in interventions (Figure 1). The outbreak course was also delayed in France and the UK with a rapid increase in case numbers 40 to 50 days into the pandemic, similar to the increase in Spain (Figures 3-4). The delay in major interventions in these European countries may have resulted in late slowing of the rate of pandemic spread and high cumulative number of cases and high peak daily case numbers in all of them (Figure 1). The models emphasize the need for rapid action without considering the initial limited number of patients. Timing of interventions in Iran was later than Turkey, but earlier than the European countries. The effect size of measures was the largest and cumulative case number was the lowest,indicating the efficacy of enforcement by the authoritarian governance.

In the literature, there are studies investigating the impact of school closures on pandemic control. In a study on the 2009 hemagglutinin type 1-neuraminidase type 1 (H1N1) pandemic, school closure reduced transmission by 25%[10]. In another study on influenza pandemics, a maximum benefit from a school closure was achieved, when less than 2% of the students became infected, while there was a minimum benefit, when the infection rate was higher than 20%[11]. The closure of schools during the 2009 H1N1 pandemic in Texas, United States (US) reduced acute respiratory illness in children by 42 to

75%[12]. In another study evaluating social distancing combined with school closure in Mexico, a dramatic decline in the number of daily cases was observed[13]. In our study, we found that school closure among all measures had the maximum effect size value in all of the countries, except for Italy. A large student population and crowding such as in Turkey and Iran enhance natural spread in outbreaks. According to the Republic of Turkey, Ministry of Education, the number of students in primary and secondary education was 18 million, accounting for 18.82% of the total population in 2018-2019 school year[14].

All formal education was six days after the first confirmed case in Turkey (E1).Although the schools were closed later in Iran, the effect size of school closure was found to be te highest (14.7).The M1 plot of this action in Iran deviated to the right of the FM peak value. Also, the school closure-related effect seemed to be strong in France (9.17) and UK (6.07). The school closure date in Turkey (E1) and regional school closure and cancelling of public gatherings in Northern Italy (E3) were similar (event time: 12 vs. 10 days, respectively). A rapid rise in daily and cumulative case numbers in the initial 10 days of the pandemic in Turkey fell below the levels in Italy after this point (Figure 4). Despite implementation of the same measures in Italy, the results were not similar to Turkey which can be attributed to implementation of regional measures and/or difficulties in execution and spread to the whole country. Implementation of a strong action in early phase is vital to prevent spread of the disease and to keep the case numbers under control. In Turkey, the M1 (school closure) model scenario effect size was 3.82, which is about a four-day deviation at the threshold of the M0 model and the fact that it is very close to the actual peak (two-day distance) supports strength of the effect. Success of the action also depends on the executional capacity. In our study, the E2 interventions, such as school closures in France and the UK, were strong enough to bring the natural M0 curve closer to the peak point, whereas the FM effect size reaching only 2.26 level, while combining all the efforts including school closure, indicated that even these interventions may be insufficient after a certain momentum (Figure 1).

The closure of businesses and workplaces is an important major challenge in pandemic control. According to Organization for Economic Cooperation and Development (OECD) data, the ratio of the population of the working age is over 60% in most of the countries, including the six countries analyzed in our study[15]. The workplaces are areas of intense social interaction with close contact. During a single influenza season, the attack rate was 15.5% among the workplaces in America[16]. Accordingly, Centers for Disease Control and Prevention in the US recommends the closure of workplaces as one of the major precautions during a severe pandemic. Although this effect is less in Turkey (1.8), there is a clear advantage for early action. The M0 model remaining close to the peak for France showed that the country failed to take early actions; nevertheless ,the closure of shopping venues was a necessary decision for France to hinder the spread of the disease, as seen in E1 (Figure 1).

The measures such as curfews and prohibition of public gatherings are strict measures during pandemics. It is recommended to carefully consider and justify restrictions on individual (patients and contacts), as well as collective freedom such as quarantine, lockdown, and curfew practices5. Mass gatherings or collective events such as concerts, festivals, and sports events pose a risk for a close contact over a considerable time[17]. In a systematic review of respiratory disease outbreaks associated with mass gatherings in the US between 2005 and 2014, 40 of 72 different outbreaks were found to be caused by fairs[18]. Mass gatherings were suspended in the Northern Italy at the initial stages of the COVID-19 outbreak which yielded a maximal clockwise rotation on the model graph and showed a very favorable result. However, once the disease spread from the regional to countrywide, the pandemic was out of control. Curfew and social distancing for individuals aged ≥65 years and/or those with comorbidities in Turkey had a strong effect (E2), and the result can be seen as a rightward movement of this estimation plot (M2 plot), to intersect with the M0 plot at the actual peak (model effect size = 5.62). The action-specific effect size was 1.8.After the action (E4), including the curfew of individuals under the age of 20 years (final plot), the number of cases remained below the threshold (5,000 cases/day) (ideal model).

In the UK, the effect size of this action is very low (0.58) which may be due to the implementation of this action as a recommendation, but not as a legal ban in the country. This finding indicates that states should act more resolutely and effectively in the form of prohibition,rather than recommendation, to achieve pandemic control. The specific effect size of the curfew is 2.11 in Spain, a country where the collective effect size was the least (2.6), and that was peculiarly higher than the UK (Figure 1). Furthermore, restriction and ban of travel are one of the major measures. However, as with others, it is important to act early in this action. A study found that mass travels close to peak time (preceding 10 days) caused a 10% increase in the peak prevalence, thereby, increasing the spread among families and region; however, this effect was very low in travels 40 days before the peak or 20 days after19. Transportation-related measures such as travel restrictions were implemented two weeks after the first case in Turkey (E3). The effect size of the M3 model (5.82) seemed to be slightly higher than the M2 and close to peak. In the Iranian model, this effect was below the threshold number of cases (ideal effect). Considering the high effect of other measures, stronger action results were achieved in Iran with a low peak and a low cumulative case number, which can be attributed to the authoritarian approach adopted in execution.

One of the most remarkable aspects of our study is the timing of easing or lifting major actions. Throughout the study, two governmental relaxation/ lift off decisions were made in Iran, which had the lowest number of cases in the pandemic (StopE1, StopE2). While the country-specific daily patient and death number trend fell successfully and rapidly down to the level of these "stop events", the trend evolved again to a plateau and, then, increased thereafter (Figure 6). This very critical finding is specifically for Iran; however, in general, all countries showed that untimely and premature relaxation of the measures posed a great risk for pandemic control.

According to the analysis of the total impact of all actions hosted by the FMs, Iran, Turkey, and France had successful models where the number of daily cases remained below the threshold. Among the remaining country models, considering the effect sizes of FMs, the UK was more successful than the other countries. On the other hand, Spain had the least successful model and Italy was in between, in consistent with the cumulative number of cases. The estimated expected pandemic period was81 days for Turkey, 100 days for Iran, 109 days for Italy, 112 days for Spain, 126 days for France, and 135 days for the UK, if the interventions were sustained in a healthy manner.

When the effects of the measures taken for pandemic control evaluated on a country basis, Turkey showed a rapid increase in the early stages of the pandemic. However, early implementation of measures provided pandemic control with the lowest fatality rates. The low fatality rate can be attributed to the young population and good health infrastructure. Italy was the first country affected by the pandemic spread in Europe and regional measures, delay in major actions, and incompetence in implementation of the restrictions may have resulted in a low impact of control measures. Iran experienced a relatively early spread of COVID-19; however, it was successful due to early action and effective implementation. The high peak and cumulative patient numbers were related to delay in major actions and inadequate implementation of the measures (low effect size) in Spain. The effectiveness of the measures in the UK and France were similar and average. The fatality rate was high in all European countries, possibly due to the higher ratio of elderly population.

Nonetheless, there are some limitations to this study. The main limitation is that countries and communities implemented a variety of regional and general minor measures which we were unable to include in the analysis. Furthermore, the estimation models are theoretical mathematical models and are almost impossible to test (i.e., the probability of the M0 model scenario where there is no intervention is almost non-existent).

In conclusion, major measures which minimize social densities such as school closure, workplaces, and curfews with travel restrictions should be implemented both very early (with limited number of cases) and very effectively for pandemic control. Correct timing of relaxation and lift of major measures are of utmost importance. In addition to preventive measures to reduce the fatality rate, the health system infrastructures should be strengthened and prepared for subsequent pandemics in the future.

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