April 2, 2020 Modeling Report

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EPIDEMIC SIZE ESTIMATE

Author	Location	Most likely value	Plausible Range	Pub / *Estimate* Date
Milan Batista	China	81,000		Mar 16
Milan Batista	South Korea	7,900		Mar 16
Tuite et al.	Italy	3,971	(95% CI: 2,907-5,297)	Mar 6
Tuite et al.	Iran	18,300	(95% CI: 3770 – 53,470)	Feb 25
Zhuang et al.	Iran	16,533	(95% CI: 5,925 - 35,538)	*Feb 25*
Lai et al.	China	114,325	(IQR: 76,776 - 164,576)	*Feb 29*
Perkins et al.	United States	22,876	(95% PPI: 7,451 - 53,044)	*Mar 12*
Yang et al.	South Korea		8,000 – 10,800	Mar 10 / *Mar 30*
Yang et al.	Italy		18,000 – 23,000	Mar 10 / *Mar 30*
Yang et al.	Iran		9,500 – 13,500	Mar 10 / *Mar 30*
Wu et al.	Japan	1,574	95% CI: 880 - 2,372	Mar 10 / *Mar 25*
Wu et al.	South Korea	7,928	95% CI: 6,341 – 9,754	Mar 10 / *Mar 30*
Wu et al.	Iran	10,804	95% CI: 8,202 - 15,060	Mar 10 / *Mar 30*
Wu et al.	Italy	59,199	95% CI: 16,796 - 107,097	Mar 10 / *Mar 25*
Wu et al.	Europe	275,451	95% CI: 178,462-545,917	Mar 10 / *Mar 25*
Filho et al.	Brazil	38,583	(IQR: 16,698 – 113,163)	Mar 17 / *1st 30 days*
Li et al.	Iran	20,000		Mar 17 / *Mar 31*
Li et al.	Italy	84,000		Mar 17 / *Mar 31*
Livio Feng	Italy	105,789		Mar 17 / *Mar 12*
Wangping	Italy	30,086	(95% CrI: 7,920 - 81,869)	Mar 20 / *Apr 25*
Caccavo	China	50,000	Peak	Mar 21 / *Feb 18*
Caccavo	Italy	42,000	Peak	Mar 21 / *Mar 28*
Raheem	Italy	26,000		Mar 21 / *Feb 24*
Zareie	Iran	27,752		Mar 23 / *Apr 10*
Scarabel	Canada	14,000		Mar 23 / *Mar 31*
Yadlowsky	Santa Clara, CA	6,500	(1,400 – 26,00)	*Mar 17*
Lourenco	UK & Italy	68% of population		Mar 26 / *Mar 19*
Li & Guo	US	300,000		Mar 26 / *Early April*
Ghaffarzadegan	Iran	1.6 million	(0.9 M – 2.6 M)	Mar 26 / *Overall*
Liebig	Australia	11,908		Mar 25 / *April 1*

EVIDENCE OF PRE-SYMPTOMATIC TRANSMISSION

Author	Estimates & Evidence
Xia et al.	73% of secondary cases were infected before symptom onset of first-gen cases
Peak et al.	Infectiousness 0.51 (short SI) or 0.77 (long SI) days before symptom onset
He et al.	Infectiousness 2.5 days before symptom onset with peak at 0.6 days before onset
Du et al.	12% of onward transmission likely pre-symptomatic
Tapiwa et al.	In Singapore: 48% (32-67%) of infections prior to onset
Tapiwa et al.	In Tianjin, China: 62% (50-76%) of infections prior to onset
Pan et al.	Viral shedding was high at and right after onset
Young et al.	Viral shedding is highest early post-onset

Cheng	Infectiousness highest at onset – high likelihood of infectiousness before onset
Ferreti et al.	1/3 – 1/2 of transmissions occur from pre-symptomatic individuals & Total contribution to R0 from pre-symptomatic individuals is 0.9 (CI: 0.2-1.1)
Wycliffe et al. (new)	6.4% of Singapore's locally acquired cases (157) were attributed to pre-symptomatic transmission

ASYMPTOMATIC RATIO OR PERCENT

Author	Most likely value	Notes
Mizumoto et al.	0.35 (95% CrI: 0.30–0.39)	Diamond Princess - True ratio Feb 5-20
Mizumoto et al.	17.9% (95% CrI: 15.5%–20.2%)	Diamond Princess – Estimated Feb 5-20

ONSET TO FIRST MEDICAL VISIT

Author	Most likely value	Notes
Li et al.	5.8 (95% CI, 4.3 to 7.5)	Onset pre-Jan 1 2020
Li et al.	4.6 (95% CI, 4.1 to 5.1)	Onset Jan 1-11 2020
Henry et al.	1 [IQR: 0-3.3] days	Pediatric: 5-15

ONSET TO DIAGNOSIS

Author	Most likely value	Notes
Dong et al.	2 days (0-42 days)	Pediatric: Age IQR 2-13, in China
Li et al.	6.6 (6.5-6.8) days	

ONSET TO HOSPITALIZATION

Author	Most likely value	Notes
Linton	3-4 days, 5-9 with right-censor	
Li et al.	12.5 days (95% CI, 10.3 to 14.8)	Onset pre-Jan 1 2020
Li et al.	9.1 days (95% CI, 8.6 to 9.7)	Onset Jan 1-11 2020
Lauer	1.2 days (range: 0.2 to 29.9)	
Wang	7.0 (range 4–8 days)	
Lu et al.	5.5 days	5.1 – 5.9
Zhang et al.	7.0 days	(IQR: 4.0-10.0)

ONSET TO ICU ADMISSION

Author	Most likely value
Zhang et al.	10.0 days (IQR, 7-13)

ONSET TO DEATH

Author	Most likely value
Linton	13 days, 17 with right-censoring
Deng et al.	12.9 days (95% CI: 2.2 to 40.2)

ONSET TO RECOVERY

Author	Most likely value
Lai et al.	7.3 days [4.7 – 16.5]
Yang et al. – onset to discharge	18.57 (95% CI: 16.07-21.08) days
Bi et al. – Shenzhen	32 days [31,33] – 50-59 y.o.a.
Bi et al. – Shenzhen	27 days - 20-29 year olds
Deng et al.– onset to discharge	16.9 days (95% CI: 8.6 to 28.9)

April 2, 2020 Modeling Report

FRACTION/PERCENT OF INFECTED TRAVELLERS - DETECTED

Author	Most likely value	Plausible range
Gostic et al.	0.31	95%: 0.17-0.48
Niehus et al.	38%	95% Interval: 22% - 64%

PERCENT OF INFECTED NOT DETECTED (estimated inverse of the above)

Author	Population/Location	Most likely value	Plausible range
Quilty et al.	Travelers	46%	95%CI: 36 - 58
Bhatia et al.	Travelers		63-73%
Tuite et al.	Italy	72%	(61-79%)

PERCENT DETECTION / ASCERTAINMENT / CONFIRMATION

Author	Location	Most likely value	Plausible range
Du et al.	China	8.95%, by Jan 22 2020	95% CrI: 2.22% - 28.72%
Li & Shaman et al.	China	14%, before Jan 23 2020	
Can Zhou	Wuhan	23.37%	95% CrI: 18.72% - 29.26%
Chinazzi et al.	China	24.4%	IQR: 12.7% - 35.8%
Wang et al.	Wuhan	41%	
Omori et al.	Japan	0.44 – among non-severe cases	95% CI: 0.37 - 0.50
Zhao et al.	China	0.0643: Jan 20-Feb 21	
Lin et al.	Wuhan	29.74% on February 9, 2020	95% CI: 28.92% - 30.60%
Raheem et al.	Italy	0.5% by Feb 24, 2020	
Siwiak	Global	0.6	Overall
Siwiak	Global	0.001 - diagnosis with mild symptoms/asymptomatic	
Lytras et al.	Wuhan	0.465%	(95% CrI 0.464–0.466%)
Menkir et al.		For 1 Wuhan-exported cases, 2.9 cases undetected exported from other Chinese cities	
Zhan et al.	US	2% - by March 19, 2020	
Zhan et al.	Japan	5% - by March 19, 2020	

REPRODUCTIVE NUMBER

(R0 – Basic, Reff – Effective). Any Chinese estimates published before Feb 9, 2020 are in the Appendix.
There are two types of reproductive numbers described, the basic reproduction number (R0) and the effective reproduction number (Re). R0 describes how many people on average are infected by one infected person in a completely susceptible population in the absence of any interventions. Reff (or Re/Rt) is an indicator of real-time transmissibility that also reflects factors that can enhance or limit transmission (seasonality, exposure variation, mixing heterogeneity, susceptibility, clinical severity, etc.). For more information, please see https://wwwnc.cdc.gov/eid/article/25/1/17-1901_article)

Author	Location	Time Period	Most likely value	Plausible range
Majumder et al.	(avg pre-print)	Pre-Feb 1	R0: 3.61	95%CI: 2.77 - 4.45
Majumder et al.	(avg peer-review)	Pre-Feb 1	R0: 2.54	95%CI: 2.17 - 2.91
Park et al.	(pooled)	Pre-Feb 28	R0: 2.9	95% CI: 2.1–4.5
Mizumoto et al.	Diamond Princess	Feb 7	Rt: 11.2	95%CrI: 7.5-16.2

Wan et al.	Wuhan	Jan 22-Feb 12	R0: 1.44	IQR: 1.40-1.47
Anastassopoulou et al	Hubei	Nov 16 – Feb 10	R0: 2.4	
Sun et al.	Non-Hubei	Jan 27	R0: 6.42	
Sun et al.	Hubei	Jan 27	R0: 7.67	
Sun et al.	Non-Hubei	Feb 3	R0: 2.39	
Sun et al.	Hubei	Feb 3	R0: 2.94	
Sun et al.	Non-Hubei	Feb 10	R0: 0.77	
Sun et al.	Hubei	Feb 10	R0: 1.01	
Li et al.	Wuhan	Pre-Jan 23	R0: 4.38	95% CI: 3.63 – 5.13
Li et al.	Wuhan	Jan 23-Feb 8	R0: 3.41	95% CI 3.16 – 3.65
Shao et al.	China	Pre-Feb 16	R0: 3.25 – 3.4	
Pan et al.	Wuhan	Pre-Jan 23	R0: 5.75	
Pan et al.	Wuhan	Jan 23-Feb 16	Reff: 1.69	
Pan et al.	Non-Wuhan, China	Pre-Jan 23	R0: 6.22	
Pan et al.	Non-Wuhan, China	Jan 23-Feb 16	Reff: 1.67	
Tariq et al.	Singapore	Jan 30-Mar5	Reff: 0.7	95% CI: 0.5, 1.0
Tariq et al.	Singapore	Mar 5	Rt: 0.9	95% CI: 0.7, 1.0
Zhang et al.	Diamond Princess	Pre-Feb 17	R0: 2.28	95% CI: 2.06-2.52
Shim et al.	South Korea	Jan 20-Feb 26	Rt: 1.5	95% CI: 1.4-1.6
Tian Hao	China	Jan 21-Feb 17	R0: 1.5 or 3.5	
Tang et al.	Xi'an, China	Jan 23-Feb 14	Reff	Range: 1.48-1.69
Xu et al.	Wenzhou	Pre-Feb 10	R0: 2.91	95% CI: 2.35-3.57
Xu et al.	Shenzhen	Pre-Feb 10	R0: 2.53	95% CI: 1.86 to 3.34
Xu et al.	Zhengzhou	Pre-Feb 10	R0: 5.95	95% CI: 5.36 to 6.67
Xu et al.	Harbin	Pre-Feb 10	R0: 3.35	95% CI: 3.07 to 3.68
Zhao et al.	Diamond Princess	Pre-Feb 20	R0: 2.2	95% CI: 2.1–2.4
Wang et al.	Hubei	Jan 13-Feb 12	R0: 2.96	95% CI: 1.82, 4.49
Wang et al.	outside Hubei	Jan 23-Feb 12	R0: 2.58	95% CI: 1.52, 4.26
Bi et al.	Shenzhen	Jan 14-Feb 12	Robs: 0.4	Range: 0.3,0.5
Chen et al.	Hubei	Feb 2	Rt: 0.0491	
Zhuang et al.	South Korea	Jan 20-Mar 5	R0: 2.6	95% CI: 2.3-2.9
Zhuang et al.	South Korea	Jan 20-Mar 5	R0: 3.2	95% CI: 2.9-3.5
Wang et al.	Wuhan	Dec – Jan 23	Reff: 3.86	95% CI: 3.74-3.91
Wang et al.	Wuhan	Jan 23-Feb 18	Reff: 0.32	95% CI: 0.28-0.37
Zhuang et al.	Italy	Jan 20-Mar 5	R0: 2.6	95% CI: 2.3-2.9
Zhuang et al.	Italy	Jan 20-Mar 5	R0: 3.3	95% CI: 3.0-3.6
Hong et al.	Beijing	Jan 24-Feb 23	R0: 3.11	
Hong et al.	Shanghai	Jan 24-Feb 23	R0: 2.78	
Hong et al.	Guangzhou	Jan 24-Feb 23	R0: 2.02	
Hong et al.	Shenzen	Jan 24-Feb 23	R0: 1.75	
Muniz-Rodriguez et al.	Iran	Feb 19-29	R0: 3.6 R0: 3.58	95% CI: 3.2 - 4.2 95% CI: 1.29 - 8.46
Wang & Qi	Non-Hubei, China	Jan 20-Mar 9	R0: 2.82	95% CI: 2.71, 2.93
Tang et al.	China	Jan 23-Mar 7	R0: 2.6	95% CI: 2.5, 2.7
Tang et al.	Guangdong	Jan 23-Mar 7	R0: 3.0	95% CI: 2.6, 3.3
Tang et al.	South Korea	Jan 23-Mar 7	R0: 3.8	95% CI: 3.5, 4.2
Abbott et al.	Italy	March 11	Reff: 1.2 – 2.3	

Abbott et al.	Iran	March 11	Reff: 1 – 1.7	
Abbott et al.	France	March 11	Reff: 1.5 – 3.7	
Abbott et al.	Spain	March 11	Reff: 1.9 – 5.6	
Abbott et al.	US	March 11	Reff: 1.9 – 5.9	
Abbott et al.	South Korea	March 11	Reff: 0.6 – 1.2	
Abbott et al.	Germany	March 11	Reff: 1.1 – 2.3	
Sugishita et al.	Japan	Jan 14-Mar 8	R0: 2.50	(95% CI: 2.43 – 2.55)
Sugishita et al.	Japan	Jan 14-Mar 8	Reff: 1.88	(95% CI: 1.68 - 2.02)
Rocklov et al.	Diamond Princess	Pre-Feb 4	R0: 14.8	
Volz et al.	Weifang City	Pre-Feb 10	R: 2.6	(95% CI:1.5-5)
Wangping et al.	Italy	Jan 22-Mar 16	R0: 4.10	(95% CrI: 2.15–6.77)
Wangping et al.	Hunan, China	Jan 22-Mar 16	R0: 3.15	(95% CrI: 1.71–5.21)
Russo et al.	Lombardy, Italy	Feb 21-Mar 8	R0: 4.04	(90% CI: 4.03-4.05)
Alizon et al.	France	Jan 21-Mar 16	R0: 2.49	95% CI: 2.39, 2.58
Bandoy et al.	Spain	Mar 1, 2020	Rt: 3.7, 10.8	(SI: 2, 7 days)
Bandoy et al.	Thailand	Mar 1, 2020	Rt: 3.8, 1.7	(SI: 2, 7 days)
Bandoy et al.	France	Mar 1, 2020	Rt: 2.9, 16.9	(SI: 2, 7 days)
Bandoy et al.	Germany	Mar 1, 2020	Rt: 3.1, 17.2	(SI: 2, 7 days)
Bandoy et al.	Kuwait	Mar 1, 2020	Rt: 2.6, 15.3	(SI: 2, 7 days)
Bandoy et al.	Italy	Mar 1, 2020	Rt: 8, 57	(SI: 2, 7 days)
Bandoy et al.	United States	Mar 1, 2020	Rt: 4.3, 1.7	(SI: 2, 7 days)
Bandoy et al.	Iran	Mar 1, 2020	Rt: 2.8, 17.1	(SI: 2, 7 days)
Stier et al.	New York-Newark-Jersey	Mar 23, 2020	R: ~7.5	
Stier et al.	Seattle-Tacoma-Bellevue	Mar 23, 2020	R: ~5.9	
Stier et al.	San Francisco-Oakland-Berkeley	Mar 23, 2020	R: ~5	
Stier et al.	Atlanta – Sandy Springs-Alpharetta	Mar 23, 2020	R: ~4.8	
Stier et al.	Oklahoma City	Mar 23, 2020	R: ~3.8	
Stier et al.	Valdosta, GA	Mar 23, 2020	R: ~0.92	
Bui et al.	Vietnam	Jan 17-Feb 11	Rt: 1.14	(95% CI: 0.7 – 1.89)
Bui et al.	Vietnam	Mar 6-Mar 24	Rt: 1.55	(95%CI: 1.29-1.87)
Bui et al.	Vietnam	Jan 17-Mar 24	Reff: 1.46	(95% CI: 1.17-1.75)

SERIAL INTERVAL/GENERATION TIME

Author	Most likely value	Plausible range
Li et al.	7.5 days	(95% CI, 5.3 to 19)
You et al.	4.41 days (SD: 3.17 days)	
Nishiura et al.	4.0 days (median)	(95% CrI: 3.1, 4.9) - 28 pairs
Nishiura et al.	4.6 days (median	(95% CrI: 3.5, 5.9) - 18 pairs
Du et al.	3.96 days, (SD: 4.75 days)	95% CI: 3.53-4.39, (SD 95% CI: 4.46-5.07)_
Juanjuan Zhang et al.	5.1 days	[1.3 – 11.6]
Li et al.	3.3 days	(2.3-4.3)
Bi et al.	6.3 days, Shenzhen	[5.2,7.6]
Tindale et al.	4.56 days for Singapore	(95% CI: 2.69, 6.42)
Tindale et al.	4.22 days for Tianjin	(95% CI: 3.43, 5.01)

Ping et al.	6.37 days in Guizhou	±4.15 days
Xu et al.	5.9 days [S.D: 4.80]	
Tapiwa et al.	5.20 days	(95%CI 3.78-6.78)
Tapiwa et al.	3.95 days	(95%CI 3.01-4.91)
Xia et al.	4.1 days (SD: 3.3)	
Wang & Teunis	4.8 days (mean) for Tiajin	Shape: 3.16, Scale: 1.52 (Gamma Distribution)
He et al.	5.8 days	(95% CI: 4.8-6.8)
Cheng	5.4 days - Overall	(95% CrI 4.1–7.2 days)
Cheng	5.57 – mainland China	(95% CrI: 4.2,7.51)
Cheng	7 – Taiwan	(95%CrI: 3.69-13.18)

INFECTIOUS PERIOD

Author	Most likely value	Plausible range
You et al.	10.91 days (SD: 3.95 days)	
Peak et al.	2.4 days – if SI=4.8	[95%CI: 1,6.7]
Peak et al.	4.8 days – if SI=7.5	[95%CI: 1.12,10.5]

INCUBATION PERIOD / LATENT PERIOD

Author	Location	Most likely value	Plausible range	Extreme Values
Liu et al.	China	4.8 (±2.6) days	Range: 1–14	
Backer et al.	Wuhan Travelers	6.4	95% CI: 5.6-7.7	97.5% show symptoms within 11.1 days
Linton	Global	5	Range: 2-14	
Zheng	Non-Hubei	5.174	(CI: 4.46-6.037)	97.5% show symptoms within 11.5 days
Li et al.	China	5.2	95% CI: 4.1 to 7.0	95% show symptoms within 12.5 days
Lauer	Non-Wuhan	5.1 (mean: 5.5)	95% CI: 4.5-5.8	97.5% show symptoms within 11.5 days
Guan	China	3	Range: 0–24	
Yang Yang et al.	China	4.8	IQR: 3.0-7.2	*Authors withdrew this
Char Leung	Hubei Travelers	1.8	(1.0, 2.7)	95% show symptoms within 14.5 days
Char Leung	Hubei non-travelers	6.9	(5.5, 8.3)	95% show symptoms within 3.2 days
Jiang et al.		4.9	95% CI: 4.4-5.5	
Zhang et al.	Non-Hubei, China	5.2	[1.8-12.4]	95% show symptoms within 10.5 days
Lu et al.	Shanghai	6.4	5.3 – 7.6	95% show symptoms within 13.1 days
Wang et al.	Henan province	7.43	95% CI: 2, 20	95% show symptoms within 14 days
Men et al.	Non-Hubei, China	5.84 (median: 5)	1-15	97.5% show symptoms within 12.89 days
Li et al.	Non-Hubei, China	7.2	(6.8 – 7.6)	
Yang et al.	Beijing	8.42 – mean	95% CI: 6.55-10.29	
Bi et al.	Shenzhen	4.8 - median	95% CI: 4.2, 5.4	95% show symptoms within 14 days

Tindale et al.	Singapore	7.1 – mean Pre-Jan 31: 5.71 Post-Jan 31: 7.86	95% CI: (6.13, 8.25) (4.55, 7.06) (6.57, 9.38)	97.5% show symptoms within 11.1 (pre-Jan 31) & 17.3 (post-Jan 31) days
Tindale et al.	Tianjin	9 – mean Pre-Jan 31: 7 Post-Jan 31: 12.4	95% CI: (7.92, 10.2) (6.1, 8.0) (10.8, 14.2)	97.5% show symptoms within 12.7 (pre-Jan 31) & 19 (post-Jan 31) days
Ping et al.	Guizhou province, China	8.06	95% CI: 6.89 – 9.36	95% show symptoms within 21.9 days
Qiu et al.	NonWuhan, China	6 - median	Range: 1-32	
Zhou et al.	Wuhan	5.9		
Xia et al.	China	4.9	95% CI: 4.4-5.4	97.5% show symptoms within 13 days
Qin et al.	China	8.13 – median	95% CI: 7.37-8.91	90% show symptoms within 14.65 days
Siwiak	Global	1.1		**non-infectious incubation**
Siwiak	Global	4.6		**infectious incubation**
Cheng	Taiwan	4.91 - mean	95%CrI: 2.72-8.43	
Cheng	Overall	5.45 - mean	95%CrI: 4.71-6.31	

CASE HOSPITALIZATION RATIO

Author	Location	Most likely value	Plausible range	Pub Date
Verity et al.	Mainland China	0-9: 0% 10-19: 0.04% 20-29: 1.1% 30-39: 3.4% 40-49: 4.3% 50-59: 8.2% 60-69: 11.8% 70-79: 16.6% 80+: 18.4%	0-9: 95% CrI (0,0) 10-19: (0.02,0.08) 20-29: (0.62,2.1) 30-39: (2.1,7.0) 40-49: (2.5,8.7) 50-59: (4.9,16.7) 60-69: (7.0,24.0) 70-79: (9.9,33.8) 80+: (11.0,37.6)	February 25

HOSPITAL TO ICU RATIO

Author	Location	Most likely value	Plausible range	Date
Cai et al.	Shenzhen	14%		Jan 11-Feb 6
Cao et al.	Shanghai	9.5%		Jan 20-Feb 15
Fang et al.	China, USA, Germany, South Korea, Vietnam, Nepal, Thailand, Singapore, Canada & Italy	11.5%		Meta-analysis preprint published March 12
Wang et al.	Wuhan, China	26.1%		Jan 1 – Feb 3
Lu et al.	Shanghai, China	8.3%		Jan 6 – Feb 19
Zhang et. al.	Wuhan, China	19.9%		Jan 2-Feb 10
Yang et. al.	Beijing, China	25.5%		Dec 27-Feb 18

DEATH TO HOSPITALIZATION RATIO

Author		Most likely value	Plausible range	
Fang et al.	China, USA, Germany, South Korea, Vietnam,	3.7%		Meta-analysis preprint

	Nepal, Thailand, Singapore, Canada & Italy			published March 12
Wang et al.	Wuhan, China	4.3%		Jan 1 – Feb 3
Lu et al.	Shanghai, China	0.3% (1/265)		Jan 6 – Feb 19
Zhang et. al.	Wuhan, China	5.4% (12/221)		Jan 2-Feb 10

CASE FATALITY RATIO

Author	Most likely value	Location	Pub Date or Time Period	Case type (asymptomatic?)
Jung et al.	5.3% (95% CI: 3.5%–7.5%)	China	Pre-Jan 25	Symptomatic only
Jung et al.	8.4% (95% CI: 5.3%–12.3%)	China	Pre-Jan 25	Symptomatic only
Imai et al.	1%	overall	Feb 10, 2020	asymptomatic also
Imai et al.	1%-5%	Mainland China	Feb 10, 2020	asymptomatic also
Imai et al.	18%	Hubei	Feb 10, 2020	asymptomatic also
Wu & McGoogan	2.3%	China	Feb 11	Symptomatic only
Wu & McGoogan	14.8% in patients aged ≥80 years	China	Feb 11	Symptomatic only
Wu & McGoogan	8.0% in patients aged 70-79 years	China	Feb 11	Symptomatic only
Atlhaus et al.	1.6% (95% CI: 0.4%-4.1%)	Outside China	Feb 21, 2020	Reported only
Liu et al.	2.8%	Hubei	Feb 13, 2020	Reported only
Liu et al.	0.24%	Non-Hubei China	Feb 13, 2020	Reported only
Cao et al.	6.50%	Wuhan	Feb 9, 2020	
Diao et al.	>10%	Wuhan	Feb 20, 2020	Reported only
Diao et al.	7%	China	Feb 20, 2020	Reported only
Zhang et al.	1.52% -6.64%	Wuhan	Feb 17, 2020	Reported only
Zhang et al.	0%-2.4%	China	Feb 17, 2020	Reported Only
Wang et al.	70.9% (95% CI: 66.8%-75.6%)	Hubei	Jan 20 – Feb 2	Reported only
Wang et al.	20.2% (18.6%-22.1%)	Hubei	Feb 3 – 14	Reported only
Wang et al.	6.9% (6.4%-7.4%)	Hubei	Feb 15 – 23	Reported only
Wang et al.	1.5% (1.4%-1.6%)	Hubei	Feb 24 – Mar 1	Reported only
Wang et al.	20.3% (17.0%-25.3%)	Non-Hubei, China	Jan 20 – 28	Reported only
Wang et al.	1.9% (1.8%-2.1%)	Non-Hubei, China	Jan 29 – Feb 12	Reported only
Wang et al.	0.9% (0.8%-1.1%)	Non-Hubei, China	Feb 13 – 18	Reported only
Wang et al.	0.4% (0.4%-0.5%)	Non-Hubei, China	Feb 19 – Mar 1	Reported only
Mizumoto et al.	0.04% (95% CrI: 0.03-0.06%) 0.12% (95%CrI: 0.08-0.17%)	Wuhan	Jan – Mar 10	Asymptomatic and symptomatic
Mizumoto et al.	1.3% (95% CI: 1.1-1.6%) 6.1% (95%CrI: 5.2-7.1%)	Non-Wuhan, Hubei	Jan – Feb 7	Reported only
Mizumoto et al.	0.27% (95%CI: 0.2-0.4%) 0.9% (95%CrI: 0.6-1.3%)	Non-Hubei, China	Jan – Feb 7	Reported only
Wilson et al.	1.37% (95%CI: 0.57%-3.22%)	Outside China	Feb 18, 2020	Reported only
Sun et al.	4.3%	Meta-analysis	Feb 25, 2020	
Deng et al.	4.52% (95% CI: 4.47-4.67%)	Mainland China	Dec 29-Feb 23	Reported only
Deng et al.	6.19% (95% CI: 6.12-6.41%)	Wuhan	Dec 29-Feb 23	Reported only
Deng et al.	0.89% (95% CI: 0.83-1.06%)	Non-Hubei, China	Dec 29-Feb 23	Reported only
Deng et al.	1.24% (95% CI: 1.24% to 1.24%)	China	Dec 29-Feb 23	Reported only
Deng et al.	11.21% (95% CI: 11.21 to 11.21%)	China	Dec 29-Feb 23	Reported only

Riou et al.	Overall: 1.6% (95% CrI: 1.4-1.8) 0-9: 0.0094% (95% CrI: 0-0.058) 10-19: 0.022% (95% CrI: 0-0.082) 20-29: 0.091% (95% CrI: 0.03-0.2) 30-39: 0.18% (95% CrI: 0.096-0.3) 40-49: 0.18% (95% CrI: 0.096-0.3) 50-59: 1.3% (95% CrI: 1-1.6) 60-69: 4.6% (95% CrI: 3.8-5.4) 70-79: 9.8% (95% CrI: 8.2-12) 80+: 18% (95% CrI: 14-22)	Hubei	Jan 1-Feb 11	Both symptomatic and asymptomatic infections
Li et al.	Overall: 2.38% 0-40 years old: < 1% 90 and over: > 51%	Non-Hubei, China	Mar 6	Reported only
Russell et al.	All ages: 0.91% (0.1%1-4.3%) 70+: 7.3% (3%-14%)	Diamond Princess	Through March 3	Both asymptomatic and symptomatic
Verity et al.	CFR: 1.38% (95% crI 1.23%-1.53%) IFR: 0.66% (95% crI 0.39%-1.33%)	China Worldwide	Through Feb 11 Through Feb 25	Symptomatic Asymptomatic also
Dehkordi et al.	CFR: 7.9% 0.76% 3.8% 4.4% 2% 7% 3.5% 0.25% (still too early to tell) 14% (still too early to tell)	Italy South Korea China Iran Japan Spain France Germany USA	Through March 12	Reported only
Bhabavathula et al.	Crude CFR: 7.7% 5.7% 4.2%	Italy Iran China	January through March	Reported cases only
Dudel et al. ()	0.7% 1.2% 1.7% 1.6% 2.3% 4.0% 10.6%	Germany US (NYC) US Overall South Korea China France Italy	January through March	Reported cases only

ESTIMATED EFFECT OF INTERVENTIONS

Author	Intervention	Results
Anzai et al.	Jan 23 travel reductions	226 exported cases prevented (95% CI: 86, 449) - 70.4 reduction
Shao & Shan	Isolation, treatment, and travel reduction	Chinese measures are preventing illness & exposed individuals need to be included in treatment and quarantine
Liu at al.	Jan 23 Travel Reductions	Without restrictions, 20 times the number of reported cases
Boldog et al.	Jan 23 Travel Restrictions	Control in China reduces likelihood of transmission elsewhere
Chowell et al.	Vaccination	Coverage of 80% is required to end the epidemic in 6 months
Ai et al.	Travel Restrictions	If implemented 2 days earlier: 1420 (1833, 1059) prevented
Chen	Jan 23 Travel Restrictions	Waiting 2 more days for restrictions: doubles epidemic

Liu & Li	Jan 23 Travel Restrictions	Waiting 1 more day: number of infections on Jan 25 would have been 1800 more than It was
Zhu et al.	SARS-like intervention	Cases reduced 70-fold, if reopen then cases reduced 25-fold
Hossain et al.	Jan 23 Travel Restrictions	Reducing travel by 90% delayed spread from Wuhan to Beijing by 10 days (if low R0, delays spread by more than a month)
Ryu et al.	Home quarantine	Quarantine can dampen outbreaks in South Korea
Zhang et al.	Jan 23 Travel Restrictions	500 fewer new cases per 10,000 over the next 11 days
Yuan et al.	Jan 23 Travel Restrictions	If implemented 3 days earlier: reduced cases by 30.72%
Kraemer et al.	Jan 23 travel Restrictions	515 exported cases with known travel history to Wuhan with pre-Jan 31 symptom onset 39 exported cases with known travel history to Wuhan with post-Jan 31 symptom onset
Lauro et al.	Social Distancing	More effective the closer in time we are to the peak
Jiang et al.	Jan 23 Travel Restrictions	After Feb 4, imported cases have had minor role in non-Hubei case increase
Lai et al.	All interventions as of 3/10	Without any interventions, expected 67 times more cases
Wan et al.	All interventions as of 3/10	Keep contacts 30% lower through April to reduce risk of epidemic resurgence in mainland China
Zhang et al.	30 day social distancing	R0 of 2.2 (1.4, 3.9) was reduced to 1.58 (1.34, 2.07) in Wuhan and Hubei R0 of 2.52 (2.43, 2.63) was reduced to 1.65 (1.63, 1.69) in rest of mainland China
Aleta et al.	Traffic restrictions within Spain	Intra-Spain traffic restrictions does not have a significant effect on infection propagation, unless coupled with other measures
Aleta et al.	Travel restrictions in China	Reduces the number of expected infected individuals, but not as impactful without other interventions
Zhou et al.	Wuhan Travel Restrictions	Without restrictions, 7.8 mil infections in Wuhan Jan 13-Feb 29
Willem et al.	50% Teleworking	10% decrease in R0 for most countries with 50% teleworking
Hernandez et al.	Quarantine-on-alert to reduce quarantine costs	When coupled with the near-ideal early warning capability reduces quarantine needs with only a small increase cases
Peak et al.	Contact-tracing + social distancing	With active monitoring: up to 33% reduction in Reff With individual quarantine: up to 66% reduction in Reff
Hong et al.	Travel restrictions	more rigorous control will contain COVID further spread; risk increases when activities resume before epidemic end
Tian et al.	Chinese Spring Festival Travel Restrictions	Interventions delayed the growth and limited the size of the COVID-19 epidemic in China
Zhan et al.	Current Interventions in South Korea, Italy, & Iran	outbreaks in all three countries will be under control by the end of April and end before June 2020
Zhao & Hua	Current quarantine in China	R0 reduced from 1.52 to 0.58 in non-Hubei China; 5.93 to 0.61 in non-Wuhan Hubei; and 4.71 to 0.76 in Wuhan
Li et al.	Reduce transmission of unidentified cases	The number of cases in the US would be 7-10 times lower (By March 1) if transmission among unidentified cases reduces
Kretzschmar et al.	Isolation and contact tracing	Measures work to control infection when transmission is low, but still reduce epidemic growth rate, depending on timeliness
Klein et al.	25%, 50% and 75% reduction in transmission	With a 75% reduction, cases reduce by a factor of almost 25
Ferguson et al.	Isolation, school/college closure, social distancing	Population-wide social distancing will have largest impact; vaccine/antivirals necessary to dissuade rebound transmission

Constantino et al.	China-Australia travel ban	Travel ban reduces imported cases by 10-fold (minimum)
Prem et al.	Social distancing in Wuhan	Reduced number of infected by 92%
Jackson et al.	Contact-rate reductions in Seattle	contact rates reduced the by 16% to 95%, and cumulative disease (non-COVID virus) incidence reduced by 3% to 9%
Sugishita et al.	Voluntary event cancellation	R0 before VEC: 2.50 (95% CI: 2.43 – 2.55) Reff after VEC: 1.88 (1.68 - 2.02)
Teslya et al.	Self-imposed measures	If slow epidemic: peak reduced; if fast epidemic: peak delayed
Odendaal	Jan Travel Restrictions	Travel restrictions to China delayed US epidemic by 26 days
Cowling et al.	Social Distancing in HK	Rt reduced from 1.28 to 0.72 – by 44% - in Hong Kong
Hu et al.	Non-pharmaceutical interventions worldwide	Delaying interventions will increase overall deaths from 7,174 to 133,608 & delay epidemic end date from June to August
Li et al.	Italian lockdown	Without intervention: 200,000; with intervention: 84,000
Nishiura et al.	Diamond Princess Quarantine	Without intervention: 1373 + 766 = 2139 (Actual: 149)
Rocklov et al.	Diamond Princes Quarantine	Without intervention: 79% attack rate by Feb 20, 2020; With intervention: only 17% by February 20
Kochanczyk	Wuhan vs. Italy quarantine	Wuhan Jan 23 intervention moved epidemic out of exponential growth, Italy Feb 21 did not move epidemic out of exponential growth phase
Zhang et al.	New medical resources	Reduced mortality and increased recovery in Wuhan
Xiao et al.	Resuming work	In Beijing R increases 0.55 to 0.8 after people go back to work
Chong et al.	Wuhan travel restrictions	Hangzhou Rt reduces below 1.0 from Feb 7 to mid-Feb
Qiu et al.	Wuhan travel restrictions	COVID-19 spread was contained in China by early February
Handel et al.	Prioritizing interventions	Allow infections in low risk groups to reduce mortality overall
Shi et al.	Wuhan travel restrictions	approximately 19,768 cases prevented in Wuhan
Shao	Lockdown + hospital capacity increase	Lockdown alone doesn't reduce cure rate and mortality – need to layer hospital capacity increase do improve outcomes
St. Onge	Mass gatherings	Cancelling gatherings greater than n=23 stops an outbreak
Kissler et al.	Social distancing in US	Might cause a larger peak after lifted (especially if seasonal)
Drake et al.	Social distancing in Georgia, USA	Social distancing interventions will reduce the incidence – rate at which prevalence increases
Russo et al.	Lombardy, Italy interventions	if the measures continue, complete fade out of the outbreak in Lombardy is expected to occur by the end of May 2020
Xie et al.	Huo-Yan diagnostics in Hubei	Without Huo-Yan tests: Suspected cases increase by 47%; With Huo-Yan full capacity: peak reduced by at least 44%
Liu et al.	US interventions w/ 25% transmission reduction	Delay epidemic progression by up to 34 days & Reduce magnitude of peak by 39%
Teles	Government mitigation & self-protection in Portugal	Unmitigated: 40,000 at peak; severe govt. measures: 800 cases; non-severe govt. measures: 7,000 cases at peak
Alizon	Transmission control in France	In worst-case scenario: without control – 89% infected in France, with 50% control – 55% infected
Zhang et al.	Social distancing in Wuhan & Shanghai	Daily contacts reduced 7-9 fold; social distancing is sufficient to control COVID
Scarabel	Italy-like intervention in Canada	Unmitigated epidemic would be 15,000 and mitigated epidemic would be 4,000 by March 31, 2020 in Canada
Gandhi et al.	Isolation, quarantine, social distancing - Global	Each alone: reduced reproduction number by 0.4-0.5, but with all 3 together: reduced reproduction number by 1.4
Koo et al.	Quarantine, school close, workplace in Singapore	Interventions reduce all infections by 60% separately, but by at least 80% if they're combined

Alvarez et al.	Quarantine in US versus South Korea versus Italy	In US Growth rate reduced from 0.926/day to 0.308/day. South Korean growth rate started same as Italy but reduced to 0 in 2 weeks, while Italy stayed the same over 20 days.
Pei Jun Zhao	7 contacts in 5 day period	This intervention can control the US COVID epidemic
Gonzalez	Any Intervention in US	If US does not implement any new measures, will be as bad as Italy, Iran, and Spain
Zhan et al.	Personal hygiene + protective measures	In US, cumulative attack rate reduced from 18% to 2.7% In Japan, cumulative attack rate reduced from 6.55% to 0.23%
Pei & Shaman	Contact rate or cross-county mobility reduction	Contact rate reduction will reduce + delay the peak, cross-county mobility reduction will only reduce the peak
Fang et al.	Wuhan restrictions	64.81% more cases in non-Hubei China, 52.64% in non-Wuhan Hubei without lockdown
Hsiang et al.	Global social distancing policies	Prevented: 74M cases in China, 5M in South Korea, 1.2M in Italy, 2.6 M in Iran, 650,000 in France, and 20,000 so far in US
Wang et al.	40 interventions in China since 1/24/2020	Interventions reduced the reproduction number from 3.38 to 0.5
Neufeld et al.	Uniform versus targeted social distancing	Focusing on vulnerable population is more efficient and robust and reduces the length of the epidemic. Uniform extends it.

SEASONAL INFLUENZA PARAMETERS

Parameter	Most likely value
Reproduction Number, R_0	1.3
Case Fatality Ratio (%)	0–4: 0.006 5–17: 0.004 18–49: 0.025 50–64:0.075 65+: 1 Overall: 0.10–0.15
Case Hospitalization Ratio (%)	0–4: 0.70 5–17: 0.25 18–49: 0.50 50–64: 1.00 65+: 9.0 Overall: 1.5
Hospitalization to ICU Ratio (%)	0–4: 15.0 5–17: 20.0 18–49: 15.0 50–64: 20.0 65+: 15.0 Overall: 15.0
Onset to Hospitalization (days)	0–4: 3.11 (2.82) 5–17: 3.33 (2.73) 18–49: 3.33 (2.73) 50–64: 3.57 (2.71) ≥65: 3.37 (2.74)
Time to seek care	≤2 days: 35% 3–7 days: 50% ≥8 days: 25%
Onset to Death	<18 years old: 6 days

	≥18: 12 days

SUMMARIES

Imai et al., Imperial College London Report 3 (reproductive number estimates)
https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-fellowships/Imperial-2019-nCoV-transmissibility.pdf

This study assesses how transmissible COVID-2019 would have to be to explain either 1000 or 4000 cumulative cases by 1/18/2020 for different numbers of zoonotically exposed human cases (between 40 and 200). The authors generate “best-case”, “central”, and “worst-case” reproductive numbers from simulated trajectories that match or exceed their cumulative case counts by 1/22/2020. The analysis suggests

- R0 is likely above 1
- R0 is likely to be in the range 1.5-3.5, with a central estimate of ~2.6 (assuming 4000 total cases, Imperial’s most likely estimate of the current cumulative case count)
- R0 is above 1 for all scenarios examined, except for the scenario of 1000 cumulative cases with 200 of those occurring from zoonotic exposure. In this scenario, only the “best-case” scenario is below 1 (R0=0.9).
- Control measures need to block prevent >60% of transmission to be effective in controlling the outbreak

The values assume

- Zoonotic exposure occurred at a constant rate through December 2019, consistent with the market closure January 1, 2020.
- A generation time distribution (mean=8.4 days) in line with SARS. Assuming a shorter generation time (mean of 6.8 days) reduces the central estimate to 2.1 but does not change overall conclusions about the likelihood of human-to-human transmission.
- Heterogeneity in individual infectiousness in line with SARS. Assuming less heterogeneity than SARS would narrow the uncertainty range but change the central estimate little
- All assumptions associated with Imperial’s estimated case counts (Imai et al., above) since they are a main input in this analysis.

Imai et al., Imperial College London Report 4, February 10, 2020
(https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-fellowships/Imperial-College-2019-nCoV-severity-10-02-2020.pdf)

This study estimates case fatality ratios (CFRs) for COVID-2019 related deaths within Hubei, non-China deaths, and overall deaths.

- Estimated fatality ratio for infections 1%
- Estimated CFR for travelers outside mainland China (mix severe & milder cases) 1%-5%
- Estimated CFR for detected cases in Hubei (severe cases) 18%

Limitations: All data sources have inherent potential biases due to the limits in testing capacity. It is possible their approach overcorrects for right-censoring and under corrects for case detection (possibly resulting in higher CFR estimates).

April 2, 2020 Modeling Report

Volz et al., Imperial College London Report 5, February 15, 2020
https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-fellowships/Imperial-College---COVID-19---genetic-analysis-FINAL.pdf

This report describes phylogenetic analyses of 53 whole Sars-Cov-2 genomes.

- The virus was likely introduced into the human population in early December, consistent with earlier estimates.
- The accumulation of mutations suggests a doubling time of ~7 days (95% CI: 4 – 12.7).
- R0 estimate: 2.15 (95% CI: 1.79 – 2.75).
    - Based on an SEIR model.
- Heterogeneity in transmission is likely SARS-like or higher.
    - A small fraction of "super-spreaders" contribute disproportionately to transmission.
- Findings best reflect situation early in outbreak. Effect of later control measures is unclear.

Limitations: Methods do not account for geographic structure, assume cases without a direct identified transmission-link have independent probabilities of being sampled.

Bhatia et al. Imperial College London Report 6, Feb 21, 2020
(https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-fellowships/Imperial-College---COVID-19---Relative-Sensitivity-International-Cases.pdf)

The authors analyzed COVID-19 cases exported from mainland China to different regions and countries, comparing the country-specific rates of detected and confirmed cases per flight volume to estimate the relative sensitivity of surveillance in different countries as of February 20, 2020.

- Relative to Singapore only: 63% of cases have gone undetected
- Relative to Singapore, Finland, Nepal, Belgium, Sweden, India, Sri Lanka, & Canada: 73% of cases have gone undetected

Ferguson et al. from Imperial College Report 7, Mar 16, 2020
(https://www.imperial.ac.uk/media/imperial-college/medicine/sph/ide/gida-fellowships/Imperial-College-COVID19-NPI-modelling-16-03-2020.pdf)

The authors use a modified individual-based simulation model, originally developed for pandemic influenza planning, to explore scenarios for COVID-19 in Great Britain and in the United States. They explore different community mitigation strategies: case isolation, household quarantine, closing schools and universities, social distancing of people aged 70+.

- Overall, results suggest that population-wide social distancing applied to the population as a whole would have the largest impact; and in combination with other interventions – notably home isolation of cases and school and university closure – has the potential to suppress transmission below the threshold of R=1 required to rapidly reduce case incidence
- To avoid a rebound in transmission, these policies will need to be maintained until large stocks of vaccine are available to immunise the population – which could be 18 months or more.

Verity et al. from Imperial College London
(https://www.medrxiv.org/content/10.1101/2020.03.09.20033357v1.full.pdf)

The authors use data from Wuhan, Hubei, non-China as of February 25, 2020, and Diamond Princess cases and deaths to estimate a case fatality ratio and an infection fatality ratio – n = 44,672

- Crude CFR: 3.67% (95% crI 3.56%-3.80%)
- Chinese CFR, adjusted for demography and case under-ascertainment: 1.38% (95% crI 1.23%- 1.53%)
- Overall IFR: 0.66% (0.39%-1.33%)

Volz et al. from Imperial College
(https://www.medrxiv.org/content/10.1101/2020.03.09.20033365v2.full.pdf)

The authors report an analysis of 20 whole SARS-CoV-2 from a single relatively small and geographically constrained outbreak in Weifang, People's Republic of China, using Bayesian model-based phylodynamic methods.

- R: 2.6 (95% CI:1.5-5)

Matteo Chinazzi et al. Northeastern University
https://www.medrxiv.org/content/10.1101/2020.02.09.20021261v1.full.pdf

This study estimates the potential outbreak size in Wuhan by January 23rd, 2020. The analysis suggests:

- The median outbreak size is 58,956 [90% CI 40,759 - 87,471] in Wuhan before Jan 23 2020
- The median outbreak size is 3,491 [90% CI 1,924 - 7,360] in other locations in mainland China before Jan 23 2020
- R0: 2.4 [90% CI 2.2-2.6]
- Generation time: 7.5

https://science.sciencemag.org/content/early/2020/03/05/science.aba9757.full

The authors use the individual-based, stochastic, and spatial model, Global Epidemic and Mobility Model (GLEAM) to model the spread of COVID-19 with data from Sun et al., Pinotti et al., and Baidu Location-Based Services.

- Travel quarantine of Wuhan delayed overall epidemic progression by only 3-5 days in Mainland China, but reduced case importations by 77% until mid-February internationally
- Sustained 90% travel restrictions to and from Mainland China only modestly affect epidemic trajectory unless combined with 50% reduction in transmission
- Median ascertainment rate of detecting an infected individual in Mainland China: 24.4% [IQR: 12.7%,35.8%]

Rambaut et al. (including Bedford and Neher), University of Edinburgh
Though not identical, similar analysis found at https://nextstrain.org/narratives/ncov/sit-rep/2020-01-23?n=0

This study uses the BEAST software package to analyze the genetic similarity between 22 full-length genomes of sufficient quality available on GISAID as of January 23, 2020, to estimate the most recent common ancestor and the reproductive number of the outbreak. The analyses suggest

- There is very little genetic diversity in the currently samples viruses
- The virus emerged in early December 2019
- The most plausible hypothesis is a single zoonotic event with subsequent human-to-human transmission
- R_0 values between 1.5 and 3.5, with the most likely value being 2–3

These values assume

- a 10-day infectious period
- The start of the outbreak was either early November or December
- A current outbreak size between 600 and 15,000 cases
- Samples with virus genome data are representative of the outbreak
- A rate of virus evolution $1X10^{-3}$. Initial data for COVID-2019 indicates a range between $0.39–3.21X10^{-3}$.
- In addition, the observed number of genetic differences in the genome is close to the error rate of the sequencing process, potentially misclassifying observed differences in the sequence. Correcting for this would result in estimates of emergence in mid-December.

Riou et al., University of Bern
https://www.biorxiv.org/content/10.1101/2020.01.23.917351v1

This paper simulates early outbreak trajectories that are consistent with the case estimates produced by Imai et al. The authors explored a wide range of parameter combinations (i.e. basic reproduction number, dispersion, generation time, number of index cases, and date of zoonotic transmission) and ran 1,000 stochastic simulations for each individual combination. The analysis suggests

- A basic reproduction number to be around 2.2 (90% uncertainty interval of 1.4–3.8)
- That the probability of large superspreading events is less likely but still possible, especially in hospital settings

The values assume

- A generation time with a mean between 7 and 14 days.
- All assumptions associated with Imperial's estimated case counts (above) since they are a main input in this analysis.

(https://www.medrxiv.org/content/10.1101/2020.03.04.20031104v1.full.pdf)

Using confirmed cases and deaths from Jan 1 – Feb 11, 2020, the authors calculate age-stratified case fatality ratios, adjusted for delayed mortality and unidentified symptomatic illnesses.

- Overall: 1.6% (95% CrI: 1.4-1.8)
- Ages 0-9: 0.0094% (95% CrI: 0-0.058)
- Ages 10-19: 0.022% (95% CrI: 0-0.082)
- Ages 20-29: 0.091% (95% CrI: 0.03-0.2)
- Ages 30-39: 0.18% (95% CrI: 0.096-0.3)
- Ages 40-49: 0.4% (95% CrI: 0.26-0.58)
- Ages 50-59: 1.3% (95% CrI: 1-1.6)
- Ages 60-69: 4.6% (95% CrI: 3.8-5.4)
- Ages 70-79: 9.8% (95% CrI: 8.2-12)
- Ages 80+: 18% (95% CrI: 14-22)

Atlhaus et al. University of Bern
(https://github.com/calthaus/ncov-cfr)

This study provides a preliminary analysis of the case fatality ratio of COVID-2019.

- 1.6% (95% confidence interval: 0.4%-4.1%)

They argue that reported COVID-2019 cases and deaths outside China are less prone to bias and could provide more precise estimates of the absolute CFR..

Majumder et al., Boston Children's Hospital and Harvard Medical School
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3524675

This study uses the cumulative publicly reported epidemic curve from December 8, 2019 through January 22, 2020 to assess the reproductive number of the outbreak via the Incidence Decay and Exponential Adjustment (IDEA) model. The study suggests:

- Modeled R0 estimates varied from 2.0 to 3.1
- The authors also truncated input data (i.e. December 8, 2019 through January 18, 19, 20, and 21) to see how stable R0 estimates were. The range was similar for these truncated values to those obtained when using all available data.

The values assume
- Currently available public information is accurate and complete
- **No change in case ascertainment over time. Therefore, these values should be interpreted cautiously as case ascertainment has likely increased over time and would bias their R0 estimates upwards.**
- Report dates are consistent with onset dates
- No zoonotic illnesses occurred
- The mean serial interval ranged from 6–10 days
- Unclear what assumptions if any about heterogeneity were made

Majumder et al. from Boston Children's Hospital
(https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3536663)

The authors use both preprint and peer-reviewed studies that estimated the transmissibility potential (i.e. basic reproduction number, R0) of 2019–nCoV on or prior to February 1, 2020 (beginning Jan 23 2020) to investigate the role preprints have had in information dissemination during the ongoing outbreak.

- Average R0 (basic) in preprint group: 3.61 [95%CI: 2.77,4.45]
    - Removing 2 outliers: 3.02 [95% CI: 2.65, 3.39]
- Average R0 (basic) in peer-reviewed group: 2.54 [95%CI: 2.17, 2.91]

Limitations: they report an average of the estimates, instead of a meta-estimate based on distribution/methodology of each individual estimate.

Read et al., Lancaster University
https://www.medrxiv.org/content/10.1101/2020.01.23.20018549v2.full.pdf

This paper fits a SEIR metapopulation transmission model to reported case information up to January 22 to estimate key epidemiological measures and to predict the possible course of the epidemic. The analysis suggests

- An R0 value of 3.11 (95% confidence interval, 2.39 and 4.13).
- 5% (3.6-7.4) case ascertainment in Wuhan

The values assume

- Currently available public information is accurate and complete
- Report dates are consistent with onset dates

- The incubation period was 6 days (previously was 4)
- Little heterogeneity in transmission

Zhan et al. from South China Normal University / Chinese University of Hong Kong
https://www.medrxiv.org/content/10.1101/2020.03.08.20032847v1.full.pdf

In this study, Zhan et al. estimate the initial trajectories of the early phases of ongoing outbreaks in South Korea, Italy and Iran and match these initial trajectories to the Chinese outbreak profiles to select which parameter sets best describe the initial outbreak trajectory and use these parameters to project what the outbreaks in South Korea, Italy and Iran will look like in the future.

- In South Korea:
  - In most cities outbreak peak will occur between 3/8 and 3/16
  - Percent of the population infected in most cities will be less than 0.01%. Daegu and Seoul are estimated to have higher percentage of the population infected (0.31% +/- 0.084 [7619 +/- 2069 infections] and 0.06% +/- 0.009 [1287+/-197 infections], respectively)
- In Italy:
  - Outbreak will peak between 3/12 and 3/26
  - Percent of the population infected in most cities will be less the 0.05%. Lombardi and Amelia Romagna are estimated to have higher percentage of the population infected (0.40%+/-0.07% [4784 +/- 788 infections] and 0.16% +/- 0.129% [1555 +/- 360 infections], respectively)
- In Iran:
  - Outbreak peak will be around 3/22
  - Percent of the population infected in most cities will be less the 0.1%. Tehran and Zanjan are estimated to have higher percentage of the population infected (0.39% +/- 0.02 [2498 +/- 566 infections] and 0.2% +/- 0.07% [1695 +/- 92 infections], respectively)
- Provided control measures remain in place, the models predict that outbreaks in all three countries will be under control by the end of April and outbreaks will end before June 2020.

Zhan et al. from South China Normal University
(https://www.medrxiv.org/content/10.1101/2020.03.25.20043380v1)

The authors use an SEIR model to determine the number of cases in the US and Japan with and without intervention, and estimating the actual epidemic size as of March 19, 2020.

- Overall attack rate without intervention:
  - US: 18.2%
  - Japan: 6.55%
- Overall attack rate with vigilant personal hygiene and exercising strict protective measures:
  - US: 2.7%
  - Japan: 0.23%
- Underreporting by March 19, 2020:
  - US: Report cases are 50 times lower than actual illnesses
  - Japan: Reported cases are 20 times lower than actual illnesses

Zhao et al., Chinese University of Hong Kong
https://www.biorxiv.org/content/10.1101/2020.01.23.916395v1.full.pdf

April 2, 2020 Modeling Report

This paper estimates the exponential growth of the epidemic using the numbers cases reported by the Wuhan Municipal Health Commission from January 10 to January 21, 2020. The authors try to account for increases in case ascertainment by assuming an increase in the reporting rate of 0.5, 1, and 2. The analysis suggest:

Mean R0 ranges from 3.30 (95%CI: 2.73-3.96) to 5.47 (95%CI: 4.16-7.10) associated with 0-fold to 2-fold increase in the reporting rate. With rising report rate, the mean R0 is likely to be below 5 but above 3. The values assume

- A generation time similar to MERS, SARS, or an average of the two
- Currently available public information is accurate and complete
- **Case ascertainment increased by 0.5, 1 or 2X in a period from 1/17–1/20. Therefore, these values should be interpreted cautiously as the actual increase in case ascertainment is unknown.**
- Report dates are consistent with onset dates
- Unclear assumptions about heterogeneity

(https://www.medrxiv.org/content/10.1101/2020.02.26.20028449v3.full.pdf)

The authors use a stochastic model and a negative binomial distribution for secondary cases to estimate basic reproduction numbers for the Diamond Princess Cruise Ship outbreak. They vary serial intervals and use an Akaike information criterion to select the best fit. They used data from Identification of Novel Coronavirus Infection on Cruise Ship in Quarantine at Yokohama Port (Ministry of Health, Labor, and Welfare of Japan).

- R0: 2.2 (2.1-2.4) – mean serial interval = 4.5 days
- Without control measures:
  - 3066 cases on the ship
  - Peak of epidemic curve around Feb 28^{th}
  - Epidemic doubling time: 4.6 days (3-9.3)
- Dispersion parameter k: 44 (95%CI: 6–88)

Chong et al. from the Chinese University of Hong Kong
(https://www.medrxiv.org/content/10.1101/2020.03.15.20036541v1.full.pdf)

The authors analyze cases in Hangzhou and Shenzhen provinces to see the effect of imported cases and the Wuhan travel restrictions on the epidemics in Hangzhou and Shenzhen from January 1 to March 13, 2020.

- Hangzhou
  - 29% of cases were imported.
  - Rt was greater than 1.0 from 16 January to 7 February due to the surge in locally transmitted cases.
  - Rt decreased steadily and dropped below 1.0 in mid-February.
- Shenzhen:
  - 83% of cases were imported.
  - Rt was kept below 1.0 through time.

Liu et al., Guangdong Provincial Center for Disease Control and Prevention
https://www.biorxiv.org/content/10.1101/2020.01.25.919787v2.full.pdf

This analysis used onset dates from confirmed COVID-2019 cases before January 23, 2020, collected from medical records, epidemiological investigations or official websites. Exponential Growth (EG) and maximum likelihood estimation (ML) were applied to estimate the reproductive number (R) of COVID-2019.

The Feb 7 2020 revision calculates the R0 (basic reproduction number) and Rt (time-varying instantaneous reproduction number) for just Wuhan and all of China using updated data.

This analysis suggests:

- The average incubation duration of COVID-2019 infection was 4.8 days cases with limited exposure to Wuhan.
- The average period from onset to isolation was 2.9 days
- The R_0 values of 2.90 (95%CI: 2.32-3.63) and 2.92 (95%CI: 2.28-3.67) estimated using EG and ML respectively, as of Jan 23 2020.
- As of Feb 7, 2020:
    - Epidemic doubling time of COVID-pneumonia in China is 2.4 days
    - R0 in China: 4.5 (95%CI: 4.4-4.6)
    - R0 in Wuhan: 4.4 (95%CI: 4.3-4.6)
    - Rt in China:
        - Before Jan 9: 6.9 (95%CI: 5.5-8.4)
        - Before Jan 16: 8.8 (95%CI: 8.3-9.4)
        - Before Feb 6: 1.59 (95%CI: 1.57-1.61)
    - Rt in Wuhan:
        - Before Jan 9: 6.2 (95%CI: 4.9-7.6)
        - Before Feb 6: 2.10 (95%CI: 2.07-2.14)
    - Crude case fatality rate:
        - 2.8% in Hubei Province
        - 0.24 % in other provinces, China.

These values assume

- Currently available public information is accurate and complete

For Jan 23 analysis: No change in case ascertainment over time. However, the authors limited the study to cases confirmed before January 23, 2020, which would help limit the impact of this bias.

Backer, RIVM, Centre of Infectious disease control, EPI-MOD
https://www.eurosurveillance.org/content/10.2807/1560-7917.ES.2020.25.5.2000062

The author used open source outbreak data to estimate the incubation period from 88 cases with a travel history to Wuhan. From the travel history of these 88 and their dates of symptom onset, the authors estimate the incubation period assuming Weibull, gamma, and lognormal distributions. The study suggests the following about the incubation period of COVID-2019:

- Weibull distribution: mean of 6.4 (95% CrI: 5.6 – 7.7) days and range: 2.1 to 11.1 days (2.5-97.5 percentile)
- Gamma distribution: mean of 6.5 (5.6 – 7.9) and range: 2.4 to 12.5 days
- Lognormal distribution: mean of 6.8 (5.7 – 8.8) and range: 2.4 to 15.5 days

These values assume

- Currently available public information is accurate and complete

April 2, 2020 Modeling Report

Linton et al., Hokkaido University, Japan

https://www.medrxiv.org/content/10.1101/2020.01.26.20018754v2.full.pdf

These collected data from official Chinese gov reports, news reports. Data will be (not yet) available in a supplemental table. They used dates of exposure (inferred from date of entry and/or exit from Wuhan), onset, hospitalization, and death to estimate:

- Incubation period: mean of 5 days with lognormal distribution
  - 95% Confidence: 2-14 days
- Onset to Hospitalization period: 3-4 days
  - 5-9 days when right truncated
- Onset to death period: 13 days
  - 17 days with right truncation/censoring

Jung et al., Hokkaido University, Japan

(https://www.medrxiv.org/content/10.1101/2020.01.29.20019547v2.full.pdf)

As of 24 January 2020, with 23 exported cases, and estimating the growth rate from 8 December 2019 (scenario 1) and using the data since growth of exported cases – 20 exported cases on Jan 24 2020 (scenario 2):

- Cumulative incidence in China:
  - Scenario 1: 6,924 cases (95% CI: 4,885 - 9,211)
  - Scenario2: 19,289cases (95% CI: 10,901 - 30,158)
- The latest estimates of the cCFR:
  - Scenario 1: 5.3% (95% CI: 3.5-7.5%)
  - Scenario 2: 8.4% (95% CI: 5.3-12.3%)
- Basic reproduction number:
  - Scenario 1: 2.1 (95% CI: 2.0, 2.2)
  - Scenario 2: 3.2 (95% CI: 2.7, 3.7)
- Mean generation time: 8.4 days

These values assume

- These analyses use incomplete public data.
- There are biases in the characteristics (severity, age, location, access to healthcare, etc.)
- A limited sample size that limits the ability to stratify by characteristics.
- Right censoring (outcomes may not have been observed yet) is not an issue

Nishiura et al. from Hokkaido University

(https://www.medrxiv.org/content/10.1101/2020.02.03.20020248v2.full.pdf)

The authors use a simple Bayes calculation in order to report asymptomatic ratio of the Japanese citizens who were evacuated from Wuhan China.

- Asymptomatic ratio is thus estimated at 41.6% (95% confidence interval (CI): 16.7%, 66.7%)

Limitation: this estimate is only based on 12 individuals, so if one of 5 asymptomatic individual develops symptoms, the overall asymptomatic ratio would reduce to 33.4% (95% CI: 8.3%, 58.3%)

Nishiura et al. from Hokkaido University

(https://www.ijidonline.com/article/S1201-9712(20)30119-3/fulltext)

The authors use publicly available case reports to aggregate 28 infector-infectee pairs of confirmed cases with known or coarsely reported dates of onset, accounting for right truncation (due to sampling in the early stages of the epidemic).

- Using all 28 infector-infectee pairs:
  - 4.0 days (95% credible interval [CrI]: 3.1, 4.9)
- Using the 18 most certain pairs:
  - 4.6 days (95% CrI: 3.5, 5.9)

Limitations: Data is limited and some dates of onset are not precise.

(https://www.medrxiv.org/content/10.1101/2020.02.28.20029272v1.full.pdf)

In a different study, the authors examine 110 cases among eleven clusters identified in Japan by February 26, 2020 to determine the odds of transmission in closed environments.

- The odds that a primary case transmitted COVID-19 in a closed environment was 18.7 times greater compared to an open-air environment (95% confidence interval [CI]: 6.0, 57.9).
- Nine of 11 super-spreading events (i.e. transmission to 3 or more people) took place in closed environments, and the odds ratio (OR) of superspreading events in closed environments was as high as 29.8 (95% CI: 5.8, 153.4).

Nishiura from Hokkaido University
(http://plaza.umin.ac.jp/infepi/nishiura_umin.pdf)

Nishiura uses back calculation and forecasting to estimate the number of cases on the Diamond Princess cruise ship, as of Feb 24, 2020 without any intervention – intervention started on February 4, 2020.

- Without intervention (estimated):
  - With close contact: 1373 (95% CI: 570, 2176)
  - Without close contact: 766 (95% CI: 587, 946)
- With intervention (actual):
  - With close contact: 102 cases
  - Without close contact: 47 cases

Anzai et al. from Hokkaido University
(https://www.medrxiv.org/content/10.1101/2020.02.14.20022897v1.full.pdf)

This study uses data on confirmed cases diagnosed outside China were analyzed using statistical models to estimate the impact of travel reduction on three epidemiological outcome measures: (i) the number of overall exported cases, (ii) the probability of a major epidemic in Japan, and (iii) the time delay to a major epidemic in Japan.

- Between Jan 28 and Feb 7 2020: 226 exported cases prevented (95% CI: 86, 449) - 70.4 reduction
- Reduced probability of major epidemic in Japan: 7-20%
- Median delay to major epidemic in Japan: 2 days

Limitation: Authors do not consider migration data in their analysis. They were unable to classify who was infected in Hubei versus elsewhere in China.

Omori et al. from Hokkaido University
(https://www.medrxiv.org/content/10.1101/2020.03.09.20033183v1.full.pdf)

The authors analyze the epidemiological dataset of confirmed cases with COVID-19 in Japan as of 28 February 2020 to estimate under-ascertainment.

- Ascertainment of non-severe cases: 0.44 (95% confidence interval: 0.37, 0.50)

Zheng et al. Johns Hopkins University
(https://github.com/HopkinsIDD/ncov_incubation)

This analysis from Johns Hopkins University, updated March 2, 2020, uses data abstracted from Chinese and global news (available on GitHub) in non-Hubei cases. They extrapolate symptom onset and exposure information. They estimate COVID-2019 incubation period from this data.

- Median incubation period lasts 5.057 days (CI: 4.5-5.785)
- 2.5% of incubation periods pass in less than 2.228 days (CI: 1.75-2.942)
- 97.5% of the population would experience symptoms by 11.478 days (CI: 8.23-15.638) since their exposure

Limitation: data source is biased to detected cases and the information about them comes from all types of published reports.

Lauer et al. from Johns Hopkins University
(https://annals.org/aim/fullarticle/2762808/incubation-period-coronavirus-disease-2019-covid-19-from-publicly-reported)

This study uses public reports for 181 confirmed cases in 50 provinces, regions, and countries outside Wuhan City, Hubei, China reported between January 4 – February 24 2020.

- Median Incubation Period: 5.1 days (95% CI 4.5-5.8) – mean 5.5
    - fewer than 2.5% of infected persons will show symptoms within 2.2 days (CI, 1.8 to 2.9 days) of exposure
- 97.5% of those who develop symptoms will do so within 11.5 days (95% CI: 8.2, 15.6) of infection
- These estimates imply that, under conservative assumptions, 10 out of every 10,000 cases will develop symptoms after 14 days of active monitoring or quarantine
- Median time from symptom onset to hospitalization was 1.2 days (range, 0.2 to 29.9 days)
- dispersion parameter was 1.52 (CI, 1.32 to 1.72)

In their analysis, if they couldn't find date of symptom onset, they assumed it to be Dec 1, 2019 (date of symptom onset for the first known case).

Bi et al. from Johns Hopkins University
(https://www.medrxiv.org/content/10.1101/2020.03.03.20028423v3)

The authors used data from Shenzhen CDC of cases and their close contacts between Jan 14th and Feb 12th. They used parametric survival methods for recovery time, parametric distributions for serial intervals, number of secondary infection for observed reproduction number, and logistic regression and random effects models for the relative odds transmissions.

- Median incubation period = 4.8 days [95% CI 4.2, 5.4]
- Median recovery time is 32 days [31,33] in 50-59 year olds
- Median recovery time is 27 days for 20-29 year olds
- Cases isolated on average 4.6 [4.1,5] days after developing symptoms

- Contact tracing reduced time to isolation by 1.9 [1.1,2.7] days
- Household contacts and those traveling with case were at higher risk of infections (ORs = 6 or 7)
- Household secondary attack rate = 15% [12.1,18.2]
- Observed reproductive number = 0.4 [0.3,0.5]
- Mean serial interval = 6.3 days [5.2,7.6]

Zhang & Wang from Chinese Academy of Sciences in Beijing (https://www.biorxiv.org/content/10.1101/2020.01.25.919688v2.full.pdf)

This analysis is based on phylogenetic data from 26 sequences of COVID-2019 that were downloaded on Jan 24 2020. They use a Bayesian framework that takes both effective reproduction number and the phylogenetic data to infer a date of emergence for COVID-2019.

- The time of origin is estimated with median 31.9 days and 95% highest posterior density (HPD) interval from 26.3 to 43.8 days before the date of the latest sample (January 18, 2020), that is, December 17, 2019 (December 5, 2019 to December 23, 2019)
- Effective reproduction number on December 31, 2019: 2.0
- Effective reproduction number Jan 13-15 2020: 2.5
- Effective reproduction number over time: highest value of 2.5 (0.5, 4.9) and lowest value of 0.3 (0.006, 1.47)

The values assume
- Samples with virus genome data are representative of the outbreak

Gostic et al. from University of Chicago, UCLA, LSHTM, and NIH
(https://kgostic.github.io/traveller_screening/)

This analysis uses existing epidemiologic parameter estimates for COVID-2019. Additionally, Gostic et al. estimates the number of people who are left behind in the screening process in order to determine what the detection rate for infected (includes asymptomatic travelers) travelers would be.

- Median fraction of infected travelers detected is only 0.31, with 95% interval extending from 0.17 up to 0.48

Limitations:

- Parameter values for nCoV, such as the incubation period, are based on the limited data currently available.
- In general, current parameter estimates may also be affected by bias or censoring, particularly in the early stages of an outbreak when most cases have been recently infected, and when data are primarily available for relatively severe, hospitalized cases.
- Another crucial uncertainty is the frequency of cases too mild or non-specific to be detected as nCoV infections.

Stier et al. from University of Chicago
(https://www.medrxiv.org/content/10.1101/2020.03.22.20041004v1.full.pdf)

Stier et al. used regression models to estimate epidemic growth rates in US cities based on county level time series data of COVID-19 cases in U.S. cities between March 13-19. They then estimated the reproduction number for each U.S. city. Stier et al. concluded that the growth rate of COVID-19 cases and the reproduction number is higher for larger cities.

- Epidemic growth rate cases in in New York-Newark-Jersey is approximately 1.5 times faster than growth rate for Ponca City, OK
- R for New York-Newark-Jersey: ~7.5
- R for Seattle-Tacoma-Bellevue: ~5.9
- R for San Francisco-Oakland-Berkeley: ~5
- R for Atlanta – Sandy Springs-Alpharetta: ~4.8
- R for Oklahoma City: ~3.8
- R for Valdosta, GA: ~0.92

Quilty et al. from London School of Hygiene and Tropical Medicine
https://www.eurosurveillance.org/content/10.2807/1560-7917.ES.2020.25.5.2000080

The authors simulate 100 infected air travelers based on varying asymptomatic proportions, sensitivity of entry and exit screening, duration of travel, incubation, and time from the start of symptoms until hospitalization.

- Estimated that 46% (95%CI: 36 to 55)of infected travelers would not be detected

Limitations:

- Proportion of asymptomatic infections undetectable by screening procedures (17%) is determined from Chan et al., a study of a family cluster (6 people).
- Estimates are based on a number of key assumptions that cannot yet be informed directly by evidence from the ongoing COVID-2019 outbreak.

Li et al. from Chinese CDC, Beijing and Hubei Provincial CDC
(https://www.nejm.org/doi/full/10.1056/NEJMoa2001316?query=featured_home)

This is the first CDC China study. With direct access to all epidemiologic data for the first 425 confirmed cases that were reported by Jan 22, 2020. They suspect that human-to-human transmission has been occurring among close contacts since the middle of December 2019.

- Mean serial interval of 7.5 days (95% CI, 5.3 to 19)
- Basic reproductive number was estimated to be 2.2 (95% CI, 1.4 to 3.9)
- Mean incubation period was 5.2 days (95% confidence interval [CI], 4.1 to 7.0), with the 95th percentile of the distribution at 12.5 days
- Median age was 59 years and 56% were male
- Majority of cases (55%) with onset before January 1, 2020, were linked to the Huanan Seafood Wholesale Market, as compared with 8.6% of the subsequent cases
- Illness onset to first medical visit:
    - Among 45 patients with onset before Jan 1 2020: 5.8 days (95% CI, 4.3 to 7.5)
    - Among 207 patients with onset Jan 1-11 2020: 4.6 days (95% CI, 4.1 to 5.1)
- Illness onset to hospitalization:
    - Among 44 patients with onset before Jan 1 2020: 12.5 days (95% CI, 10.3 to 14.8)
    - Among 189 patients with onset Jan 1-11 2020: 9.1 days (95% CI, 8.6 to 9.7)

Limitations:

- The initial focus of case detection was on patients with pneumonia, but patients can present with gastrointestinal symptoms and can be asymptomatic.
- Early infections with atypical presentations may have been missed, and it is likely that infections of mild clinical severity have been under-ascertained among the confirmed cases.
- The authors did not have detailed information on disease severity for inclusion in this analysis.

Wu and McGoogan from Chinese CDC in Beijing
(https://jamanetwork.com/journals/jama/fullarticle/2762130)

This is China CDC study describes clinical characteristics of cases until Feb 11, 2020 – 72,314 cases.

- 72,314 Cases (as of February 11, 2020)
  - Confirmed cases: 44,672 (62%)
  - Suspected cases: 16,186 (22%)
  - Diagnosed cases: 10,567 (15%)
  - Asymptomatic cases: 889 (1%)
- Age distribution (N = 44,672)
  - ≥80 years: 3% (1,408 cases)
  - 30-79 years: 87% (38,680 cases)
  - 20-29 years: 8% (3,619 cases)
  - 10-19 years: 1% (549 cases)
  - <10 years: 1% (416 cases)
- Spectrum of disease (N = 44,415)
  - Mild: 81% (36,160 cases)
  - Severe: 14% (6,168 cases)
  - Critical: 5% (2,087 cases)
- Case-fatality rate
  - 2.3% (1,023 of 44,672 confirmed cases)
  - 14.8% in patients aged ≥80 years (208 of 1,408)
  - 8.0% in patients aged 70-79 years (312 of 3,918)
  - 49.0% in critical cases (1,023 of 2,087)
- Health care personnel infected
  - 3.8% (1,716 of 44,672)
  - 63% in Wuhan (1,080 of 1,716)
  - 14.8% cases classified as severe or critical (247 of 1,668)
  - 5 deaths

Kucharski et al. from London School of Hygiene and Tropical Medicine
https://cmmid.github.io/ncov/wuhan_early_dynamics/index.html
https://www.medrxiv.org/content/10.1101/2020.01.31.20019901v2.full.pdf

Error! Hyperlink reference not valid. This study estimates time-varying R0 using sequential Monte Carlo for COVID-2019 before Jan 23, 2020 travel restrictions. They fit to multiple data sources in order to account for unreliability in data.

- Median daily production number (Rt) declined from 2.35 (95% CI: 1.15-4.77) on Jan 16 2020 to 1.05 (95% CI: 0.413-2.39) on Jan 31 2020. Once there are at least 4 independently introduced cases in places with similar transmission potential as Wuhan in early January, there is a more than 50% chance infection will establish within that population.

- The outbreak will peak mid-to-late February

Data used:

- Daily incidence of exported cases from Wuhan (or lack thereof) in countries with high connectivity to Wuhan (i.e. top 30 most at risk), by date of onset. The most recent two data points are omitted during fitting as they are likely to be strongly influenced by delays in reporting. Source: WHO
- Daily incidence of exported cases from Wuhan (or lack thereof) in countries with high connectivity to Wuhan (i.e. top 30 most at risk), by date of confirmation. Source: News reports, WHO, [Kraemer et al data repo]
- Daily incidence of initial cases in Wuhan with no market exposure, by date of onset. Source: Huang et al
- Daily incidence of early cases in China, by date of onset. We assume that these are all in Wuhan.

Assumptions:

- Population was initially fully susceptible.
- All infectious people eventually became symptomatic and would be eventually be detected in destination country if they travelled by plane.
- The population at risk was 10m (rather than 19m assumed in Imperial analysis) because most cases to date are adults and this group is more likely to travel.

Abbott et al. London School of Hygiene and Tropical Medicine
(https://epiforecasts.io/WuhanSeedingVsTransmission/articles/output.html)

The authors modelled the outbreak using a stochastic branching process model. They used three scenarios for the serial interval distribution informed by previous outbreaks of coronaviruses: SARS-like, with a mean of 8.4 days and standard deviation of 3.8 days; SARS-like before interventions, with a mean of 10 days and standard deviation of 2.8 days; and MERS-like, with a mean of 6.8 days and standard deviation of 4.1 days.

- An estimated R0 between 2 - 2.7 (90% Crl)
- The most likely scenario was the SARS-like serial interval, with outbreak size 200, and duration of 1 day

Limitation: The authors only fitted to the cumulative data at one time point, on 25 January 2020, as time-resolved data of onsets was not available.

(https://cmmid.github.io/topics/covid19/current-patterns-transmission/global-time-varying-transmission.html)

The authors estimate basic and time-varying reproductive numbers for countries with the highest case count as of March 11, 2020.

- Reff Italy: 1.2 – 2.3
- Reff Iran: 1 – 1.7
- Reff Spain: 1.9 – 5.6
- Reff France: 1.5 – 3.7
- Reff US: 1.9 – 5.9
- Reff South Korea: 0.6 – 1.2
- Reff Germany: 1.1 – 2.3

(https://wellcomeopenresearch.org/articles/5-17)

The authors used a stochastic branching process model to simulate the Wuhan outbreak. For parameters they could not obtain, they used parameter values from the 2002 – 2003 SARS outbreak. They ran the simulation to match the 1,975 confirmed cases observed on January 25th varying serial interval distribution (SARS-like, initial SARS-like and MERS-like) and R0 bounds.

- R0: 2-2.7 (90% confidence interval)
- Pre-intervention serial interval R0: 2-3 (90% confidence interval) – MERS-like
- Pre-intervention serial interval R0: 2.8-3.8 (90% confidence interval) – SARS-like

Limitations: They do not clearly state where they obtained data from for the parameter values.

Hellewell et al. London School of Hygiene and Tropical Medicine
(https://www.sciencedirect.com/science/article/pii/S2214109X20300747)

- With R0 of 1.5, the outbreaks were controllable with under 50% of contacts successfully traced
- R0 of 2.5, the outbreaks were controllable with more than 70% contacts successfully traced
- R0 of 3.5, the outbreaks were controllable with more than 90% contacts successfully traced

A major assumption here is that contact tracing is achievable for the amount of cases that are currently confirmed. As of today (Feb 10 2020) Hubei province would probably not be able to trace even 50% of contacts of cases.

Clifford et al. from London School of Hygiene and Tropical Medicine
(https://www.medrxiv.org/content/10.1101/2020.02.12.20022426v2.full.pdf)

This study explores the effect of traveler sensitization – educating travelers on COVID and encouraging them to self-isolate if they experience symptoms. They assume basic reproduction number is gamma distributed with Cis ranging from 1.4 to 3.9.

- For 50% effectiveness of traveler sensitization and baseline traveler entry screening, and assuming 1 infected traveler per week, we find that in 50% of simulations the outbreak is delayed by at least 83 (75% of simulations: at least 36, 97.5% 8) days.

Limitations: They assume a constant rate of travelers. The estimated delay of outbreak is very sensitive to dispersion parameter (determines the effect of super-spreading events on transmission).

Funk, Abbott & Flasche from London School of Hygiene and Tropical Medicine
(https://cmmid.github.io/ncov/time-varying-r/)

This study estimates the change in the basic reproduction number during the course of the outbreak, as of Jan 30 2020.

- R0 95% Confidence: 2.0 – 3.8
- Delays in confirmation of cases have decreased over time to 5 days
- Seems to be an uptick in the R0 as of Jan 30, 2020.

Limitations: This report is almost 2 weeks old as of Feb 13, 2020.

Russell et al. from London School of Hygiene and Tropical Medicine
(https://www.medrxiv.org/content/10.1101/2020.03.05.20031773v2.full.pdf)

April 2, 2020 Modeling Report

The authors use Diamond Princess data to estimate IFR (infection fatality ratio) and CFR (case fatality ratio), correcting for confirmation-death delays, and the age-structure of the population. Naïve estimates were substantially higher than corrected.

- Corrected CFR:
    - All ages- 1.9% (0.6%1-4.3%) non-truncated; 2.3% (0.75%-5.3%) truncated
    - 70+ - 14% (6%-27%) non-truncated; 18.0% (7.3%-33%) truncated
- Corrected IFR:
    - All ages- 0.91% (0.1%1-4.3%) non-truncated; 1.2% (0.39%-2.7%) truncated
    - 70+ - 7.3% (3%-14%) non-truncated; 9.0% (3.8%-17%) truncated

Prem et al. from the London School of Hygiene and Tropical Medicine
(https://www.medrxiv.org/content/10.1101/2020.03.09.20033050v1.full.pdf)

The authors use an SEIR model with parameters from the literature to measure effects of various interventions and social mixing in Wuhan, China

- Changes in mixing patterns may have helped to reduce number of infected by 92% (IQR: 66-97%)
- Beneficial to continue social distancing until April in terms of reducing peak height and overall epidemic size
- Short infectious periods lead to relaxing social distancing in March and half the cases in school children and older adults would be avoided
- Longer infectious periods suggest relaxing social distancing in April
- If children were less infectious, there wouldn't be much difference between relaxing social distancing in April versus March

Wu et al. from Hong Kong University, Jan 31 2020
(https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(20)30260-9/fulltext)

The authors used data from Dec 31, 2019, to Jan 28, 2020, on the number of cases exported from Wuhan internationally (known days of symptom onset from Dec 25, 2019, to Jan 19, 2020) to infer the number of infections in Wuhan from Dec 1, 2019, to Jan 25, 2020. Cases exported domestically were then estimated. Data on confirmed cases were obtained from the reports published by the Chinese Center for Disease Control and Prevention.

- Basic reproductive number for COVID-2019 was 2.68 (95% CrI 2.47–2.86)
- 75,815 individuals (95% CrI 37,304–130,330) have been infected in Wuhan as of Jan 25 2020
- Epidemic doubling time: 6.4 days
- Chinese imported infections from Wuhan:
    - Chongqing: 461 (95% CrI 227–805)
    - Beijing: 113 (57–193)
    - Shanghai: 98 (49–168)
    - Guangzhou: 111 (56–191)
    - Shenzhen 80 (40–139)

Limitations:

- Serial interval estimates were based on previous studies of severe acute respiratory syndrome coronavirus (SARS-CoV).

- Assumed that travel behavior was not affected by disease status and that all infections eventually have symptoms.
- Their estimate of transmissibility and outbreak size was sensitive the assumption regarding the zoonotic mechanism that initiated the epidemic at Wuhan.
- The epidemic forecast was based on inter-city mobility data from 2019 that might not necessarily reflect mobility patterns in 2020
- Little is known regarding the seasonality of coronavirus transmission. Therefore, the forecast might not be reliable.

Cao et al. from Chinese Academy of Sciences, Beijing, Jan 29 2020 – updated Feb 9 2020
(https://www.medrxiv.org/content/10.1101/2020.02.07.20021071v1.full.pdf)

The authors estimate R0 and case fatality ratio in this study. They use the average latent period, the average latent infectious period, the logarithmic growth rate of the case counts as reported by China CDC to calculate R0. They use a SEIRDC (Susceptible-Exposed-Infectious-Recovered-Death-Cumulative) model to estimate the case fatality ratio.

- R0: 3.24 in Wuhan City before Jan 23 2020 lockdown
- Case fatality ratio: 6.50%
- Case counts at end of simulation period (80 days): 35,454
- Latent infection ratio: 1.12% (18,556 people)

Note: This study previously used 6 time points and the cases reported on these days to determine R0: Dec 31 2019 with 27 cases, Jan 4 2020 with 19 cases, Jan 22 2020 with 37 cases, Jan 23 2020 with 38 cases, Jan 24 2020 with 39 cases, and Jan 25 2020 with 40 cases. They omitted Jan 5-20 2020 because of significant changes experienced in this time period in the case reporting requirements and practice. However, now they've incorporated data before Jan 23 2020 back in and removed anything after that in their R0 calculation.

Shao & Shan from Xi'an Polytechnic University
(https://outbreaksci.prereview.org/10.1101/2020.01.28.923169)

The authors implement an SEIRD (Susceptible-Exposed-Infectious-Recovered-Death) model to determine the need for interventions to control COVID-2019 infection. The three interventions considered: isolate the infected, reduce movement of people between communities, and improve the level of treatment.

They find that current control measures in China are very necessary, that asymptomatic transmission is likely, and that targeting exposed individuals for intervention would be beneficial to infection control.

Limitations: Authors do not provide any numerical summaries as evidence, as they mainly compare the shape of the epidemic curves to draw conclusions.

(https://www.medrxiv.org/content/10.1101/2020.03.13.20035253v1.full.pdf)

The author used simulations with an SAIRD model and mobility data to investigate the impact of city and residential lockdowns.

- Stringent implementation and early lockdown of residential units effectively controlled spread of epidemic and reduced number of hospital beds
- City lockdown alone did not reduce proportions of infected individuals and led to higher mortality rates
- City lockdown and adding a larger number of hospital beds improved cure rates and reduced mortality rates

April 2, 2020 Modeling Report

Du et al. from The University of Texas at Austin and University of Hong Kong
(https://www.medrxiv.org/content/10.1101/2020.01.28.20019299v4.full.pdf)
Error! Hyperlink reference not valid.

The authors estimated the probability of COVID-2019 importations from Wuhan to cities throughout China before January 23rd using a simple model of exponential growth coupled with a stochastic model of human mobility among 370 Chinese cities. They use air, rail, and road travel.

- R0 of 1.90 (95% CrI: 1.47 - 2.59)
- 12,400 (95% CrI: 3,112–58,465) cumulative infections in Wuhan up to January 22nd
    - By January 26th, 107 of these high risk cities had reported cases and 23 had not, including five cities with importation probabilities exceeding 99% and populations over two million people: Bazhong, Fushun, Laibin, Ziyang, and Chuxiong.
    - 4,326 (95% CrI: 715 - 16,479) cumulative infections occurred by January 12, 2020
- 8.95% (95% CrI: 2.22% - 28.72%) may have been confirmed in Wuhan by January 22nd
- Epidemic doubling time of 7.31 (95% CrI: 6.26 – 9.66) days

They use travel data from December 2017 – March 2018 to estimate ground travel from Wuhan from December 8, 2019 to January 22, 2020: https://heat.qq.com/

(https://www.medrxiv.org/content/10.1101/2020.02.19.20025452v3)

In a subsequent study, the authors analyze serial intervals–the time period between the onset of symptoms in an index (infector) case and the onset of symptoms in a secondary (infectee) case–of 468 infector-infectee pairs with confirmed COVID-19 cases reported by health departments in 18 Chinese provinces between January 21, 2020, and February 8, 2020.

- Serial Interval: mean of 3.96 days (95% confidence interval: 3.53-4.39), a standard deviation of 4.75 days (95% confidence interval: 4.46-5.07)
- 12.1% of reports indicating pre-symptomatic transmission

Limitations: They report a range of -11 days to 20 days.

Tian et al. from Beijing Normal University, Oxford, Princeton
(https://www.medrxiv.org/content/10.1101/2020.01.30.20019844v4.full.pdf)

This study determines how the travel bans implemented on January 23 2020 delayed the dispersal of the nCoV epidemic from Wuhan to other cities. They use data from lab-confirmed cases between Dec 31 2019 and January 28 2020 and QQ/WeChat for transportation between cities. The authors also evaluate the effect of the Wuhan travel restrictions during Chinese Spring Festival.

- 2.91 days (95% CI: 2.54-3.29) delay in dispersal of nCoV between Wuhan and other Chinese cities
- This early analysis suggests that transmission control (non-pharmaceutical) measures initiated during Chinese Spring Festival holiday delayed the growth and limited the size of the COVID-19 epidemic in China.

Liu et al. from Beijing Normal University
(https://arxiv.org/pdf/2002.12298.pdf)

April 2, 2020 Modeling Report

The authors use an SEIR model that includes a compartment for number of unreported symptomatic infections and data from the National Health Commission of the People's Republic of China from Jan 20th to Feb 15th with effects of public policy measures.

- Lowering or raising fraction of underreported cases significantly decreases/increases total number of cases
- Implementing governmental policies later would have increased the number of reported cases from 4,500 to 820,000

Park et al. from Princeton University
(https://www.medrxiv.org/content/10.1101/2020.01.30.20019877v4.full.pdf)

This study reviews R0 from several other studies and uses posterior samples to pools them together.

- R0 from the pooled distribution has a median of 2.9 (95% CI: 2.1–4.5)

The authors advocate that confidence intervals must combine different sources of uncertainty. The authors may have used incorrect estimates for Read et al, so the results might change once they clarify it.

(https://www.medrxiv.org/content/10.1101/2020.03.09.20033514v1.full.pdf)

Yuan et al. from City University of China
(https://www.medrxiv.org/content/10.1101/2020.02.01.20019984v1.full.pdf)

This study calculates the mean critical time at which the cumulative number of secondary cases generated by the imported cases is larger than the critical threshold (7.27 cases in a city) in a higher and lower R0 (basic) scenario, for the top 20 cities connected to Wuhan City, Hubei, China.

- Under the high R0 (2.92) scenario: The mean arrival time of outbreak into different cities (since Dec 31, 2019): 17.9 days
- Under the low R0 (1.4) scenario: The mean arrival time of outbreak into different cities (since Dec 31, 2019): 26.2 days

They use a simple mathematical formula to estimate the outbreak potential at neighboring cities and built a meta-population model based on a classical SIR approach to understand the outbreak spreading dynamics at different cities.

Sun et al. from National Institutes of Health
(https://www.medrxiv.org/content/10.1101/2020.01.31.20019935v1.full.pdf)

This study describes a line list created and curated by NIH:
https://docs.google.com/spreadsheets/d/1jS24DjSPVWa4iuxuD4OAXrE3QeI8c9BC1hSlqr-NMiU/edit#gid=1180262595

Qin et al. from National Institutes of Health
(https://www.medrxiv.org/content/10.1101/2020.03.06.20032417v1.full.pdf)

The authors estimate incubation period from cases reported outside of Hubei province by February 15, 2020.

- Median incubation period: 8.13 days (95% CI: 7.37-8.91)
- Mean incubation period: 8.62 days (95% CI: 8.02-9.28)

April 2, 2020 Modeling Report

Boldog et al. from University of Szeged
(https://www.medrxiv.org/content/10.1101/2020.02.04.20020503v2.full.pdf

These authors estimate the country-level risk of novel coronavirus COVID-2019 outbreaks outside mainland China based on several factors:

1. the evolution of the cumulative number of cases in mainland China outside the closed areas
2. the connectivity of the destination country with China, including baseline travel frequencies
3. the effect of travel restrictions, and the efficacy of entry screening at destination; (iii) the efficacy of control measures in the destination country (expressed by the local reproduction number Rloc)

In order to estimate how control measures might work in countries other than China, the authors compare the outbreak size in those countries when the Rloc is 1.6 (baseline) versus 1.4 and 1.1. When Chinese cases grow to 600,000 in the Rloc = 1.6 scenario, foreign outbreaks are very likely. In the Rloc = 1.4 scenario, outbreaks are somewhat likely in non-China nations when the Chinese outbreak reaches 1 million. And when Rloc = 1.1, outbreaks in other countries are unlikely even when it reaches to 1 million individuals in China.

Limitation: The authors do not provide a quantitative assessment of their results.

Niehus et al. from Harvard University
https://www.medrxiv.org/content/10.1101/2020.02.13.20022707v2.full.pdf

Estimates the proportion of cases detected worldwide, relative to the level of ascertainment in Singapore, a country known for highly sensitive surveillance, contact-tracing, and case-finding.

- Many symptomatic travel-associated cases have likely gone undetected.
  - Global ascertainment is likely ~38% of the level in Singapore (95% Interval: 22% - 64%)
  - 40%, 39%, and 37% in countries with high, intermediate, and low surveillance capacity (as assessed by the Global Health Security Index).
  - Estimates the actual number of travel-associated cases to be 2.8 times higher than reported.
  - Selected Singapore as benchmark because it had highest ratio of detected imported cases to inbound travel volume from Wuhan (1 detected case per 5 daily travelers).
- Point prevalence of infection is likely higher in residents than transient travelers during an outbreak.
- Due to points above, analyses based on exported cases may underestimate the size of the Wuhan outbreak and overestimate disease severity.

Chowell et al. from Georgia State University
(https://www.medrxiv.org/content/10.1101/2020.02.03.20020271v1.full.pdf)

This is one of the first studies to explore the effect of vaccination on the COVID-2019 outbreak. Using an SEIR-type transmission model, the authors contrasted two alternate strategies by modeling the proportion of the population that needs to be protected from infection by onetime vaccination (assuming 100% effectiveness) or by testing with isolation and treatment of individuals within six, 24, or 48 hours of symptom onset. They use an R0 of 2.2 in their calculations.

- Vaccination coverage of 55% would drive R below 1, but with persistent transmission for years.
- Coverage of 80% is required to end the epidemic in 6 months
- The epidemic could be ended in just under a year if testing with isolation and treatment reached 80% of symptomatically infected patients within 24 hours of symptom onset (assuming 10% asymptomatic transmission)

- The epidemic could be ended in six months if testing with isolation and treatment reached 90% of symptomatic patients.

Limitations: This study assumes 100% effectiveness. This is difficult to interpret when we have no vaccine for COVID-2019 yet, and any future vaccine would probably not have VE of 100%.

Tariq et al. from Georgia State University
Error! Hyperlink reference not valid.(https://www.medrxiv.org/content/10.1101/2020.02.21.20026435v6.full.pdf)

In this analysis, the authors estimate the time-varying reproductive number, *R(t)*, in Singapore based on the reported dates of symptom onset for imported and local cases. The authors also use a branching process model and the distribution of case-cluster sizes to derive the reproductive number.

- Reff peaked at ~1.0 on February 6-12
- The most recent estimate of R(t) was 0.9 (94% CI: 0.7 – 1.0), using data as of March 5th
- Overall Effective reproductive number: 0.7 (95% CI: 0.5 – 1.0)
- Dispersion parameter estimated to be 0.4 (0.1, infinity).
- Epidemic growth in Singapore has been sub-exponential.
- The relatively low values of the time-varying and effective reproductive numbers suggest that social distancing and case-finding/isolation have had a significant impact on observed transmission in Singapore.
    - Public health authorities in Singapore have advised the public to avoid mass gatherings and confined spaces.

Sanche et al. from Los Alamos National Laboratory
(https://www.medrxiv.org/content/10.1101/2020.02.07.20021154v1.full.pdf)

This study uses exported cases to estimate R0 and epidemic doubling time.

- Estimating R0 between 4.7 and 6.6
- Epidemic doubling time of 2.4 days

Limitations: This is based on 140 individual case reports. They also assumed perfect detection of infected cases outside of Hubei province, i.e. the dates of first arrival and the number of case counts are accurate.

Hermanowicz from University of California Berkeley
(https://www.medrxiv.org/content/10.1101/2020.02.04.20020461v2.full.pdf)

This study estimates R0 using a back-trend analysis and final epidemic size using a simple logistic growth model. They use data collected until January 28, 2020 unless otherwise noted.

- R0 estimated to be between 2.4 and 2.5
- Max number of cases will be 21,000, 28,000, and 35,000 – reaching in mid-February – depending on if data was collected until Jan 31, Feb 3, or Feb 6 2020.
- Using all available data, until publishing time (Feb 6 2020), the max number of cases is estimated to be 65,000

Limitations:. The conservative estimates provided have been surpassed already, though the estimate using all data has not.

April 2, 2020 Modeling Report

Hsiang et al. from University of California at Berkeley
(https://www.medrxiv.org/content/10.1101/2020.03.22.20040642v2.full.pdf)

The authors use reduced-form econometric methods, specifically panel regression models, to estimate the effect anti-contagion policies had on the growth rate of infections in 936 regions in 6 countries. Data for each country is listed in article.

- Without policy actions, early infections exhibit exponential growth rates of 45% per day
  - 25.23% per day in China
  - 65.04% in Iran
  - South Korea, Italy, France, and US near 45% average
- Policies have collectively had significant impact slowing this growth
  - Social distancing in France and Italy were not significant
- Similar policies may have different impacts on different populations
- To date, current policies have prevented or delayed on the order of 80M infections
  - 74M more in China
  - 5M more in South Korea
  - 1.2M more in Italy
  - 2.6 M more in Iran
  - 650,000 more in France
  - 20,000 more in US (still too early to tell for US)

Ai et al from Sun Yat-sen University in Guangzhou
(https://www.medrxiv.org/content/10.1101/2020.02.04.20020339v1.full.pdf)

These authors also use Baidu data to track the migrant population, in addition to China Health Commission for epidemic reports. They use simple flow equations to estimate how many cases would have been prevented if the travel restricted were implemented earlier and how many more cases would have happened if the travel restrictions were implemented later.

- Two days earlier, 2020-01-21: -1420 (-1833, -1059)
- One day earlier, 2020-01-22: -687 (-886, -512)
- One day later, 2020-01-24: 722 (539, 932)
- Two days later, 2020-01-25: 1462 (1090, 1886)

Limitations: They assume that surveillance and public health response is the same for all cities, and that infected individuals are randomly distributed.

Li et al. from Sun Yat-sen University
(https://www.medrxiv.org/content/10.1101/2020.02.18.20024315v1.full.pdf)

The authors use confirmed cases from China National Health Commission for Jan 10th – Feb 8th and four estimation techniques: exponential growth, maximum likelihood method, sequential Bayesian method, and time-dependent reproduction numbers (R0 package in R) to estimate R0.

- Before closure, R0 for Wuhan was 4.38 and dropped to 3.41.
- Entire period for Wuhan, R0 = 3.39
- By Feb 8th :
  - 37,198 cases confirmed nationally
  - 27,100 in Hubei

- 14,982 in Wuhan

Limitations: They do not estimate values of parameters for transition rate from exposed to infection or for infectious to recovered. R0 package was last updated in 2015.

Muniz-Rodriguez et al. from Georgia Southern University
(https://www.medrxiv.org/content/10.1101/2020.02.05.20020750v4.full.pdf)

The authors estimate the epidemic doubling time using data from the National health Commission of China, double checking against the reported numbers of the provinces according to the Centre of Health Protection in Hong Kong.

- Epidemic doubling time in Hubei: 2.5 days (2.4-2.7)
- Mean doubling time in mainland China except Hubei: 1.7 days
- Doubling time for Hunan: 1.4 (1.2-2.0)
- Doubling time for Xinjiang: 3.0 (2.0-4.9)

Limitations: Values assume mean incubation period of 6.4 days and mean duration from onset of symptoms to isolation of 0.7 days.

(https://www.medrxiv.org/content/10.1101/2020.03.08.20030643v1.full.pdf)

The authors estimate epidemic doubling time and R0 in Iran using 2 methods: with daily curve of reported cases and 10,000 simulations of epidemic doubling times. They use serial interval estimate of mean: 4.41 days; standard deviation: 3.17 days.

- Daily Curve Method (M1):
  - R0: 3.6 (95% CI: 3.2, 4.2)
  - Epidemic growth rate: 0.85 (95% CI: 0.69, 1)
  - Sclaing parameter: 0.89 (95% CI: 0.84, 0.95)
- Simulation Method (M2):
  - R0: 3.58 (95% CI, 1.29, 8.46)
  - Epidemic doubling times: 1.20 (95% CI, 1.05, 1.44)

Guan et al. from Guangzhou Institute of Respiratory Health
(https://www.medrxiv.org/content/10.1101/2020.02.06.20020974v1.full.pdf)

This study summarizes the characteristics of 1,099 patients in 31 Chinese provinces with lab-confirmed COVID-2019 acute respiratory disease through January 29, 2020.

- 31.30% had been to Wuhan
- 71.80% had contact with people who had been in Wuhan
- median incubation period was 3.0 days (range, 0 to 24.0 days)

Limitations: observation for most of these patients was still ongoing at the time of analysis, so they did not evaluate a number of metrics.

Diao et al. from Wuhan University
(https://www.medrxiv.org/content/10.1101/2020.02.18.20024513v1.full.pdf)

They authors use data from the National Health Commission of Wuhan, National Health Commission of Hubei Province, and COVID-19 Working Group of State Council from Jan 20th to Feb 14th to calculate case fatality ratios and the cure (or recovery) rate. Cure rate is measured as sum of cumulative discharges on a day divided by the (cumulative discharges on day + cumulative deaths on 8-10 days before).

- CFR: National 7%, Wuhan >10%,
- Cure ratio: 93% nationwide, 87% in Wuhan (Nationwide CR on Feb16th was 15.37%?)
- Approx. deaths = 4,938

Limitations: They are missing some data from Jan 20th to 23rd. For principle data, use average of before and after dates. For Wuhan and national data are missing, use Hubei data.

Zhang et al. from Wuhan University
(https://www.medrxiv.org/content/10.1101/2020.03.02.20030452v1.full.pdf

Retrospective case series of 221 patients admitted at single hospital.

- onset of symptoms to ICU admission was 10.0 days (IQR, 7-13)
- onset of symptoms to hospital admission was 7.0 days (IQR, 4.0-10.0)

Qi et al. from Wuhan University
(https://www.medrxiv.org/content/10.1101/2020.02.26.20028076v2.full.pdf

The authors estimate the CFR among confirmed cases (cCFR) in China using a simple method of dividing cumulative observed deaths by the cumulate confirmed cases, excluding cases reported less than the average time from confirmation to death in the past from the denominator. Only lab-confirmed cases are included.

- cCFR in China, excluding Wuhan, was estimated to be ~0.85%
- cCFR in Wuhan was estimated to be ~5.4%

Limitations: It seems that clinically-confirmed (i.e., not lab-confirmed) deaths were included in the numerator but not the denominator, which could lead to the CFR being somewhat overestimated. This method accounts for right-censoring but not under-ascertainment of mild or asymptomatic cases, or shortages of testing kits.

Zhao et al. from University of Cambridge
(https://www.medrxiv.org/content/10.1101/2020.02.06.20020941v1.full.pdf)

This study uses exported case data to determine epidemic doubling size and basic reproduction number (R0).

- Epidemic was doubling in size every 2.9 days (95% CrI: 2—4.1 days)
- Basic R0: 5.7 (95% CrI, 3.4—9.2)

Limitations: Only 46 cases (from Hong Kong, Japan, Korea, Macau, Singapore, and Taiwan) were used to parameterize their models

Labadin et al. from Universiti Malaysia Sarawak
(https://www.medrxiv.org/content/10.1101/2020.02.07.20021188v1.full.pdf)

This study uses an SEIR model to model COVID-2019 infection in Malaysia's population. They verify an incubation period of 6.5 days (based on 88 cases outside of Wuhan, China. They also estimate that without intervention, there will be about 3 million cases.

Limitations: parameters are based on preliminary data, most from very small samples of the infected populations.

April 2, 2020 Modeling Report

Zhang et al. from Shaanxi University & Xianyang CDC
(https://www.medrxiv.org/content/10.1101/2020.01.30.20019836v4.full.pdf)

This study describes general epidemiology of 31,774 total confirmed cases COVID-19 cases in 31 provinces.

- 60.61% of COVID-19 patients are between 30 and 50 years old
- Fatality rate in Wuhan: 1.52% -6.64%
- Fatality rate in China: 0%-2.64%

Limitation: The authors do not consider right-censoring in their analysis, so their fatality rates are crude.

Yang Yang et al. from the University of Florida
(https://www.medrxiv.org/content/10.1101/2020.02.10.20021675v1.full.pdf)

This study uses data from 8866 suspected and confirmed patients by January 26, 2020 in 30 Chinese provinces to estimate CFR, R0, and assess severity of COVID-2019.

- R0: 3.77 (95% CI 3.51-4.05), ranging 2.23-4.82
- CFR was estimated be 3.06% (95% CI 2.02-4.59%)
- Median incubation period was 4.8 (interquartile range: 3.0-7.2) days

Limitations: the epidemic has grown substantially since January 26, so it would be helpful to see an updated version of this analysis.

Zhao et al. from Chinese Academy of Sciences
(https://www.medrxiv.org/content/10.1101/2020.02.27.20028639v2.full.pdf)
(https://www.medrxiv.org/content/10.1101/2020.02.27.20028639v1.full.pdf)

The authors use a SUQC model (susceptible, un-quarantined infected, quarantined infected, and confirmed infected) with data from daily records of confirmed cases from Jan 20th to Feb 21st from National Health Commission of the People's Republic of China.

- Confirmation rate of Wuhan: 0.0643
- Confirmation rate of Hubei: 0.1914 (excluding Wuhan)
- Confirmation rate of China: 0.2189 (excluding Hubei)
- Un-quarantined infected individuals in Wuhan on Feb. 12 = 3,509 and decreases to 33 on Feb. 21st
- End of COVID-19 for Wuhan and Hubei are late March and mid March for China
- Total of 80,511 people infected in whole country, 49,510 from Wuhan, and 17,679 from Hubei (excluding Wuhan)
- Effect of quarantine rate on R0:
    - 51.2% quarantine rate reduced R0 from 1.52 to 0.58 with 19% baseline quarantine (China excl Hubei)
    - 48.8% quarantine reduced R0 from 5.93 to 0.61 with 5% baseline quarantine (Hubei ecl Wuhan)
    - 39.2% quarantine reduced R0 from 4.71 to 0.76 with 6% baseline quarantine; 61.9% quarantine further reduced R0 to 0.48 (Wuhan)

You et al. from Peking University
(https://www.medrxiv.org/content/10.1101/2020.02.08.20021253v2.full.pdf)

This study estimates serial interval and infectious period. Additionally, the authors estimated basic and controlled reproduction numbers based on a stochastic SIR model.

- Serial interval: Mean 4.41 days with a standard deviation of 3.17 days
- Infectious Period: Mean 10.91 days with a standard deviation of 3.95 days

Limitations: they do not provide quantitative estimates/metrics from this R0 and Rc analysis.

Lin et al. from Peking University

(https://www.medrxiv.org/content/10.1101/2020.02.12.20022277v1.full.pdf)

This study provides estimates of the daily trend in the size of the epidemic in Wuhan based on detailed information of 10,940 confirmed cases outside Hubei Province.

- By Jan 11, 2020: 4,090 (95% CI: 3,975 – 4,206)
- By Feb 9, 2020: 56,833 (95% CI: 55,242 – 58,449)
- Reporting rate: 1.41% (95% CI: 1.37% - 1.45%) on January 11, 2020
- Reporting rate: 29.74% (95% CI: 28.92% - 30.60%) on February 9, 2020
- Date of first infection estimate: November 30, 2019

Assumptions:

1. The daily probability of departing from Wuhan is constant over time.
2. There is a d = $d1$ + $d2$-day window between infection to detection, including a $d1$- day incubation period and a $d2$-day delay from symptom onset to detection.
3. Trip durations are long enough that a traveling patient infected in Wuhan will develop symptoms and be detected in other places rather than after returning to Wuhan.
4. All travelers leaving Wuhan, including transfer passengers, have the same risk of infection as local residents.
5. Traveling is independent of the exposure risk to COVID-19 or of infection status.
6. Patients are not able to travel d days after infection.
7. Recoveries are not considered in this method.

Sun et al. from Peking University

(https://www.medrxiv.org/content/10.1101/2020.02.17.20024257v1.full.pdf)

The authors use NHCC and Shenzen Government Online data sources to parameterize their vSIR (time-varying coefficient SIR model). Their infectious rate changes with time, so how susceptibles move to the infected compartment depends on the state of both compartments. Their effective reproduction number estimates are based on a 14 day infectious period.

- Jan 27:
  - Reff in 27 provinces: 6.42 (1.57)
  - Reff in 7 Hubei cities: 7.67 (2.46)
- Feb 3 2020:
  - Reff in 30 provinces: 2.39 (0.70)
  - Reff in 15 Hubei cities: 2.94 (0.56)
- Feb 10:
  - Reff: 0.77 (0.33) for the 30 provinces
  - Reff: 1.01 (0.43) for the 15 provinces
- Hubei will reach peak between Feb 20 and 22 2020.
- Many non-Hubei provinces reached peak before Feb 20-22

Limitations: Estimations are dependent on the infectious period being 14 days, and that all diagnosed can be quarantined immediately.

Chen from Peking University
https://arxiv.org/ftp/arxiv/papers/2002/2002.07096.pdf

The authors use a compartmental model with a quarantined suspected infected group and a quarantine diagnosed infected group using data from the 2019-nCov data repository and the Baidu map to investigate city closure in China.

- Shifting quarantine date earlier or later by 2 days could result in an almost double amount of decrease or increase in cumulative infected people
- If quarantine had been cancelled after daily peak, a possible second peak could have occurred
- Cumulative confirmed patients = 50,000

Liu & Li et al. from Southeast University in Nanjing
(https://www.medrxiv.org/content/10.1101/2020.02.09.20021444v1.full.pdf)

(https://www.medrxiv.org/content/10.1101/2020.02.14.20022913v1.full.pdf)

The authors use Baidu Migration data and nCoV infection confirmed pneumonia patients with a Flow-SEIR model to model the magnitude and time of peak, along with the effect of mitigation measures on the peak.

- Predicted peak date in Hubei: February 29 2020 (95% CI: Feb 25- March 8)
- Predicted peak magnitude in Hubei: 62,800 (95%: 56,900 – 70,300)
- Predicted peak date in non-Hubei areas in China: March 8 – March 25, 2020
- Most provinces have predicted peak value < 1000
- 1.5-2 months from peak to end of epidemic
- Epidemic will possibly be stable March 2020-June 2020
- Provincial level traffic lockage can only alleviate 21.06 – 22.38% of peak number of patients.
- If false negative rate is 50% and the potential transmission rate is 1-4 times higher than that of the confirmed patients, the real peak number of patients is likely to be between 214,400-472,500
- If the traffic quarantine happened on Jan 22 2020 instead of Jan 23 2020, there would be 3600 less infected people, while if the quarantine happened on Jan 24 2020, 1800 more people would have been infected.
- Quarantine can reduce the number of infections by 90%.
- R0 after Jan 23 2020 travel restrictions: 2.5

Limitations; They do not consider heterogeneity in transmission. The authors also do not consider underdiagnosis and misdiagnosis in their model.

Zhu et al. from Hong Kong Polytechnic University
(https://www.medrxiv.org/content/10.1101/2020.02.09.20021360v1.full.pdf)

The authors use an SIR model to determine the number of infected individuals by March 2, 2020 in all of mainland China under 3 different mitigation (or lack thereof) scenarios.

- Scenario 1 - keeping the trend: 10,529,530 infected people
- Scenario 2 - controlling the disease as successfully as SARS in 2003: 148,137
- Scenario 3 - increasing person-to-person contacts due to work/school resuming): 411,082

Limitations: They do not consider transmission between other cities (only Wuhan and cities in China). Infection and recovery rates are assumed to be the same between different age groups. And similarly to other models, parameters are based on preliminary estimates of COVID-2019 transmission dynamics.

Zhuang et al. from Hong Kong Polytechnic University
(https://www.medrxiv.org/content/10.1101/2020.03.02.20030312v2.full.pdf)

The authors use a stochastic model for the transmission process in South Korea and Italy with data from the WHO Situation Report from Jan 20th to March 5th. R0 was estimated with the maximum likelihood estimate to fit cases with a Poisson distribution framework.

- South Korea:
  - exponential growth starting Jan 31st:
    - R0: 2.6 (95% CI: 2.3-2.9)
    - Dispersion parameter: 10 (95% CI: 5-56)
  - exponential growth starting Feb 5th:
    - R0: 3.2 (95% CI: 2.9-3.5)
    - Dispersion parameter: 22 (95% CI: 8-61)
- Italy:
  - exponential growth starting Jan 31st:
    - R0: 2.6 (95% CI: 2.3-2.9)
    - Dispersion parameter: 13 (95% CI: 5-61)
  - exponential growth starting Feb 5th:
    - R0: 3.3 (95% CI: 2.9-3.5)
    - Dispersion parameter: 37 (95% CI: 13-61) i

(https://www.medrxiv.org/content/10.1101/2020.03.02.20030320v1.full.pdf)

The authors use flight data from WorldData and Variflight, WHO data for reported cases in Iran, and population data from World Bank to estimate the Iranian epidemic size by February 25, 2020 with a simple binomial equation.

- Total Iranian cases: 16533 (95% CI: 5925, 35538) by 25 February

Hossain et al. from City University of Hong Kong
(https://www.medrxiv.org/content/10.1101/2020.03.13.20035261v1.full.pdf

The authors use a meta-population model based on an SIR model with mobility matrices (from International Air Transport Association database from Dec 30th – Jan 20th) to explore imported cases and second wave of transmission with border closures and quarantine implementations.

- Under a higher R0 setting (2.92), the effect of obtaining 10 extra days before outbreak emergence (compared to baseline) requires an enhanced border control measure to reduce more than 90% of passengers or very efficient quarantine measure.
- Under a low R0 (1.4), the same border control measure gained an extra 32.5 days of outbreak arrival time.
- With R0 = 1.4, if quarantine occurred immediately, 44 days were gained.

Xiong & Yan from Hainan University
(https://www.medrxiv.org/content/10.1101/2020.02.10.20021519v1.full.pdf)

April 2, 2020 Modeling Report

This study uses a novel EIR model to estimate peak infected individuals and date of peak. They claim that this is a better alternative to an SEIR model because the E compartment is not suitable for COVID-2019 infection, as it assumes that exposed individuals are not infectious.

- R0: 2.7
- Peak infected individuals: 49,093
- Date of Peak: Feb 16 2020
- Epidemic end in March 2020

Limitations: There is not enough information to claim that exposed individuals are infectious. There doesn't seem to be clear reasoning as to why removing the S compartment might solve the issue of asymptomatic/exposed transmission. It's also not clear what geographic region they are estimating epidemic size for.

Wang et al. from Synyi Medical Technology Co. Shanghai, China
(https://www.medrxiv.org/content/10.1101/2020.02.17.20023630v5.full.pdf)

This study estimates the adjusted case fatality ratio of COVID-19 in Hubei province (including Wuhan) and also in all of China excluding Hubei.

- CFRs in Hubei:
  - Jan 20 – Feb 2, 2020: 70.9% (95% CI: 66.8%-75.6%)
  - Feb 3 – 14, 2020: 20.2% (18.6%-22.1%)
  - Feb 15 – 23, 2020: 6.9% (6.4%-7.4%)
  - Feb 24 – Mar 1, 2020: 1.5% (1.4%-1.6%)
- CFRs in other areas of China:
  - Jan 20 – 28, 2020: 20.3% (17.0%-25.3%)
  - Jan 29 – Feb 12, 2020: 1.9% (1.8%-2.1%)
  - Feb 13 – 18, 2020: 0.9% (0.8%-1.1%)
  - Feb 19 – Mar 1, 2020: 0.4% (0.4%-0.5%)

Assumption: Relies on aggregate counts. Model doesn't include underacertainment of cases.

Mizumoto et al. from Kyoto University
(https://www.medrxiv.org/content/10.1101/2020.02.12.20022434v2)

This study estimates of the transmissibility and virulence of 2019–nCov in Wuhan City, China, by reconstructing the underlying transmission dynamics. They use the daily series of laboratory–confirmed nCov cases and deaths in Wuhan City and epidemiological data of Japanese evacuees from Wuhan City on board government–chartered flights.

- R0 in Wuhan before Jan 23, 2020: 5.20 (95%CrI: 5.04-5.47)
- Rt in Wuhan after Jan 23, 2020: 0.58 (95%CrI: 0.51-0.64)
- Total infections in Wuhan: 1,905,526 (95%CrI: 1,350,283-2,655,936)
  - Proportion of infected individuals in Wuhan: 9.1% (95%CrI: 13.5-26.6%)
- Infection fatality ratio: 0.04% (95% CrI: 0.03-0.06%)
  - Time-delay-adjusted IFR: 0.12% (95%CrI: 0.08-0.17%)

Limitations: The Japanese evacuees are not a representative population of Wuhan, China. Data from Wuhan itself is still preliminary

(https://www.medrxiv.org/content/10.1101/2020.02.19.20025163v1.full.pdf)

In an analysis of the case fatality ratio, the authors use Wuhan and Hubei Province governmental data on cases and death data on 50 Chinese deaths (by February 7, 2020) to calculate crude and adjusted case fatality ratios.

- Crude case fatality ratios:
  - Wuhan: 4.1% (95% CI: 3.8%-4.5%)
  - Hubei, excluding Wuhan: 1.3% (95% CI: 1.1-1.6%)
  - China, excluding Hubei: 0.27% (95%CI: 0.2-0.4%)
- Time-delay adjusted CFR:
  - Wuhan: 18.9% (95%CrI: 17.1-20.8%)
  - Hubei, excluding Wuhan: 6.1% (95%CrI: 5.2-7.1%)
  - China, excluding Hubei: 0.9% (95%CrI: 0.6-1.3%)

(https://www.medrxiv.org/content/10.1101/2020.02.20.20025866v2.full.pdf)

In a subsequent study, the authors estimate the percent of asymptomatic cases (asymptomatic ratio) of the Diamond Princess Cruise ship, as of February 20, 2020. Most of the infections occurred before the start of the 2-week quarantine (started February 4, 2020).

- Asymptomatic ratio: 17.9% (95% CrI: 15.5%–20.2%),

Limitations: Most of the passengers were 60-years of age or older. The presence of symptoms with COVID-19 might be related to comorbidities.

https://www.medrxiv.org/content/10.1101/2020.02.24.20027649v2.full.pdf

Using mathematical modeling and time-series incidence data describing the trajectory of the outbreak among passengers and crew members, they characterize how the transmission potential varied over the course of the outbreak.

- Maximum Rt on Feb 7, 2020 in the confined setting reached values as high as ~11

(https://www.eurosurveillance.org/content/10.2807/1560-7917.ES.2020.25.10.2000180?emailalert=true)

The authors use Diamond Princess COVID testing data from February 5, 2020 to February 20, 2020 and a Bayesian framework using Hamiltonian Monte Carlo

- True asymptomatic proportion among the reported asymptomatic cases is at 0.35 (95% CrI: 0.30–0.39)
- Estimated asymptomatic proportion at 17.9% (95% CrI: 15.5%–20.2%)

(https://www.medrxiv.org/content/10.1101/2020.03.09.20033142v1.full.pdf)

The authors use 313 domestically-acquired cases in Japan to estimate the age-stratified attack rate

- Age 0-19:
  - Male: 7.2% (95% Confidence Interval (CI): 3.0%, 14.3%)
  - Female: 3.8% (95% CI: 0.8%, 10.6%)
- Age 50-59:
  - Male: 22.2% 49 (95% CI: 16.3%, 29.0%)
  - Female: 21.9% (95% CI: 14.4%, 31.0%)

April 2, 2020 Modeling Report

Hilton & Keeling from the University of Warwick
(https://www.medrxiv.org/content/10.1101/2020.02.26.20028167v1.full.pdf)

The authors use data from China to determine the country-specific R0 of COVID-19 in China and how R0 estimates in the rest of the world vary in relation to China. They calculate this based on the contact-networks in each country.

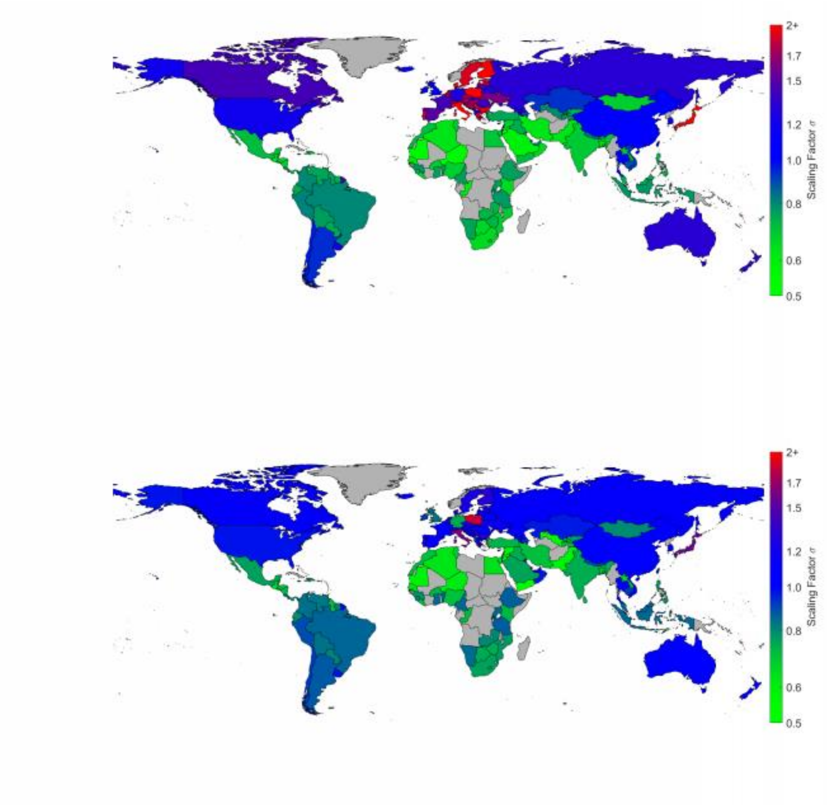

Figure 2: Estimated scaling factor σ for each country based on case data from Li *et al.* [1] (upper map) and Yang *et al.*[2] (lower map). Gray countries are those not included in Prem *et al.*'s study [3].

Limitations: They do not provide numeric results of their assessment.

Li & Shaman et al. from Columbia University
(https://www.medrxiv.org/content/10.1101/2020.02.14.20023127v1.full.pdf)

The authors use observations of reported infection and spread within China in conjunction with mobility data, a networked dynamic metapopulation model and Bayesian inference, to infer critical epidemiological characteristics associated with the emerging coronavirus, including the fraction of undocumented infections and their contagiousness.

- 86% of infections are undocumented prior to Wuhan travel shutdown (Jan 23 2020) – 14% detection rate.
- Undocumented infections were 52% (44%-69%) as contagious as documented infections
- Undocumented infections were the source of infection for 2/3 of documented cases
- Reff: 2.23 (1.77-3.00)

Limitation: They assume a complete travel shutdown with no inter-city human mobility; however, the degree and initial date of travel restrictions has varied among cities.

April 2, 2020 Modeling Report

Pei & Shaman from Columbia University
(https://www.medrxiv.org/content/10.1101/2020.03.21.20040303v2)

The authors metapopulation model applied at county resolution to simulate the spread and growth of COVID-19 incidence in the continental United States, calibrated against county-level incidence data collected between February 21, 2020 and March 13, 2020. They project the outbreak in the continental US for 180 days after March 13, 2020 and evaluate the effects of social distancing and travel restrictions on the outbreak.

- Unmitigated curve: peak incidence on May 21, 2020 of 470,000 new infections
- 25% reduction in contacts: peak incidence on Jun 30, 2020 of 270,000 new infections
- 50% reduction in contacts: curve is fully flattened – very low incidence and no peak is seen in the 6 months after March 13
- 95% of cross-county mobility: peak incidence on May 21, 2020 of 300,000 new infections & curve reduces slowly

Char Leung from Deakin University
(https://www.medrxiv.org/content/10.1101/2020.02.13.20022822v1.full.pdf)

Leung used media to find confirmed cases outside Hubei province and within China. They used the maximum likelihood method to estimate the incubation period distribution. The incubation period (a Weibull distribution) for those that did not travel was longer and more volatile.

- The mean for non-travelers: 6.9 (5.5, 8.3) days – 95th percentile: 14.5 (11.2, 17.5)
- The mean for travelers to Hubei: 1.8 (1.0, 2.7) days – 95th percentile: 3.2 (1.0, 3.8)
- They recommend extending the quarantine period for 3 weeks

Limitations: They are only using data from the internet/media sources.

Wan et al. from Wuhan Ammunition Life-Tech Co. Ltd in Wuhan, Hubei, China
(medrxiv.org/content/10.1101/2020.02.16.20023804v1.full.pdf)

The authors use an SEIR Epidemic Transmission Model parameterized by data from the Hubei Provincial Health Committee (http://wjw.hubei.gov.cn/) from Jan 22 to Feb 12 2020 to determine basic reproduction number and epidemic peak of Wuhan city.

- R0: 1.44 (IQR: 1.40-1.47)
- Peak: Feb 19, 2020 – 45,000 infected individuals.

Limitations: This analysis assumes 200,000 susceptibles, though Wuhan City is known to have a population of 11 million.

Can Zhou et al. from Texas A&M University
(https://www.medrxiv.org/content/10.1101/2020.02.15.20023440v1.full.pdf)

Zhou uses an SEIR model to estimate a basic reproduction number and to determine if there was asymptomatic transmission. Zhou used data from internationally exported cases, evacuated foreign nationals, and Baidu migration data to estimate parameters for this SEIR model.

- R0: 2.12, 95% CrI: [2.04, 2.18]
- Probably no asymptomatic transmission
- Estimated case confirmation rate on Feb 10 2020: 23.37%, CrI: [18.72%, 29.26%]

April 2, 2020 Modeling Report

Milan Batista from University of Ljubljana, Slovenia
(https://www.medrxiv.org/content/10.1101/2020.02.16.20023606v5.full.pdf)

The authors use a logistic growth model to estimate final epidemic size and peak time of the COVID-19 epidemic. They start off with data from a published graph from Jan 16 to Jan 21. Then, they use WorldMeter's estimates for Jan 22 to Feb 16 2020.

- Final number of cases will be 83,700 (+/- 1300)
- Peak was Feb 9, 2020

Limitations: The analysis was conducted on data collected until Feb 12, 2020.

(https://www.medrxiv.org/content/10.1101/2020.03.11.20024901v1.full.pdf)

The author uses a logistic growth regression model and fully daily reports to estimate the final size and peak time of epidemic.

- China:
  - Final size: 81,000 cases
  - Peak on Feb 8th
- South Korea
  - Final size: 7900 cases
  - Peak: March 1st
- Rest of the world:
  - 90,000 (author states this is unreliable)
  - Peak: March 15th

Ryu et al. Konyanh University, South Korea
(https://www.medrxiv.org/content/10.1101/2020.02.15.20023234v1.full.pdf)

Over 37,000 Chinese students attend South Korean universities, with the spring semester starting in early March. In this paper, the authors estimate the risk of a subsequent outbreak under different intervention strategies.

- Findings suggest that outbreaks could be dampened if home quarantine is adhered to at high levels, although significant resources may be needed to ensure proper implementation.

Zhang et al. from Fujian Normal University
(https://www.medrxiv.org/content/10.1101/2020.03.02.20030064v3.full.pdf)

The authors use NHCC cumulative death data from January 21 to February 29, 2020 with a Boltzmann function and Monte Carlo to forecast total deaths due to COVID-19.

- Total deaths in Mainland China: 3342 (95% CI, 3214, 3527)
- in non-Hubei provinces: 111 (109, 114)in Hubei province: 3245 (3100, 3423)
- in Wuhan province: 2613 (2498, 2767)
- in non-Wuhan cities in Hubei: 627 (603, 654)

Wilson et al. from University of Otago in New Zealand
(https://www.medrxiv.org/content/10.1101/2020.02.15.20023499v1.full.pdf)

The authors used confirmed cases from outside China from news reports in February.

- Estimated a case fatality risk of 1.37% for cases outside China.

Limitations: They only used data from news sources and did not consider mild cases. It could also only be a symptomatic CFR since it is likely that patients were only tested if they showed symptoms.

Bo Zhang et al. from Renmin University in Beijing
(https://www.medrxiv.org/content/10.1101/2020.02.16.20023770v1.full.pdf)

The authors used an SEIR model in Python. They divided epidemic area in China by three parts (Wuhan, Hubei (without Wuhan), and China (without Hubei and Wuhan). They used Baidu migration data to assess number of infected cases that migrated from Wuhan to other areas.

- R0 was 3.6 in the early stage of epidemic.
- Effective reproduction number decreased from 3.6 to 0.67 (Wuhan), 3.4 to 0.83 (Hubei), and from 3.3 to 0.63 (China).
- 42073 cases in Wuhan, 21342 in Hubei, and 13384 in China by April.
- 2179 deaths in Wuhan, 633 in Hubei, and 107 in China by April.

Limitations: Might not cover all the people who have migrated. No accurate medical resource limitation published.

Wang et al. from Shanghai Jiao Tong University
(https://www.medrxiv.org/content/10.1101/2020.02.18.20024281v1.full.pdf)

The authors used an SEIR model to estimate epidemic trend in Wuhan under a few assumptions of effective reproductive number. They used parameter values from other pre-published papers.

- Number of infections between December 1, 2019 and February 29, 2020:
  - Rt = 1.9: 11,044
  - Rt = 2.6: 70,258
  - Rt = 3.1: 227,989
  - Rt = 0.9: 58077 – 84520
  - Rt = 0.5: 55869 - 81393
- First phase: Dec1 – Jan23
  - R0 = 3.1 and num infections = 17656 – 25875 in Wuhan
- Second phase: Jan24 – Feb2
  - Rt = 2.6 and num infections = 32061 – 46905
- Third phase: Feb3 – Feb15
  - Rt = 1.9 and num infections = 53070 – 77390

Limitations: We cannot use model outside Wuhan since dynamics would be different. They do not provide model fit information. There seem to be some inconsistencies to what they refer to as R0 vs Rt.

Zhang et al. from Shanghai Jiao Tong University
(https://doi.org/10.1016/j.ijid.2020.02.033)

This study estimates R0 for theCOVID-19 outbreak on the Diamond Princess Cruise Ship – as of Feb 16, 2020, when 355 cases were confirmed. They use the “earlyR” R-package to estimate R0 and applied “projections” package in R to simulate the plausible cumulative epidemic trajectories and future daily incidence by fitting the data of existing daily incidence, a serial interval distribution, and the estimated R0 into a model based on the assumption that daily incidence obeys approximately Poisson distribution determined by daily infectiousness.

- R0: median 2.28 (95% CI: 2.06-2.52)
- Estimated cumulative cases would reach 1514 (1384-1656) at the tenth day in the future (Feb 26, 2020)
- R0 value was reduced by 25%: the estimated total number of cumulative cases would be reduced to 1081 (981-1177)
- R0 value was reduced by 50%: the estimated total number of cumulative cases would be reduced to 758 (697-817)

Limitations: The proportion of susceptible population will decrease rapidly, so the results might change after considerable cases were infected. Second, some confirmed cases were intentionally removed from the ship for treatment, so R0 could be underestimated. Third, data from Ministry of Health, Labour and Welfare could be delayed in case confirmation or reporting - might result in an underestimation of R0.

Dong et al. from Shanghai Jiao Tong University
(https://pediatrics.aappublications.org/content/pediatrics/early/2020/03/16/peds.2020-0702.full.pdf)

This study characterizes 2143 pediatric patients (median age 7 years, IQR: 2-13 years of age) with COVID-19 reported to the Chinese CDC from Jan 16-Feb 8, 2020.

- Median time from illness onset to diagnosis: 2 days (0-42 days)
- Over 90% of all patients were asymptomatic, mild, or moderate cases.

Anastassopoulou et al. from University of Athens
(https://www.medrxiv.org/content/10.1101/2020.02.11.20022186v5.full.pdf)

Based on the publicly available epidemiological data (WHO, CDC, ECDC, NHC and DXY) for Hubei from January 11 to February 10, 2020, the authors provide estimates of the main epidemiological parameters, i.e. the basic reproduction number (R0) and the infection, recovery and mortality rates. Their computations and analysis were based on a mean field Susceptible-Infected-Recovered-Dead (SIRD) model.

- R0
  - mean, 2.4 – Nov 16 – Feb 10
  - Jan 11-16: 4.8 (90%: 3.36, 6.67)
  - Jan 11-17: 4.60 (3.56, 5.65)
  - Jan 11-18: 5.14 (4.25, 6.03)
- Recovery rate: 0.05 (0.05 – 0.055)
- Mortality rate: 2.94%, (2.9% – 3%)
- Infections: 180,000 (45,000-760,000), by Feb 29, 2020
- Deaths: 9,000 (3,200 – 34,000)

They do a sensitivity analysis to see the effect on the above results with case and recovery underreporting.

Maier and Brockmann from the Robert Koch Institute in Berlin, Germany
(https://www.medrxiv.org/content/10.1101/2020.02.18.20024414v1.full.pdf)

The authors use a parsimonious model that captures both, quarantine of symptomatic infected individuals as well as population wide isolation in response to mitigation policies or behavioral changes. They show that the observed scaling law is a direct consequence of containment policies that effectively deplete the susceptible population.

- For a basic reproduction number of 6.2, the Reff values in this model were found to be:
    - Hubei: 3.28
    - All Chinese Provinces Excluding Hubei: 1.93
    - Guangdong: 3.02
    - Henan: 2.41
    - Zhejiang: 3.10
    - Hunan: 3.28
    - Anhui: 1.70
    - Jiangxi: 3.46
    - Jiangsu: 1.75
    - Chongqing: 1.36
- Fixed mean infectious duration = 8 days
- Peak time for Hubei = Feb. 7th

Ding et al. from Anhui Provincial Hospital
(https://www.medrxiv.org/content/10.1101/2020.02.18.20024661v1.full.pdf)

The authors use data for Hefei and Shenzhen from municipal and provincial CDC for Jan 9th through Feb 11th, migration data from Baidu Migration. The perform a Spearman correlation analysis between R0 and population flow form the epicenter.

- No significant correlation between R0 and Shenzhen, but strong association with Hefei and population flow from Wuhan or Hubei in general.
- R0 during initial stage:
    - Hefei = 3.04 ±1.12
    - Shenzhen = 3.03 ± 1.22
- R0 during last week:
    - Hefei, 1.94 ± 0.18
    - Shenzhen, 1.59 ± 012

Shao et al. from Fudan University
(https://www.medrxiv.org/content/10.1101/2020.02.17.20023747v2.full.pdf)

The authors use the framework of Wallinga and Lipsitch to determine R0 based on data from Chinese Center for Disease Control and Prevention.

- R0 = [3.25 – 3.4]

Table 1: The growth rate r and the reproductive number R_0

	r(first strategy)	R_0	r(second strategy)	R_0
Wuhan	0.2830	3.1225	0.3100	3.3250
Hubei(without Wuhan)	0.2692	3.0190	0.3166	3.3745
China(without Hubei)	0.2720	3.0400	0.3122	3.3415
Beijing	0.3012	3.2590	0.3038	3.2785
Shanghai	0.2995	3.2462	0.3082	3.3115

Assuming a mean serial interval of 7.5.

April 2, 2020 Modeling Report

Zhang et al. from Fudan University
(https://www.medrxiv.org/content/10.1101/2020.02.21.20026328v1.full.pdf)

The authors use data on confirmed laboratory cases (8,579) outside Hubei province until Feb. 17th. Used Weibull, gamma, and lognormal to estimate parameters and selected best fir based on minimum Akaike information criterion (AIC). Used a Bayesian approach to estimate net reproduction number. However, they say it is collected from websites of national, provincial, and municipal Health Commission and websites of national and local government affiliated medias.

- Delay from symptom onset to hospital admin decreased from 4.4 days to 2.6 days
- Mean incubation period: 5.2 days [1.8-12.4] – well approximated by lognormal distribution
- Mean serial interval: 5.1 days [1.3 – 11.6] – gamma distribution
- Net reproduction number: 1.4 in Shenzhen [1.04 – 1.85] and 2.17 in Shandong [1.69 – 2.76]

Limitations: Analysis focuses on 9 of the most affected areas in mainland China without Hubei. Still unclear what the differences between symptomatic and asymptomatic infections are, how they transmit, and how they are detected. Non-homogenous sampling over time and by location. Individual records taken from different data sources and may be affected by geographical heterogeneities in sampling with specific exposure.

(https://www.medrxiv.org/content/10.1101/2020.03.19.20039107v1.full.pdf)

The authors conducted surveys in Wuhan and Shanghai as well as developed an SIR model with data from Hunan Provincial Center for Disease Control and Prevention.

- Daily contacts were reduced 7-9 fold during COVID outbreak -most interactions restricted to household
- Children under 14 were 59% (95%CI: 7-82%) less susceptible than adults over 65
- Social distancing alone is sufficient to control COVID
- Proactive school closures reduce peak incidence by half and delay epidemic

Lu et al. from Fudan University
(https://www.medrxiv.org/content/10.1101/2020.02.19.20025031v1.full.pdf)

The authors use publicly accessible data on 265 patients admitted to Shanghai Public Health Center before Feb. 7th which were confirmed with real time PCR to estimate incubation period and onset-to-admission.

- Incubation period: 6.4 (5.3 – 7.6)
- Onset-Hosp admin: 5.5 days (5.1 – 5.9)
- Median time for COVID-10 progressed to severe diseases: 8.5 days (4.8 – 11)
- Transmission rate in Shanghai had all decreased more than 95% than previously speculated.
- First lab -confirmed case in Shanghai was Jan 20th

Limitations: They could not fully evaluate control measures. Most patients still hospitalized at time of manuscript submission.

Pan et al. from Fudan University in Shanghai
(https://www.medrxiv.org/content/10.1101/2020.02.19.20025387v2.full.pdf)

The authors used confirmed cases by nucleic acid test from 16th Jan to 16th of Feb by National Health Commission of People's Republic of China, Provincial Health Commissions of China and government reports from Hong Kong, Macao, Taiwan and other cities, and demographic data from Statistical Yearbook of National

Bureau of Statistics and from Provincial Bureau of Statistics to fit their two SEIR models used to simulate epidemic.

- From Jan 18th to Feb. 16th
  - R0 went from 5.75 to 1.69 in Wuhan
  - R0 went from 6.22 to 1.67 in China
- Peaks in Wuhan:
  - Confirmed cases: Feb 6th (1,718 cases)
  - asymptomatic cases per day: Feb 6th (1,017 cases)
  - Infections of super-spreading events: 419 – peak on Feb 3, 2020
  - symptomatic infection: Feb 3rd (12,418 cases)
- Peaks in China (except Wuhan):
  - asymptomatic cases per day: Jan 30th (766 cases)
  - Infections of super-spreading events: 438 – peak on Jan 29
  - New symptomatic infection: Jan 29th (13,006 cases)
  - COVID-19 inpatients: Feb 10th (14,008 cases)
- Number of confirmed cases decreases to single digits by March 27 2020Cities with top risk index (except Wuhan)
  - Huanggang
  - Xiaogan
  - Jingzhou
  - Chongqing
  - Xiangyang city

Limitations: There was not enough data to provide accurate information about quarantine rates and detection rates at each stage of epidemic. The authors were unable to obtain some relevant data such as exposure and infection rates of healthcare workers.

Li et al. from Fudan University
https://www.medrxiv.org/content/10.1101/2020.02.25.20027672v2.full.pdf

The authors analyze information on 5,319 cases, including 76 fatalities, that were reported in China outside of Hubei province.

- Among reported cases, the CFR was estimated to be < 1% for those under 40, but rises to over 50% for those over 90, significantly higher than previous estimates.
- Overall, 2.38% of reported cases died, which is lower than the crude rate reported in Wuhan.
- CFR is estimated to be 5 times higher in Hubei than in other Chinese provinces, likely due to strains on the local healthcare system.

Zhang et al. from Fudan University
(https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3548372)

Non-Hubei provinces in China initiated level-1 responses during a three-day period between January 23rd and 25th. This analysis explores whether provinces that responded earlier during the three-day window were subsequently more successful at controlling the spread of coronavirus, while controlling for other socioeconomic, demographic, and policy factors.

- The authors estimated that responding one day earlier was associated with ~500 fewer new cases per 10,000 population per square kilometer over the next 11 days

Deng et al. from Fudan University
https://www.medrxiv.org/content/10.1101/2020.03.04.20031005v1.full.pdf

The authors use data from websites of various levels of Health Commissions from Dec 29th to Feb 23rd to estimate the CFR in mainland China. They used right-censoring, survival analysis, and Garske's method for the CFR.

- CFR: 0.89-1.24%
  - Garkse's method
    - Mainland: 4.52% (95% CI: 4.47-4.67%)
    - Wuhan: 6.19% (6.12-6.41%)
    - Outside Hubei: 0.89% (0.83-1.06%)
  - Survival Analysis:
    - 1.24% (1.24% to 1.24%) among all cases
    - 11.21% (11.21 to 11.21%) among sever and critical patients outside Hubei
- Time interval from symptom onset to death was estimated to be 12.9 days (95% CI: 2.2 to 40.2)
- Time interval from symptom onset to discharge was 16.9 days (8.6 to 28.9)

Hu et al. from Fudan University
(https://www.medrxiv.org/content/10.1101/2020.03.11.20033639v1.full.pdf)

The authors use a modified auto-encoder (MAE), an artificial intelligence (AI) based method for real time forecasting of the new and cumulative confirmed cases of Covid-19 under various interventions in more than 100 countries across the world.

- Delaying intervention 4 weeks after March 8, 2020 would cause the maximum number of cumulative cases of death increase from 7,174 to 133,608
- Delaying intervention 4 weeks after March 8, 2020 would move ending points of the epidemic postponed from Jun 25 to Aug 22

Jiang et al. from Guangzhou Institute of Pediatrics
(https://onlinelibrary.wiley.com/doi/epdf/10.1002/jmv.25708)

The authors fit Weibull, lognormal, and gamma functions to datasets with patients who had well-defined exposure periods to determine incubation times for SARS, MERS, and COVID-19. There is no observable difference between incubation time for SARS-CoV-2 (COVID-19), SARS, and MERS:

- SARS-CoV-2 = 4.9 days (95% CI: 4.4-5.5)
- SARS = 4.7 days (95% CI: 4.3-5.1)
- MERS = 5.8 days (95% CI: 5.0-6.5)

Limitations: It is unclear where the COVID-19 data comes from. There is a need for larger and well annotated datasets.

Lai et al. from University of Milan in Milan, Italy
(https://onlinelibrary.wiley.com/doi/pdf/10.1002/jmv.25723)

April 2, 2020 Modeling Report

The authors use phylogenetic data (52 SARS-CoV-2 genomes that were available February 4, 2020) to estimate the basic reproduction number.

- R0 = 2.6 [2.1-5.1]
- Increased from 0.8 to 2.4 in Dec 2019
- Mean doubling time of epidemic between 3.6 and 4.1 days
- Effective reproductive number increased from <1 [95% HPD: 0.3-1.3] to mean of 2.4 [95% HPD: 1.5-3.5]in Dec. 2019
- Estimated recovery rate = 7.3 days [4.7 – 16.5]
- Transmission rate increased from 40.5 to 112.4 units per year in Dec. 2019

Limitations: Small number of sequences and relatively short sampling period. Analysis includes isolates collected outside mainland China

Wang et al. from Henan University
(https://www.medrxiv.org/content/10.1101/2020.02.21.20026112v2.full.pdf)

The authors estimated epidemiological characteristics in Henan for 483 cases from 21 Jan to 14 Feb using official reported cases.

- Mean Incubation period: 7.43 days (95% CI: 2, 20)
- Model estimates of incubation period:
    - ME: 7.43 days (95% CI: 1.9, 20.2)
    - OLS: 10.7 (95% CI: 1.8, 35.9)
      MLE: 9.1 (95% CI: 1.2, 33.5)

Wu et al. from Henan University
(https://www.medrxiv.org/content/10.1101/2020.02.21.20026229v1.full.pdf)

The authors fit epidemic data to SIR models to model COVID-19 R0, infection intensity, peak time, and the epidemiological end time.

- Hubei Province:
    - 51,673 cases
    - R0 was as high as 6.27, then it decreases gradually
    - It is expected to approach to zero in early May
- Nationwide without Hubei:
    - Cases were much lower than Hubei – peaking at 9,145 cases
    - The peak will arrive around February 10.
    - R0 was as high as 2.44, then it decreases gradually
    - Approach to zero in the end of March.
- Henan Province:
    - Incidence stays very low, the parabolic fitting curve is similar to the nationwide without Hubei.
    - Epidemic reaches peak on around February 12
    - Epidemic will end in early April.

Sun et al. from Zibo Central Hospital in Zibo, Shandong Province, China
(https://www.medrxiv.org/content/10.1101/2020.02.18.20024539v2.full.pdf)

The authors searched PubMed, Cochrane Library, and Embase databases with articles dated up until Feb. 2020. They used 10 articles in a single arm Meta-analysis to summarize clinical characteristics of patients with COVID-19.

- Case fatality rate of patients = 4.3%

Limitations: The studies were retrospective studies with large heterogeneity. Most patients were Chinese, and they'd like to include other countries and races.

Wang & Qi from Shandong University
https://www.medrxiv.org/content/10.1101/2020.03.08.20032854v1.full.pdf

This study used a deterministic compartmental model of cumulative cases, deaths and recovery reports to estimate key epidemiological parameters and the trajectory of the outbreak in China given the implementation of control measures. The authors fit this model to the cumulative number of cases, recoveries and deaths reported in all mainland Chinese provinces except Hubei (due to major changes in case reporting over time) since January 20.

- Estimated R_0: 2.82 [95% CI: 2.71, 2.93] between 1/20/2020 and 3/9/2020
- Date when Re =1 (i.e. when transmission dies out): between 3/20/2020 and 3/22/2020
- Predict the number of current daily infections would be less than 1 after 4/2/2020

Limitations:

- This model assumes homogenous contact structure and contact structure does not change after interventions implemented (though number of infectious contacts, β, decreases)
- Does not consider differences in implementation of interventions across provinces in China
- Model cannot accommodate sudden changes in control measures or reporting (i.e., can't be fit to data in places like Hubei where there was a major, sudden change in case reporting over a short period of time)

Tuite et al. from University of Toronto – Ontario, Canada
(https://www.thelancet.com/journals/laninf/article/PIIS1473-3099(20)30227-9/fulltext)

The authors use data from the International Air Transport Association for Feb. 2015 and from the United Nations World Tourism Organization with methods from Faser et al. to estimate the underlying epidemic in Italy.

- Estimated true outbreak size: 3971 (95% CI 2907-5297) on February 29, 2020
- Implies a non-identification of 72% (61-79%) of cases

(https://annals.org/aim/fullarticle/2763328/estimation-coronavirus-disease-2019-covid-19-burden-potential-international-dissemination

The authors assessed interconnectivity between Iran and other countries using direct and total traveller volumes and final destination cities of travellers originating in Iran in February 2019, using data from the International Air Transport Association (IATA) to estimate the size of the underlying epidemic in Iran necessary in order for these cases to be observed with a reasonable probability.

- 18,300 (95% confidence interval: 3770 – 53,470)
- Odds of a single case being imported from Iran:
    - To Iraq rather than to Canada would be 33.6:1

- To Iraq rather than to Lebanon would be 15.4:1
- To Azerbaijan rather than to Canada would be 3.8:1
- To Azerbaijan rather than to Lebanon would be 1.7:1
- To Syria rather than to Canada would be 3.7:1
- To Syria rather than to Lebanon would be 1.7:1

Liu et al. from Xiamen University Tan Kah Kee College, Zhangzhou, China
(https://academic.oup.com/jtm/advance-article/doi/10.1093/jtm/taaa021/5735319)

This is a review of basic reproduction number results posted on PubMed, bioRxiv, and Google Scholar from Jan 1, 2020 to Feb 7, 2020.

- Estimates ranged from 1.4 to 6.49, with a mean of 3.28, a median of 2.79 and interquartile range (IQR) of 1.16

Limitations: They do not include medRxiv.

Shi et al. from Xiamen University
(https://www.medrxiv.org/content/10.1101/2020.03.15.20034199v1.full.pdf)

The authors used data from National and Provincial Health Committee reports from Jan 19th to Feb 29th and data from Baidu Migration index with cross-correlations functions and an autoregressive integrated moving average model to examine time-lagged association between traffic volume and incidence.

- Outbound traffic from Wuhan was positively associated with COVID incidence in all provinces (Correlation coefficients: 0.22-0.78)
- 42% of provinces showed <1 week of lag between traffic volume and incidence
- 39% with 1 week
- 19% with 2-3 weeks
- Travel ban prevented approximately 19,768 cases (95% CI: 13589-25946) in Wuhan by Feb. 29th

Japanese National Institute for Infectious Disease
(https://www.niid.go.jp/niid/en/2019-ncov-e/9417-covid-dp-fe-02.htmll)

The Japanese NIID provides an update, as of February 20, 2020, on the status of the Diamond Princess Cruise Ship passengers, when 619 passengers tested positive.

- Among confirmed COVID-19 cases with recorded symptom onset (n=197), there were 34 (17.3 %) with onset dates before 6 February, which was the first full day of quarantine, and 163 (82.7%) with onset dates on or after the 6th.
- 163 occurred during the quarantine period (48 crew, 115 passengers), with 52–92 among passengers in cabins without a previously confirmed case.
    - 3–7 occurred after the median quarantine day (day 7).
- The proportion of COVID-19 cases confirmed among passengers increased with cabin occupancy.
- A total 318 (51%) of all confirmed cases were asymptomatic when the respiratory specimen was collected (10 crew and 308 passengers).

This is only as of February 20, and date of summary is Feb 28, 2020.**Sugishita et al. from National Institute of Infectious Diseases in Tokyo**
(https://www.medrxiv.org/content/10.1101/2020.03.12.20035220v1.full.pdf)

The authors use an SIR model with data from January 14th to March 8th to measure the effect voluntary event cancellation (VEC) had on the outbreak in Japan.

- R0 before VEC: 2.50 (95% CI: 2.43 – 2.55)
- Reff after VEC: 1.88 (1.68 - 2.02)
- VEC can reduce infectiousness by 35%

Shim et al. from Soongsil University in Seoul, Republic of Korea
(https://www.medrxiv.org/content/10.1101/2020.02.27.20028829v1.full.pdf)

The authors obtained data on daily confirmed cases in South Korea from Jan. 10th – Feb 26th from the Korea Centers for Disease Control and Prevention. They create epidemic curves by dates of symptom onset and derived a mean incidence curve. They also use a generalized growth model to characterize the daily local case incidence.

- Rt (effective reproduction number): 1.5 (1.4-1.6) in South Korea

Tian Hao from Chino Hills, CA
(https://www.medrxiv.org/content/10.1101/2020.02.26.20028571v1.full.pdf)

The authors use Eyring's rate process to describe infectious disease transmission and use data from Jan 21st to Feb 17th from the Chinese Center for Disease Control and Prevention. They use modified SIR and SEIR models (individuals can become re-infected) to determine R0 and infection peak.

- Higher temperatures can reduce disease transmission
- R0: 1.5 based on SIR model
- R0: 3.5 based on SEIR model (contains exposed compartment)
- Infected peaks 158-160 days after Jan 21st

Tang et al. from Shaanxi Normal University
(https://www.medrxiv.org/content/10.1101/2020.02.25.20027615v1.full.pdf)

The authors obtained data of confirmed cases in Shaanxi province from National Health Commission of the People's Republic of China and the Health Commission of the Shaanxi Province and mobility data from Baidu Qianxi. They use an SEIHR model with quarantine for suspectible and suspected infected individuals.

- Control reproduction number: (1.48-1.69) in Xi'an
- Effective reproduction number < 1 after Jan 27th

Tang et al. from Xi'an Jiaotong University
(https://www.mdpi.com/2077-0383/9/2/462/htm)

The authors use a deterministic compartment model: SEAIHR with quarantined suspectible, isolated exposed, and isolated infected compartments. They fit their model to data of laboratory confirmed cases from WHO situation report, the NHCC, and the Health Commission of Wuhan City and Hubei Province from Jan 10th-15th, to estimate the control reproduction number.

- Control reproduction number: 6.47 (95% CI: 5.71-7.23)
- Under most restrictive measures, peak is expected two weeks after Jan 23rd
- Travel restrictions can lower number of infected in seven days by 91.14%

(https://www.medrxiv.org/content/10.1101/2020.03.09.20033464v1.full.pdf)

April 2, 2020 Modeling Report

The authors estimate basic numbers for China, Guangdong province, and South Korea COVID epidemics using White and Pagano method (likelihood-based method). They use an SEIAHR model to determine if enhanced control measures including self-isolation/self-production, effective quarantine and rapid detection/testing can reduce cases.

- Basic reproduction number:
  - Mainland China: 3.8 (95%CI: 3.5, 4.2)
  - Guangdong: 3.0 (95%CI: 2.6, 3.3)
  - South Korea: 2.6 (95%CI: 2.5, 2.7)
- Improving detection (via testing) and reducing social contacts in South Korea can reduce the effective reproduction number over time so that the epidemic slows similarly to how it did in Guangdong Province, China.

Xu et al. from Wenzhou Medical University in Wenzhou, China
(https://www.medrxiv.org/content/10.1101/2020.02.25.20024398v1.full.pdf)

The authors obtained data for 434 confirmed patients in Wenzhou from National Health Commission of the People's Republic of China and the Health Commission of Wenzhou by Feb. 10th. They used deterministic compartmental SEIR model to determine incidence peak, epidemic end.

- Peak illness onset was Jan 26th, 2020
- Incidence reaches 0 on March 3-9th, 2020
- R0:
  - Wenzhou: 2.91 (2.35-3.57)
  - Shenzhen: 2.53 (1.86-3.34)
  - Zhengzhou: 5.95 (5.36-6.67)
  - Harbin: 3.35 (3.07 – 3.68)

Limitations: The authors say they use an SEIR model, but do not describe the model.

Li et al. from Wuhan Red Cross Hospital
(https://www.medrxiv.org/content/10.1101/2020.02.27.20027169v1.full.pdf)

The authors forecasted using a modified SEIR model and obtained data from the Hubei Provincial Center for Disease Control and Prevention.

- Peak time of newly diagnosed
  - Feb 5th (non-Hubei)
  - Feb 19th (Hubei)
- Peak of cumulative cases
  - March 3rd (non-Hubei)
  - March 10th (Hubei)
- Total patients diagnosed
  - 18,000 in non-Hubei
  - 78,000-96,000 in Hubei
- R0
  - 4.9-9.9 (median 7.5) in Hubei
  - 2.5-4.8 (median 3.7) in non-Hubei

Limitations: They are not using a different infectivity for those in latent and infected compartments, isolations measure could differ by region, isolation time still unknown, and epidemic relapse not considered.

Men et al. from Xi'an Medical University in Xi'an, Shaanxi, China
(https://www.medrxiv.org/content/10.1101/2020.02.24.20027474v1.full.pdf)

The authors use data from 10 regions in China (except Hubei) using 59 confirmed cases from Dec 29th to Feb 5th and used a Monte Carlo simulation and manifold learning and various statistical analysis to obtain estimates of the incubation period.

- Incubation did not follow general distribution
    - Mean = 5.84 days and median = 5 days
    - Min incubation period = 1
    - Max = 15 days
    - 2.5 percentile: 2.69
    - 97.5 percentile: 12.89
- Significant different in incubation period for those young and older than 40 (longer for those younger).

Limitations: The authors do not discuss limitations, though it is not clear where they obtain their data.

Li et al. from Donghua University in Shanghai
(https://www.medrxiv.org/content/10.1101/2020.02.26.20028431v1.full.pdf)

The authors use data on cases from China (excluding Hubei) from officially published daily updates. They fit the data to gamma, log-normal, and exponential distributions using Markov Chain Monte Carlo and selected the one with the smallest Deviance Information Criterion.

- Mean generation time: 3.3 (2.3-4.3) days
- Mean incubation time: 7.2 (6.8 – 7.6) days
- 3.7 (3.5-3.9) days to isolate patient after symptom onset
- 6.6 (6.5-6.8) days to diagnose patient after symptom onset
- Patients become infectious 3.9 days before showing major symptoms
- R0: 1.54 with contact tracing, quarantine, and isolation
- On average, a quarantine period of 14 days leads to failure rate of 6.7%
    - Recommend a quarantine period of 22 days

Limitations: They are essentially describing an effective reproduction number, though they describe it as a basic reproduction number.

Lai et al. from the University of Southampton in the UK
(https://www.worldpop.org/resources/docs/COVID_NPI/WorldPop_COVID-19_outbreak.pdf)
(https://www.medrxiv.org/content/10.1101/2020.03.03.20029843v3.full.pdf)

This is study explores the effect of NPIs on the COVID-19 outbreak using an SEIR (suspectible-exposed-infectious-removed) model, parameterized by WHO reported data.

- Estimating a total of 114,325 COVID-19 cases (IQR: 76,776 - 164,576) in mainland China as of February 29, 2020
- Without current NPIs, the number of COVID-19 cases would likely have shown a 67-fold increase (IQR: 44 - 94)

- If NPIs could have been conducted one week, two weeks, or three weeks earlier in China, cases could have been reduced by 66%, 86%, and 95%, respectively, together with significantly reducing the number of affected areas.

Yang et al. from National Clinical Research Center for Infectious Diseases
(https://www.medrxiv.org/content/10.1101/2020.02.28.20028068v1.full.pdf)

The authors use Cox regression analysis, chi-squared, Fisher exact, t, or Mann-Whitney tests to identify prognostic factors on data of 55 lab-confirmed cases admitted to Fifth Medical Center of PLA General Hospital (Beijing) from Dec. 27th to Feb. 18th.

- Mean incubation: 8.42 (95% CI 6.55-10.29) days
    - 9.06 (6.55-10.29) for those without pneumonia
    - 7.54 (5.29-9.79) for those with pneumonia
- Mean duration from first positive test to conversion: 9.71 (95% CI 8.21 – 11.22) days
    - Without pneumonia: 9.24 days (7.10-11.37)
    - Pneumonia: 10.45 (8.10-12.81)
- Mean duration from onset to admission: 5.81 (4.95-6.68) days
    - Without pneumonia: 4.86 (3.46-6.25)
    - With pneumonia: 6.42 (5.23-7.53)
- Mean duration from illness onset to discharge: 18.57 (16.07-21.08) days
    - Without pneumonia: 17.76 (14.45-21.08)
    - With pneumonia: 19.82 (15.39-24.24)
- Course (duration) was approximately 2 weeks

Limitations: They did not know the effect of antiviral treatment, half the patients were still hospitalized, and they were not able to contact trace one patient's family.

Wang et al. from the University of Michigan
(https://www.medrxiv.org/content/10.1101/2020.02.29.20029421v1.full.pdf)

The authors develop a toolbox to analyze coronavirus dynamics and incorporates quarantine, control for case under-reporting, and provide an R software package. They used publicly available data from China CDC.

R0 from different models:

- No quarantine model
    - In Hubei: 2.96 (95% CI 1.82-4.49)
    - Outside Hubei: 2.58 (95% CI 1.52-4.26)
- Exponential
    - In Hubei: 4.88 (2.35-8.42)
    - Outside: 3.36 (1.96-5.26)
- Step-function
    - In Hubei: 4.31 (2.34-6.90)
    - Outside: 3.02 (1.74-4.89)
- Including Quarantine:
    - In Hubei: 5.04 (2.30-9.36)
    - Outside: 3.58 (1.85-6.10)

Limitations: The authors declared limited data as part of their limitations.

April 2, 2020 Modeling Report

Yuan et al. from Hunan Agricultural University
(https://www.medrxiv.org/content/10.1101/2020.02.29.20029561v1.full.pdf)

The authors use a simple regression model on Baidu Migration data and National Health Commission of China to determine the effectiveness of Wuhan lockdown.

- Only 1.2 million people travelled from Jan 24th to Feb 15th which is 92.61% less than this time in the previous year and 92.62% less than the first half of January.
- Mean intensity for 316 cities in mainland China was 2.61/day
    - Down 42.42% from same period last year (4.53/day)
    - Down 50.27% from first 23 days (5.25/day)
- If the lockdown had occurred 3 days later, there would have been a 35.21% increase in cases in non-Wuhan areas by Feb. 27th
- If it occurred three days before, it would have reduced cases by 30.72% and with stricter enforcement by 48.59%

Limitations: Data from Baidu Migration is not as accurate as the authors would like.

Fang et al. from University of Shanghai for Science and Technology
(https://arxiv.org/ftp/arxiv/papers/2002/2002.10616.pdf)

This analysis uses agent-based models of crowd movement to predict the final number of cases on the Diamond Princess cruise ship and evaluate the potential impact of control measures.

- between 850 and 1000 people would ultimately be infected on the Diamond Princess, which is higher than the observed number of cases to date (~700 according to the latest WHO sitrep).

Chen et al. from University of Electronic Science and Technology of China
https://arxiv.org/ftp/arxiv/papers/2003/2003.00305.pdf

The authors use an extended Wallinga-Teunis method and Monte Carlo simulation to predict the temporal reproduction number using data from scattered news sources from Jan 11th to Feb 22nd.

- R_temporal for last week/when it becomes less than 1
    - Hubei: 0.0491/Feb 2nd

Wang et al. from Huazhong University
https://www.medrxiv.org/content/10.1101/2020.03.03.20030593v1.full.pdf

The authors use data through February 18th from Notifiable Disease Report System on an SEIR model. They fit the model using Markov Chain Monte Carlo methods.

- Attack rate peaked Jan 23rd – Feb 1st
- Effective reproductive number dropped from 3.86 (95% CI: 3.74-3.91) before interventions to 0.32 (0.28-0.37) after
- Interventions prevented 94.5% (93.7-95.2%) of infections until Feb. 18th
- 59% of infected cases were unascertained in Wuhan
- Lag between onset and confirmation date median:
    - Before Jan. 11th: 22 days
    - Jan 11th-22nd: 14 days
    - Jan 23rd – Feb 1st: 10 days

- Feb 2nd -18th: 5 days

Xia et al. from Huazhong University of Science and Technology
https://www.medrxiv.org/content/10.1101/2020.03.06.20031955v1.full.pdf

The authors assessed asymptomatic transmission through a study of 50 infection clusters with 124 cases. Cases limited to those with accurate exposure period of ≤3 days and symptom onset prior to Chinese Spring Festival for a final 106 cases.

- Mean incubation period 4.9 days (95% CI 4.4-5.4)
- Mean serial interval 4.1 days (sd 3.3)
- 73% of secondary cases were infected before symptom onset of first-gen cases, 18.9% of secondary cases were infected on the date of symptom onset for first-gen case, 8.1% were infected after

Tindale et al. from University of British Columbia
(https://www.medrxiv.org/content/10.1101/2020.03.03.20029983v1.full.pdf)

The authors collected outbreak information from Singapore and Tianjin, China, reported from Jan.19-Feb.26 and Jan.21-Feb.27, respectively, and estimated incubation periods and serial intervals in both populations.

- mean incubation period:
    - 7.1 (6.13, 8.25) days for Singapore
    - 9 (7.92, 10.2) days for Tianjin
- mean serial interval:
    - 4.56 (2.69, 6.42) days for Singapore
    - 4.22 (3.43, 5.01) for Tianjin
- Infection was transmitted before onset:
    - 2.55 days in Singapore
    - 2.89 days in Tianjin
- estimated basic reproduction number:
    - Singapore: 1.97 (1.45, 2.48) secondary cases per infective
      Tianjin: 1.87 (1.65, 2.09) secondary cases per infective.

Tapiwaet al. from Hasselt University in Belgium
(https://www.medrxiv.org/content/10.1101/2020.03.05.20031815v1.full.pdf)

The authors collected outbreak information from Singapore and Tianjin Province, China, reported from Jan.19-Feb.26 and Jan.21-Feb.27, respectively, and estimated generation intervals in both populations. Seems to be using the same data from the above study.

- Generation interval:
    - Singapore: 5.20 (95%CI 3.78-6.78) days
    - Tianjian: 3.95 (95%CI 3.01-4.91) days
- Evidence of pre-symptomatic transmission:
    - Singapore: 48% (32-67%) of infections prior to onset
    - Tianjin, China: 62% (50-76%) of infections prior to onset

Kraemer et al. from the University of Oxford
(https://www.medrxiv.org/content/10.1101/2020.03.02.20026708v1.full.pdf)

The authors use migration data to determine how well the January 23 travel restrictions and other interventions reduced the exportation and proliferation of COVID-19.

- outside Hubei province:
    - Pre-Jan 31 Symptom onset date: 515 cases with known travel history to Wuhan
    - Post-Jan 31 Symptom onset date: 39 cases with known travel history to Wuhan
- Growth rates and human mobility are highly correlated.

Lourenco et al. from University of Oxford
https://www.medrxiv.org/content/10.1101/2020.03.24.20042291v1.full.pdf

The authors use an SIR model to simulate the spread with parameter values coming from the literature and data from the Italian Department of Civil Protection GitHub and the John Hopkins University Center for System Science and Engineering.

- By March 19th, approx. 36-40% of the population had been exposed in UK
- By March 6th, 60-64% of Italy's population exposed
- suggests that 68% would have been infected by 19/03/2020.

Ferretti et al. from University of Oxford
(https://www.medrxiv.org/content/10.1101/2020.03.08.20032946v2.full.pdf)

The authors use a mathematical model with various forms of transmission and parameter values from literature.

- Viral spread is too fast to be contained by manual contact tracing
- If process was faster, more efficient, and happened at scale, it can be controlled
- Suggest an app that keeps contacts and immediately notifies contacts of positive cases
- By targeting only those at risk, can control epidemic without need for mass quarantines.
- 1/3 – ½ of transmissions occur from pre-symptomatic individuals
- Total contribution to R0 from pre-symptomatics is 0.9 (CI: 0.2-1.1)

Ping et al. from Guizhou CDC
(https://www.medrxiv.org/content/10.1101/2020.03.01.20028944v1.full.pdf)

This study describes various epidemiological parameters in 162-lab confirmed cases in Guizhou province.

- Incubation period: 8.06 days (95% confidence interval [CI]: 6.89 – 9.36)
- Serial Interval: 6.37 days ±4.15 days
- Estimated basic reproduction number (R0) was 1.09 (95% CI: 0.94 – 1.26)

Lauro et al. from La Trobe University, Australia
(https://www.medrxiv.org/content/10.1101/2020.03.02.20030007v1.full.pdf)

The authors use a well-mixed SIR and metapopulation model to measure the impact of a "one-shot", limited duration intervention.

Well-mixed model:

- Early interventions have little effect on attack rate or peak prevalence
- The more effective the intervention, the more impact it will have being implemented closer to the peak

- Optimal time to introduce intervention is when current prevalence matches peak prevalence that would occur once disease rebounds.
- Later intervention start times cause later peak times

- Metapopulation model
    - Impacts are similar to that of well-mixed model
    - Best when timing in each subgroup is based on infection levels of that subgroup rather than population as a whole

Xu et al., Dalian Minzu University
https://www.medrxiv.org/content/10.1101/2020.03.02.20029868v1.full.pdf

The authors observe household transmission chain with data from city or provincial Health Commissions of China from Jan 24th to Feb 19th.

- Mean serial interval: 5.9 days [S.D: 4.80]

Jiang et al. from Southwestern University
(https://www.medrxiv.org/content/10.1101/2020.03.01.20029645v1.full.pdf)

To model the relative contribution of imported cases and local transmission to COVID spread in Chinese provinces over time, the authors fit the number of cases in a given province at time *t* against the number of cases in each province at time *t-1*.

- Since February 4th, within-province transmission has accounted for most of the increase in case-counts across China, with imported cases from "source" provinces having only a minor contribution.
- The authors argue that these results support the effectiveness of government-imposed travel restrictions

Wan et al. from the Swiss Tropical and Public Health Institute
(https://www.medrxiv.org/content/10.1101/2020.03.01.20029629v2.full.pdf)

The authors use an SEIR model to evaluate the effect of the non-pharmaceutical interventions implemented in mainland China.

- The authors estimate that the effective reproductive number in China has been < 1 since the end of January, suggesting that containment and mitigation efforts have been successful so far.
- contact rates should stay at least 30% lower than usual through April to reduce resurgence of epidemic
- If this occurs, the outbreak can be ended by April in the non-Hubei provinces of mainland China.

Zhang et al. from Soochow University
(https://www.medrxiv.org/content/10.1101/2020.03.04.20031187v1.full.pdf)

The authors use a compartmental model (SEI-Quarantine-R) to estimate impact of social distancing and epicenter lockdown interventions in Wuhan, the rest of Hubei province, and other rest of mainland China. Scenarios assessed the impact of social distancing initiation enacted on different dates (Jan 3, 6, 11, 15, 17, or 19), in different areas, and the varying strength.

After 30 day social distancing intervention:

- Base R0 of 2.2 (95% CI: 1.4, 3.9) was reduced to 1.58 (95% CI: 1.34, 2.07) in Wuhan and Hubei
- Base R0 of 2.52 (95% CI: 2.43, 2.63) was reduced to 1.65 (95% CI: 1.63, 1.69) in rest of mainland China

- The ratio λ0 of isolating susceptibles was 0.1108 (95% CI: 0.0957, 0.1254) in Wuhan
- The ratio λ0 of isolating susceptibles was 0.2326 (95% CI: 0.2125, 0.2538) in Hubei
- The ratio λ0 of isolating susceptibles was 0.4113 (95% CI: 0.3794, 0.4432) in the rest of mainland China

The authors found that the decrease on nationwide outbreak size and deaths from early initiation of social distancing was partly neutralized by earlier epicenter lockdown.

Baker et al. from University of Washington
(https://www.medrxiv.org/content/10.1101/2020.03.02.20030288v1.full.pdf)

The authors aimed to estimate the US burden of occupational exposure to infection and disease using Labor Statistics Occupational Employment database and O*NET database.

- 10% (14.4 mill) workers employed with exposure to disease/infection at least 1x per week
- 18.4% (26.7 mill) have exposure at least 1x per month
- High exposure risk occupations are: healthcare workers, protective service occupations (police, correctional officers, firefighters), office and administration support, education, community and social services, and construction and extraction occupations (plumbers, septic tank installers, elevator repair)

Limitations: This assesses self-reported exposure to the broad category of any infection/disease, and is not specific to the assumed exposure pathways for COVID-19

Qiu et al. from University of South China
(https://www.medrxiv.org/content/10.1101/2020.03.04.20026005v1.full.pdf)

The authors summarize clinical characteristics of 104 non-Wuhan, China cases.

- median incubation period was 6 (range, 1-32) days

Aleta et la. From University of Zaragoza, Spain
(https://www.medrxiv.org/content/10.1101/2020.03.01.20029801v2.full.pdf)

The authors use a province-level meta-population SEIR model of Spain to model the efficacy of different traffic/transportation control interventions on the propagation of COVID-19. Mobility data is obtained from the Ministry of Development of Spain, and case data was collected until February 28, 2020.

- These measures are useless when it comes to completely stop the disease from propagating.
- Indeed, a significant reduction in the estimated incidence is only obtained when other actions are feasible.

(https://www.medrxiv.org/content/10.1101/2020.03.05.20031740v2.full.pdf)

- The authors use basic metapopulation SEIR model of 31 regions in China (except Hong Kong, Macau and Taiwan) with homogeneous mixing to evaluate the effect of travel reductions on the trajectory of the outbreak.When the travel restrictions are implemented, the flow of population had peaked already just before the Spring festival.
- They find that most of the second wave might have not taken place yet and thus, there is still a high risk that a subsequent large outbreak or increase in the number of newly infected individuals happens.
- Travel restrictions are efficacious in the short term, effectively decreasing the expected number of infected individuals in most of the regions in mainland China.
- At the same time, reducing the travel does not appear to have a long-term impact on the spreading of the disease if not accompanied by other measures.

April 2, 2020 Modeling Report

Zhou et al. from Nanjing University
https://www.medrxiv.org/content/10.1101/2020.03.03.20030445v2.full.pdf

The authors use data from Jan 13th to Feb 29th from Tencent social networks, National Health Commission of China and other regions, and WHO on a refined SEIR model and various government interventions. They fit model parameters per time point and put an interactive online application online.

- Without control, peak infected cases in Wuhan: 7.78 million and total deaths: 319,000 based on current mortality rate (4.1%)
- Average incubation period: 5.9 days in Wuhan

Willem et al. from the University of Antwerp, Belgium
https://www.medrxiv.org/content/10.1101/2020.03.03.20030627v1.full.pdf

The authors use social contact data from a systematic review under the grant TransMID and from the United Nation's World Population Prospects 2015 to create an online tool to show that social distancing could have an impact on COVID-19 transmission.

- Predict a 10% decrease in R0 for most countries with 50% telework proportion
- Effect of school closure is school specific. For some, can decrease R0 by 20%

Hernandez et al. from MIT Lincoln Lab
https://www.medrxiv.org/content/10.1101/2020.03.06.20029793v2.full.pdf

The authors use an extended SEIR model with five different intervention policies to estimate impact on population.

- Quarantine-on-alert (ideal early warning) coupled with near-ideal early warning reduces needed quarantine with only a small increase in infections
- The highly specific early detection system increases additional infections relative to near ideal system
- The highly sensitive early detection system increases percentage of population in quarantine while reducing number of additional infections to levels by quarantining entire population a priori

Peak et al. from Harvard University
https://www.medrxiv.org/content/10.1101/2020.03.05.20031088v1.full.pdf

The authors use a stochastic branch model to compare the efficacy of individual quarantine and active monitoring of contacts. They used estimates from previously published data.

- Individual quarantine has short serial interval only in settings with high intervention performance (3/4 infected contacts individually quarantine)
- Short serial interval estimates:
    - Mean duration of infectiousness: 2.4 days [95%CI: 1,6.7]
    - Mean time of peak relative infectiousness: 43% of duration of infectiousness [0%,97%]
    - Mean time of infectiousness onset 0.77 days before symptom onset [1.98 days before, 0.29 days after]
    - Reproductive number under individual quarantine: 0.57
    - Reproductive number under active monitoring: 1.55
    - Reff<1 achieved only by individual quarantine in 84% of the simulations, by either interventions in 12% of simulations, and with no interventions in 4% of the simulations in a high feasibility setting

- Longer serial interval estimates:
  - Mean duration of infectiousness: 4.8 days [95%CI: 1.12,10.5]
  - Mean time of peak relative infectiousness: 38% of duration of infectiousness [0%,97%]
  - Mean time of infectiousness onset 0.51 days before symptom onset [0.77 days before, 1.50 days after]
  - Reproductive number under individual quarantine: 0.49
  - Reproductive number under active monitoring: 0.54
- Tracing 10%, 50%, or 90% of contacts on top of social distancing results in median reduction of Reff of 3.2%, 15%, and 33%, respectively, for active monitoring, and 5.8%, 32%, and 66%, respectively, for individual quarantine.

Hong et al. from Peking Union Medical College Hospital
(https://www.medrxiv.org/content/10.1101/2020.03.06.20032177v1.full.pdf)

The authors use Chinese government and municipal data, Baidu Migration Big Data Platform, Center for Systems Science and Engineering of Johns Hopkins University, and the WHO coronavirus disease (COVID-2019) situation reports to calibrate their SEIR Model. They study the effects of different travel restrictions or regulation measures on transmission dynamics and peak number of cases.

- health interventions would reduce the risks of COVID-19 spreading and more rigorous control and prevention measures will effectively contain its further spread
- risk increases when businesses and social activities returning back before the ending date.
- R0 is 3.11 in Beijing, 2.78 in Shanghai, 2.02 in Guangzhou, and 1.75 in Shenzhen

Henry et al. from Cincinnati Children's Hospital Medical Center
(https://www.medrxiv.org/content/10.1101/2020.03.01.20029884v2.full.pdf)

The authors use 82 pediatric (non-Hubei, China and non-China) cases from data collected from open-access line-lists crowdsourced online. The median age was 10 [IQR: 5-15] years.

- Delay between symptom onset and first seeking medical care:
  - All cases: 1 [IQR: 0- 3.3] days
  - In international Cases: 3.5 [IQR: 1.5-7] days
  - Chinese cases: 1 day [IQR: 0-2.5]

Li et al. from Cedars Sinai Medical Center in California
https://www.medrxiv.org/content/10.1101/2020.03.06.20031880v1.full.pdf

The authors used a SEIR compartmental model to estimate the scale the of outbreak in the U.S. from imported Wuhan cases. Several scenarios were assessed. Below z= zoonotic force.

- Most plausible model:
  - R0=2.4 and z=2.5 estimates 8-16 imported cases by Jan 23 (in 65.3% of simulations)
  - Estimates 9,484 (90% CI 2,054-24,241) cases in U.S. by March 1 if no successful intervention
  - Estimates 1,013 (90%CI 107-2,474) cases in U.S. by March 1 if current interventions reduced transmissibility by 25%
- Less plausible models:
  - R0=2.5 and z=2 or 1.5 estimates 8-16 imported cases by Jan 23 (56.6% and 58.4% respectively)
  - Estimates 14,141 (90% CI 3,773-31,156) cases in U.S. by March 1 if no successful intervention (z=2)

- Estimates 1,501 (90%CI 296-3,606) cases in U.S. by March 1 if current interventions reduced transmissibility by 25% (z=2)

Kretzschmar et al. from Utrecht University in the Netherlands
(https://www.medrxiv.org/content/10.1101/2020.03.10.20033738v1)

The authors use a stochastic transmission model – in the Netherlands – to determine the effect of reducing household versus other contacts in the population on.

- Isolation and contact tracing can be an effective means to control early epidemics, but only if transmissibility is not very high (R0 of 2-2.5 instead of 3+).
- Our analyses showed that isolation and contact tracing can contribute to reducing the growth rate and doubling time of epidemics, thereby buying time, spreading the number of severe cases out over a longer period of time, and potentially also reducing the total number of infections

Teslya et al. from Utrecht University in the Netherlands
(https://www.medrxiv.org/content/10.1101/2020.03.12.20034827v2)

They authors developed a transmission model to evaluate the impact of self-imposed prevention measures (handwashing, mask-wearing, and social distancing) due to COVID-19 awareness and of short-term government imposed social distancing on the peak number of diagnoses, attack rate and time until the peak number of diagnoses.

- A large epidemic can be prevented if the efficacy of these measures exceeds 50%.
- For slow awareness spread, self-imposed measures reduce the peak number of diagnoses and attack rate but do not affect the timing of the peak.
- Early implementation of short-term government interventions can only delay the peak.
- Early-initiated 18 short-term government-imposed social distancing can buy time for healthcare systems to prepare for an increasing 19 COVID-19 burden.

Klein et al. from Institute for Disease Modeling
(https://institutefordiseasemodeling.github.io/COVID-public/reports/Working%20paper%20%E2%80%93%20model-based%20estimates%20of%20COVID-19%20burden%20in%20King%20and%20Snohomish%20counties%20through%20April%207.pdf)

The authors use a SEIR model to quantify the effect of social distancing on the Snohomish County, Washington epidemic, starting on March 10 through April 7, 2020 (published March 10 at 4pm).

- The model shows that any social distancing that results in reduced transmission rates will slow the rate of growth of the epidemic, but only large changes in contact rate can interrupt ongoing transmission.
- Effects of Social distancing for each intervention scenario:

Intervention	Estimated Infections	Destined Deaths
Business as Usual	25,000	400
25% Reduction in Transmission	9,700	160
50% Reduction in Transmission	4,800	100
75% Reduction in Transmission	1,700	30

Perkins et al. from the University of Notre Dame
(http://perkinslab.weebly.com/uploads/2/5/6/2/25629832/perkins_etal_sarscov2.pdf)

April 2, 2020 Modeling Report

The authors use a stochastic simulation model that combined importation and local transmission processes of COVID-19 to estimate the epidemic size in the US by March 12, 2020. Reported cases by March 12, 2020 was 1,514 reported cases with 39 reported deaths. They start simulations on January 1, 2020.

- Simulating from January 1, we obtained 22,876 (95% PPI: 7,451 - 53,044) local infections cumulatively in the US by March 12.
  - Due to the exponential growth posited by our model, 2,958 (95% PPI: 956 - 7,249) local infections were predicted to have occurred on March 12 alone
- Our estimate of cumulative local travel infections by March 12 would have been only 5,018 (95% PPI: 2,350 - 12,445).

Constantino et al. from University of New South Wales in Australia
(https://www.medrxiv.org/content/10.1101/2020.03.09.20032045v1.full.pdf)

Constantino et al. used an age structured, deterministic compartmental model to assess the impact of Australia's ban on travel from China on the number of imported cases of COVID-19 in Australia. They estimated the number of imported cases to Australia for three scenarios of Chinese travel bans.

- No travel ban
  - 122 total estimated imported cases between 1/26 and 4/4
- Complete travel ban from 2/1-3/8, followed by full lift of the ban
  - 13 total estimated imported cases between 1/26 and 4/4
- Complete travel ban from 2/1-3/8, followed by partial lift of the ban (allowing university students, no tourists)
  - 7 total total estimated imported cases between 1/26 and 4/4

This analysis assumes that R_0=2.2 and that quarantine results in 50% reduction in R_0

Jackson et al. from Kaiser Permanente Washington Health Research Institute in Seattle
(https://www.medrxiv.org/content/10.1101/2020.03.02.20027599v1.full.pdf)

The authors use an SEIR model to estimate daily counts of Seattle Flu Study specimens for 9 respiratory viruses, including human coronaviruses.

- Disruption in contact patterns reduced effective contact rates during intervention period by 16% to 95%
- Cumulative disease incidence reduced by 3% (95% CI: 2-3.7%) to 9% (6.2-10.3) through the rest of the season
- Incidence reductions were greatest for viruses that were peaking when the disruption occurred and least for viruses in early epidemic
- High intensity, short-duration social distancing measures may substantially reduce total incidence if implemented near epidemic peak

Willem Odendaal from Virginia Tech
(https://www.medrxiv.org/content/10.1101/2020.03.11.20034512v1.full.pdf)

The authors use a simple mathematical model to measure the effect of the travel restrictions on the US epidemic.

- US epidemic was delayed by 26 days because of January travel restrictions.

April 2, 2020 Modeling Report

Ghaffarzadegan et al. from Virginia Tech

https://www.medrxiv.org/content/10.1101/2020.03.22.20040956v1.full.pdf

The authors use and SEIR model with Markov Chain Monte Carlo simulations for calibration to data from Iran International and BBC.

- Currently 493,000 (90% CI: 271k – 810k) cases in Iran
- Estimate for cumulative cases until March 20th: 916,000 (508k – 1.5M)
- Total death until March 20th: 15,485 (8.4k – 25.8k)
- Estimate for total cases overall: 1.6 million (0.9 M – 2.6 M)
- Death toll: 58,000 (32K-97K)
- Worse case death toll: 103,000 (56K-172K)

Yang et al. from Tsinghua University in Beijing
(https://www.medrxiv.org/content/10.1101/2020.03.12.20034595v1.full.pdf)

Based on the public COVID-19 data of seven provinces/cities in China reported during the spring of 2020, we make a systematical investigation on the forecast ability of eight widely used empirical functions, four statistical inference methods and five dynamical models widely used in the literature. They compare these methods and use them all to estimate South Korean, Iranian, and Italian COVID epidemics (using data until March 10) by March 30, 2020.

- South Korea: 8,000 − 10,800
- Italy: 18,000 − 23,000
- Iranian: 9,500 − 13,500

Cowling et al. from the University of Hong Kong
(https://www.medrxiv.org/content/10.1101/2020.03.12.20034660v1.full.pdf)

The authors reviewed policy interventions and measured changes in population behaviors through two telephone surveys, on January 20-23 and February 11-14. We analyzed data on laboratory-confirmed COVID-19 cases, influenza surveillance data in outpatients of all ages, and influenza hospitalizations in children.

- Influenza transmission declined substantially after the implementation of social distancing measures and changes in population behaviors in late January, with a 44% (95% confidence interval, CI: 34% to 53%) reduction in transmissibility in the community (Rt from 1.28 [95% CI: 1.26-1.30] to 0.72 [95% CI: 0.70-0.74]), and a 33% (95% CI: 24% to 43%) reduction in transmissibility based on pediatric hospitalization rates.
- In the two surveys they estimated that 74.5% and 97.5% of the general adult population wore masks when going out, and 61.3% and 90.2% avoided going to crowded places, respectively

He et al. from Guangzhou Medical University & University of Hong Kong
(https://www.medrxiv.org/content/10.1101/2020.03.15.20036707v2.full.pdf)

The authors use 94 laboratory-confirmed COVID-19 patients admitted to Guangzhou Eighth People's Hospital and identified and estimated serial interval (using gamma distribution). Then, ML estimation of the infectious period from serial intervals. Sensitivity analysis with start of infectiousness 4 and 7 days before symptom onset. Assumed duration of infectiousness of 10 days.

- Viral load was the highest on the day of illness onset. Decreased gradually 21 days post onset.

- Estimated a mean serial intervals= 5.8 days (95% CI: 4.8-6.8)
- Infectiousness started from 2.5 days before symptom onset and reached its peak at 0.6 days before symptom onset
- Viral shedding peaked on or before onset of symptoms. Likely that there is a substantial proportion of presymptomatic transmission. Urgent to change contact tracing criteria to capture transmission events 2-3 days before symptom onset.

Pan et al. from Guangzhou Medical University
(https://www.sciencedirect.com/science/article/pii/S1473309920301146?via%3Dihub)

The authors analyze symptom onset and trace infection in a family cluster of 3

- Family cluster of 3 positive (1 symptomatic and 2 asymptomatics)

Wu et al. from Southern University of Science and Technology
(https://www.medrxiv.org/content/10.1101/2020.03.11.20034363v1.full.pdf)

They calibrate a logistic growth model, the generalized logistic growth model, the generalized growth model, and the generalized Richards model to the reported number of infected cases from January 19 to March 10, 2020 for the whole of China, 29 provinces in China, four severely affected countries and Europe to estimate the epidemic sizes.

- Japan:
  - By March 25: 1574 (95% CI: [880, 2372])
  - By June: 5669 (95% CI: [988, 11340])
- South Korea:
  - By March 30: 7928 (95% CI: [6341, 9754])
- Iran:
  - By March 20: 10,719 (95% CI: [8,178, 14,390])
  - By March 30: 10,804 cases (95% CI: [8,202, 15,060])
- Italy:
  - By March 25: 59,199 (95% CI: [16,796, 107,097])
  - By end of epidemic: 91,719 (95% CI: [16,944, 183,440])
- Europe:
  - By March 20: 114,867 cases (95% CI: [85,827, 172,995])
  - By March 25: 275,451 cases (95% CI: [178,462, 545,917])

Filho et al. from Universidade de Brasilia
(https://www.medrxiv.org/content/10.1101/2020.03.14.20035873v1.full.pdf)

The authors use SEIR (Susceptibles, Exposed, Infectious, Recovered) model, with additional Hospitalized variables (SEIHR model) and age-stratified structure to analyze the expected time evolution during the onset of the epidemic in the metropolitan area of São Paulo.

- In the first 30 days of epidemic:
  - 1,368 (IQR: 880 - 2,407) cases
    - 301 (22%) in older people (≥60 years)
  - 81 (50, 143) hospitalizations
  - 14 (9, 26) deaths
- In the first 60 days of epidemic:

- 38,583 (IQR: 16,698 – 113,163) cases
  - 8,427 (21.8%) in older people (≥60 years)
- 2181 (914, 6392) hospitalizations
- 397(166, 1205) deaths

Wang & Teunis from Emory University
(https://www.medrxiv.org/content/10.1101/2020.03.10.20033852v1.full.pdf)

The authors use detailed data for 112 confirmed cases between Jan 21, 2020 and Feb 12, 2020 in Tianjin province to estimate the serial interval of COVID-19.

- Mean Serial Interval: 4.8 days
  - Gamma Distribution:
    - shape parameter: 3.16
    - scale parameter: 1.52

Li et al. from Beijing University
(https://www.medrxiv.org/content/10.1101/2020.03.14.20036202v1.full.pdf)

The authors use the Gaussian distribution to analyze the transmission of viruses in China, South Korea, Italy, and Iran.

- If the Wuhan travel restrictions had occurred 5 days before they did, the epidemic size would be 0.42 what it is in China.
- Infection began in Jan 7, 2020 in South Korea
- If control was not implemented in Italy, there would be 200,000 cases in Italy by the end of March 2020. Now that control has been implemented as of March 8, 2020, there will be 84,000 cases in Italy by the end of March.
- Iranian infections are expected to reach 20,000 by the end of March.

Kissler et al. from Harvard University
https://www.medrxiv.org/content/10.1101/2020.03.04.20031112v1.full.pdf

The authors used viral testing data from the US National Respiratory and Enteric Virus Surveillance System on HCoV-OC43 and HCoV-HKU1 to estimate parameters for a three-strain SEIR compartment model with SARS-CoV-2 and allowed for ranges of cross-immunity.

- SARS-CoV-2 can proliferate at any time of year and will lead to longer outbreaks with shorter peaks in winter/spring establishments
- If SARS-CoV-2 doesn't lead to permanent immunity, it will enter into regular circulation with shorter term immunity (40 weeks) leading to annual outbreaks and longer term (two years) leading to biennial outbreaks
- If SARS-CoV-2 is permanent, it could disappear for over five years, and if it induced a 70% cross-immunity with HCoV-HKU1 and HCoV-OC43, it could lead eliminate the latter two
- Low levels of cross-immunity could make SARS-CoV-2 appear to die out, but to resurge after a few years. A 30% cross-immunity with HCoV-HKU1 and HCoV-OC43 could make SARS-CoV-2 disappear for 3 years
- Dynamics SARS-CoV-2 in temperate regions depends heavily on establishment

(https://dash.harvard.edu/bitstream/handle/1/42638988/Social%20distancing%20strategies%20for%20curbing%20the%20COVID-19%20epidemic.pdf?sequence=1&isAllowed=y)

April 2, 2020 Modeling Report

The authors used a deterministic (ordinary differential equation) mathematical model to simulate the transmission of SARS-CoV-2 in order to understand the effect of social distancing (and determine necessary during of these interventions) in the US population if COVID is seasonsal.

- A single period of social distancing will not be sufficient to prevent critical care capacities from being overwhelmed by the COVID-19 epidemic, because a rebound in transmission after the end of the period will lead to an epidemic that exceeds this capacity.
    - This resurgence could be especially intense if it coincides with a wintertime rise in R0
- Intermittent social distancing can maintain critical care demand within current thresholds, but widespread surveillance will be required to time the distancing measures correctly and avoid overshooting critical care capacity.

Menkir et al. from Harvard University
(https://www.medrxiv.org/content/10.1101/2020.03.23.20038331v2)

The authors use travel/flight data from BlueDot and Baidu data to estimate the number of undetected cases that were exported from China.

- for every one case from Wuhan exported internationally, there were approximately 2.9 cases from large Chinese cities exported internationally that likely remained undetected
- t the number of exported cases in six destinations for which predictions on exported cases have yet to be made, surveillance has likely been low, and where health care systems will likely face issues in managing current or potential outbreaks

Pei Jun Zhao from Harvard University
(https://www.medrxiv.org/content/10.1101/2020.03.23.20041798v1.full.pdf)

The authors model social networks using weighted graphs, where vertices represent individuals and edges represent contact. They assess the connectivity of the American social network to determine what measures to implement to control the current COVID-19 epidemic.

- In the U.S., the public is able to contain viral transmission by limiting the average number of contacts per person to less than 7 unique individuals over each 5 day period

Livio Fenga from the Italian National Institute of Statistics in Rome
(https://www.medrxiv.org/content/10.1101/2020.03.14.20036103v1.full.pdf)

The author uses the Maximum Entropy Bootstrap scheme and estimation procedure with official data from the Italian Authorities from Feb24th to March 12th to estimate total infected population in Italy, including those that could be asymptomatic.

- With official dating stating there are 12,839 infected in Italy as of March 12th, predict there to be a total as high as 105,789.

Dehkordi et al. from Institute for Research in Fundamental Sciences from Tehran
(https://www.medrxiv.org/content/10.1101/2020.03.15.20036418v1.full.pdf)

The authors use linear regression to use CFRs in comparing policies and behaviors with data from Jan 22nd to March 10th from data repositories and the WHO.

- CFR
    - Italy: 7.9%

- South Korea: 0.76%
- China: 3.8%
- Iran: 4.4%
- Japan: 2%
- Spain: 7%
- France: 3.5%
- Germany: 0.25% (still too early to tell)
- US: 14% (still too early to tell)

Rocklov et al. from Umea University in Sweden
(https://academic.oup.com/jtm/advance-article/doi/10.1093/jtm/taaa030/5766334)

The authors estimate the effect of the February 4, 2020 quarantine intervention on the Diamond Princess Cruise Ship COVID epidemic. On February 20, 2020, 619 (17%) passengers and crew (out of 3700 total) tested positive for COVID-19.

- Without any public health measures on the Diamond Princess:
  - By February 19, 2020: 2920 (79%) of the 3700 crew and passengers would have been infected
- R0 was 14.8 before quarantine
- Rt = 1.78 after quarantine

Kochanczyk et al. from Polish Academy of Sciences
(https://www.medrxiv.org/content/10.1101/2020.03.13.20035485v1.full.pdf)

The authors fit data from the Wuhan, China and from northern Italy COVID epidemics to an SIIE (suspectible, infected, infectious, excluded) model to evaluate the effect of the quarantine/interventions on the growth rate of the respective epidemics.

- The Wuhan intervention reduced the contact rate/exclusion rate quotient 50-fold – allowing the epidemic to move from the exponential growth rate to exponential reduction rate phase.
- The northern Italy intervention (February 21) only reduced the contact rate/exclusion rate quotient 3-fold – not enough to exit the exponential growth phase.

Zhang et al. from Sichuan University
(https://www.medrxiv.org/content/10.1101/2020.03.13.20035410v1.full.pdf)

The authors find that a great number of newly supplied medical resources, including more than 42000 aided health workers, over 26000 makeshift beds and 23000 acute care beds, enabled overwhelming patients to be treated effectively in hospitals.

- mortality rate: exponentially decays (R2>0.93)
- recovery rates: grows (R2 25 >0.95),

Xiao et al. from Beihang University
(https://www.medrxiv.org/content/10.1101/2020.03.13.20034082v1.full.pdf)

The authors use a Cybernetics-based Dynamic Infection Model to simulate the epidemiologic characteristics of SARS-COV-2. Two polymorphic models for different city types are derived with considerations on their medical, immigration/emigration population and administrative conditions. Shanghai, Beijing, Wenzhou and Wuhan were studied to validate the infection models.

- Shanghai:
  - R0: 2.5
  - R after Wuhan lockdown: 0.55 (95% CI, 0.48 to 0.59).
  - final number of infected cases in Shanghai was estimated to be 344 (95% CI, 311 to 378)
- Beijing:
  - R after work resumes: 0.8
  - Incidence reduced 77.3% by postponing work
- Wenzhou:
  - R0: 4.5
  - R after Wuhan lockdown on Jan 23: 0.5 (95% CI, 0.435 to 0.556)
  - Final epidemic size: 527 (95% CI, 475 to 582)
- Wuhan:
  - There were 1.4% confirmed cases in the total evacuated population.

Qiu et al. from Jinan University
(https://www.medrxiv.org/content/10.1101/2020.03.13.20035238v1.full.pdf)

The authors use data from all over China between January 19 to February 15, 2020, Baidu travel data, and meteorological data from the National Oceanic and Atmospheric Administration (NOAA) with a machine learning (Lasso regression) model to determine if the January 23 Wuhan travel restrictions on the Chinese COVID epidemic.

- The estimates show that the positive effect of an infection in generating new local infections is observed within one week, and there is evidence that people's responses can break the chain of infections.
- COVID-19 has been effectively contained by early February, especially for cities outside Hubei province, the epicenter of the outbreak.

Handel et al. from the University of Georgia
(https://www.medrxiv.org/content/10.1101/2020.03.13.20034892v1.full.pdf)

The authors look at a scenario using a simple simulation model where containment is no longer possible and herd immunity can be implemented with controlled spread.

- Allowing infections to occur in low risk groups might lead to an overall greater reduction in mortality than trying to protect everyone equally

Drake et al. from the University of Georgia
(http://2019-coronavirus-tracker.com/stochastic-GA.html)

The authors calibrate their stochastic transmission model with data from Hubei, China to apply to the epidemic in the US state Georgia.

- They show that social distancing interventions starting on March 12 in Georgia slows the trajectory of the epidemic.

(http://2019-coronavirus-tracker.com/early-intervention.html)

The authors use a simple linear regression model to compare the relationship between the number of cases in Chinese provinces on January 23 and the final outbreak size (as of March 9, 2020).

- They find a statistically significant relationship between the number of cases on the day of Wuhan lockdown and the number of cases by the end of the Chinese epidemic
- These results illustrate the importance of taking early actions to mitigate transmission prior to confirmation of a large number of local cases.

Wangping et al. from the National Clinical Research Center for Geriatric Diseases
(https://www.medrxiv.org/content/10.1101/2020.03.18.20038570v1.full.pdf)

The authors use Markov Chain Monte Carlo methods to estimate basic reproduction number and an eSIR (extended susceptible-infected-removed) model to estimate the epidemic trend in Italy (and Hunan province as a comparison). They use data from Jan 22-Mar 16, 2020.

- Basic Reproduction Number R0:
    - Italy: 4.10 (95% CrI: 2.15–6.77)
    - Hunan Province, China: 3.15(95% CrI: 1.71–5.21)
- Epidemic Size under current Italian intervention measures:
    - Italy: 30,086 infected cases (95% CrI: 7,920 - 81,869)
    - If it was imposed 5 days later, infection scale would be 1.5 times the above
- Epidemic end in Italy under current intervention Measures:
    - Italy: April 25, 2020 (95% CrI: Mar 30 to Aug 07)

St-Onge et al. from Universite Laval in Quebec, Canada
(https://arxiv.org/pdf/2003.05924.pdf)

The results presented are for an *SIS model* at *steady state*. They use different heterogeneous distributions for

both and assume that all structures are cliques where every node can transmit the disease to each other to provide an estimate for what types of events can be cancelled for the most benefit and efficiency.

- Reducing the number of large gatherings (perhaps by setting a hard limit on size) can stop an outbreak on realistic heterogenous social networks.
- For a particular combination of parameters, the cutoff size of gatherings is n_c = 23 persons.
- Reducing the number of group settings people attend or visit may curb an outbreak, too.

Russo et al. from Institute of Science and Technology for Energy and Sustainable Mobility
(https://www.medrxiv.org/content/10.1101/2020.03.17.20037689v1.full.pdf)

The authors use a compartmental Susceptible/ Exposed/ Infectious/ Recovered/ Dead (SEIRD) model with two compartments of infectious persons: one modelling the total cases in the population and another modelling the confirmed cases to estimate: (a) the DAY-ZERO of the outbreak in Lombardy, Italy; (b) the actual number of exposed/infected cases in the total population; (c) the basic reproduction number (R0); (d) the "effective" per-day disease transmission and mortality rates; and, importantly, (e) a forecast for the fade out of the outbreak, on the basis of the released data of confirmed cases for Lombardy from February 21 to March 8, the day of lockdown.

- According to this scenario, the DAY-ZERO for the outbreak in Lombardy was the 21st of January 2020.
- The actual cumulative number of exposed cases in the total population in Lombardy on March 8 was of the order of 15 times the confirmed cumulative number of infected cases.
- Based on these values, the basic reproduction rate R0 was found to be 4.04 (90% CI: 4.03-4.05).

- The "effective" per-day disease transmission rate for the period until March 8 was found to be 0.779 (90% CI: 0.777-0.781), while the "effective" per-day mortality rate was found to be 0.0173 (90% CI: 0.0154-0.0192).
- Importantly, by reducing the transmission rate by 90% on March 8 to reflect the suspension of almost all activities in Italy, we run the simulator to forecast the fade out of the epidemic. Simulations show that if the measures continue, the complete fade out of the outbreak in Lombardy is expected to occur by the end of May 2020.

Diego Caccavo et al. from University of Salerno
(https://www.medrxiv.org/content/10.1101/2020.03.19.20039388v1.full.pdf)

The author uses an SIRD model with data from Johns Hopkins University Center for Systems Science and Engineering and optimization by minimization of the Sum of Square Errors.

- Peak for China: Feb 18th with 50,000 people infected
- Peak for Italy: March 28th with 42,000 infected people

Xie et al. from BGI-Shenzhen
(https://www.medrxiv.org/content/10.1101/2020.03.15.20036624v2.full.pdf)

The authors use a differential model with non-linear transfer coefficients and competitive compartments with data from the Health Commission of Hubei Province and Huo-Yan Laboratory to evaluate trends in cases.

- Without Huo-Yan (emergent clinical virus testing structure)
  - Suspected cases increase by 47%
  - Cost of quarantine doubled
  - Turning point of increment of suspected cases and achievement of daily settlement (no suspected cases each day) delayed for a whole week and 11 days, respectively
- If Huo-Yan ran at full capacity:
  - Number of suspected cases would decrease at least a week earlier
  - Peak of suscpected cases would be reduced by at least 44%
  - Quarantine cost reduced by more than 72%
- If daily testing capacity of 10,500 occurred right after Hubei lockdown, daily settlement for all cases achieved immediately

Raheem et al. from South London and Maudsley NHS Foundation Trust
(https://www.medrxiv.org/content/10.1101/2020.03.17.20037697v2)

The authors use a linear retrospective model to estimate past point prevalence with daily number of deaths from the World Health Organization up til the 16th of March.

- By the time the first 3 cases had been identified in Italy, there were already nearly 30 cases
- By the 24th of Feb. only 0.5% of cases had been detected and confirmed in Italy
- Estimate of 26000 cases on the 24th of Feb.
- Case-doubling period of 2.5 days

Liu et al. from Washington University in St. Louis, MO
(https://www.medrxiv.org/content/10.1101/2020.03.17.20037770v1.full.pdf)

The authors use an SEIR model with network-driven dynamics in the United States COVID epidemic with air traffic. Their data can be found in supplementary materials, which was not included.

- No containment plan:
  - National epidemic peak: Early June
  - Daily active count of 7% of US population
  - Peaks in Washington and NY by May 21st and 25th respectively
- Model 25% reduction in transmissibility via community level interventions:
  - Delay epidemic progression by up to 34 days
  - Reduce magnitude of peak by 39%
- Whole interstate traffic restriction is ineffective in delaying epidemic outbreak, but does affect arrival of state-wise epi peaks
- It's important for states with a large fraction of vulnerable, uninsured, and liquid-asset-poverty populations to be prepared and have timely-interventions

Pedros Teles from University of Porto in Portugal
(https://www.medrxiv.org/content/10.1101/2020.03.18.20038612v1.full.pdf)

The author uses an SEAIHR model to predict and describe the Portuguese COVID-19 epidemic, using a South Korean MERS framework and Italian data where data in Portugal is scarce.

- With NO mitigation: peak of 40,000 cases on April 6th, 2020
- Scenario in which the government takes severe mitigating measures and the population mildly adheres to self-protecting measures: The effectiveness of the control measures seems to be at a maximum, and a maximum of just about 800 cases would be reached. This seems unlikely as of March 18, 2020, there are 642 active cases in Portugal.
- Scenario in which the government fails to implement mitigating measures, yet still implements some, and the population mildly adheres to self-protecting measures: the maximum is shifted to the 20th of April, reaching a maximum number of ~7,000 active cases in the country. In this scenario, the transmission rate has been cut to a half, but the government has not been effective in implementing control measures.
- The actual figures probably lie between the interval (~800-7,000) and the peak will be reached between 9th and the 20nd of April 2020.

Alizon et al. from MIVEGEC, IRD, Montpellier in France
(http://alizon.ouvaton.org/Report2_Immunization.html)

The authors use R0 and calculating controllability threshold to calculate the overall attack rate in France at the end of COVIDF epidemic in the presence of transmission contral and without it.

- Without control measures, the epidemic threshold in the worst case scenario would be achieved when 89% of the population infected.
- With 50% control, the epidemic threshold in the worst case scenario would be achieved with when 55% of the population infected.

(http://alizon.ouvaton.org/Rapport1_R0_France.html)

The authors use incidence data in France from January 21-March 16, 2020, neglecting delay in reporting time for cases, spatial structure, and imported versus locally transmitted cases.

- R0 = 2.49 [95% CI: 2.39, 2.58]

April 2, 2020 Modeling Report

Bandoy et al. from University of California, Davis
(https://www.medrxiv.org/content/10.1101/2020.03.17.20037481v1.full.pdf)

The authors find country specific R estimates using Wallinga and Teunis method and used genome sequences to quantify a pathogen genome identity score that estimates transmission time and epicurve stage. They used data from the Chinese CDC and WHO compiled by John Hopkins University as of March 1, 2020.

- Population density and local temperature had variables relationships to outbreaks.
- Instantaneous R0 on March 1, 2020 using 2 serial intervals: 2, 7 days:
    - Mainland China: 1.6, 2.1
    - South Korea: 2.8, 25.6
    - Italy: 8, 57
    - Iran: 2.8, 17.1
    - Japan: 3.6, 2.2
    - Singapore: 3.3, 1.6
    - France: 2.9, 16.9
    - Hong Kong: 2.6, 1.6
    - Germany: 3.1, 17.2
    - United States: 4.3, 1.7
    - Kuwait: 2.6, 15.3
    - Spain: 3.7, 10.8
    - Thailand: 3.8, 1.7

Zareie et al. from Hamadan University of Medical Sciences in Iran
(https://www.medrxiv.org/content/10.1101/2020.03.19.20038950v1.full.pdf)

The authors use a generalized additive model with parameters from the Chinese outbreak and data from Jan 22nd to March 8th to predict the epidemic in Iran.

- 925 people are expected to be infected daily in Iran
- Epidemic peaks within a week: 3/15 – 3/21
- Peak on 3/18 with 1126 cases
- Estimated total: 27,752 people infected

Siwiak et al. from Data 3.0 Ltd. In United Kingdom
(https://www.medrxiv.org/content/10.1101/2020.03.21.20040444v2)

The authors use the Global Epidemic and Mobility Model (GLEAM) framework with data from Johns Hopkins University of Medicine Coronavirus Resource from Jan 22 to March 16th to simulate the spread of the epidemic across the globe.

- R0: 4.4
- Latent non-infectious period: 1.1 days
- Presymptomatic infectious period: 4.6 days
- Probability of developing sever symptoms: 0.01
- Probability of being diagnosed when presenting symptoms: 0.6
- Probability of diagnosis with mild symptoms/asymptomatic: 0.001
- Higher testing rate per country, the lower the discrepancy between data and model

April 2, 2020 Modeling Report

Scarabel et al. from York University in Toronto
(https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3559929)

The authors fit an exponential curve to the daily reported cases in Italy and Canada to predict epidemic trends in Canada with and without intervention. Published March 23, 2020.

- The growth rate in Canada has increased from 0.13 between March 1st and 13th, to 0.25 between March 13th to 22nd
- Unmitigated in Canada, project 15,000 cases by March 31st.
- Mitigated in Canada (if the same as Italy's interventions): 4,000 by March 31st

Gandhi et al. from GITAM in India
(https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3560688)

The authors estimate the reproduction number of 4 different groups of countries and then evaluates the efficacy of different intervention measures using an SIR model.

- Case isolation at home (Zero stage individuals remain at home for 7 days for decreasing non family contacts by 75%): reduction in R by 0.4
- Home quarantine (During the 14-days, household contact rates may twofold- yet contacts in the community lessen by 75%): reduction in R by 0.5
- Social distancing (All households decrease contact outside household/shopping centers/schools/work environment/enormous or moderate functions. At that point, contact rates additionally decreased by 25%): reduction in R by 0.5
- Layering all of the above an reduce r by 1.4 overall

Koo et al. from National University of Singapore
(https://www.thelancet.com/journals/lancet/article/PIIS1473-3099(20)30162-6/fulltext)

The authors use FluTE – a flu epidemic model – to evaluate the effect of different interventions (isolation of infected individuals and quarantine of their family members; quarantine plus immediate school closure for 2 weeks; quarantine plus immediate workplace distancing, in which 50% of the workforce is encouraged to work from home for 2 weeks; and a combination of quarantine, immediate school closure, and workplace distancing) on the Singaporean epidemic.

- Quarantine reduces overall infections by 60-95%, depending on transmissibility (reproduction number)
- School closure reduces overall infections by 63-96%
- Workplace distancing reduces overall infections by 79-99%
- Combining all interventions reduces overall infections by 80-99%

Lytras et al. from National Public Health Organization in Athens, Greece
(https://www.medrxiv.org/content/10.1101/2020.03.24.20042218v1.full.pdf)

The authors use a modified Bayesian SEIR model with publicly reported case data until March 9, 2020 to estimate the ascertainment ratio of SARS-CoV-2 infection in Wuhan, China.

- Ascertainment ratio: 0.465% (95%CI: 0.464–0.466%)
- outbreak in Wuhan was abated by depletion of susceptibles, rather than public health action alone
- This suggests a high-transmissibility/low-severity profile

April 2, 2020 Modeling Report

Alvarez et al. from Technologico de Monterrey
(https://www.medrxiv.org/content/10.1101/2020.03.23.20041590v1.full.pdf)

The authors use a simple epidemiological model that is amenable to implementation in Excel spreadsheets and sufficiently accurate to reproduce observed data on the evolution of the COVID-19 pandemics in different regions: Italy, Spain, New York City, Mexico.

- New York City:
  - Growth rate before intervention measures: μ_o = 0.926/day
  - Growth rate after federal, state, and city-level measures: μ = 0.308/day
  - By March 22: 12,000 cases, but still exponential growth with no signs of reduction.
- Italy and South Korea have very similar initial growth rates (μ_o)
  - Italy maintained the same growth rate for 20 days
  - South Korea reduced their growth rate to 0 in just 2 weeks.

Gonzalez et al. from Universidad Mayor and Universidad de Chile
(https://www.medrxiv.org/content/10.1101/2020.03.23.20042002v1.full.pdf)

The authors calculate a time-varying COVID-burden index for several countries with this equation:

(0.15 * COVID-19 Cases) / (0.25 * Number of Beds)

- As of March 23, if the US does not implement any other measures to reduce transmission, they will be in the same position as Italy, Spain, and Iran.

Yadlowsky et al. from Stanford University and UC Berkeley
(https://www.medrxiv.org/content/10.1101/2020.03.24.20043067v1.full.pdf)

The authors estimate the prevalence of COVID-19 in Santa Clara County in California as of March 17, 2020 using the number of hospitalized COVID patients in Santa Clara Country.

- As of March 17 2020, there are 6,500 infections (0.34% of the population)
- Best case: 1,400
- Worst case: 26,000

Cheng et al. from Taiwan Centers for Disease Control and Prevention
(https://www.medrxiv.org/content/10.1101/2020.03.18.20034561v1.full.pdf)

Taiwan made COVID a nationally notifiable disease on January 15, 2020, while their first case was declared on January 20th. All of their cases and the contacts were enrolled in a prospective case-cohort study from Jan 15-Feb 26, 2020. Along with this data and other data from Hong Kong, Macau, Japan, China, Germany, and others, they calculated serial interval and incubation period.

- they found high transmission around symptom onset (so pre-symptomatic transmission is likely)
- also estimate a serial interval (they use the dataset by Nishiura and added some pairs (48 in total) and used Backer's method to estimate the serial interval):
  - Overall (all locations): mean SI= 5.4 days (95% CrI 4.1–7.2 days)
  - Mainland China: 5.57 (95% CrI: 4.2,7.51)
  - others (Germany, HK, Macau, Singapore, SK, Vietnam): mean = 4.99 (95%CrI: 2.75,9.38)
  - Taiwan: mean = 7 (95%CrI: 3.69-13.18)
- estimate an overall incubation period
  - Overall (all locations): mean incubation = 5.45 (95%CrI: 4.71-6.31)

- Mainland China (4.54, 95%CrI: 3.9- 5.26)
- others (Germany, HK, Macau, Singapore, SK, Vietnam): mean = 6.35 (95%CrI: 5.19-7.75)
- Taiwan (mean= 4.91, 95%CrI: 2.72-8.43)

Young et al. National Centre for Infectious Disease in Singapore
(https://jamanetwork.com/journals/jama/fullarticle/2762688)

The authors analyzed virological data from 18 patients in Singapore.

- Median duration of viral shedding from first to last positive nasopharyngeal swab collected as part of clinical care was 12 days (range, 1-24)
- 15 patients (83%) had viral shedding from the nasopharynx detected for 7 days or longer

Cai et al. from Shenzhen in Guangdong Province, China
(https://www.medrxiv.org/content/10.1101/2020.02.17.20024018v1.full.pdf)

All confirmed COVID-19 cases, 298 cases, treated in the Third People's Hospital of Shenzhen, from January 11, 2020 to February 6, 2020, were included in this study to estimate several clinical features of COVID-19 patients.

- Hospitalization to ICU ratio: 32/229 = 14%
- Of those that came to hospital for care – 32/298 went to the ICU: 10.7%
- Of those that came to the hospital for care – 76% were hospitalized.

Cao et al. from Shanghai University of Chinese Traditional Medicine
(https://www.medrxiv.org/content/10.1101/2020.03.04.20030395v1.full.pdf)

The authors use a hospital cohort of 198 from Shanghai between January 20 to February 15, 2020.

- 9.5% admitted to ICU from hospitalized patients.

Fang et al. from Guangzhou, China
(https://www.medrxiv.org/content/10.1101/2020.03.07.20032573v2.full.pdf)

The authors perform a meta-analysis to estimate several different clinical features among 72 different studies in China, USA, Germany, South Korea, Vietnam, Nepal, Thailand, Singapore, Canada, and Italy.

- Hospital CFR: 3.7%
- Hospital ICU ratio: 11.5%

Wang et al. from Wuhan University
(https://jamanetwork.com/journals/jama/fullarticle/2761044)

In this single-center case series involving 138 patients with NCIP in Wuhan, China Zhongnan Hospital, 26% of patients required admission to the intensive care unit and 4.3% died. Patients were admitted between Jan 1 and Jan 28 and follow up was completed on February 3, 2020.

Li & Guo from Indiana University and University of Pennsylvania
(https://www.medrxiv.org/content/10.1101/2020.03.28.20044578v1)

The authors propose an empirical Bayesian time series framework to predict US cases using different countries as prior reference

- Using data up to March 26: 108,595 cases by March 27

- When Italy is used as prior in the prediction, which the US data resemble the most:
  - the cases in the US will exceed 300,000 by the beginning of April unless strong measures are adopted

Fang et al. from University of Pennsylvania
https://www.medrxiv.org/content/10.1101/2020.03.24.20042424v1.full.pdf

The authors use difference-in-difference estimations with Baidu Migration data and data from the China CDC from January 11th to February 29th to explore the effect of Wuhan lockdowns.

- Lockdown reduced inflow into Wuhan by 76.64%
- Reduced outflow by 56.35%
- Reduced within-Wuhan movements by 54.15%
- Without lockdown cases would be 64.81% higher in the 347 Chinese cities outside Hubei, 52.64% higher in the 16 non-Wuhan cities inside Hubei.
- There were substantial undocumented infection cases in early days of COVID
- Social distancing policies are effective in reducing the impact of population inflows from the epicenter cities in Hubei province

Liebig et al., from Commonwealth Scientific and Industrial Research Organisation Canberra, Australian Capital Territory, Australia
(https://www.medrxiv.org/content/10.1101/2020.03.25.20043877v1.full.pdf)

Leibig et al. summarized WHO COVID-19 data to anticipate what the trajectory of COVID-19 in Australia could look like. They also used a seasonal autoregressive integrated moving average model to predict global travel patterns to Australia and assess importation risks.

- By April 1st the number of COVID-19 cases in Australia could be as high as 11,908
- Based on predicted travel patterns into Australia, the authors identified that many visitors from China and South Korea travel into Australia, thus travel restrictions focused on those countries may be more effective than travel from other countries, where a greater proportion of the travelers are Australian residents or citizens.

Wang et al. from Fujian Medical University in Fuzhou, Fujian, China
(https://www.medrxiv.org/content/10.1101/2020.03.24.20036285v1.full.pdf)

Wang et al. used a transmission model to estimate the impact of different public health interventions policies on the burden of COVID-19 in China. From this model Wang et al. estimated the basic reproduction number and effective reproduction number over time.

- R_0 in Wuhan from 1/24 – 1/21: 3.38 (95% confidence interval: 3.25-3.48)
- R_e in Wuhan:
  - 1/24: 2.37
  - 1/30: 1.78
  - 2/5: 0.83

The authors found that the 40 public health interventions implemented in China since 1/24/2020 have reduced the reproduction number from 3.38 to 0.5. The authors concluded that these public health interventions should remain in place until COVID-19 is no longer a global threat.

April 2, 2020 Modeling Report

Neufeld et al. from University of Queensland
(https://www.medrxiv.org/content/10.1101/2020.03.23.20041897v1.full.pdf)

The authors use a simple SIR model to estimate the impact of social distancing and targeted isolation.

- Targeted isolation of vulnerable subpopulation provides more efficient and robust strategy at a lower economic and social cost with a shorter timeframe.
- Uniform social distancing alone could extend the duration of the epidemic and results in insufficient overall immunity of the majority population.

Bhabavathula et al. from United Arab Emirates University
(https://www.medrxiv.org/content/10.1101/2020.03.26.20044743v2.full.pdf)

Bhabavathula et al. collected opensource surveillance data from 154 countries and territories and estimates changes in crude incidence rate, case-fatality rate and recovery rates from January 22 – February 29 and from March 1 – March 16.

- Globally (As of March 16, from 154 countries/territories)
    - 181,546 cases
    - Crude case-fatality rate: 3.92%
    - Recovery rate: 43%
- Global change in incidence from January to March: 276.2%
- Countries with high mortality (crude case-fatality rates)
    - Italy: 7.7%
    - Iran: 5.7%
    - China: 4.2%

Bui et al. from Center for Research in Hanoi, Vietnam
(https://www.medrxiv.org/content/10.1101/2020.03.28.20046136v1.full.pdf)

The authors used case data in Vietnam from the Ministry of Health with the growth rate of the epidemiological curve to estimate the reproduction number.

- R0 for first period (Jan17-Feb11): 1.14 (95% CI: 0.7 – 1.89)
- R0 for second period (Mar 6 – March 24): 1.55 (95%CI: 1.29-1.87)
- Overall R0 in Vietnam: 1.46 (95% CI: 1.17-1.75)

Wycliffe et al. from Singapore Ministry of Health and National Centre for Infectious Diseases Singapore (new)
(https://www.cdc.gov/mmwr/volumes/69/wr/mm6914e1.htm?s_cid=mm6914e1_e&deliveryName=USCDC_921-DM24694)

From January 23-March 16, 7 clusters and 243 cases of COVID-19 were identified in Singapore. Only 157 of these cases were locally-acquired.

- 10 cases (6.4%) could be attributed to pre-symptomatic transmission.

Dudel et al. from Max Planck Institute for Demographic Research (new)
(https://www.medrxiv.org/content/10.1101/2020.03.31.20048397v1.full.pdf)

April 2, 2020 Modeling Report

The authors calculate the CFR for each country at the latest data point and for Italy also over time. They use demographic decomposition to break the difference between CFRs into unique contributions arising from the age-structure of confirmed cases and the age-specific case-fatality.

- Germany: 0.7%
- US (NYC): 1.2%
- US Overall: 1.7%
- South Korea: 1.6%
- China: 2.3%
- France: 4.0%
- Italy: 10.6%