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*Supplementary Data*

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# Modeling the transmission dynamics of COVID-19 epidemic: a systematic review

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***Supplementary Table 1*** **Extending models of COVID-19**

| Extending on SEIR | Number of studies |
|---|---|
| Unascertained proportion | 7[1–7] |
| Population flow | 8[1,4,8–14] |
| Network model | 5[2,13,15–17] |
| Different transmission rate of *E vs. I* | 19[5,10,12,17–32] |
| Disease severity stage | 16[7,16–17,19,27,31,33–42] |
| Age structure | 5[4,25,33,39,43] |
| Impact of temperature | 1[44] |
| Quarantine | 17[7,14,16,21–23,26,29,30,32,36–37,39–40,42,45–46] |
| Effect indicator for control measures | 16[3,6,17,25–27,32,41–43,46–51] |

***Supplementary Table 2*** **Objective of models**

| Objective | Number of studies |
|---|---|
| Epidemiological parameter estimation | 14[1,2,4–9,13,17–18,28,52,53] |
| Trend prediction | 30[1,7,9–12,15–16,18–23,29–30,32–35,44–49,51,53–55] |
| Evaluation of control measures | 35[3,6,10,13–14,17,20,22–27,29–33,36–43,47–48,50,52,54–58] |

***Supplementary Table 3*** **Epidemiological parameters setting**

| Parameters | Interpretation | Frequency | Fixed or estimated |
|---|---|---|---|
| Transmission rate | The rate from *S* to *E* | 43/63 | Estimated |
| | | 2/63 | Fixed |
| Incubation period | | 10/63 | Estimated |
| | | 42/63 | Fixed |
| Transmissibility factor | Transmission rate (*E* or A)/transmission rate (*I*) | 7/63 | Estimated |
| | | 4/63 | Fixed |

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***Supplementary Table 4*** **Number of parameters**

| Study | Total No. of parameter | No. of fixed parameter | No. of fitted parameter |
|---|---|---|---|
| Li *et al*[2] | 8 | 0 | 8 |
| Kucharski *et al*[8] | 13 | 7 | 6 |
| Wei *et al*[19] | 23 | 14 | 9 |
| Hou *et al*[24] | 11 | 11* | 0 |
| Kim *et al*[39] | 10 | 4 | 6 |
| Tuite *et al*[33] | 14 | 14 | 0 |
| Tian *et al*[3] | 9 | 0 | 9 |
| Yang *et al*[10] | 13 | 9 | 4 |
| Fanelli *et al*[59] | 7 | 0 | 7 |
| Gatto *et al*[20] | 17 | 5 | 12 |
| Peirlinck *et al*[15] | 6 | 6 | 0 |
| Liu *et al*[21] | 14 | 10 | 4 |
| Shi *et al*[44] | 8 | 7 | 1 |
| Zhao *et al*[48] | 9 | 6 | 3 |
| Kim *et al*[45] | 7 | 5 | 2 |
| Ngonghala *et al*[37] | 28 | 23 | 5 |
| Weitz *et al*[25] | 7 | 4 | 3 |
| Zhao *et al*[34] | 12 | 10 | 2 |
| Zhao *et al*[34] | 11 | 1 | 10 |
| Mandal *et al*[46] | 14 | 11 | 3 |
| Kissler *et al*[16] | 11 | 1 | 10 |
| Wu *et al*[4] | 13 | 5 | 8 |
| Linka *et al*[13] | 6 | 6 | 0 |
| Liu *et al*[1] | 14 | 11 | 3 |
| Childs *et al*[27] | 16 | 11 | 5 |
| Su *et al*[14] | 10 | 3 | 7 |
| Ogbunugafor *et al*[28] | 13 | 6 | 7 |
| Cui *et al*[29] | 8 | 0 | 8 |
| Bentout *et al*[52] | 6 | 4 | 2 |
| Zu *et al*[32] | 25 | 8 | 17 |

* (1 assumed)

Four published studies have estimated the transmission rate in Wuhan by January 23 or without any control measures. An early analysis based on a modified SEIR model and travel data between 375 cities in China between January 10 to 23 estimated the transmission rate in Wuhan is 1.12 (95% confidence interval [CI], 1.06–1.19), using log-likelihood method[2]. Considering the delayed diagnosis and infectiousness of exposed infections and infections, another study analyzed the confirmed cases in Wuhan from January 15 to February 2 and estimated the transmission rate is 1.22 (95% CI, 0.12–3.32) of infections[5]. Another two studies estimated the transmission rates are 1.1[48] and 3.44[36].

Similarly, three studies using cases diagnosed in the United States estimated the transmission rate without any control measures. A study based on the confirmed cases by April 7 estimated the transmission rate is 0.86[37] in New York, compared with 1.4 (95% CI, 1.35–1.46) another study estimated[41] using cases by April 2, and 1.10 in entire America, 0.61 (95% CI, 0.50–1.20) before May 4 one other study estimated[38].

Lower transmission rates of European countries were estimated compared with that of China and the United States. The estimate of the transmission rate in France was 0.32 before March 17[60]. A study based on data of Germany between March 2 to 15 estimated transmission rate is 0.41 in the absence of interventions using Bayesian Markov chain Monte Carlo method[50]. In addition, without any control measures, the transmission rate in European Union is 0.25.

However, transmission rate of Republic of Korea was estimated much higher. An analysis based on confirmed cases up to March 10 estimated the transmission rates are 7.06 in entire Republic of Korea and 6.18 in Daegu/Gyeongbuk.

The transmission rate of asymptomatic carriers is different from that of infected persons, and 4 studies consider the difference (***Supplementary Table 6***). Current estimates of the transmissibility factor for COVID-19 ranges from 0.0275 to 0.55 from two published studies. Li *et al*[2] is the earliest one using a transmissibility factor, the infectiousness of asymptomatic carriers compared with infected cases, in SEIR model to calculate the transmission rate of asymptomatic carriers, and their estimates of this factor were 0.55 (95% CI, 0.46 –0.62) between January 10 to 23, 0.50 (95% CI, 0.37–0.69) between January 24 to February 3 and 0.43 (95% CI, 0.31 –0.61) between January 24 to February 3. Another study[42] estimated the transmissibility factor was 0.0275 (SD 0.0128) based on confirmed cases up to April 21, while 2 other studies[25,41] used 0.5 as the fixed transmissibility factor.

Four studies considered the different transmission rates of exposed infections and infections and reported the transmissibility factor ranging from 0.32 to 1 (***Supplementary Table 7***). Two studies used fixed transmissibility factor, 0.5[19] and 1[23]. Developing a compartmental model of SEIR type, where delay in diagnosis is considered, a study[5] estimated the transmissibility factor was 0.32 based on confirmed cases up to March 5 in Wuhan. In addition, another study[21] estimated the factor was 0.49, comparable to

***Supplementary Table 5*** **Transmission rate of COVID-19**

| Study | Data up to | Region | Transmission rate | 95% CI lower limit | 95% CI upper limit |
|---|---|---|---|---|---|
| Li *et al*[2] | 2020/1/23 | Wuhan | 1.12 | 1.06 | 1.19 |
| Rong *et al*[5] | 2020/2/2 | Wuhan | 1.22 | 0.12 | 3.32 |
| Zhao *et al*[48] | 2020/1/8 | Wuhan | 1.10 | | |
| Tang *et al*[36] | 2020/1/22 | Wuhan | 3.44 | | |
| Ngonghala *et al*[37] | 2020/4/7 | New York | 0.86 | | |
| | 2020/4/7 | United States | 1.10 | | |
| Eikenberry *et al*[41] | 2020/4/2 | Washington | 0.50 | 0.49 | 0.52 |
| | 2020/4/2 | New York | 1.40 | 1.35 | 1.46 |
| Kennedy *et al*[38] | 2020/5/4 | United States | 0.61 | 0.50 | 1.20 |
| Tang *et al*[42] | 2020/3/14 | Ontario, Canada | 1.70 | | |
| Roques *et al*[60] | 2020/3/17 | France | 0.32 | | |
| Dehning *et al*[50] | 2020/3/15 | Germany | 0.41 | | |
| Linka *et al*[13] | 2020/4/13 | European Union | 0.246 | | |
| Kim *et al*[45] | 2020/3/10 | Republic of Korea | 7.059 | | |
| | 2020/3/10 | Daegu/Gyeongbuk | 6.184 | | |
| Bentout *et al*[52] | 2020/3/31 | Algeria | 0.41 | | |
| Carcione *et al*[53] | 2020/2/24 | Lombardy, Italy | 0.75 | | |
| Cadoni[58] | 2020/2/23 | Three regions in north Italy | 0.33 | | |

***Supplementary Table 6*** **Transmissibility factor of *A vs. I***

| Source | Study | Value (95% CI) |
|---|---|---|
| Fixed | Weitz *et al*[25] | 0.5 |
| | Eikenberry *et al*[41] | 0.5 |
| Estimated | Li *et al*[2] | 0.55 (0.46, 0.62) |
| | | 0.50 (0.37, 0.69) |
| | | 0.43 (0.31, 0.61) |
| | Tang *et al*[42] | 0.0275 (SD 0.0128) |

***Supplementary Table 7*** **Transmissibility factor of *E vs. I***

| Source | Study | Value |
|---|---|---|
| Fixed | Wei *et al*[19] | 0.50 |
| | Cao *et al*[23] | 1.00 |
| Estimated | Rong *et al*[5] | 0.32 |
| | Liu *et al*[21] | 0.49 |
| | Cui *et al*[29] | 0.69 |
| | | 0.63 |
| | Zu *et al*[32] | 0.58 |

***Supplementary Table 8*** **Unascertained proportion**

| Study | Type | Date | Fixed or Estimated | Value | Region |
|---|---|---|---|---|---|
| Liu *et al*[1] | Unascertained compartment | 2020/3/18 | Fixed | 0.2 | China |
| Wei *et al*[22] | Unascertained compartment | January | Estimated | 0.55 (95% CI, 0.42, 0.71) | Wuhan |
| Li *et al*[2] | Ascertained rate | 2020/1/10–2020/1/23 | Estimated | 0.14 (95% CI, 0.10, 0.18) | Wuhan |
| | | 2020/1/24–2020/2/3 | | 0.65 (95% CI, 0.60, 0.69) | |
| | | 2020/1/24–2020/2/8 | | 0.69 (95% CI, 0.65, 0.72) | |
| Tian *et al*[3] | Ascertained rate | 2020/1/23 | Estimated | 0.002 (95% CI, 0.001–0.003) | Wuhan |
| Rong *et al*[5] | Ascertained rate | 2020/1/15–2020/2/2 | Estimated | 0.40 (95% CI, 0.30, 0.65) | Wuhan |
| Wu *et al*[4] | Ascertained rate | 2020/1/4 | Estimated | 1.8% (95% CI, 0.9%–3.3%) | Wuhan |
| Reis *et al*[6] | Ascertained rate | 2020/4/6 | Estimated | 0.132 (SD 0.0224) | Brazil |
| | | | | 0.290 (SD 0.0283) | Italy |
| | | | | 0.956 (SD 0.0233) | Republic of Korea |
| Roques *et al*[60] | Ascertained rate | 2020/3/17 | Estimated | 0.125 (95% CI, 0.083–0.200) | France |

***Supplementary Table 9* Fixed incubation period**

| Value | Reference |
|---|---|
| 2.5[33] | [61] |
| 2.56[13,15] | Mean incubation period over all Chinese provinces |
| 3.5[27] | [62–63] |
| 4[25,35,46] | [2,64] |
| 4.1[39,45] | Republic of Korea government[65] |
| 4.6[16] | [66–67] |
| 5[26,42,52,55–56] | [68–72] |
| 5.1[37,41] | [73] |
| 5.2[5,19,22,32,43–44,46–48,54,57] | [69,74–76] |
| 5.4[46] | [77] |
| 5.5[17,28] | [78] |
| 6[11,14] | Mean[73] |
| 6.5[4] | [79] |
| 7[10,12,23–24,36,40,80] | [68–69,81–85] |
| 10[21] | |

***Supplementary Table 10* Estimated incubation period**

| Study | Value | 95% CI lower limit | 95% CI upper limit |
|---|---|---|---|
| Wan *et al*[18] | 3.00* | 2.80* | 3.10* |
| Gatto *et al*[20] | 3.32 | 3.03 | 3.66 |
| Li *et al*[2] | 3.69 | 3.30 | 3.96 |
| | 3.60 | 3.41 | 3.84 |
| | 3.42 | 3.30 | 3.65 |
| Steven *et al*[86] | 4.20 | 3.50 | 5.10 |
| Tian *et al*[3] | 4.90 | 4.32 | 5.47 |
| Song *et al*[87] | 5.01 | 4.31 | 5.69 |
| Reis *et al*[6] | 3.32 | 1.21# | |
| | 3.88 | 0.63# | |
| | 5.34 | 1.25# | |
| Huang *et al*[49] | 6.14 | 5.97 | 6.32 |
| Cui *et al*[29] | 7.69 | | |
| | 6.67 | | |
| Carcione *et al*[53] | 4.25 | | |

*Interquartile range; #Standard deviation.

***Supplementary Table 11* Short-term prediction of confirmed cases**

| Study | Fitting up to | Region | Predicted date | Predicted size of infections | Actual size of infections | Deviation |
|---|---|---|---|---|---|---|
| [47] | 2020/2/17 | Wuhan | 2020/2/19 | 55 869–81 393 | 44 412 | 24 219 |
| | | | 2020/2/23 | 58 077–84 520 | 46 201 | 25 098 |
| [18] | 2020/2/12 | Wuhan | 2020/2/19 | 47 000 | 44 412 | 2588 |
| [10] | 2020/2/9 | Hubei | 2020/2/20 | 42 792 (95% CI, 30 149–52 941) | 62 031 | 19 239 |
| [21] | 2020/2/20 | Hubei | 2020/2/29 | 65 000 | 66 337 | 1337 |
| [32] | 2020/2/17 | China | 2020/2/23 | 60 890 (95% CI, 60 350–61 431) | 76 936 | 16 046 |
| [59] | 2020/3/15 | Italy | 2020/3/21 | 26 000 | 53 578 | 27 578 |
| [30] | 2020/4/8 | Tunisia | 2020/4/21 | 648 | 864 | 216 |

that of *A vs. I*.

All eleven estimates extracted from seven published studies have the mean (or median) and uncertainty of shorter than 6 days.

Current estimates for the mean or median incubation period range from 3 to 5.34 days, approximate to SARS-CoV (4.4 days)[88]. One of the earliest modeling study of COVID-19 based on confirmed cases and travel data between 375 cities in China between January 10 to 23 estimated that the incubation period was 3.69 (95% CI, 3.30 –3.96) between January 10 to 23, 3.60 (3.41–3.84) between January 24 to February 3 and 3.42 (95% CI, 3.30–3.65) between January 24 to February 8[2]. Based on the data of 22 days from January 22 to February 12 when Wuhan city, Wan *et al*[18] estimated the incubation period was 3 (interquartile range 2.8–3.1), similar to the result of the last study. Collecting 137 individual case reports from January 15 to 30, 2020 from China, Steven *et al*[86] estimated the incubation period was 4.20 (95% CI, 3.50–5.10). Tian *et al*[3] used a modified SEIR model involving the control measures taken in Wuhan, and, by Bayesian Markov Chain Monte Carlo (MCMC) method, estimated the incubation period was 4.9 (95% CI, 4.32–5.47). Another study of Wuhan reported a mean incubation period of 5.01 (95% CI, 4.31–5.69)[87].

Similarly, a study[20] using cases diagnosed in Italy reported a median incubation period of 3.32 (95% CI, 3.03–3.66), comparable to that of Wuhan. Based on

***Supplementary Table 12*** **Long-term prediction of infections**

| Study | Fitting up to | Region | Predicted date | Predicted size of infections | Actual size of infections | Deviation |
|---|---|---|---|---|---|---|
| [36] | 2020/1/22 | Wuhan | 2020/3/10 | 163 000 | 49 965 | 113 035 |
| [10] | 2020/2/9 | Hubei | Late April | 59 578 (95% CI, 39 189–66 591) | 68 128 (2020/4/30) | 9550 |
| [19] | 2020/2/12 | China | 2020/2/29 | 80 417 | 79 251 | 1166 |
| [29] | 2020/3/2 | Wuhan | 2020/5/12 | 51 308 | 50 333 | 975 |
| [10] | 2020/2/9 | China | 2020/2/28 | 59 764 (95% CI, 51 979–70 172) | 78 824 | 19 060 |
| [48] | 2020/2/6 | Wuhan | Final size | 163 350 | 50 333 | 113 017 |
| [12] | 2020/2/10 | Wuhan | Final size | 45 000 | 50 333 | 5333 |
| [22] | 2020/3/30 | Wuhan | Final size | 69 957 | 50 333 | 19 624 |
| [32] | 2020/2/17 | Hubei | Final size | 72 023 (95% CI, 71 815–72 023) | 68 135 | 3888 |
| [51] | 2020/3/14 | Hunan | Final size | 3369 (840, 8013) | 1019 | 2350 |
| [29] | 2020/3/2 | China | Final size | 82 005 | 85 677 | 3672 |
| [10] | 2020/2/9 | China | Final size | 122 122 (95% CI, 89 741–156 794) | 85 677 | 36 445 |
| [32] | 2020/2/17 | China | Final size | 86 763 (95% CI, 86 067–87 460) | 85 677 | 1086 |
| [49] | 2020/2/22 | China | Final size | 103 321 | 85 677 | 17 644 |
| [1] | 2020/3/18 | China | Final size | 80 043 | 85 677 | 5634 |
| [15] | 2020/4/4 | The United States | 2020/5/10 | 3 000 000 | 1 309 541 | 1 690 459 |
| [46] | 2020/4/27 | Maharashtra in India | 2020/5/31 | 83 958 | 67 655 | 16 303 |
| | | Delhi in India | 2020/5/31 | 19 667 | 19 844 | 177 |
| | | Tamil Nadu in India | 2020/5/31 | 5133 | 22 333 | 17 200 |
| [55] | 2020/4/25 | India | 2020/5/15 | 42 918 | 82 103 | 39 185 |
| [45] | 2020/3/10 | Republic of Korea | Final size | 13 800 | 13 551 | 249 |
| [51] | 2020/4/2 | Italy | Final size | 182 051 (95% CI, 116 114–274 378) | 242 827 | 60 776 |
| [53] | 2020/5/5 | Lombardy, Italy | Final size | 2 690 000 | 95 173 | 2 594 827 |

***Supplementary Table 13*** **Prediction of peak date**

| Study | Date of data | Region/country | Peak date | Actual peak date |
|---|---|---|---|---|
| [47] | 2020/2/17 | Wuhan | 2020/2/19 | 2020/2/14 |
| | | | 2020/2/23 | 2020/2/14 |
| [18] | 2020/2/12 | Wuhan | 2020/2/19 | 2020/2/14 |
| [19] | 2020/2/12 | Wuhan | 2020/2/9 | 2020/2/14 |
| [44] | 2020/2/2 | Wuhan | 2020/3/5 | 2020/2/14 |
| [23] | 2020/2/24 | Hubei | 2020/2/19 | 2020/2/14 |
| [10] | 2020/2/9 | Hubei | 2020/2/20 | 2020/2/14 |
| [10] | 2020/2/9 | China | 2020/2/28 | 2020/2/14 |
| [32] | 2020/2/17 | China | 2020/2/23 | 2020/2/14 |
| [30] | 2020/4/8 | Tunisia | 2020/4/18 | 2020/3/26 |
| [55] | 2020/4/25 | India | 2020/5/15 | |
| [15] | 2020/4/4 | United States | 2020/5/10 | |

the classic compartmental SIRD model, Reis *et al*[6] estimated incubation periods were 3.32 (SD 1.21) of Brazil, 3.88 (SD 0.63) of Italy, and 5.34 (SD 1.25) of Republic of Korea.

**_Supplementary Table 14_ Theoretical prediction**

| Study | Parameter | Assumption | Result | | |
|---|---|---|---|---|---|
| [24] | Contact rate of latent individuals | 6 (the same with $I$)–18 | Peak time: 2020/3/29–2020/2/18 | | |
| [48] | Contact rate | 0.5 of contact rate before January 8 | | Peak size 0.20 (95% CI, 0.17−0.24) infections per 1000 population in Wuhan | Final size: the final size at 0.40% (95% CI, 0.36%−0.46%) of total population |
| | | 0.25 of contact rate before January 8 | | Peak size 0.18 (95% CI, 0.15−0.21) infections per 1000 population in Wuhan | Final size: the final size at 0.30% (95% CI, 0.28%−0.33%) of total population |
| | | 0.125 of contact rate before January 8 | | Peak size 0.16 (95% CI, 0.14−0.19) infections per 1000 population in Wuhan | Final size: the final size at 0.26% (95% CI, 0.24%−0.29%) of total population |
| [14] | Contact rate | Increasing 2 times/40% reduction | Peak time: | Peak size: | |
| | | | 2020/2/8 (2020/3/4) in Beijing | 642 (286) | |
| | | | 2020/2/8 (2020/3/3) in Shanghai | 592 (309) | |
| | | | 2020/2/8 (2020/3/3) in Guangzhou | 515 (279) | |
| | | | 2020/2/9 (2020/3/8) in Shenzhen | 688 (377) | |
| [36] | Contact rate | 0.5 (0.1) of contact rate before January 23 | Peak time: 33.8 (3.4) days from 2020/1/10 | Peak size: 115 000 (2420) | On 2020/1/29, the size of infections would reach 4335 (2731) |
| [39] | Contact rate of school opening delay in Republic of Korea | Transmission rate between children increasing 10 times | 60 cases from March 2 to March 9, and approximately additional 100 children cases from March 9 to March 23. | After March 23, cases for children is 28.4 for 7 days and 33.6 for 14 days | The delay reduced at least 200 cases |
| [58] | Contact rate | Without control | | The final size would reach 1.88×10$^7$ in north Italy | |
| | | 50% control | | The final size would reach 1.16×10$^7$ in north Italy | |
| [55] | Transmission rate | Increase from 0.19 to 0.23 if the lockdown is removed in India on May 3 | Peak time: May 15 | Peak cases: 45 939 | |
| | | 0.28 | May 14 | 48 411 | |
| | | 0.33 | May 14 | 50 447 | |
| | | 0.38 | May 13 | 52 086 | |
| [36] | Quarantine rate | 10 (20) times of quarantine rate before January 23 | Peak time: 12.8 (10.3) days from 2020/1/10 | Peak size: 19 800 (10 800) | |
| [29] | Quarantine rate of exposed ($E$) | Decrease from 0.57 to 0.53 | | The peak size of infections increased from 33 720 to 42 285 in Wuhan | The peak size of infections increased from 75 915 to 88 997 in mainland China |
| | Quarantine rate of infections ($I$) | Increased from 0.76 to 0.78 | | The peak size of infections decreased from 52 393 to 51 308 in Wuhan | |
| | | Increased from 0.74 to 0.78 | | | The peak size of infections decreased from 83 556 to 80 536 in mainland China |
| | Quarantine rate of susceptible ($S$) | Increased from 0.09 to 0.13 | | | The peak size of infections decreased from 120 731 to 62 729 in mainland China |

***Supplementary Table 14*** **Theoretical prediction** (continued)

| Study | Parameter | Assumption | Result | | |
|---|---|---|---|---|---|
| [10] | Wuhan travel ban | A five-day delay | Peak time: February 26 and 25 peaks in Guangdong and Zhejiang provinces. February 21 and March 17 (second peak) in Wuhan.March 4 2020 in mainland China. | Peak size: 3553 and 3522 cases in Guangdong and Zhejiang provinces 173 372 cases in mainland China. | The cases would reach 166 930 at the end of April in Wuhan. By the end of April the total epidemic size will be 351 874 cases in mainland China |
| | | Five days earlier | Peak time: February 11 in Hubei | Peak size: 8031 cases in Hubei | The final epidemic size of Hubei is 15 965 cases |
| [9] | Control measures | Without any control measures in Wuhan | | 233 400 (95% CI, 38 757–778 278) cases on January 31 | |
| [54] | Policy | Restriction policies remain unchanged in France | | The number of infections would reach 2 500 000 (2 000 000, 3 200 000) on May 10 | |
| [30] | Quarantine rate | Without quarantine strategy in Tunisia | | The number of infections would reach $375\times10^5$ on 2020/4/3 | |
| [27] | Contact rate in Santa Clara County, California | Without any non-pharmaceutical interventions | Peak time: August 12 (95% CI, July 23 to September 9) | Peak size: 171 667 (95% CI, 124 307–211 640) | 5478 deaths (95% CI, 1767–11 632) on August 12 |

**Supplementary Table 15** Actual effect of single control measures

| Study | Actual/theoretical effect | Type of Control measures | Control measures | Effect | |
|---|---|---|---|---|---|
| Tian *et al*[3] | Actual effect | Travel ban | Wuhan travel ban | 2.91 days delay of other cities (95% CI, 2.54 to 3.29 days) on average | 542 000 cases avoided in China (except Wuhan) |
| | | Traffic restriction | | reported 33.3% (95% CI, 11.1% to 44.4%) fewer laboratory-confirmed cases during the first week of outbreaks | *R0* decrease from 3.15 to 0.97, 2.01, and 3.05 |
| | | the national emergency response | | | 545 000 cases avoided in China (except Wuhan) |
| Yang *et al*[10] | Actual effect | Travel ban | Wuhan travel ban | | 13 602 cases avoided in Hubei |
| Gatto *et al*[20] | Actual effect | Social distance | Containment measures and changes in social behavior and awareness in Italy | Reduced the transmission by 45% (95% CI, 42% to 49%) | |
| Wei *et al*[22] | Actual effect | | Clinical diagnosis and universal symptom surveys in Wuhan | Reduced nearly 20 000 infections in Wuhan | |
| Cao *et al*[23] | Actual effect | Social distance | The construction of Huoshenshan Hospital, Leishenshan Hospital and other hospitals and implementation of intensive treatment measures | Reduced 20 000 cases in a month in Hubei | |
| Linka *et al*[13] | Actual effect | Travel ban | Strict border control and massive travel bans in Europe | Reduced the number of new cases to a current fraction of 10% of its all time high three weeks ago | |
| Roques *et al*[54] | Actual effect | Travel ban | Lockdown of France on March 17 | *R0* decreased from 3.2 (95% CI, 3.1–3.3) to 0.47 (95% CI, 0.45–0.50) | |

**Supplementary Table 16** Actual effect of comprehensive control measures

| Study | Actual/theoretical effect | Type of Control measures | Control measures | effect | |
|---|---|---|---|---|---|
| Tian *et al*[3] | Actual effect | Comprehensive control measures | All the measures taken in China | 96% cases were avoided in China (except Wuhan) | |
| Zu *et al*[32] | Actual effect | Comprehensive control measures | All the measures taken in China | 58 613 197 (99.85%) cases were avoided in mainland China | |
| Wang *et al*[47] | Actual effect | Comprehensive control measures | Control measures taken in Wuhan | $R_t$ decrease from 3.1 to 0.5 in Wuhan | |
| Gatto *et al*[20] | Actual effect | Comprehensive control measures | All the measures taken in Italy | 226 000 averted cases (95% CI, 172 000, 347 000), as of March 25, 2020. | 649 000 averted cases (95% CI, 481 000, 1 010 000) in total |
| Dehning *et al*[50] | Actual effect | Comprehensive control measures | 3 strategies in Germany | Transmission rate decrease from 0.43 (0.32,0.51) to 0.09 (0.06, 0.13) | |
| Wirawan *et al*[56] | Actual effect | Comprehensive control measures | Control measures taken in Bali, Indonesia | a 30% reduction in transmission from cases of mild infections. | |
| Childs *et al*[27] | Actual effect | Comprehensive control measures | Control measures taken in Santa Clara County, California | *R0* decreased from 2.88 (2.47, 3.45) to 0.98 (0.85 – 1.11) | |

***Supplementary Table 17*** **Actual effect of comprehensive control measures**

| Study | Actual/theoretical effect | Control measures |
|---|---|---|
| Ngonghala *et al*[37] | Theoretical effect | Social distance strategies taken in New York and entire US |
| Weitz *et al*[25] | Theoretical effect | Modeling Shield Immunity |
| Zhou *et al*[26] | Theoretical effect | media reports |
| Kennedy *et al*[38] | Theoretical effect | The stepping-down opening strategy |
| Chowdhury *et al*[43] | Theoretical effect | Dynamic non-pharmacological interventions with intervals of relaxed social distancing |
| Eikenberry *et al*[41] | Theoretical effect | Face mask |
| Tang *et al*[42] | Theoretical effect | De-Escalation opening strategy |
| Morozova *et al*[17] | Theoretical effect | phased lifting of social distancing restrictions in Connecticut, the United States |
| Tsay *et al*[31] | Theoretical effect | Optimal control policy in the United States |

Short-term predictions provided the evidence policymakers may need in the short term to allocate resources or plan interventions[89]. Considering the floating population, Steven Sanche[9] developed a modified SEIR model based on confirmed cases in Wuhan up to January 26, and, without any control measures, the confirmed cases will reach 233 400 (95% CI, 38 757–778 278) on January 31, while the number of actual confirmed cases in Wuhan is 3215[90]. The deviation is 230 185, indicating the effective of control measures. Also based on confirmed cases in Wuhan up to January 26, Wu *et al*[11] modified SEIR model with a floating parameter and predicted 75 815 (95% CI, 37 304 –130 330) individuals infected on January 25 in Wuhan, compared with 1287 reported. The deviation is 74 528.

Deviations between predictions studies based on data after January and actual data made were much lower, ranging from 1337 to 25 098. Besides, 95% confidence intervals were also much narrower. Wang *et al*[47] used a basic SEIR model with 4 stages of control measures in Wuhan, and they predicted the numbers of cases on February 19 and February 23 are 55 869–81 393 and 58 077–84 520 (actually 44 412 and 46 201), the deviations of which were 24 219 and 25 098. Wan *et al*[18] developed a modified SEIR model, considering infectiousness of the incubation period, and predicted the number of cases on February 19 is 47 000, while the actual number on February 19 is 44 412. Based on the traditional SEIR model, Liu *et al*[21] developed a Delay Differential Epidemic Analyzer ($D^2EA$) model innovatively introduces a set of quarantine states and applies both ordinary differential equations and delay differential equations to describe the transition between two states. They predicted in Hubei province the accumulated infected cases will reach its end around February 29, increasing to around 65 000, compared with 66 337 reported. Yang *et al*[10] modified the SEIR model with floating population, and predicted the peak size of China will be 59 764 (95% CI, 51 979–70 172) on February 28 (78 824 reported actually), and with current prevention and control measures, the peak size of Hubei will reach 42 792 (95% CI, 30 149–52 941) on February 20, while 62 031 cases were reported on February 20.

Two predictions of Italy show two widely different results and deviations. Fanelli and Piazza[59] predicted 26 000 confirmed cases on March 21, while 53 578 reported, and Gatto *et al*[20] estimated 733 000 cases on March 25, but actually only 74 386 were reported.

Deviations of long-term prediction show more changeful results, ranging from 177 to 1 690 459. 3 studies predicted the final size of Wuhan, ranging from 45 000 to 163 350, while 1 predicted that of Hubei and 3 predicted the final size of China, ranging from 80 043 to 122 122. Under the intervention before 22 January 2020, Tang *et al*[36] predicted the cases of Wuhan on March 10 will reach 163 000, compared with actually 49 965. Yang *et al*[10] predicted final size of confirmed cases in China will reach 122 122 (95% CI, 89 741–156 794), while 84 638 reported on June 9, and the final size in Hubei province will reach 59 578 (95% CI, 39 189–66 591) in late April, while accumulated confirmed cases in Hubei province reach 68 128 and have few increases after April 18. A SEIR+CAQ model developed by Wei *et al*[19], including quarantine compartment and different severity stages of COVID-19, predicted the confirmed cases in China will be 80 417 (79 251 reported) on February 29 with current intervention and control. A modified SEIR model with a parameter of control measures was developed by Zhao *et al*[48] and, using data of Wuhan's daily cases up to February 6, they predicted the final size of accumulated cases reach 163 350 in Wuhan, compared with 50 333 reported on

May 6. And other 2 studies predicted the final size of Wuhan reach 45 000[12] and 69 957[22], using data up to February 10 and March 30. For predictions of entire China, Huang *et al*[49] and *Liu et al*[1] predicted final size will reach 103 321 and 80 043, while the cumulative cases of China reach 84 570 on June 9.

For regions outside China, Kim *et al*[45] predicted the final size of cases in Republic of Korea will reach 13 800, compared with 11 468 cases confirmed on June 9. Based on data of confirmed cases up to April 27 in India, Mandal *et al*[46] predicted, on May 31, cumulative confirmed cases will reach 83 958 in Maharashtra, 19 667 in Delhi, and 5133 in Tamil Nadu (67 655, 19 844 and 22 333 actually). Focused on the United States, Peirlinck *et al*[15] predicted without massive political mitigation strategies the cases on May 10 will reach 300 million, while actually 1 309 541 cases on May 10.

Four published studies have predicted the peak date in Wuhan, from January 29 to March 5. A study[47] based on data up to February 17 predicted the peak date is February 19 or February 23. And another study, considering infectiousness of the incubation period, also predicted the peak date is February 19[47]. The study[19] which had the lowest deviation in short-term prediction predicted the peak date of Wuhan was February 9. Based on a modified SEIR model adding a temperature parameter to calculate transmission rate, Shi *et al*[44] predicted the peak date of Wuhan is March 5.

Two studies have predicted the peak date of Hubei province. A study using confirmed cases of Hubei up to February 24 developed a SEIR model modified with quarantine and reported that the epidemic in Hubei had reached the peak on February 19. Based on data up to February 9, Yang *et al*[10] predicted the peak date would be February 20 in Hubei and February 29 in entire China. According to actual data in China, the epidemic had reached its peak before February 14[90–92]. Besides, Peirlinck *et al*[15] predicted the epidemic of the United States would reach its peak on May 10, while there is no evidence to suggest that the epidemic had reached the peak till June 24.

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