

1 **Transmission potential of COVID-19 in Iran**

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17 Research Letter

18 Figure, n = 1

19 Technical Appendix, n = 1, with 6 supplementary tables and 8 supplementary figures

20 **Abstract: n=50; Word limit = 50**

21 We estimated the reproduction number of 2020 Iranian COVID-19 epidemic using two different methods:

22 R_0 was estimated at 4.4 (95% CI, 3.9, 4.9) (generalized growth model) and 3.50 (1.28, 8.14) (epidemic

23 doubling time) (February 19 - March 1) while the effective R was estimated at 1.55 (1.06, 2.57) (March 6-

24 19).

25

26 **Keywords:** Communicable Diseases; Coronavirus; COVID-19; Epidemiology; Infections; Iran.

27 **Main text**

28 Iran has been experiencing a devastating epidemic of COVID-19 in 2020 (1). The virus appears
29 to be spreading rapidly with multiple cases reported among the elite (2). One model estimated that 18,300
30 (95% CI, 3,770 to 53,470) cases would have had occurred by February 24 (3). The Iranian authorities
31 have adopted social distancing measures to slow disease transmission (4). As the epidemic continues, our
32 results call for efforts to minimize COVID-19-related morbidity and mortality.

33 To confront the epidemic, the transmission potential of COVID-19 is a useful metric to guide the
34 outbreak response efforts including the scope and intensity of interventions. During the early transmission
35 phase, the basic reproduction number, R_0 , represents such a measurement quantifying the average number
36 of secondary cases that primary cases generate in a completely susceptible population in the absence of
37 interventions or behavioral changes. $R_0 > 1$ indicates the possibility of sustained transmission, whereas
38 $R_0 < 1$ implies that transmission chains cannot sustain epidemic growth. As the epidemic continues its
39 course, the effective reproduction number, R_e , offers a time-dependent record of the average number of
40 secondary cases per case as the number of susceptible individuals gets depleted and control interventions
41 takes effect. Herein we employed two different methods to quantify the reproduction number using the
42 curve of reported COVID-19 cases in Iran and its five regions (Table S1).

43 Using a Wikipedia entry as a starting point, Farsi-speaking coauthor SFR double-checked the data
44 of daily reported new cases, from February 19 through March 19, 2020 (the day before the Iranian New
45 Year), using Iranian official press releases and other credible news sources, and corrected the data as per
46 the official data (Figure S1, Tables S2 and S3). Incident cases for the 5 regions were missing for two
47 days: March 2-3, 2020, which were not included in our analysis. We noted that the reported national
48 number of new cases did not match the sum of the new cases reported in Iran's five regions on March 5,
49 2020; we decided to treat each time series as independent and used the data as reported. Using Method 1,
50 we estimated R_0 using data from February 19 through March 1, 2020. Using Method 2, we estimated R_0
51 from the early transmission phase (February 19 through March 1, 2020) and R_e based on the growth rate

52 estimated from March 6 through 19, 2020 during which the epidemic slowed down likely reflecting the
53 impact of social distancing measures.

54 Two methods were utilized to estimate the reproduction number. The first method utilized a
55 generalized growth model (GGM) (5) with the growth rate and its scaling factor to characterize the daily
56 reported incidence, followed by simulation of the calibrated GGM, using a discretized probability
57 distribution of the serial interval and assuming a Poisson error structure. See Technical Appendix for
58 detailed description of Method 1.

59 The second method for estimating the reproduction number is based on the calculation of the
60 epidemic's doubling times, which correspond to the times when the cumulative incidence doubles. We
61 estimated the epidemic doubling time using the curve of cumulative daily reported cases. To quantify
62 parameter uncertainty, we used parametric bootstrapping with a Poisson error structure around the
63 number of new reported cases in order to derive 95% confidence intervals of our estimates (6-8).
64 Assuming exponential growth, the epidemic growth rate is equal to $\ln(2)/\text{doubling time}$. Assuming that
65 the pre-infectious and infectious periods follow an exponential distribution, R_0 is approximately equal to 1
66 + growth rate \times serial interval. See Technical Appendix and Equation 4.14, Table 4.1 in Vynnycky and
67 White (9).

68 In both methods, the serial interval was assumed to follow a gamma distribution (mean: 4.41
69 days; standard deviation: 3.17 days) (10, 11). MATLAB version R2019b and R version 3.6.2 were used
70 for data analyses and creating figures. It was determined *a priori* that $\alpha = 0.05$.

71 Using Method 1, we estimated an R_0 of 4.4 (3.9, 4.9) for the COVID-19 epidemic in Iran. We
72 estimated a growth rate of 0.65 (95% CI, 0.56, 0.75) and a scaling parameter of 0.96 (95% CI, 0.93, 1)
73 (Table S4). The latter indicated a near-exponential growth of the epidemic (**Figure**). Using Method 2, we
74 found that from February 19 through March 1, the cumulative incidence of confirmed cases in Iran had
75 doubled 8 times. The estimated epidemic doubling time was 1.20 (95% CI, 1.05, 1.45) days and the

76 corresponding R_0 estimate was 3.50 (95% CI, 1.28, 8.14). From March 6 through March 19, the
77 cumulative incidence of confirmed cases had doubled 1 time, with a doubling time of 5.46 (5.29, 5.65)
78 days. The corresponding effective R estimate was 1.55 (95% CI, 1.06, 2.57) (Table S5, Figures S7, S8).
79 Our results are robust, as they are consistent with the Iranian COVID-19 R_0 estimates of 4.7 and 4.86
80 generated by Ahmadi et al. and Sahafizadeh and Sartoli (12, 13), respectively, but are higher than the R_0
81 of 2.72 estimated by Ghaffarzagdegan & Rahmandad (14).

82 Our study has limitations. First, our analysis is based on the number of daily reported cases
83 whereas it would be ideal to analyze case counts by date of symptoms onset, which were not available.
84 Second, case counts could be underreported due to underdiagnosis, given subclinical or asymptomatic
85 cases, or limited testing capacity to test mild cases. The rapid increase in case counts might represent a
86 belated realization of the severity of the epidemic and a rapid process of catching up with testing many
87 suspected cases. If the reporting ratio remains constant over the study period, and given the near-
88 exponential growth of the epidemic's trajectory, our estimates would remain reliable; however, this is a
89 strong assumption. Third, while data are not stratified according to imported and local cases, we assumed
90 that they were infected locally, as it is likely that transmission has been ongoing in Iran for some time (3).

91 In conclusion, we used two different methods to compute the R_0 of COVID-19 epidemic in Iran.
92 Our mean estimate was at 4.4 (95% CI, 3.9, 4.9) for Method 1, and at 3.50 (95% CI, 1.28, 8.14) for
93 Method 2, which means that on average around four susceptible individuals were infected by one
94 infectious individual during the early growth phase. When social distancing interventions are in place, the
95 epidemic slows. The doubling time of the COVID-19 epidemic in Iran increased from 1.20 (95% CI,
96 1.05, 1.45) to 5.46 (95% CI, 5.29, 5.65) days, and the effective R dropped to 1.55 (95% CI, 1.06, 2.57).
97 While the COVID-19 epidemic in Iran has now slowed down substantially, the situation in Iran is still
98 dire with the average daily number of ~2290 new reported cases over 14 days from March 20 through
99 April 2, 2020. Tightening social distancing interventions is needed to bring the epidemic under control in
100 Iran.

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102 **Co-first authors' biographies**

103 Kamalich Muniz-Rodriguez, a doctoral student in epidemiology, and Dr. Isaac Chun-Hai Fung, an
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112 **Conflict of interest statement**

113 We do not have any conflict of interest to declare.

114 **Disclaimer**

115 This article does not represent the official positions of the Centers for Disease Control and Prevention, the
116 National Institutes of Health, or the United States Government.

117 **Ethics statement**

118 The Georgia Southern University Institutional Review Board has made a non-human subjects
119 determination for our project (H20364), under G8 exemption category.

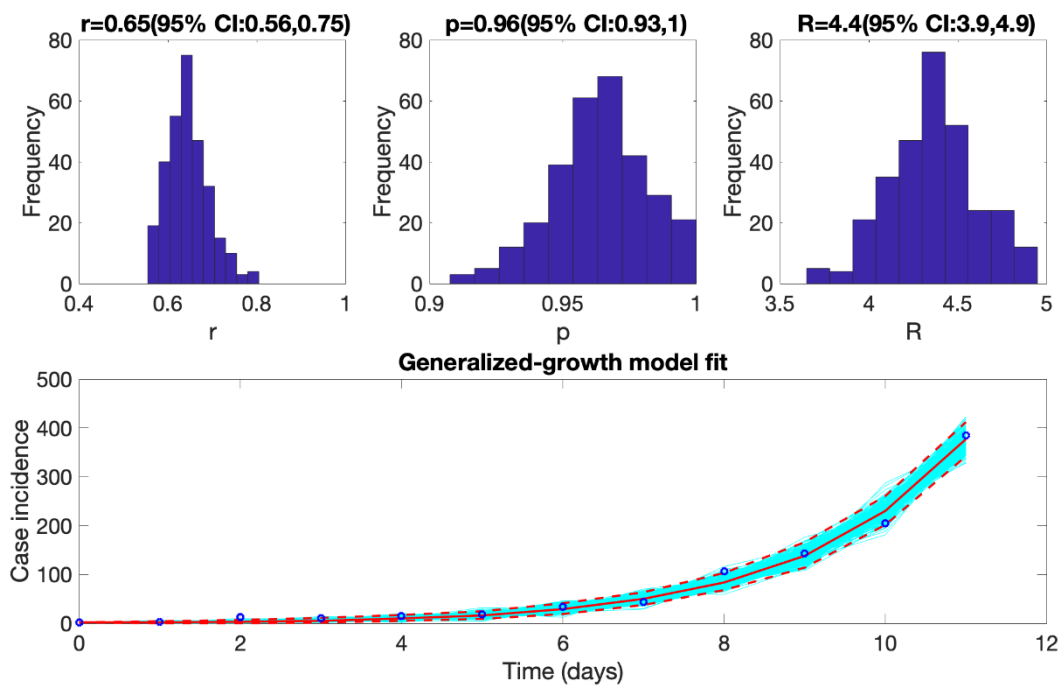
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157 **Figure.** The mean basic reproduction number of COVID-19 epidemic in Iran, with 95% confidence
158 interval. Estimates for growth rate, r , and the scaling of the growth rate parameter, p , are also provided.
159 The plot in the lower panel depicts the fit of the Generalized Growth Model (Method 1) to the Iranian
160 data assuming Poisson error structure as of March 1, 2020.



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