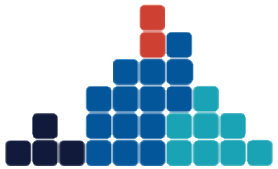
감염병의 자연사와 전파동태

Natural history and transmission dynamics of infectious diseases

가톨릭대 예방의학교실 유석현



ONE HEALTH Lab
with Computational Epidemiology

가톨릭대학교
THE CATHOLIC UNIVERSITY OF KOREA

27 March 2025

ONE HEALTH Lab
with Computational Epidemiology

onehealth.or.kr

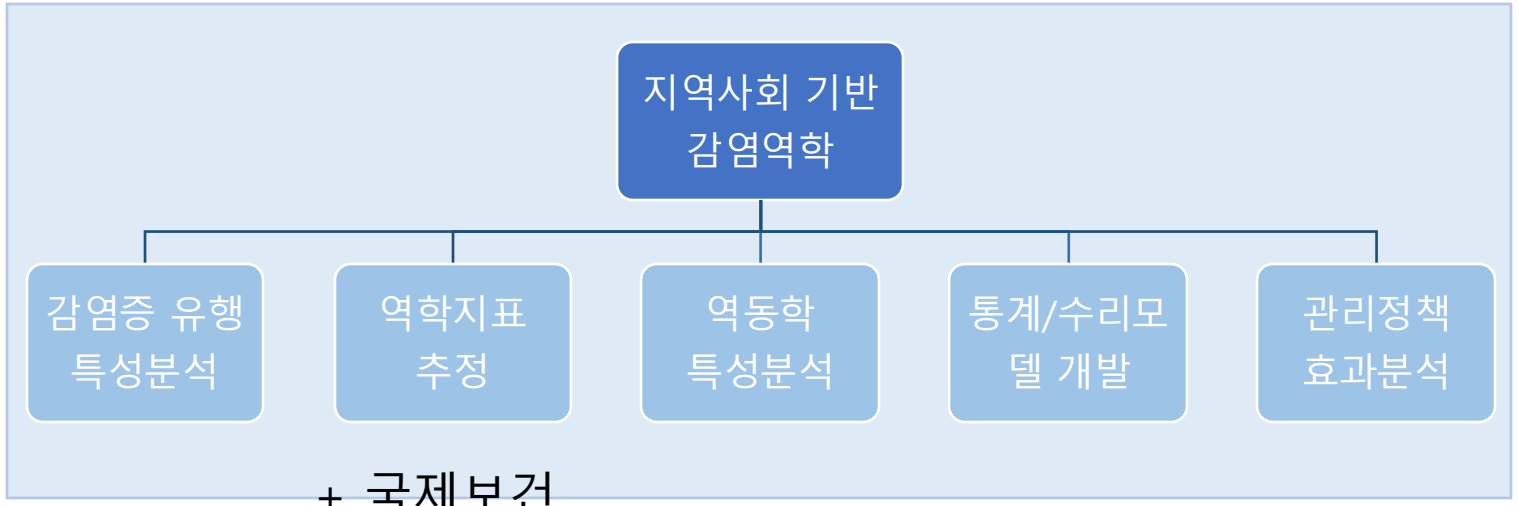
Sukhyun Ryu

ASSISTANT PROFESSOR

gentryu@onehealth.or.kr

- Surveillance
  - 질병관리청 감염병감시과 책임연구원
- Control
  - 경기도청 감염병관리과 역학조사관
- Research
  - 홍콩의대 WHO협력 감염역학관리 연구소

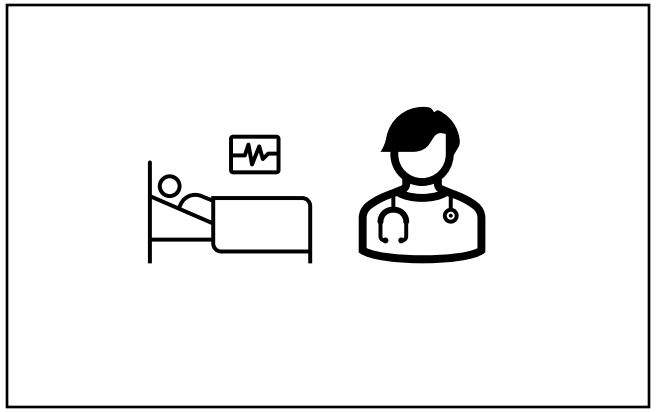
Research area



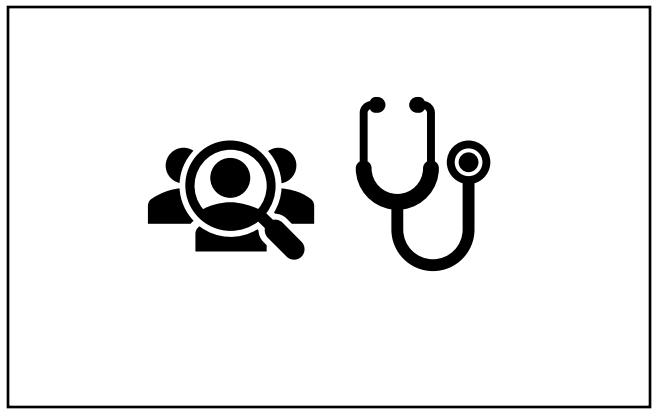
+ 국제보건

Background

Diagnosis/treatment of each patient's problem



Diagnosis/management of problems in community



Background

- Problem based learning

  - **S** **S**ubjective : Complaint, symptoms
  - **O** **O**bjective: Physical exam and test result
  - **A** **A**ssessment: Diagnosis
  - **P** **P**lan: Plan for diagnosis and treatment

- Example of simple SOAP note

S) 배가 계속 아프다. 토한다. 기운이 없다.
O) fever (+) Abdomen : soft & flat, hypoactive BS, T/RT (+-/-)
A) R/O UTI R/O hidden intraabdominal infection
P) NPO/hydration 증상 호전없고 fever subside 안되어 AP CT 시행하기로 함

Join at menti.com | use code 2380 4680

Mentimeter

다음 감염 역학 지표중 시간의 속성이 가장 적은 것은?

0%	0%	0%	0%
잠복기	세대기	과대산포력	연쇄발병간격

1. Anatomy
   - Incubation period
   - Serial interval

2. Transmission dynamics
   - Effective reproduction number
   - Superspreading events

3. PHSMs (Public health and social measures)
   - Pharmaceutical interventions
   - Nonpharmaceutical Interventions

S

잠복기 14일 맞나? 21일·16일 만에도 확진자 나와

BUSAN 부산일보 .com

잠복기 넘긴 환자 잇따라

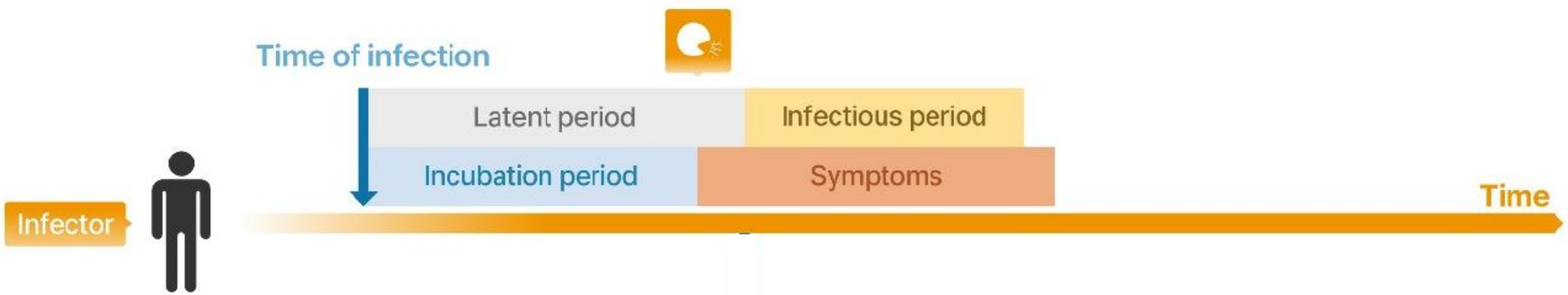
입력 : 2020-03-08

"잠복기 2주 맞나" 논란 확산…자가격리 후 음성→양성 잇따라

NEWSIS

등록 2020-03-10 14:20:00

O



Ryu S, et al. Viruses 2022

ㅇ

- Description of case

울산#7	여/23 세/울주군	확진자(경북 성주) 접촉	2/27 (재입원:3/27)

2 월 23 일(일) : (19:00~21:00) 성주(부모댁)→ 울주군(자택) 도착(성주 확진자와 동승, 자차 이용)
2 월 24 일(월) : (07:30~17:30) '이손요양병원' 근무→ 동생(여/13 세), 유증상으로 '서울산보람병원' 선별진료소 같이 방문, 검체 채취
2 월 25 일(화)~26 일(수) : 여동생과 자가 격리
2 월 26 일(수) : (12:30) 여동생 확진 판정, (14:20) 동생 김천의료원 이송
2 월 26 일(수) : 자택 검체 채취

Public health authorities published the reports including information of infectee (time, place, person) & information of symptoms

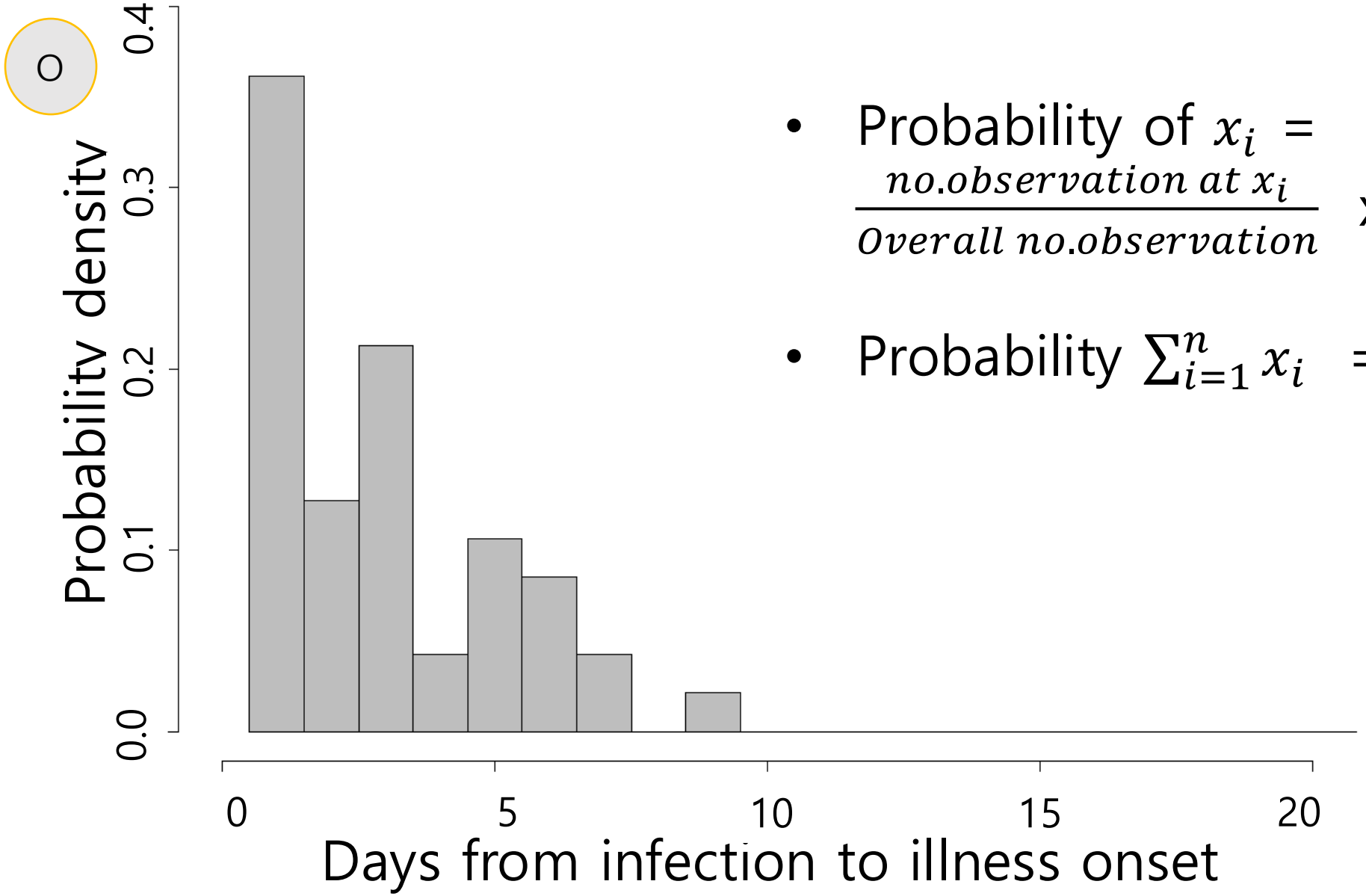
O

Line list of lab-confirmed cases in Busan city

ase n	Exp_date_min	Exp_date_max	Symptom onset	Date of confirm	Type of symptom
1		19 Feb 2020	21 Feb 2020	21 Feb 2020	fever, headache
2	17 Feb 2020	18 Feb 2020	21 Feb 2020	21 Feb 2020	cough, chill
3		16 Feb 2020	21 Feb 2020	22 Feb 2020	headache
4		18 Feb 2020	19 Feb 2020	22 Feb 2020	
5	17 Feb 2020	19 Feb 2020	20 Feb 2020	22 Feb 2020	
6	17 Feb 2020	19 Feb 2020	21 Feb 2020	22 Feb 2020	chill
7	12 Feb 2020	21 Feb 2020	NA	22 Feb 2020	
8		19 Feb 2020	20 Feb 2020	22 Feb 2020	cough, sore throat
9	20 Feb 2020	21 Feb 2020	21 Feb 2020	22 Feb 2020	sore throat
10		18 Feb 2020	19 Feb 2020	22 Feb 2020	feverile sense, cough, sputum,headacl
11		17 Feb 2020	18 Feb 2020	22 Feb 2020	sore throat
12		16 Feb 2020	21 Feb 2020	22 Feb 2020	muscle ache, facial flushing
13	13 Feb 2020	15 Feb 2020	17 Feb 2020	22 Feb 2020	feverile sense, cough, chill, sore throat
14		19 Feb 2020	20 Feb 2020	22 Feb 2020	cough, feverile sense
15	15 Feb 2020	16 Feb 2020	21 Feb 2020	22 Feb 2020	feverile sense, cough
16		19 Feb 2020	20 Feb 2020	22 Feb 2020	feverile sense
17		NA	22 Feb 2020	23 Feb 2020	chill, muscle ache, headache
18	13 Feb 2020	15 Feb 2020	21 Feb 2020	23 Feb 2020	
19		21 Feb 2020	NA	23 Feb 2020	
20		17 Feb 2020	20 Feb 2020	23 Feb 2020	chill, feverile sense
21	14 Feb 2020	16 Feb 2020	NA	23 Feb 2020	
22	14 Feb 2020	16 Feb 2020	19 Feb 2020	23 Feb 2020	feverile sense, cough, sore throat, mu
23		21 Feb 2020	23 Feb 2020	23 Feb 2020	muscle ache, facial flushing
24		16 Feb 2020	22 Feb 2020	23 Feb 2020	feverile sense, muscle ache
25		19 Feb 2020	22 Feb 2020	23 Feb 2020	headache, chill, feverile sense

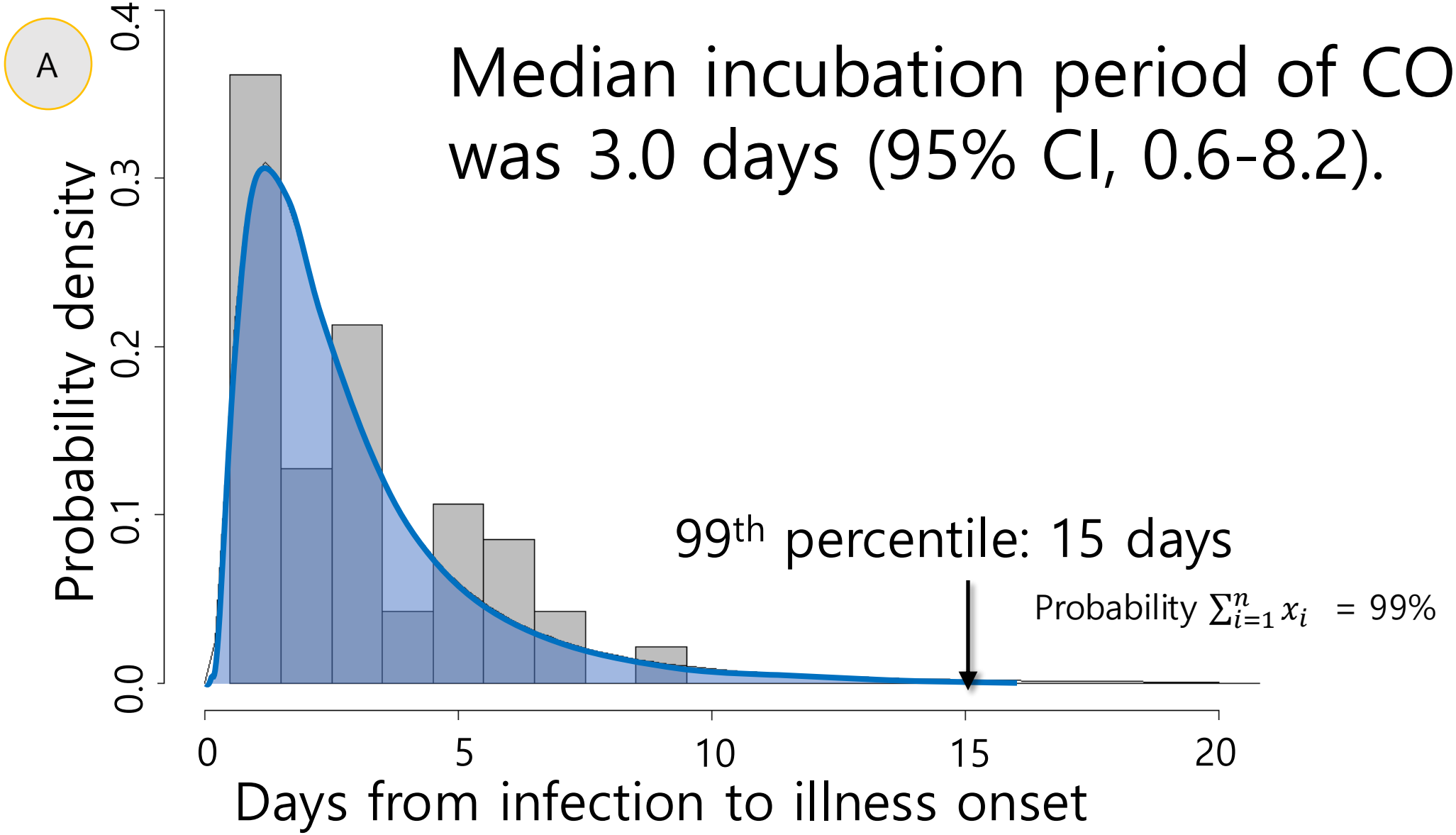
Sheet1 | 경기_가평 | 경기_과천 | 경기_광주 | 경기_성남 | 경기_구리 | 경기_김포

Lee H, et al. 2020 J Infect Chemo.



- Probability of x_i = $\frac{no.observation\ at\ x_i}{Overall\ no.observation}$ x 100%
- Probability $\sum_{i=1}^{n} x_i$ = 100% (i.e., 1)

Lee H, et al. 2020 J Infect Chemo.



Median incubation period of COVID-19 was 3.0 days (95% CI, 0.6-8.2).

99th percentile: 15 days

Probability $\sum_{i=1}^{n} x_i$ = 99%

Lee H, et al. 2020 J Infect Chemo.

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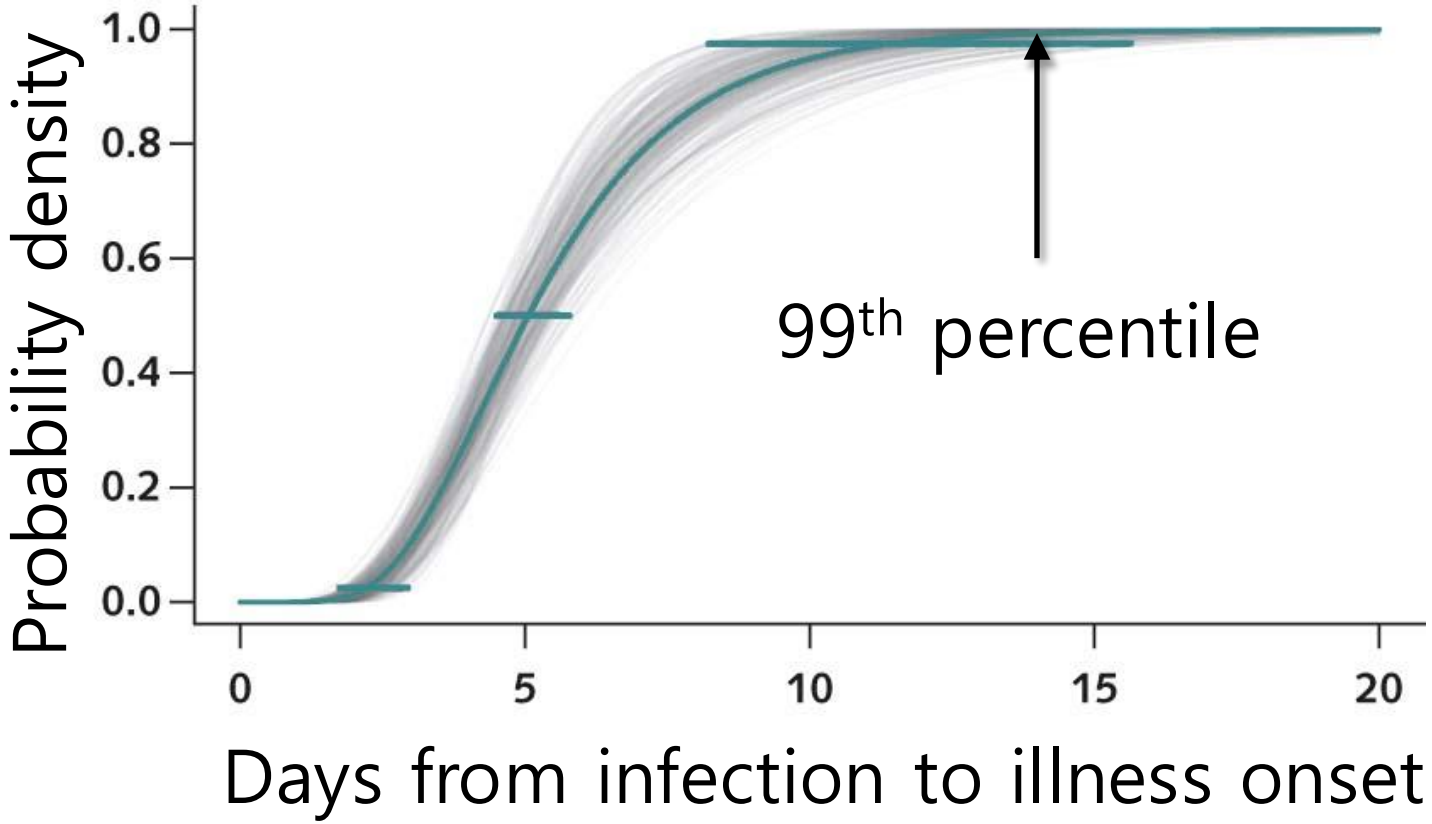
Median incubation period of COVID-19 was 5.1 days (95% CI, 4.5-5.8).



101 out of every 10000 cases will develop symptoms after 14 days of active monitoring.

Lauer SA, et al 2020 J Internal Med.

P

잠복기 14일 맞나? 21일·16일 만에도 확진자 나와

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등록 2020-03-10 14:20:00

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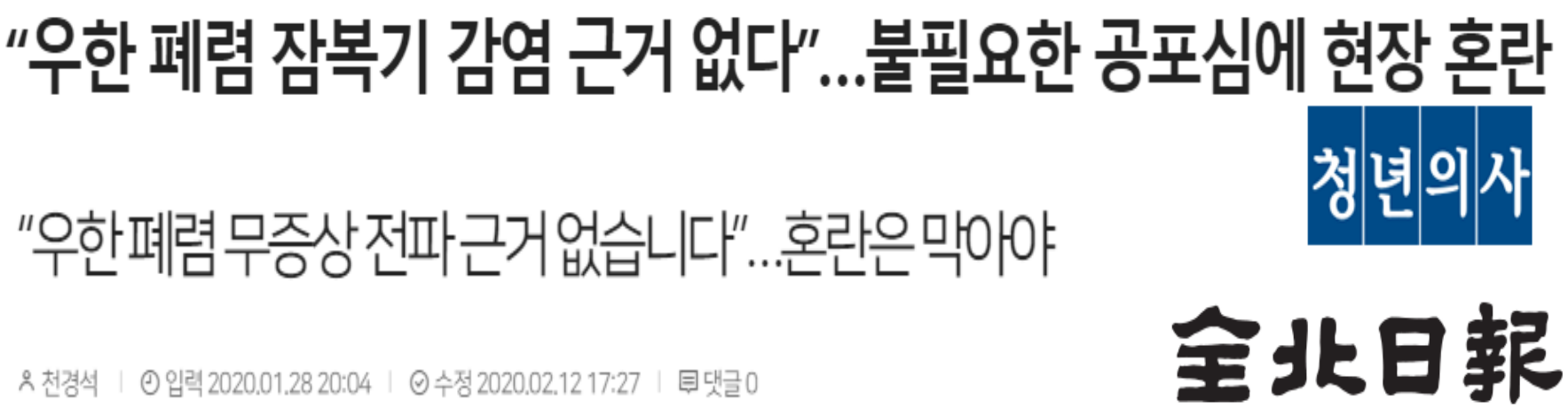

"No evidence for asymptomatic transmission from COVID-19 patients?"
- 28 Jan. 2020

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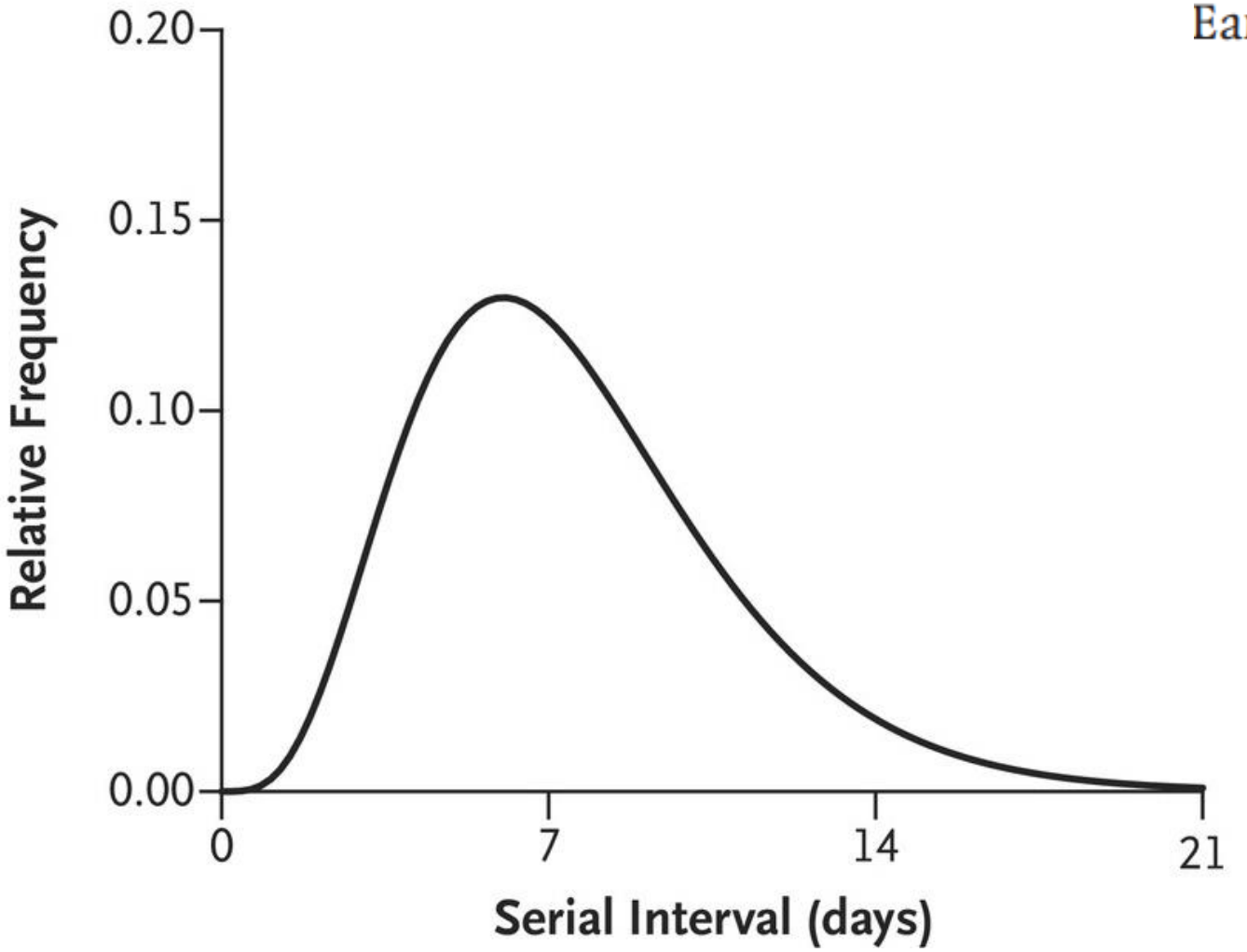
“우한 폐렴 잠복기 감염 근거 없다”··불필요한 공포심에 현장 혼란

청년의사 송수연/박기택 기자 | 입력 2020.01.28 12:46 | 댓글 9

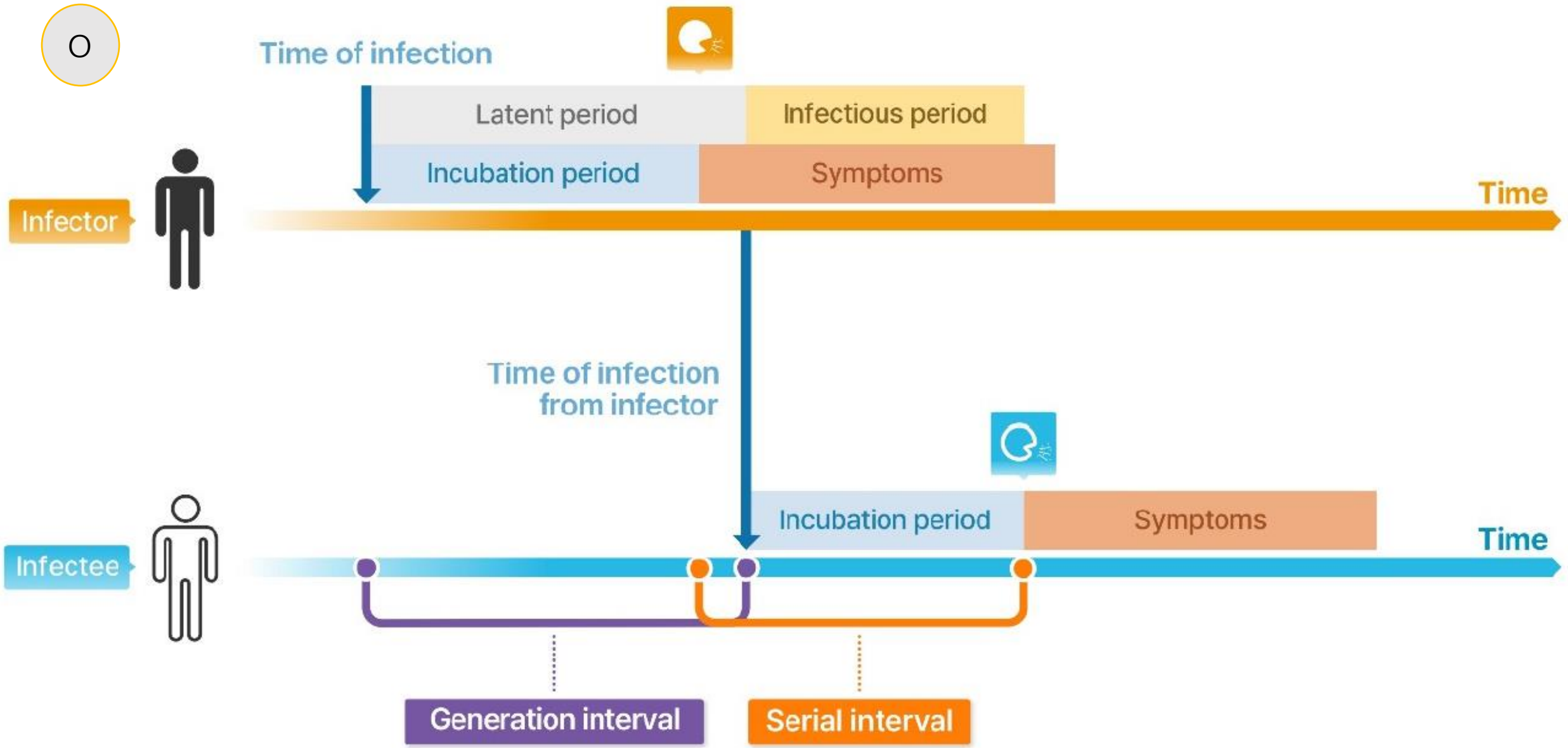


Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus–Infected Pneumonia

Data from the 5 Clusters Used in the Estimation of Serial Interval

Case	Serial Interval (days)
1.2	5
1.3	9
2.2	7
3.3	7
4.3	3
5.2	7

Li Q, et al. NEJM 2020



Ryu S, et al. Viruses 2022

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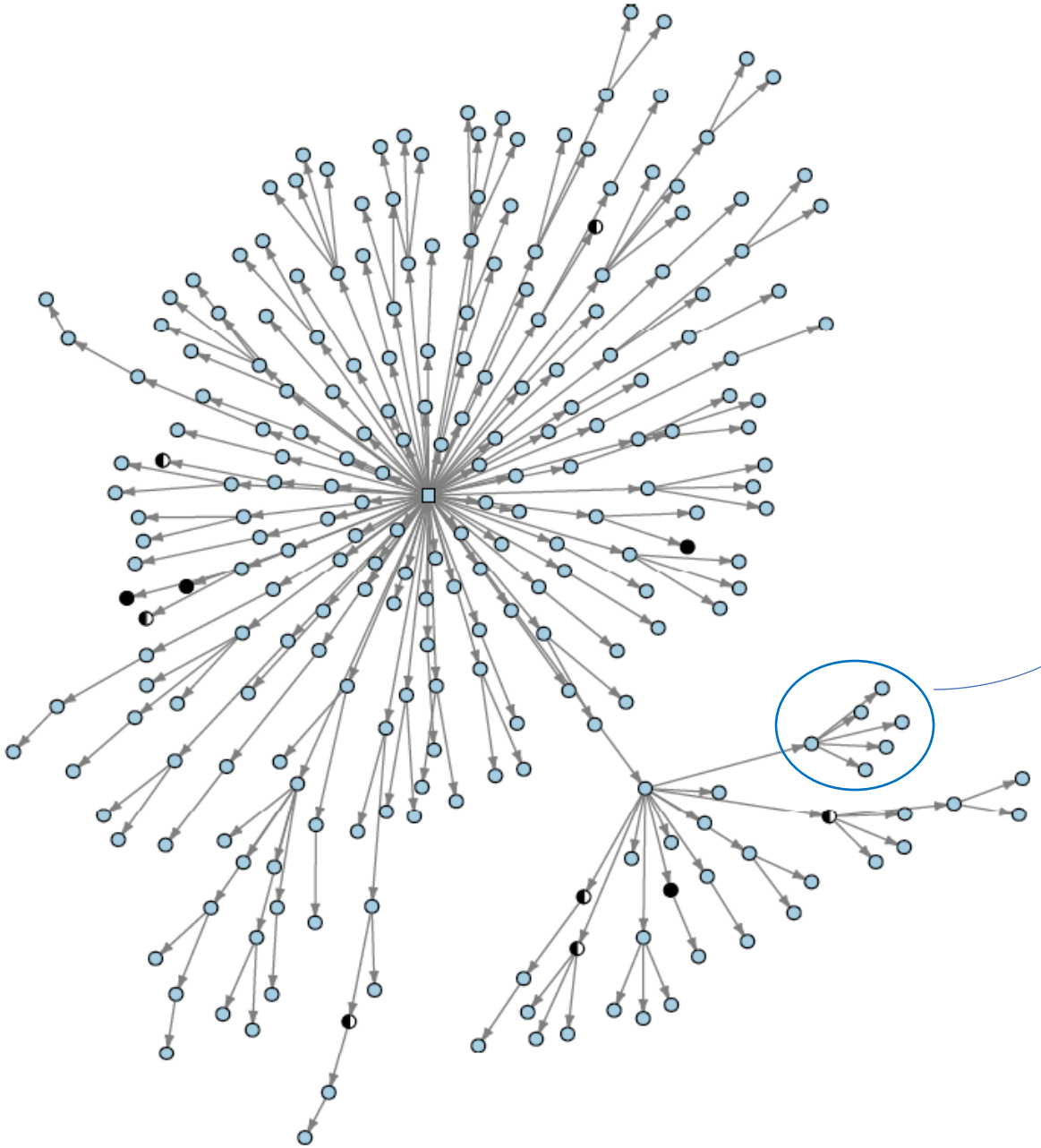
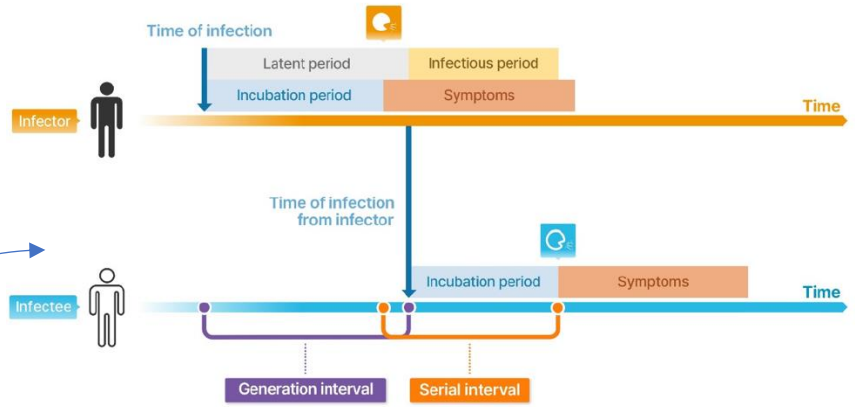
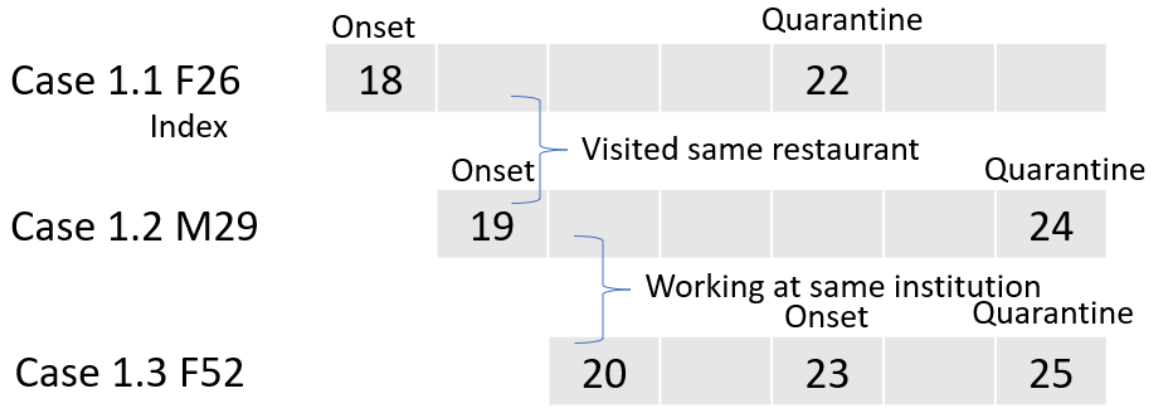


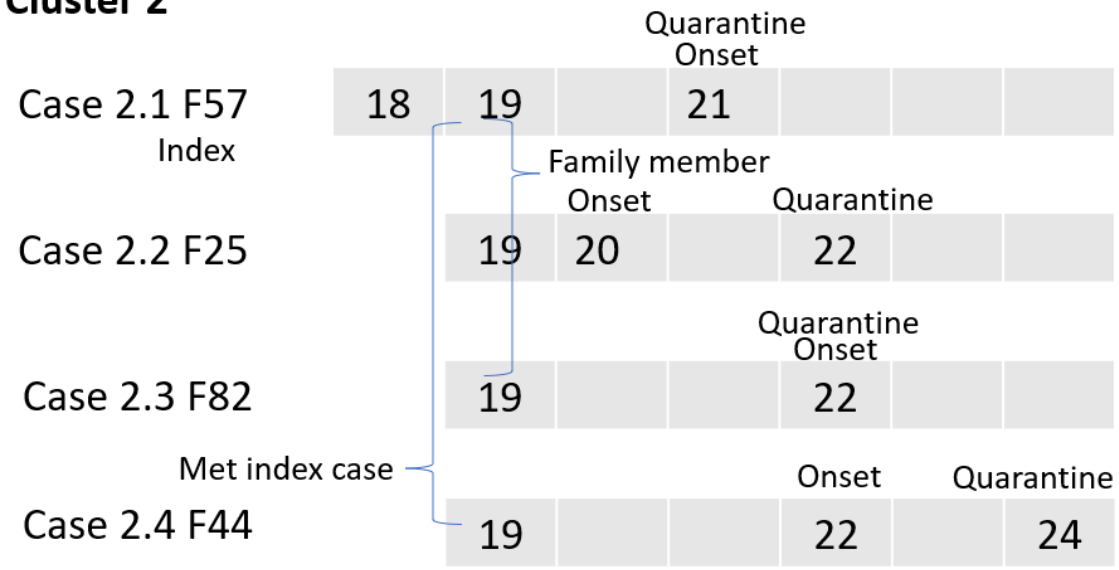


Hwang H, et al. J Infect Dis. 2022

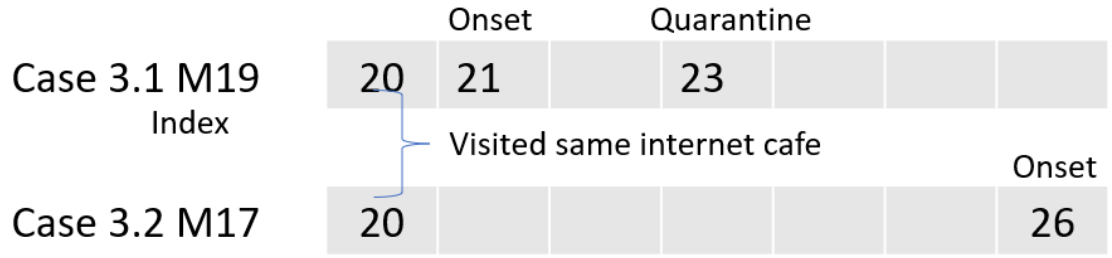
Cluster 1



Cluster 2

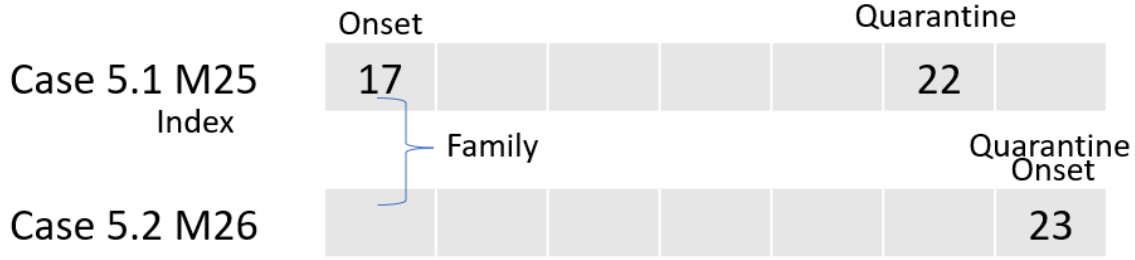


Cluster 3



Cluster 4

Cluster 5



Ryu S, et al. Emerg Infect Dis 2020

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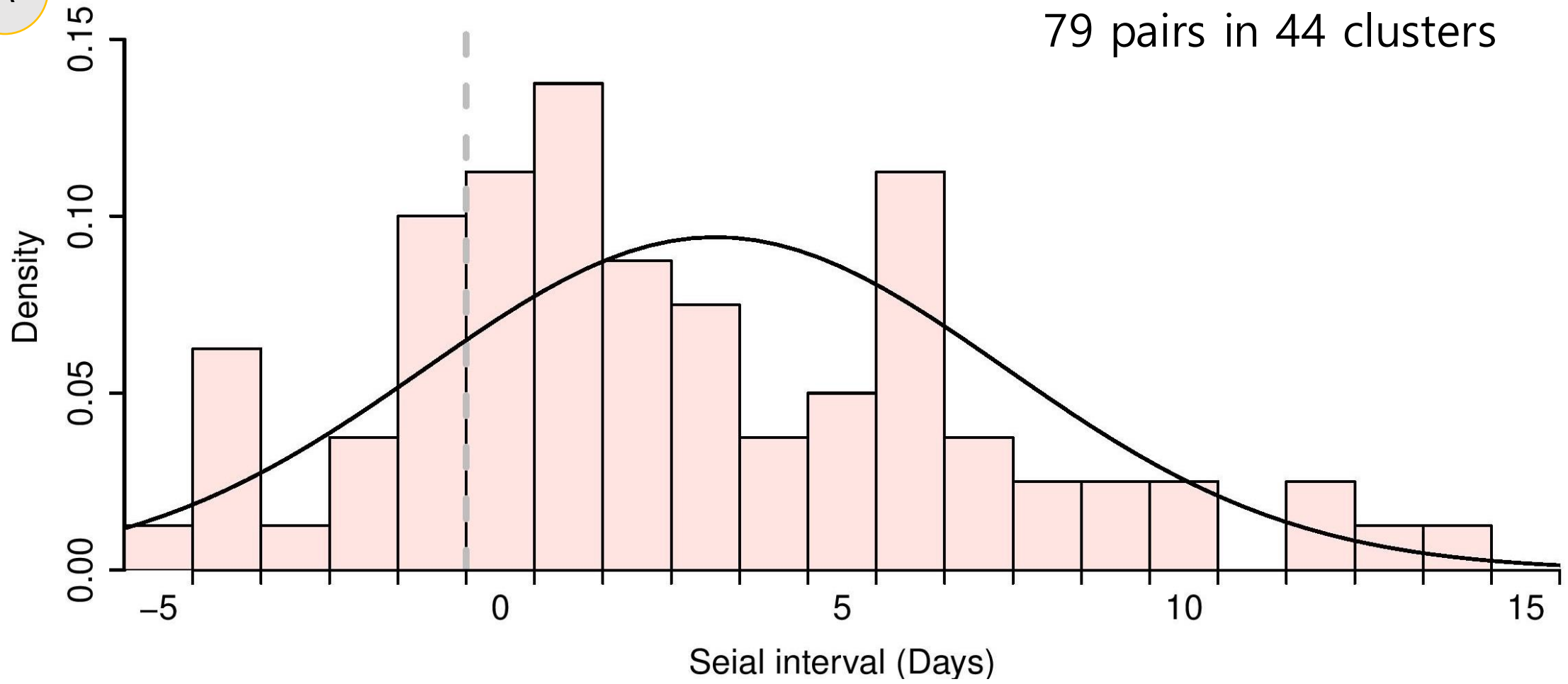
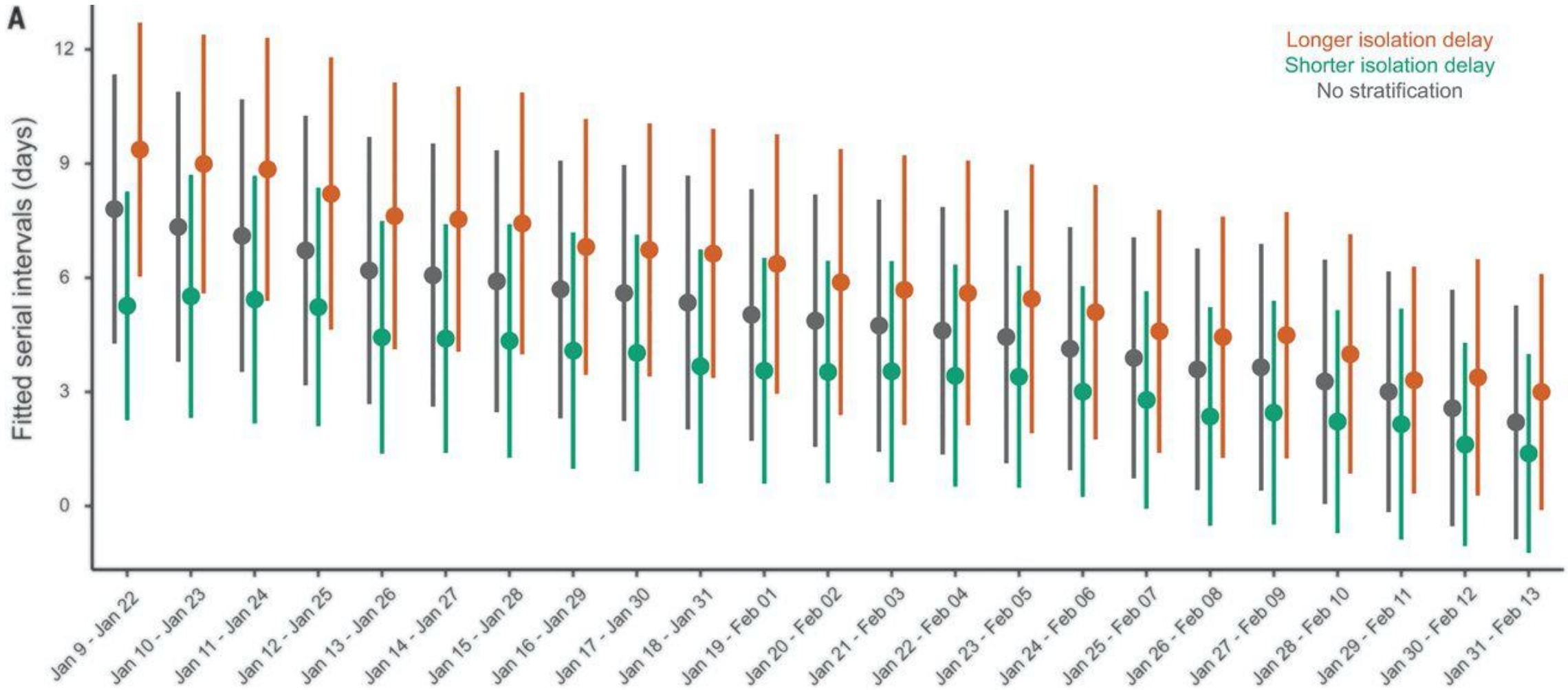
79 pairs in 44 clusters



Ryu S, et al. Emerg Infect Dis 2020

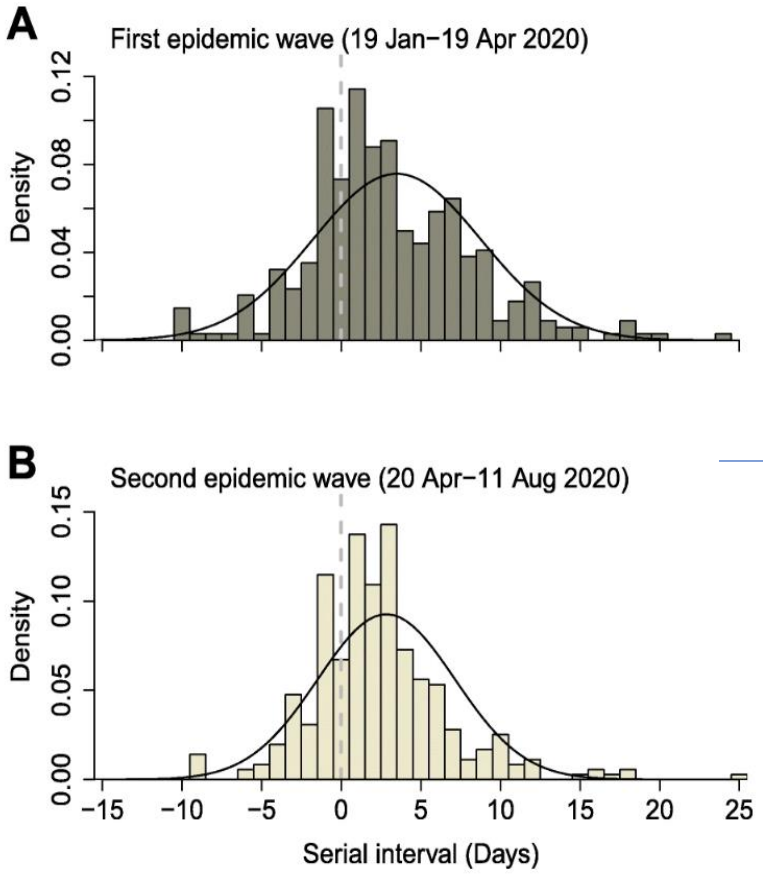
- Serial interval was shortened over time by nonpharmaceutical interventions

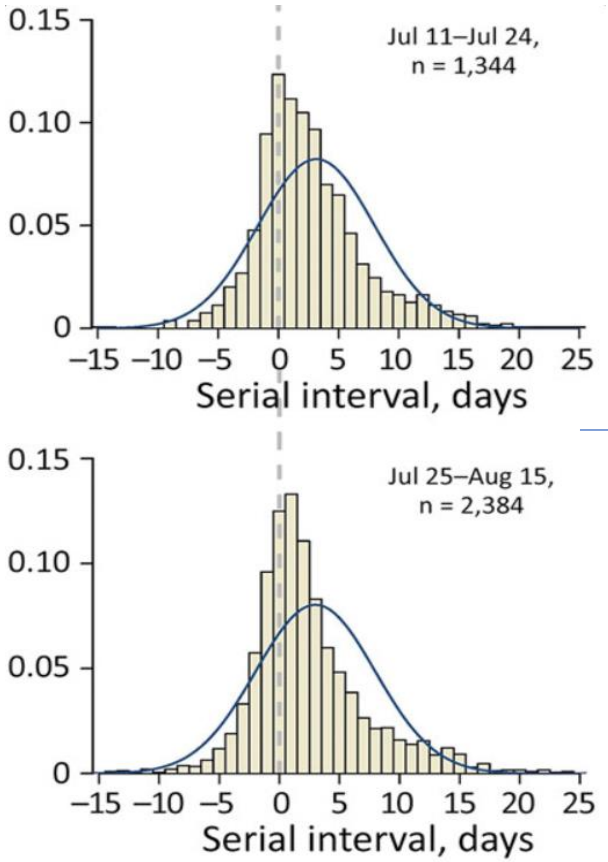


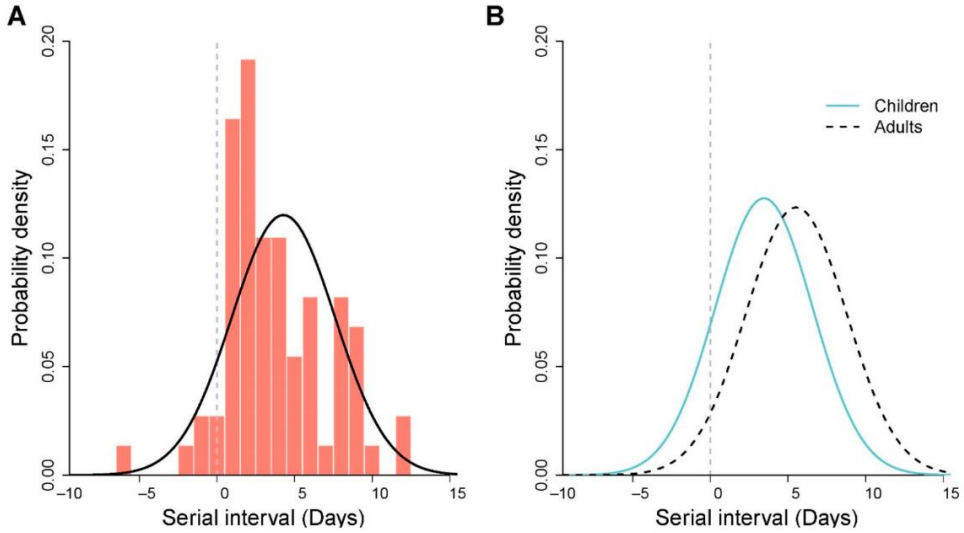
Ali ST, et al. Science 2020

P

SARS-CoV-2 Wild type in 2020 Delta variant in 2021 Omicron variant in 2022







Ryu S, et al. BMC Infect Dis 2021

Ryu S, et al. Emerg Infect Dis 2022

Kim D, et al. Viruses 2022

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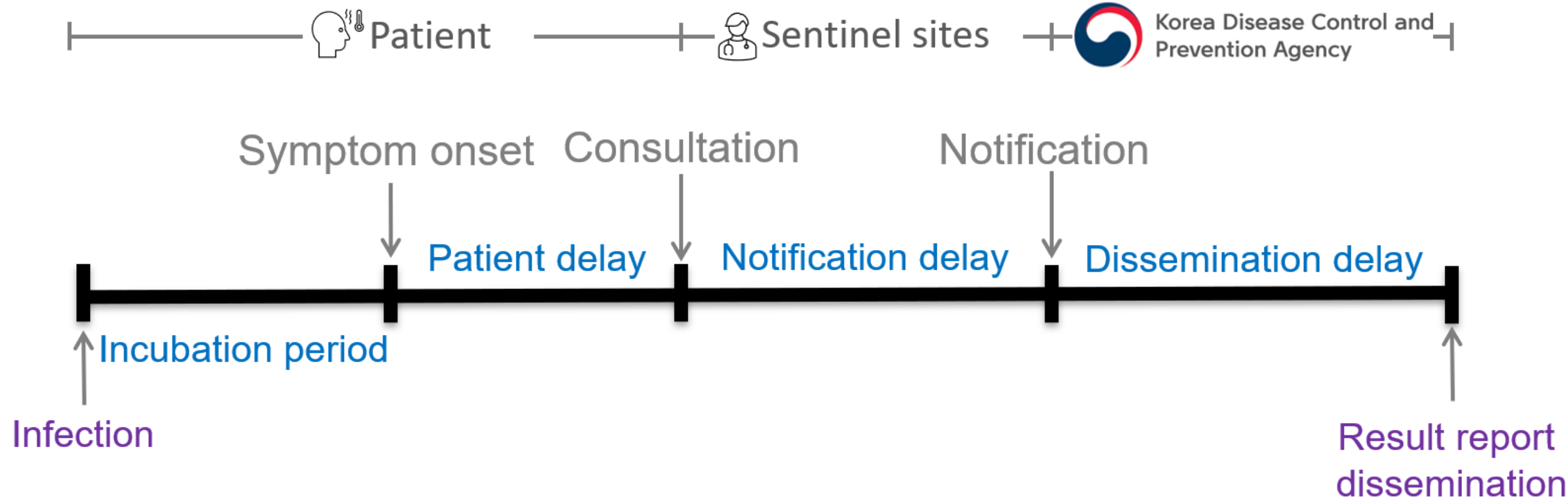

Kim BI, et al. JMIR Public Health Surveill. 2024

Expo bridge, Daejeon South Korea

https://blog.naver.com/yuseonggu

1. Anatomy
   - Incubation period
   - Serial interval

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   - Effective reproduction number
   - Superspreading events

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   - Pharmaceutical interventions
   - Nonpharmaceutical Interventions

S

코로나19 '심각' 단계 격상... 뒷북 대응 효과 있겠나

편집국 | 승인 2020.02.24 07:57 | 댓글 0

Bloomberg

South Korea Signals Unprecedented Steps to Contain Outbreak

By Jihye Lee
February 23, 2020, 4:26 PM GMT+9 *Updated on February 23, 2020, 10:55 PM GMT+9*

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Effective reproduction number (R_t)

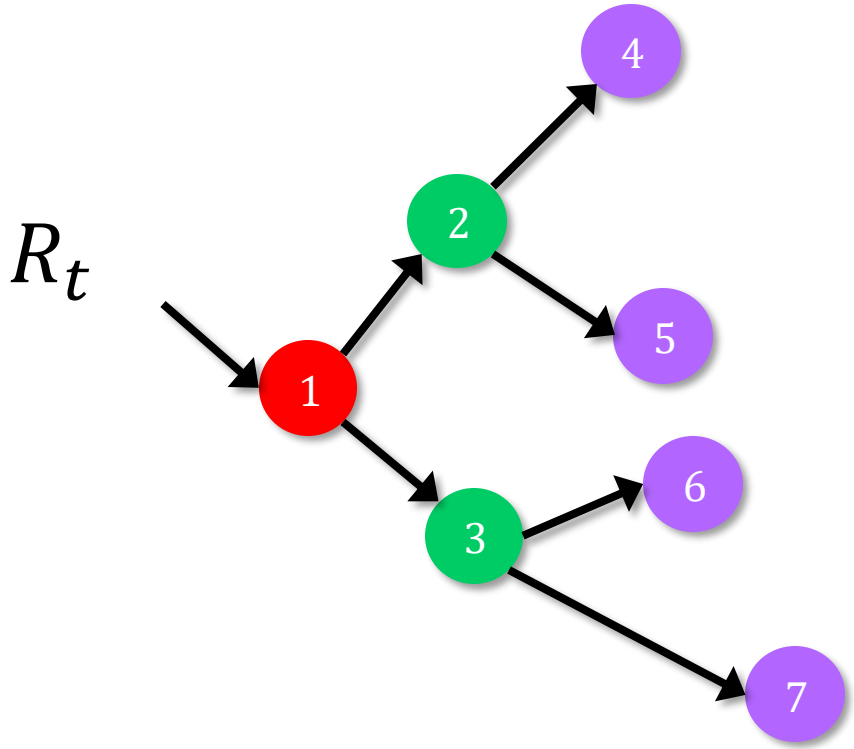
- Mean number of infections generated

  by a primary case at time t

  ※ Critical threshold = 1

- Classical R_t estimate based on symptom onset

  ※ Cori's or Wallinga's method



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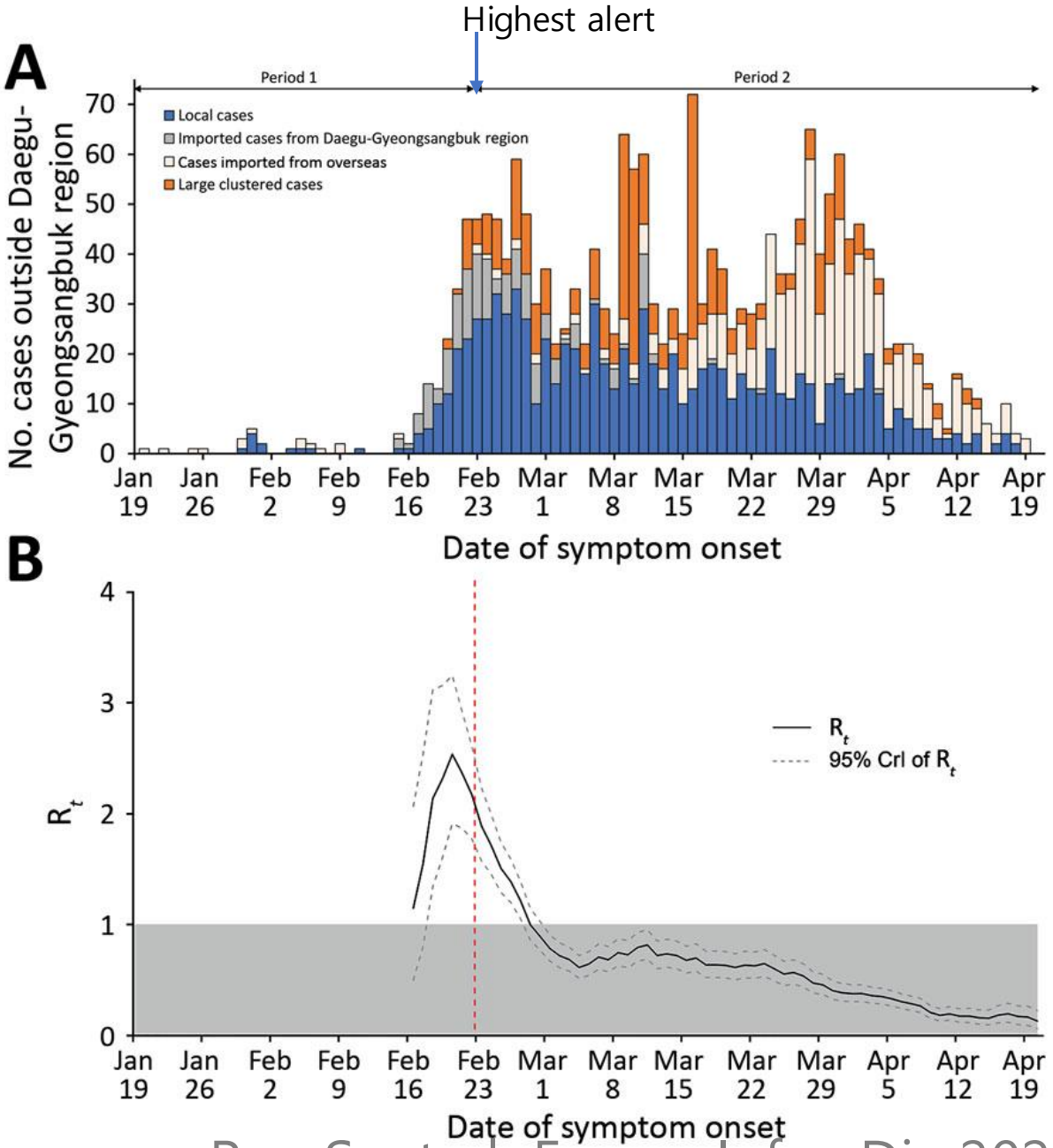
- Transmissibility was examined by estimating daily R_t
- R_t was reduced 33% by public alert without strict lockdown.



Ryu S, et al. Emerg Infec Dis 2020

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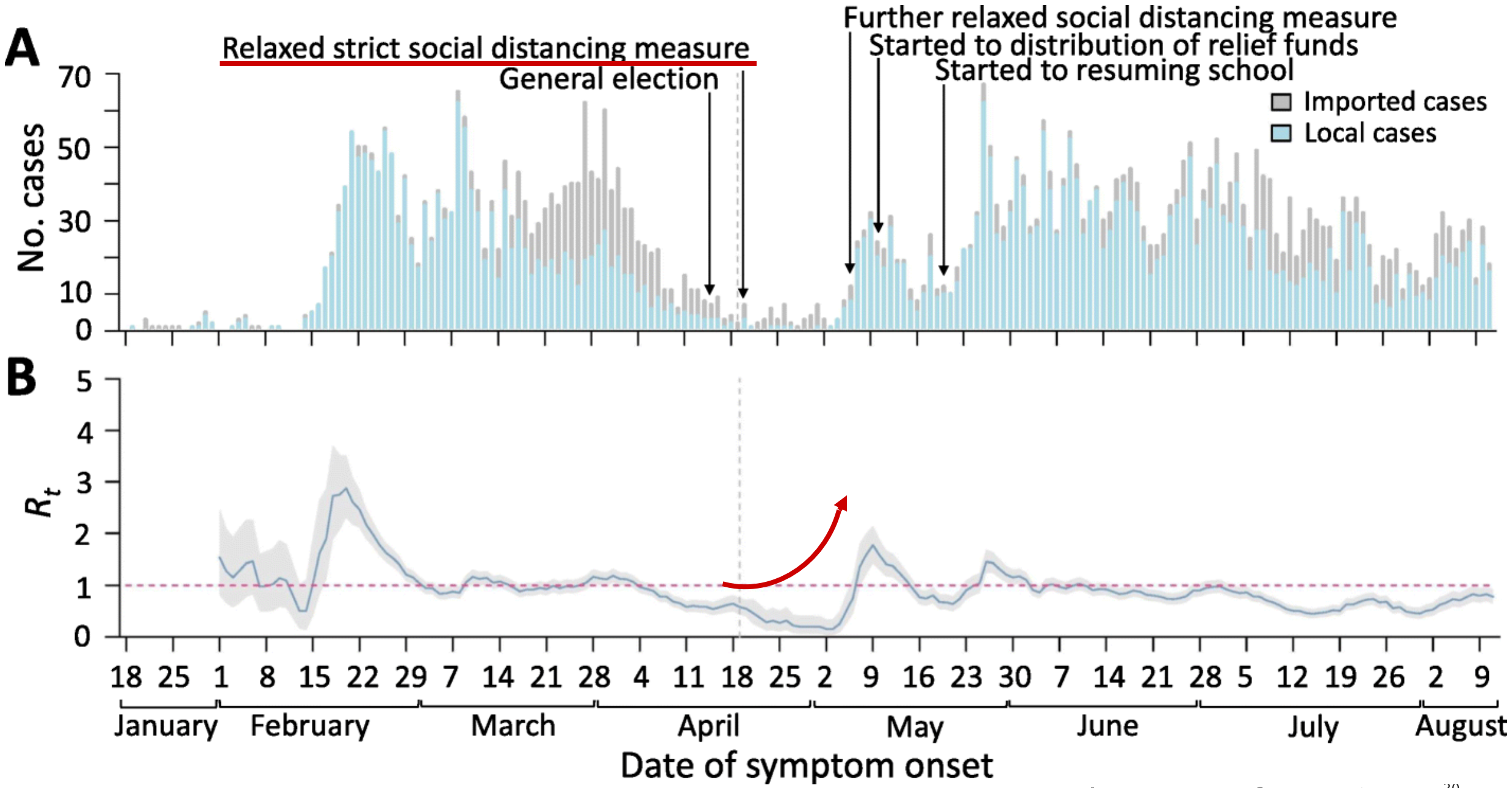
Ongoing monitoring of R_t can provide relevant information to help policymakers control a potential second wave of COVID-19.

Ryu S, et al. Emerg Infec Dis 2020



Ryu S, et al. BMC Infect Dis 2020

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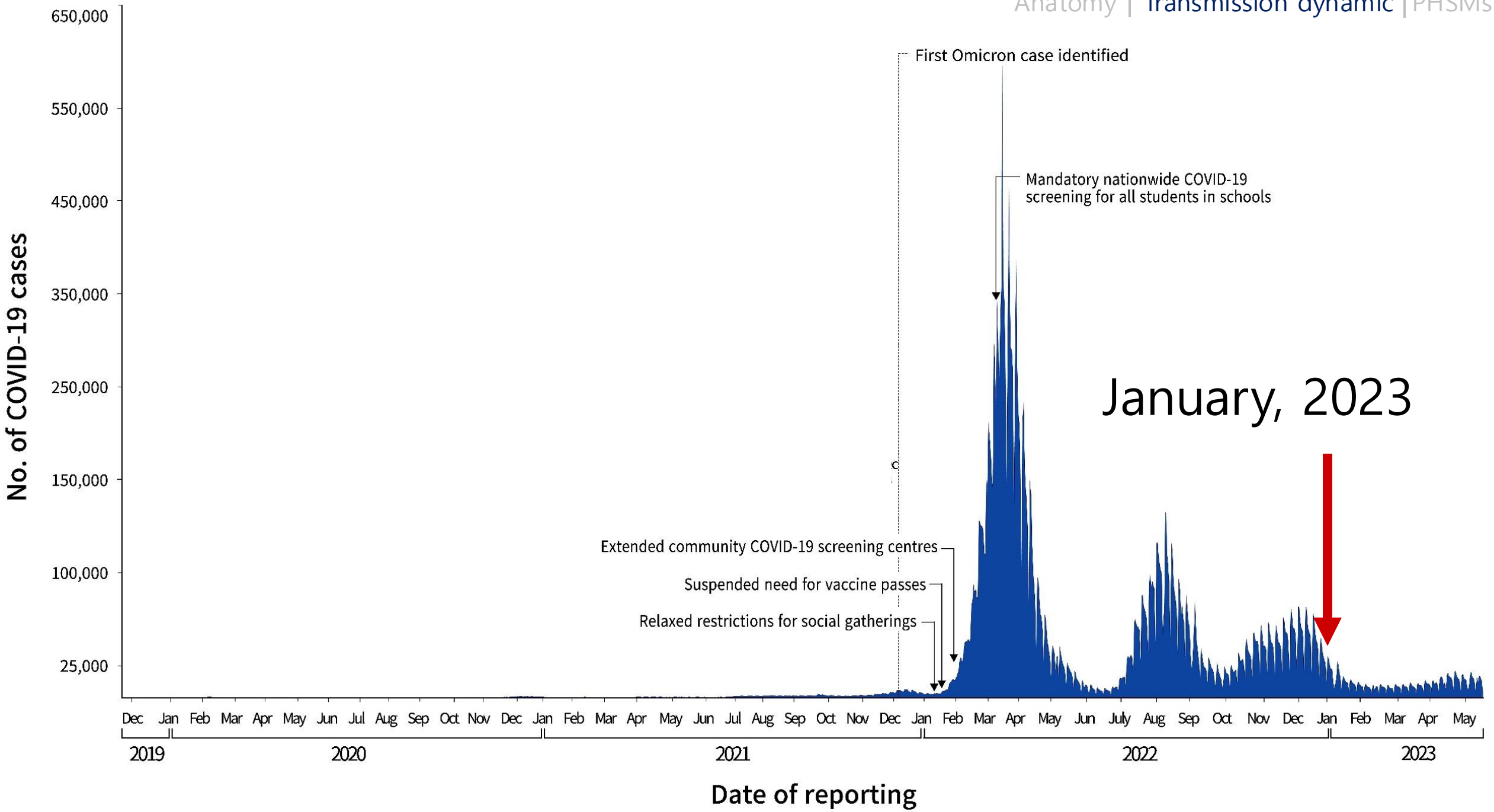
January 2, 2023, South Korean authorities suspended travel visa issuance for inbounding travelers from China

CNN travel Destinations Food & Drink News Stay Video

China stops issuing some visas for South Koreans, Japanese in retaliation for travel restrictions

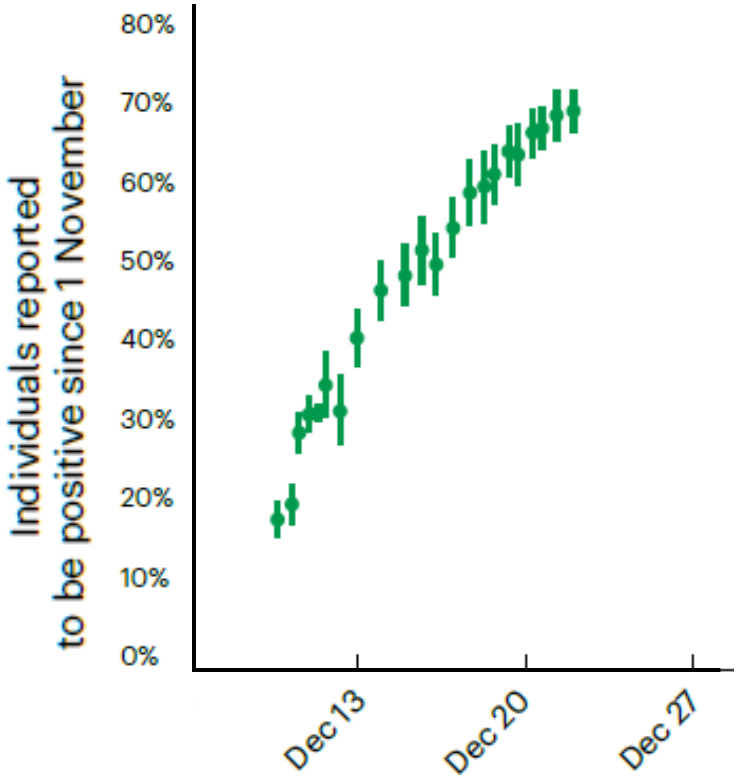
By Simone McCarthy and Wayne Chang, CNN
Updated 2:50 AM EST, Wed January 11, 2023

Han C, et al. J Travel Med 2023


650,000
550,000
450,000
350,000
250,000
150,000
100,000
25,000
No. of COVID-19 cases
First Omicron case identified
Mandatory nationwide COVID-19 screening for all students in schools
Extended community COVID-19 screening centres
Suspended need for vaccine passes
Relaxed restrictions for social gatherings
January, 2023
Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun July Aug Sep Oct Nov Dec Jan Feb Mar Apr May
2019
2020
2021
2022
2023
Date of reporting

After relaxing public health measure in China, SARS-CoV-2 infection would expect at peak on mid December 2022

- 75% of population in Beijing would expect to be infected.



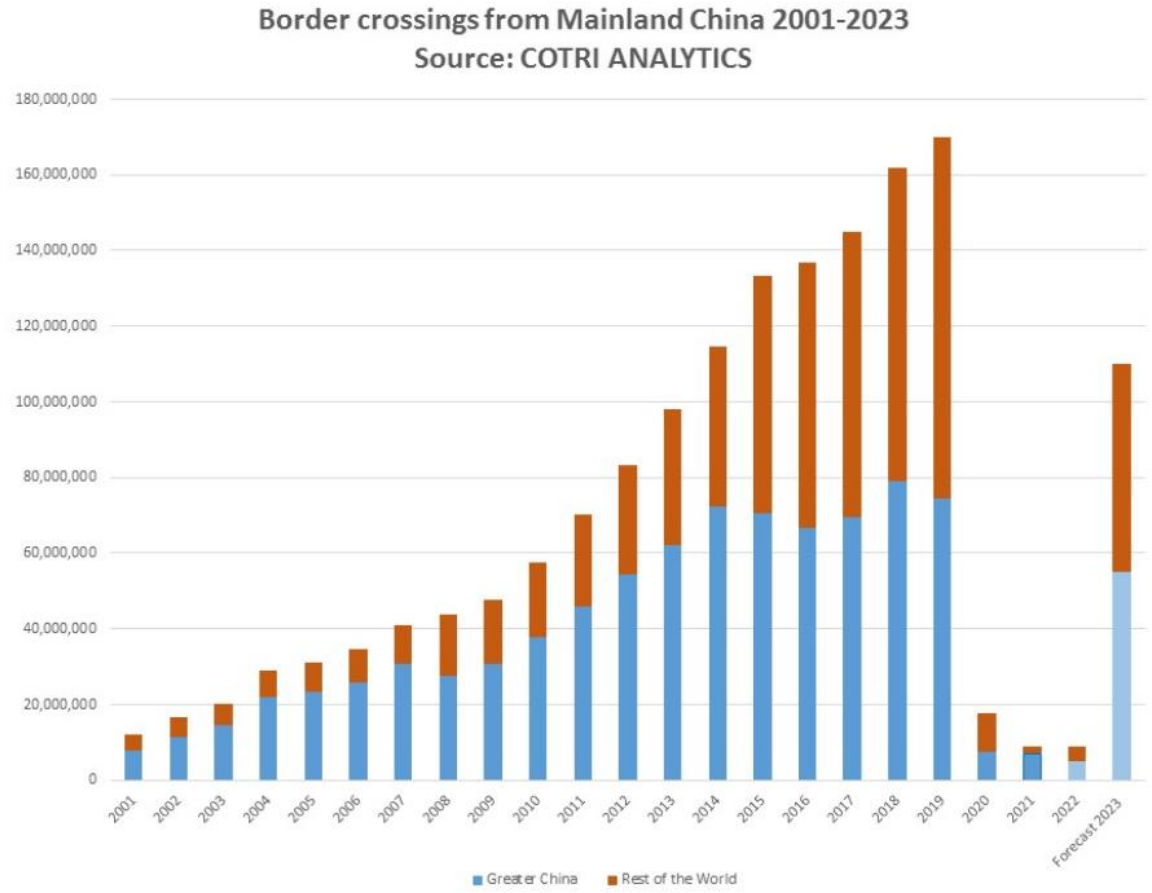
Leung K, et al. Nature Medicine 2023

O

China to drop quarantine requirement for overseas visitors

Eight days of isolation will no longer be needed, and officials say citizens' ability to travel will be slowly restored

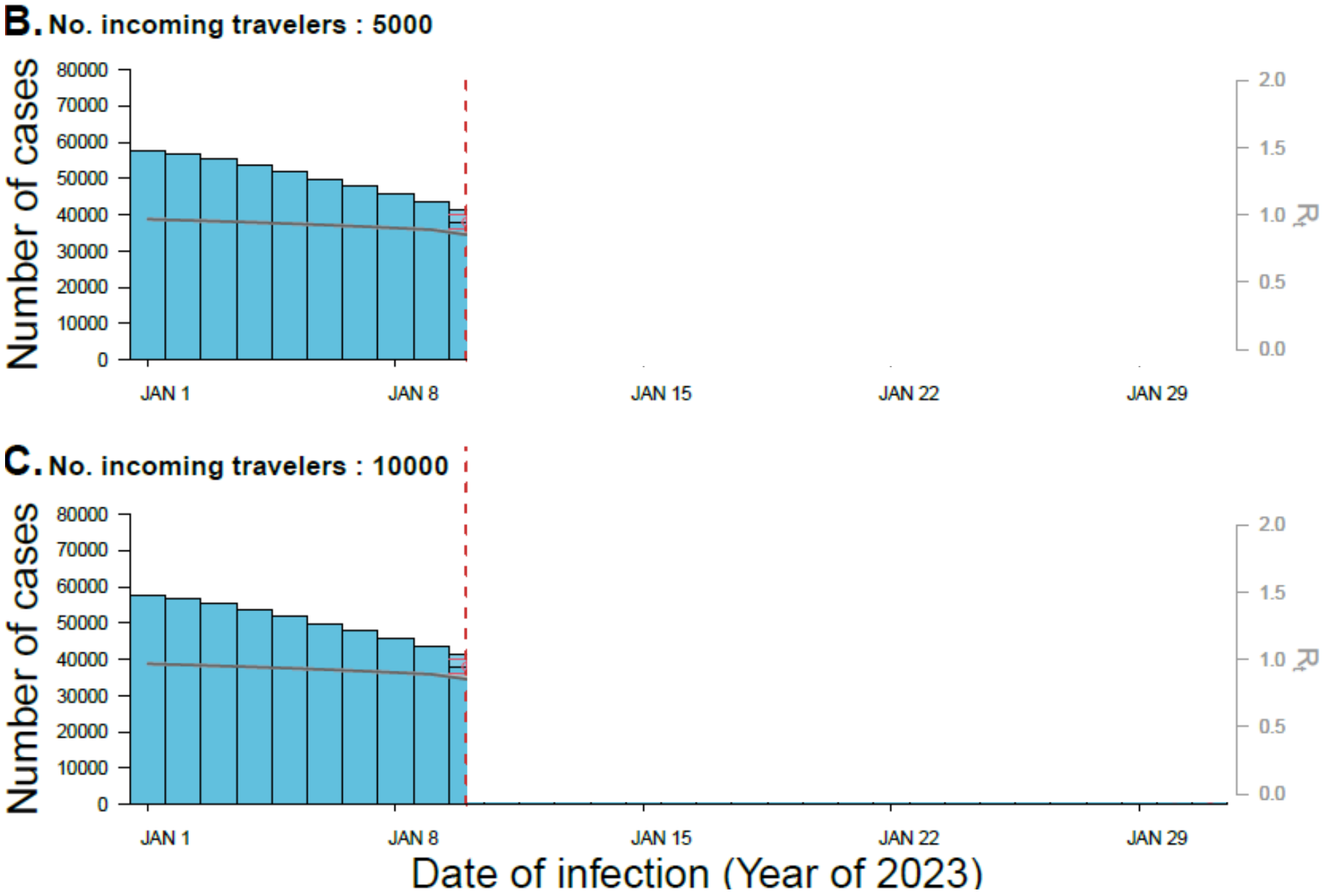
https://www.theguardian.com/world/2022/dec/26/china-starts-to-drop-quarantine-requirement-for-overseas-passengers



Health & Science

1 in 8 travelers from China test positive at Incheon despite pre-entry PCR requirement

https://www.koreatimes.co.kr/www/nation/2023/01/119_343128.html



Han C, et al. J Travel Med 2023

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Input

- No. of inbound travers
- Probability of travelers infected in China
- Specificity of exit screening test conducted in China
- Domestic cases infected with SARS-CoV-2 which relying on the Initial R_t (on 10 January 2023)
- Distribution of stay period

Output

- Daily number of SARS-CoV-2 infections in South Korea

Han C, et al. J Travel Med 2023

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Set the scenarios

Daily arrivals in South Korea	Probability of travelers infected with SARS-CoV-2 in China	Specificity of PCR test conducted in China	
		90%	70%
1,000	10%	10	30
	30%	30	90
5,000	10%	50	150
	30%	150	450
10,000	10%	100	300
	30%	300	900

Han C, et al. J Travel Med 2023

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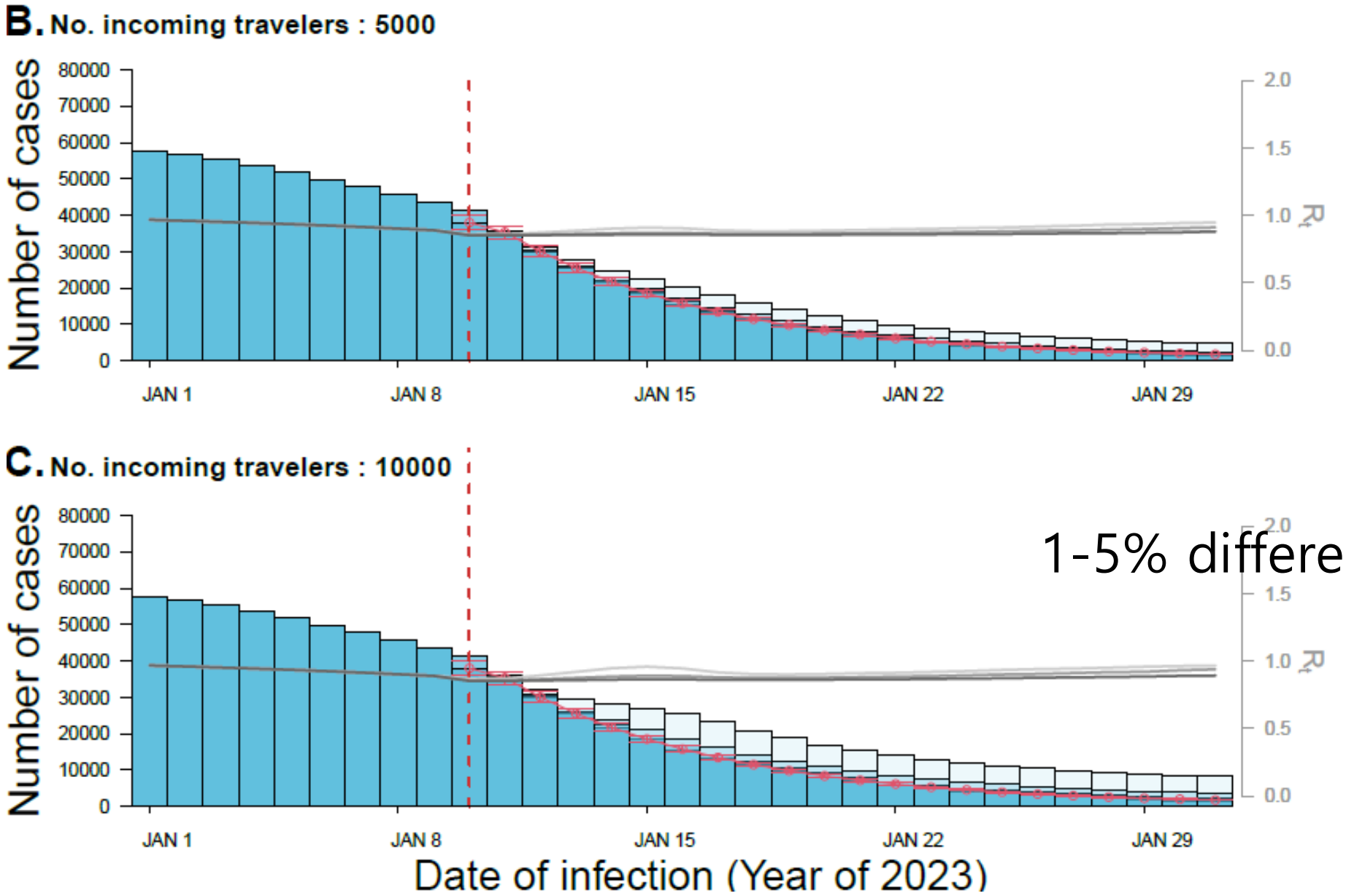

1-5% differences

Han C, et al. J Travel Med 2023

S

코로나 델타 변이 1명이 7명 감염 기본...누구나 슈퍼전파자 될 수 있다

2021.07.06 14:07 동아사이언스

Superspreader 'explosions' plague efforts to curb pandemic

NEWS

July 14, 2021, 6:00 PM KST

By Denise Chow

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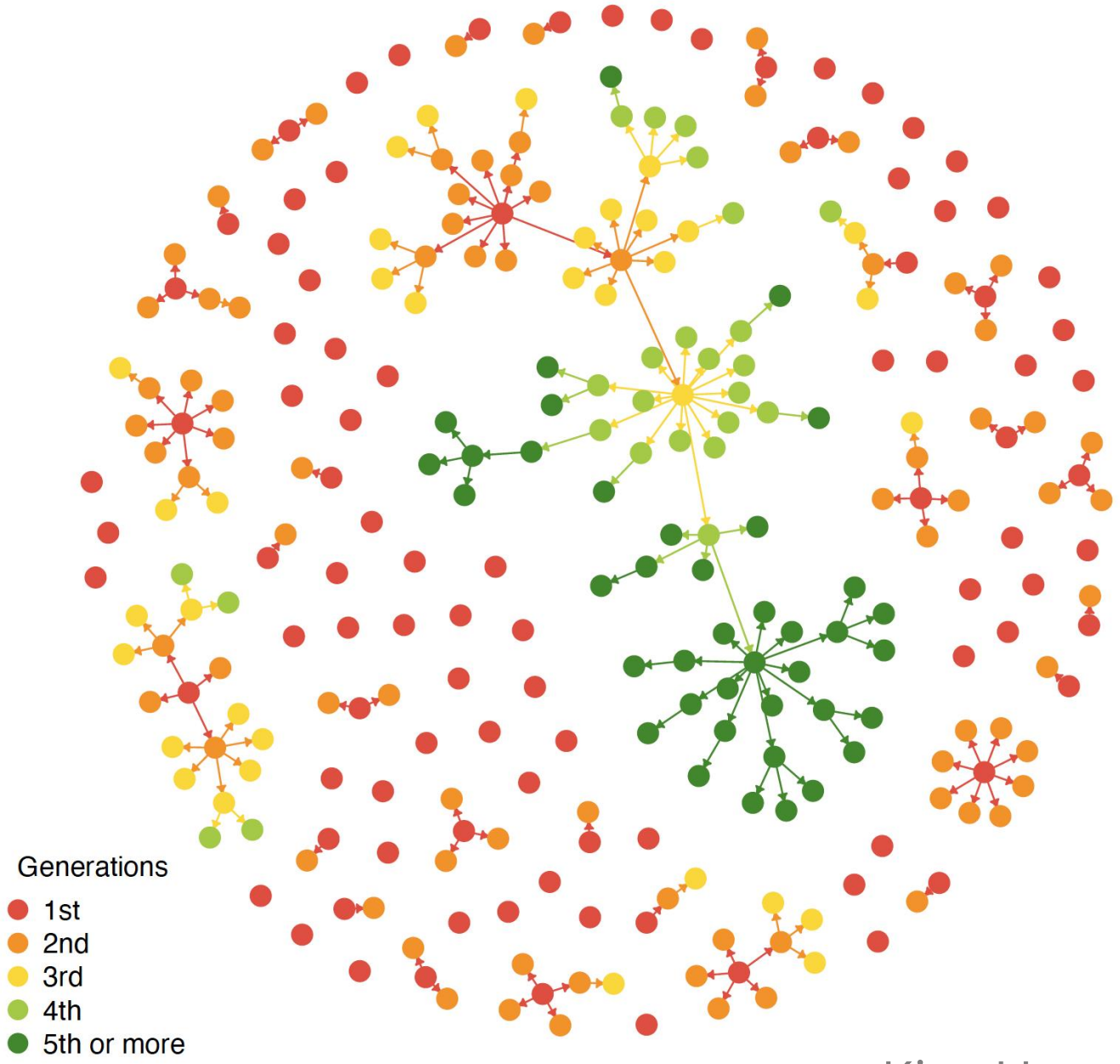

Kim H, et al. Under review 2025

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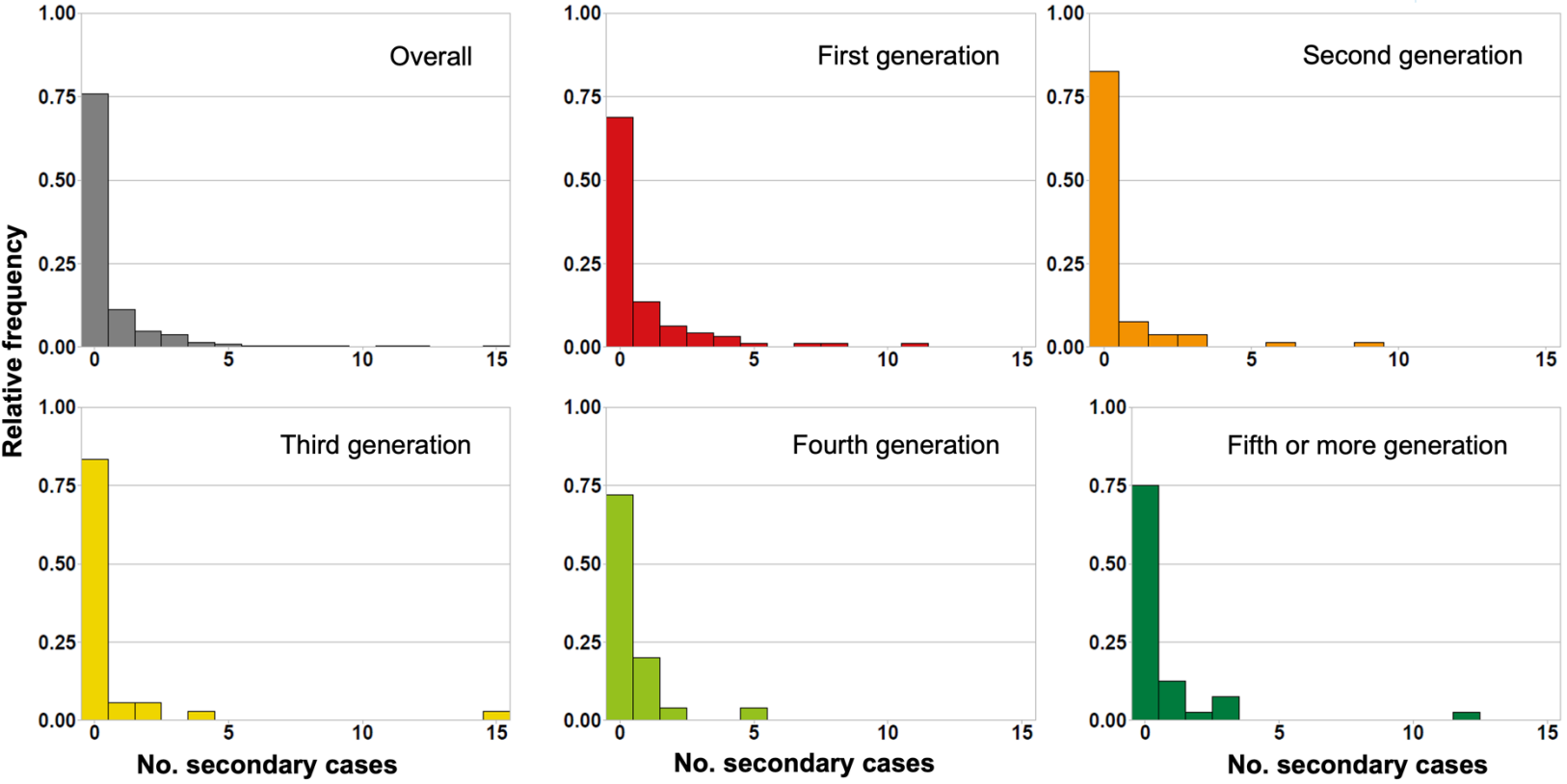

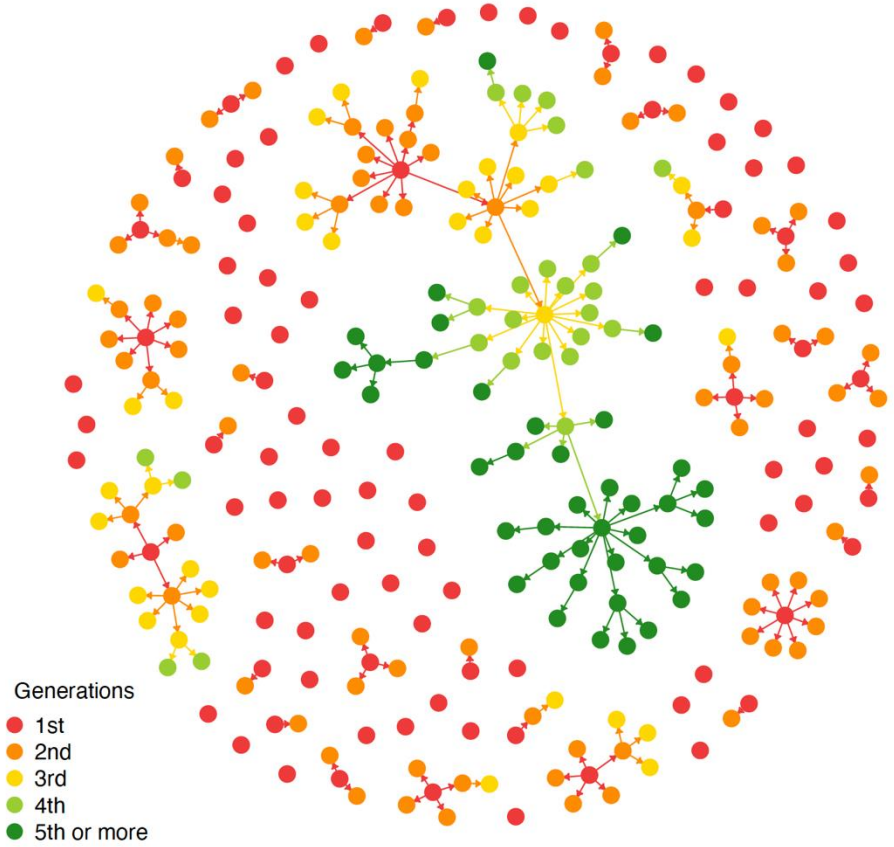

Kim H, et al. Under review 2025

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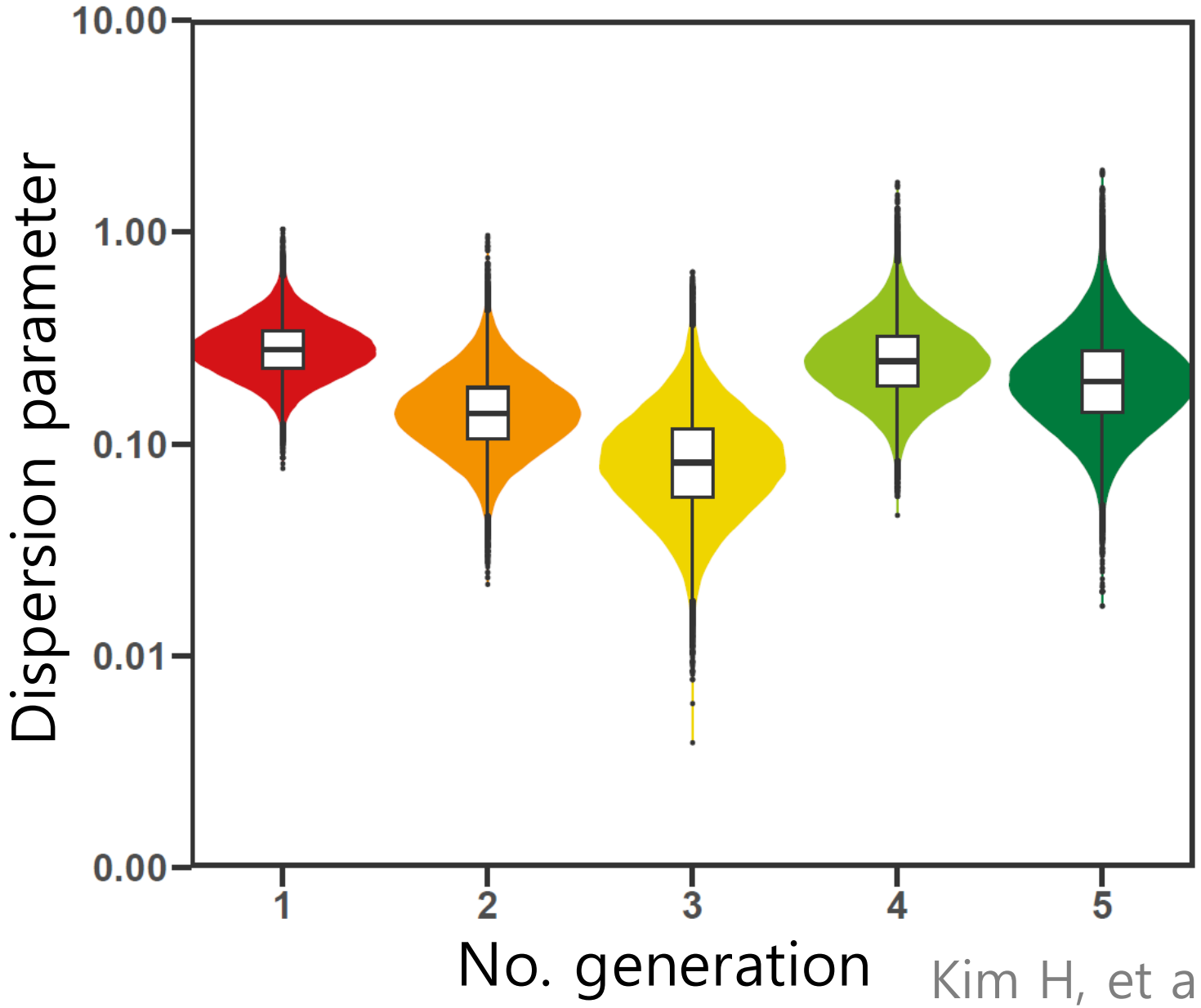
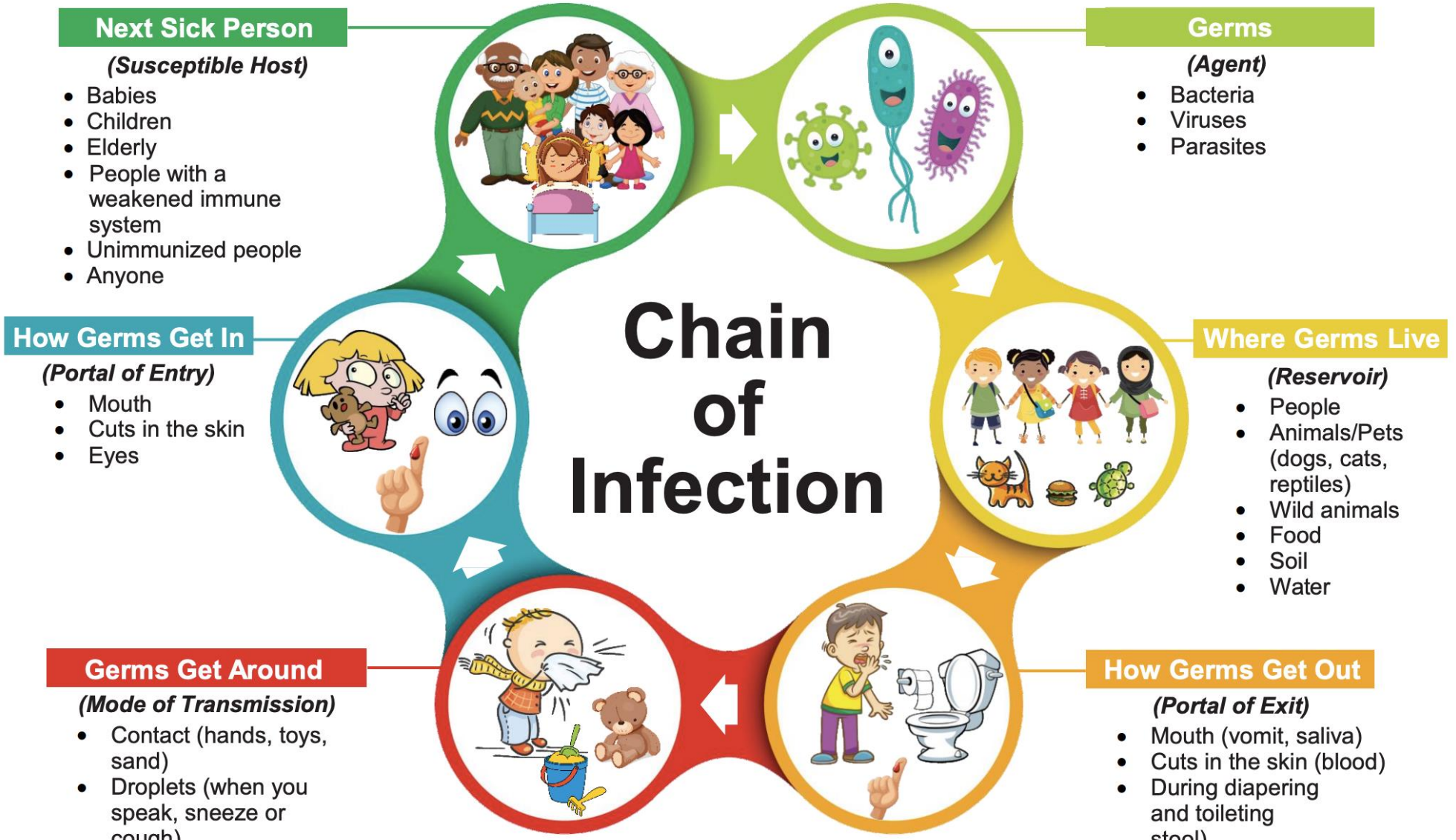
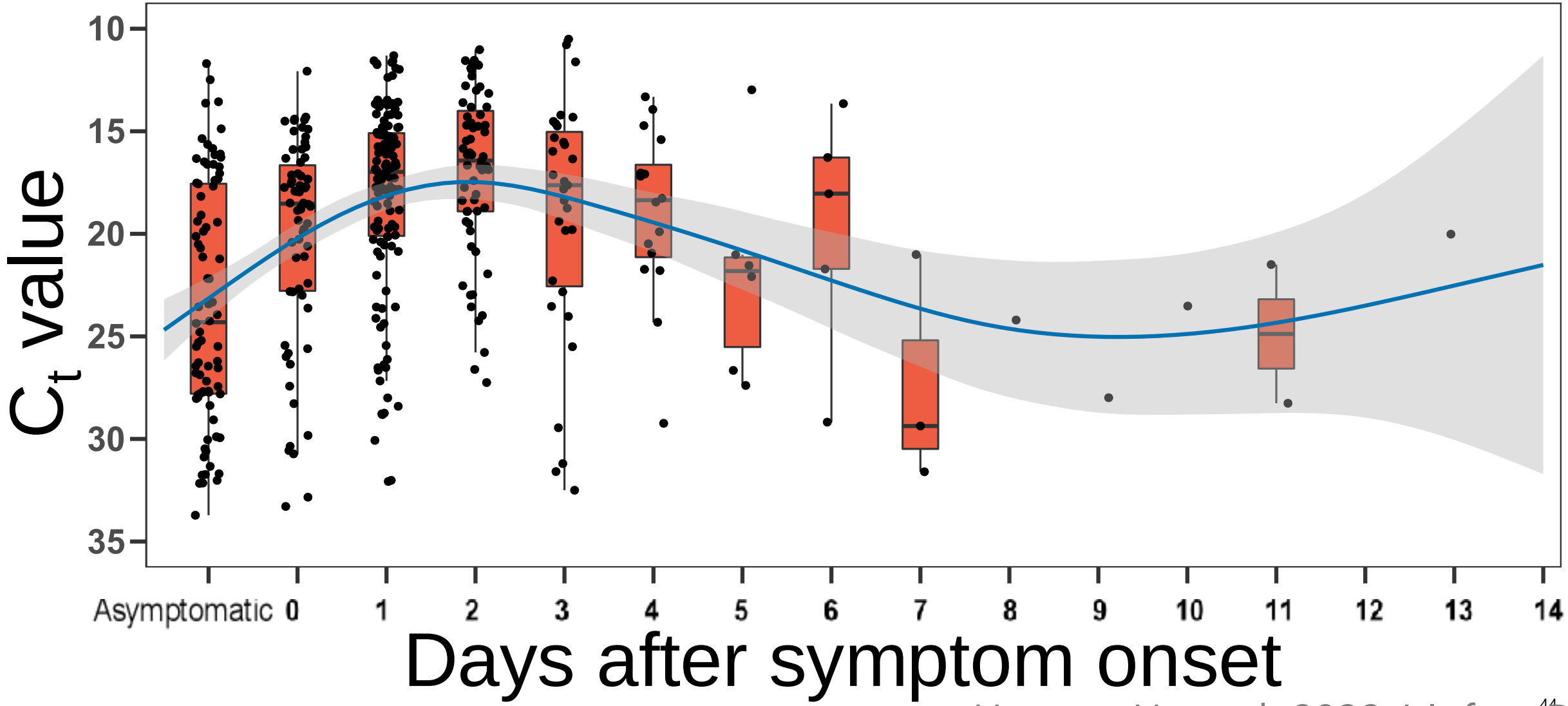


Kim H, et al. Under review 2025

Host factors





Hwang H, et al. 2022 J Infect Dis.

https://k-life.co/events/5131

1. Anatomy
   - Incubation period
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2. Transmission dynamics
   - Effective reproduction number
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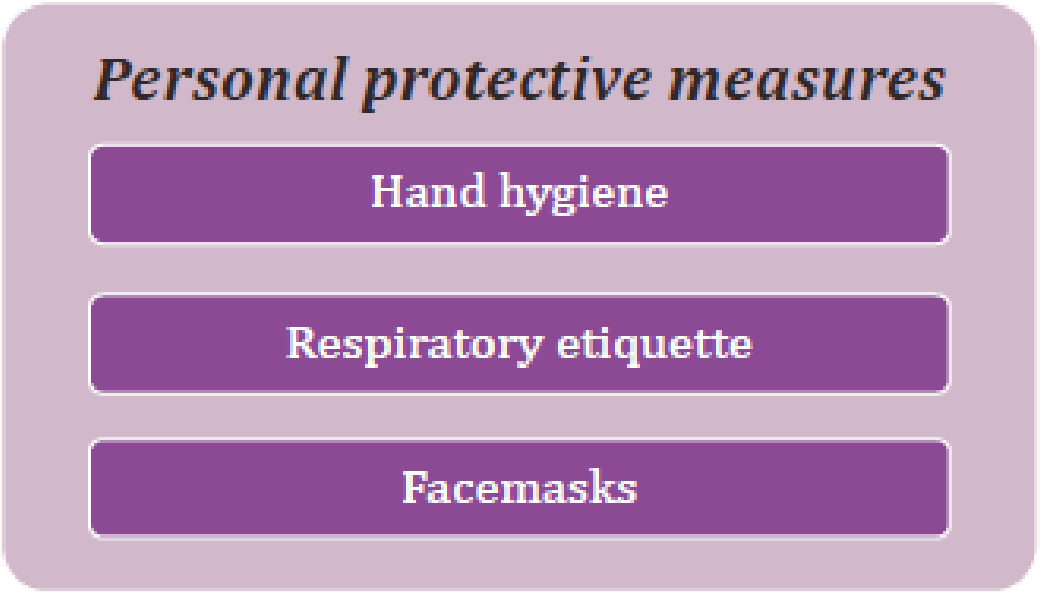
3. PHSMs (Public health and social measures)
   - Pharmaceutical interventions
   - Nonpharmaceutical Interventions

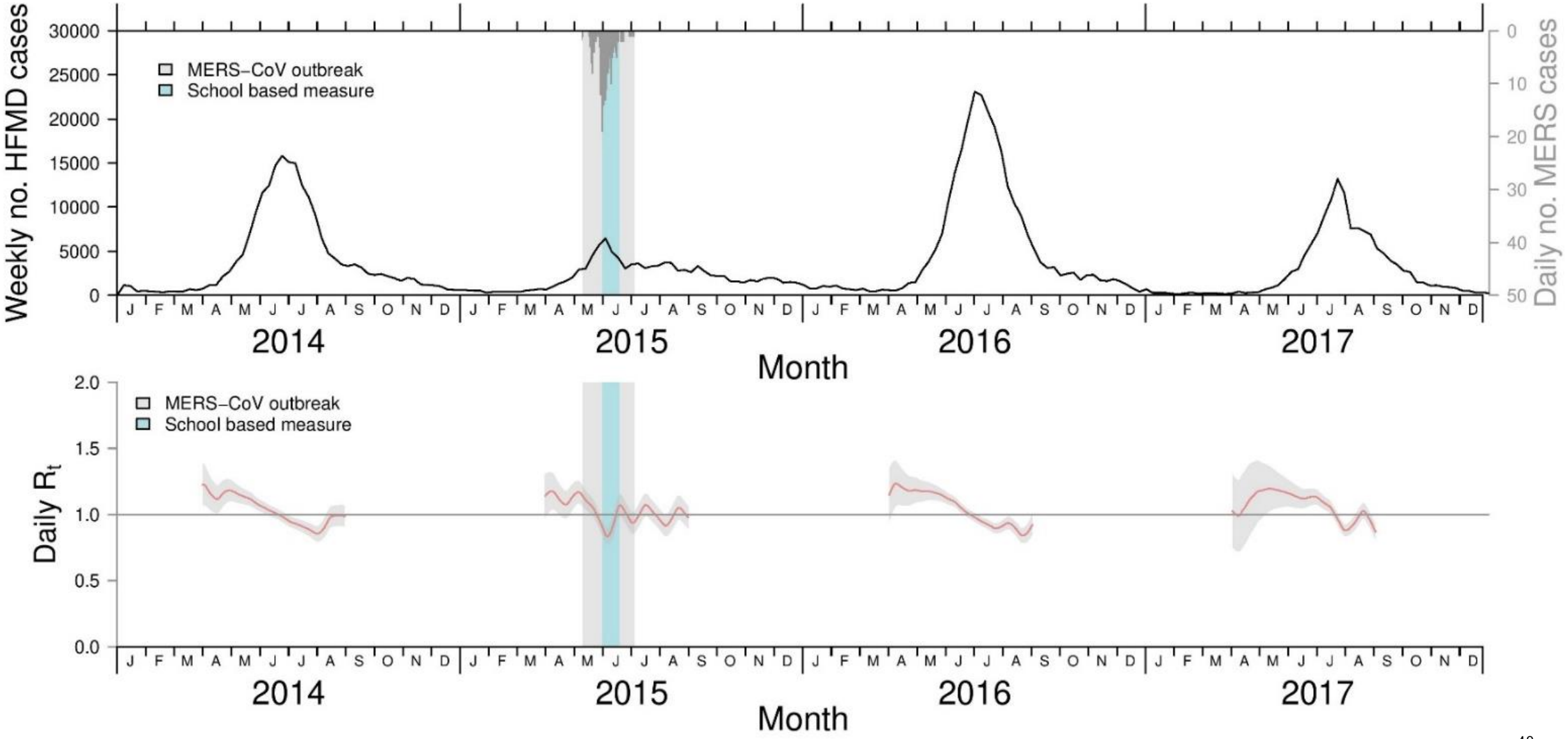
Public Health and Social Measures

- Options for control
  - Pharmaceutical interventions
  - Nonpharmaceutical interventions



Ryu S, et al. 2020 WHO Technical consultation meeting

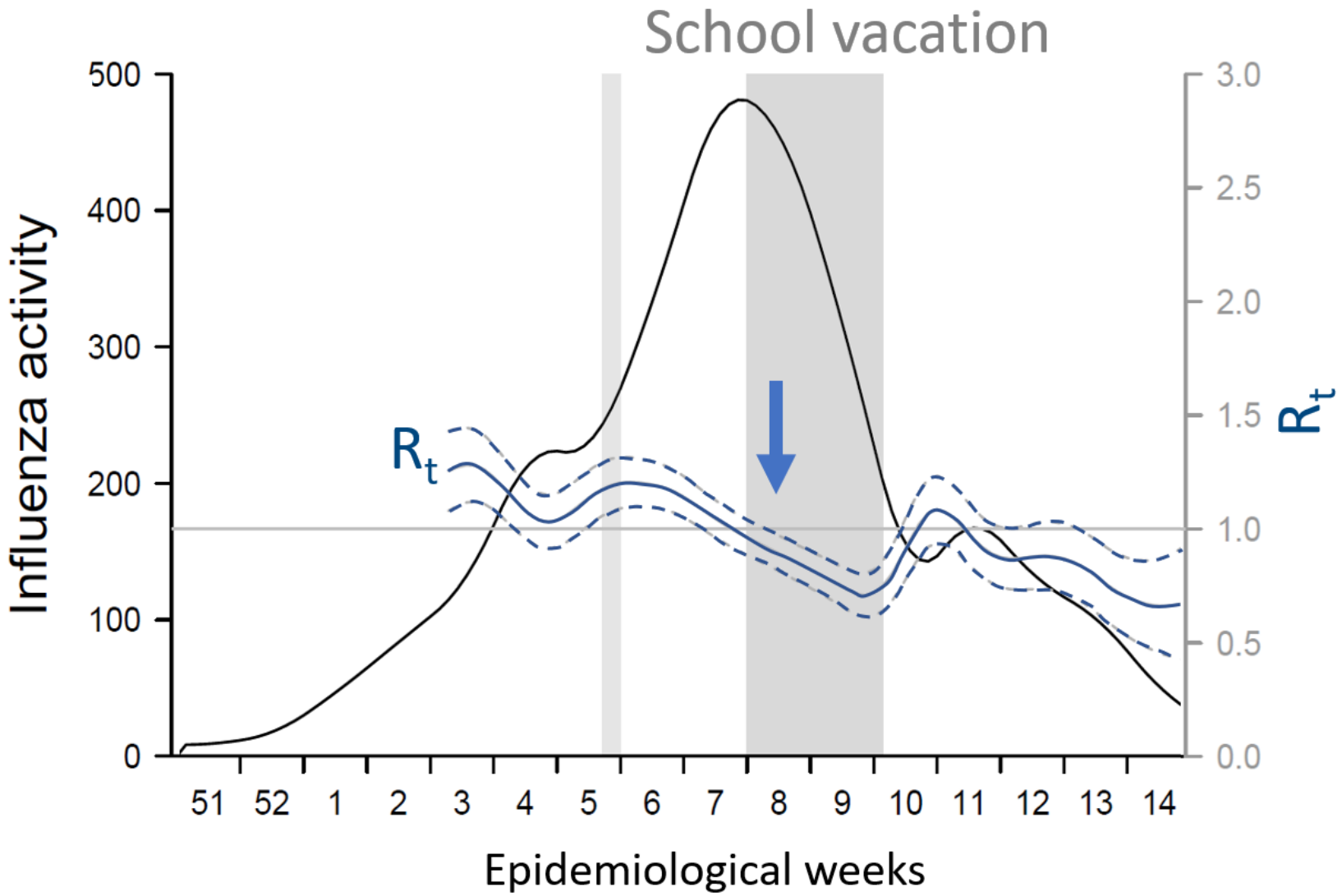
NPIs



Ryu S, et al. J Infect Public Heal 2023

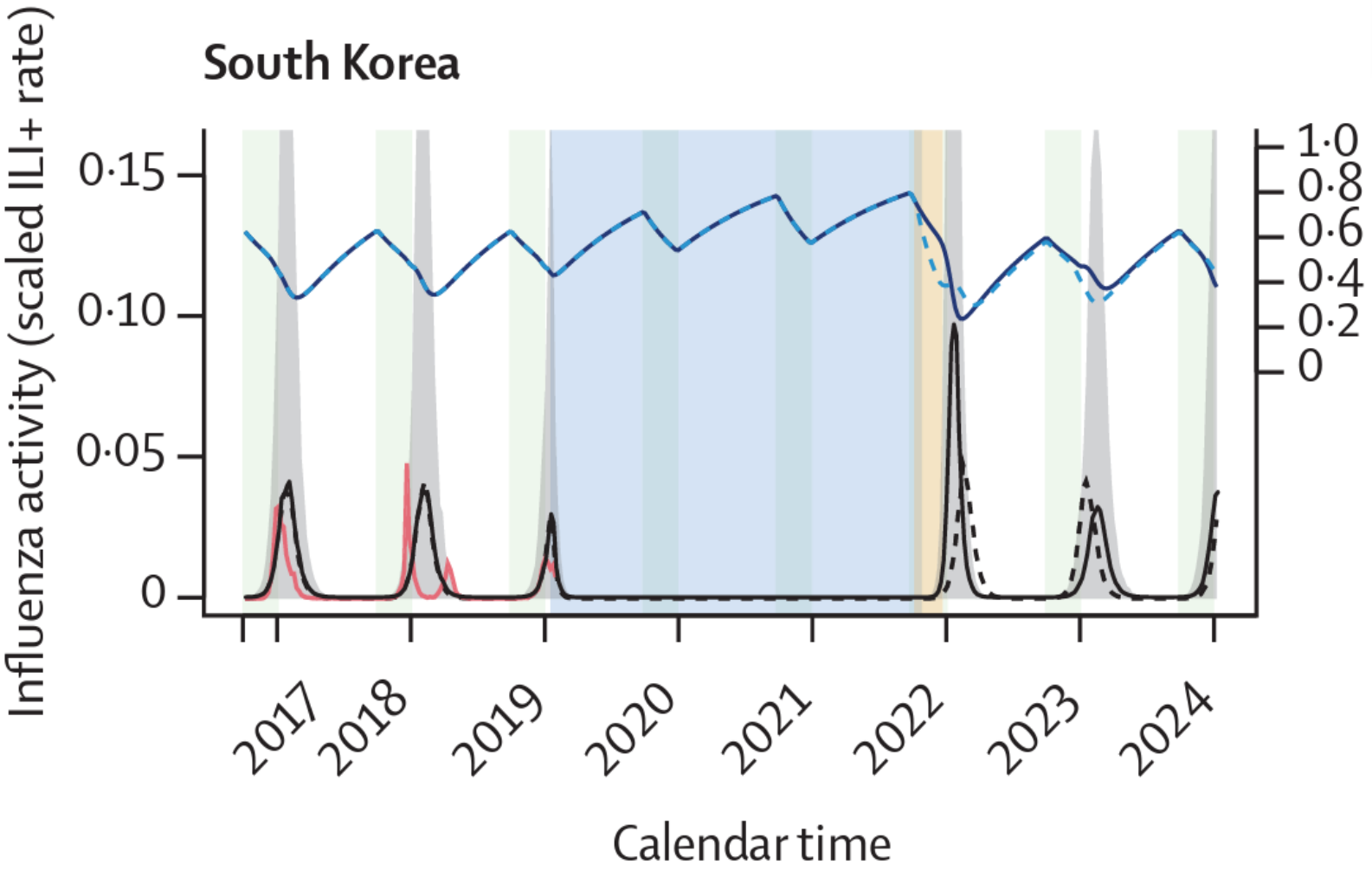
NPIs

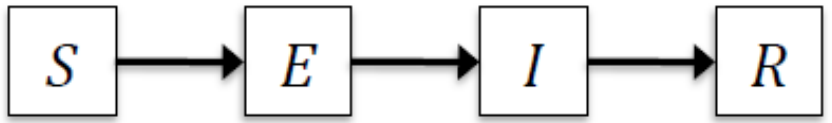
- Immediate reduction of R_t : 16% - 27%
- Overall reduction of R_t: 3% - 10%



Ryu S, et al. J Infect Dis 2020

NPIs

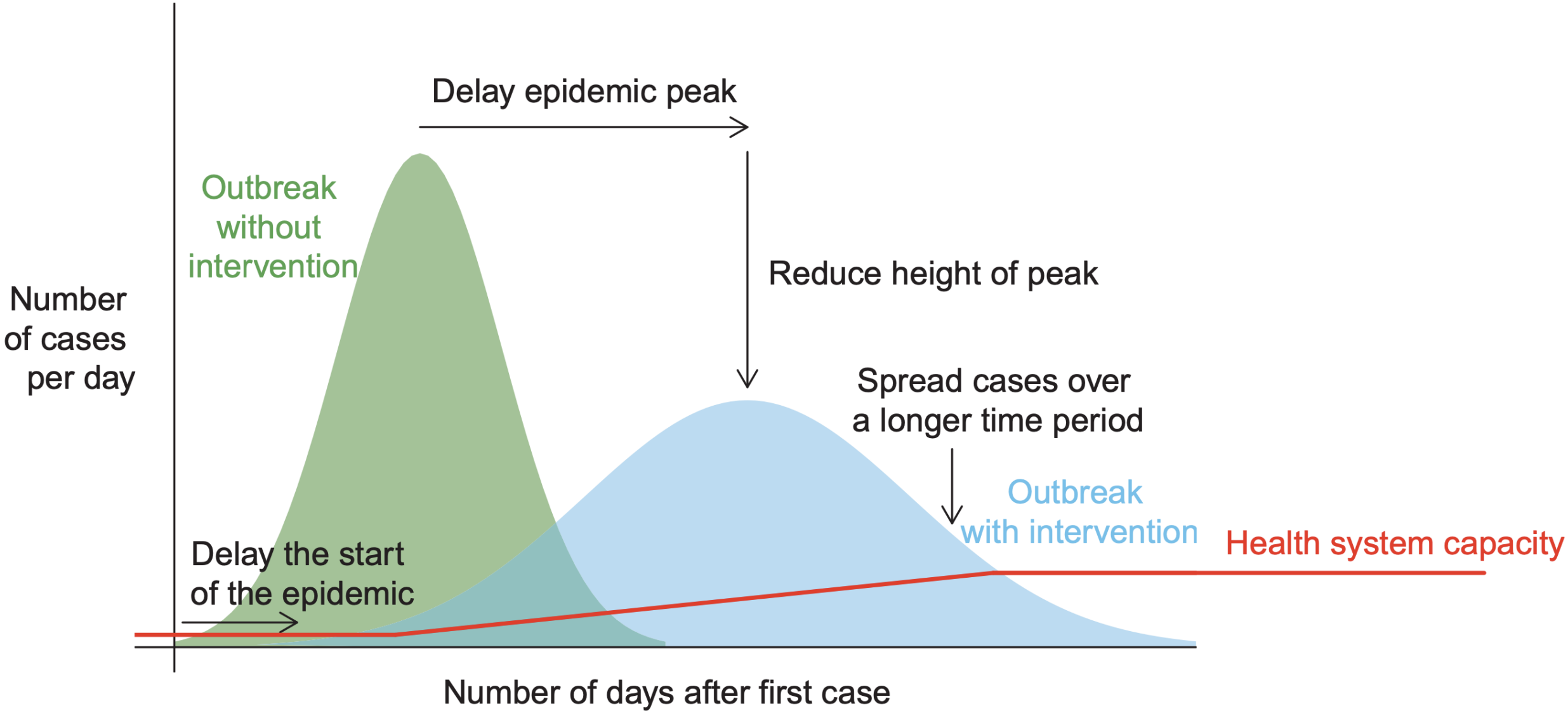




Prediction of infection burden of influenza after PHSM relaxation

Ali ST. Lancet Global Health. 2022

NPIs



Ryu S, et al. Cold Spring Harb Perspect Med. 2020

PIs

S

백신접종-자연감염 복합면역군, 코로나 재감염 상대적으로 낮아

이재원 기자 | 입력 2023.08.09 11:03 | 의학신문

PIs

- O

Characteristics	SARS-CoV-2 infection alone (n=536)	Vaccination alone (n=73)			Vaccine after infection (n=5)	Vaccine breakthrough Infection [a] (n=127)	Unvaccinated and uninfected (n=245)	Total (n=986)
		1st dose (n=2)	2nd dose (n=52)	3rd dose (n=19)				
Age, years								
Median (IQR)	9 (7–11)	9.5 (7.3–11.8)	14.0 (13.0–16.0)	15.0 (13.5–17.0)	7 (7–10)	14 (13–16)	9 (7–11)	10.0 (8.0–13.0)
Range (Min–Max)	14 (4–18)	9 (5–14)	12.0 (6.0–18.0)	6 (12.0–18.0)	6 (6–12)	9 (9–18)	4 (4–18)	14 (4.0–18.0)

Measure antibodies against the SARS-CoV-2 spike protein (S), known to develop from both natural SARS-CoV-2 infection and vaccination

Choi HW, et al. 2023 Frontiers Immun.

PIs

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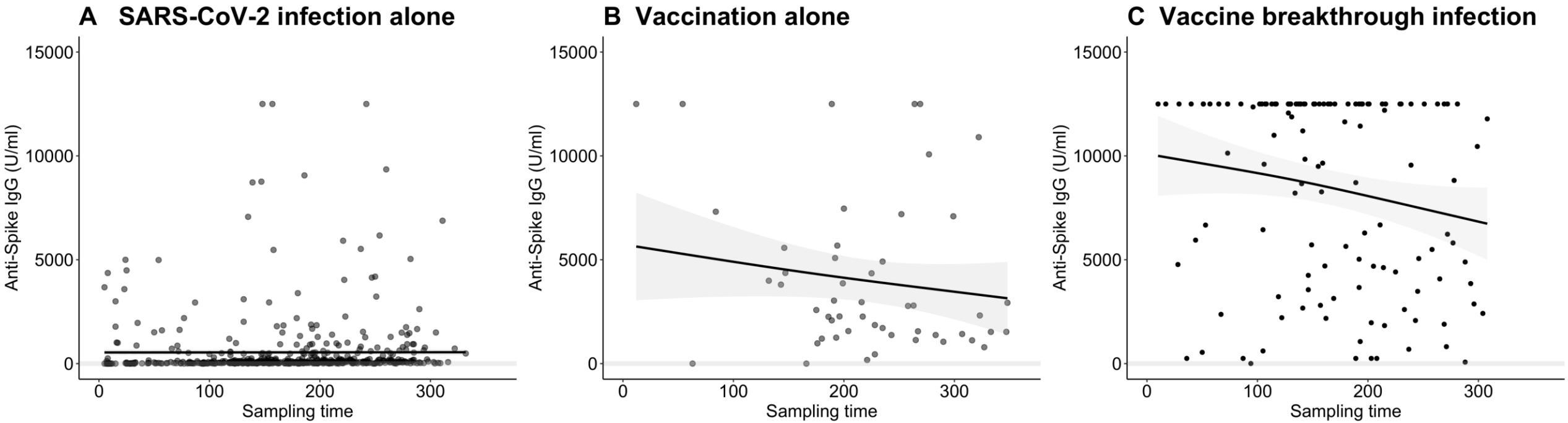
986 children aged 4–18 years (June 2022-January 2023)



Choi HW, et al. 2023 Frontiers Immun.

PIs

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기초·응용과학 | 김은영 객원기자

백신접종으로 코로나19 집단면역이 이뤄질까?

집단면역은 어렵지만 백신 접종은 최선의 선택

2021-04-21

https://www.sciencetimes.co.kr/nscvrg/view/menu/248?nscvrgSn=219986

PIs

- O

Characteristic		Wave 3 (13 November 2020 and 6 July 2021)	Wave 4 (7 July 2021 and 29 January 2022)	Wave 5 (30 January 2022 and 25 June 2022)	Wave 6 (26 June 2022 and 16 October 2022)	Wave 7 (17 October 2022 and afterward)	*P-value*
Sex							0.87
	Male	1,478 (45.3%)	1,335 (44.1%)	924 (44.27%)	798 (43.9%)	582 (44.5%)	
	Female	1,788 (54.7%)	1,689(55.9%)	1,163(55.7%)	1,021 (56.1%)	726 (55.5%)	
Age							<0.05
	0-17 years	266 (8.14%)	207(6.85%)	166 (7.95%)	127 (6.98%)	56 (4.28%)	
	18-49 years	1,335(40.9%)	1,068(35.3%)	775 (37.1%)	779 (42.8%)	431 (33.0%)	
	50-64 years	831(25.4%)	806(26.7%)	530 (25.4%)	476 (26.2%)	354 (27.1%)	
	≥65 years	834(25.5%)	943(31.2%)	616 (29.5%)	437 (24.0%)	467 (35.7%)	

Kim A, et al. Under review. 2025

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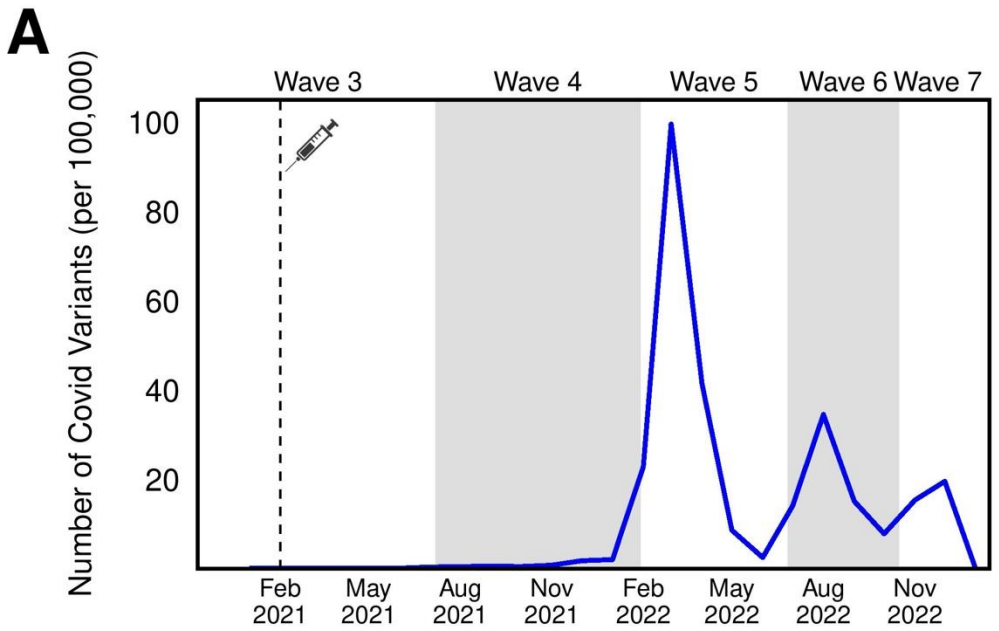

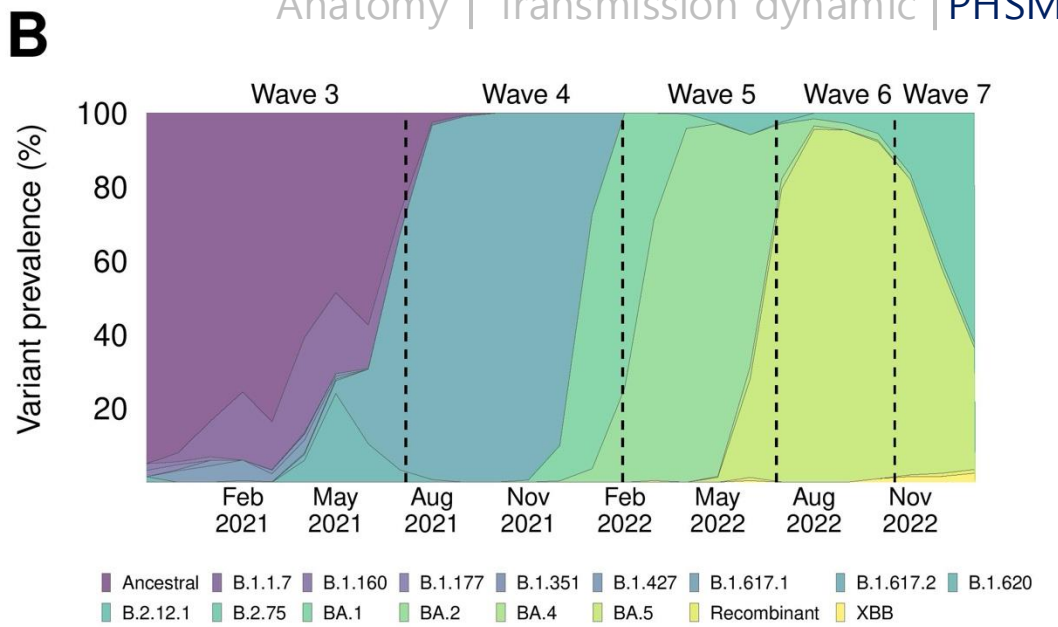

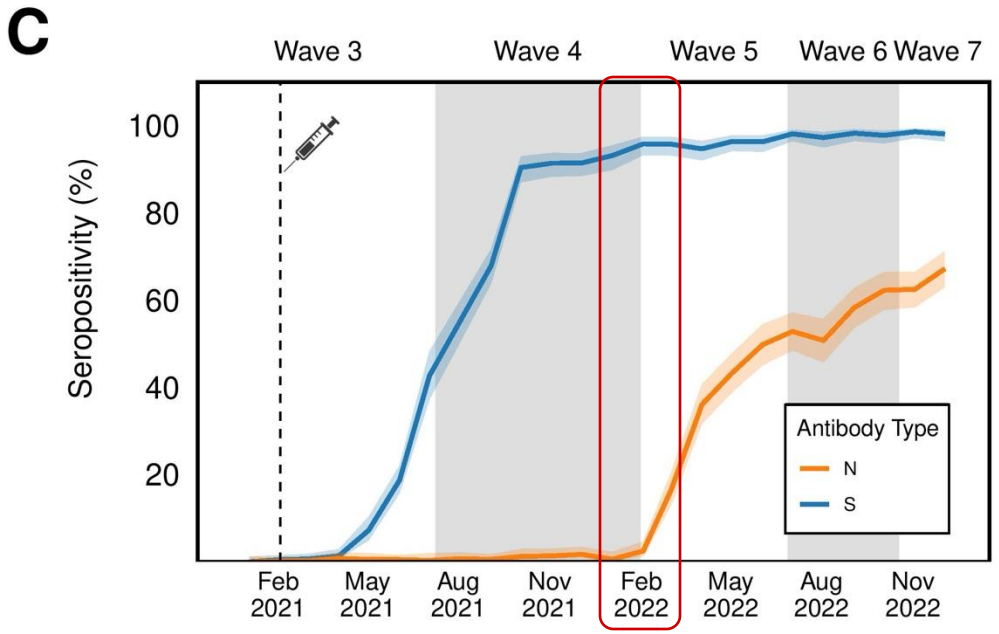

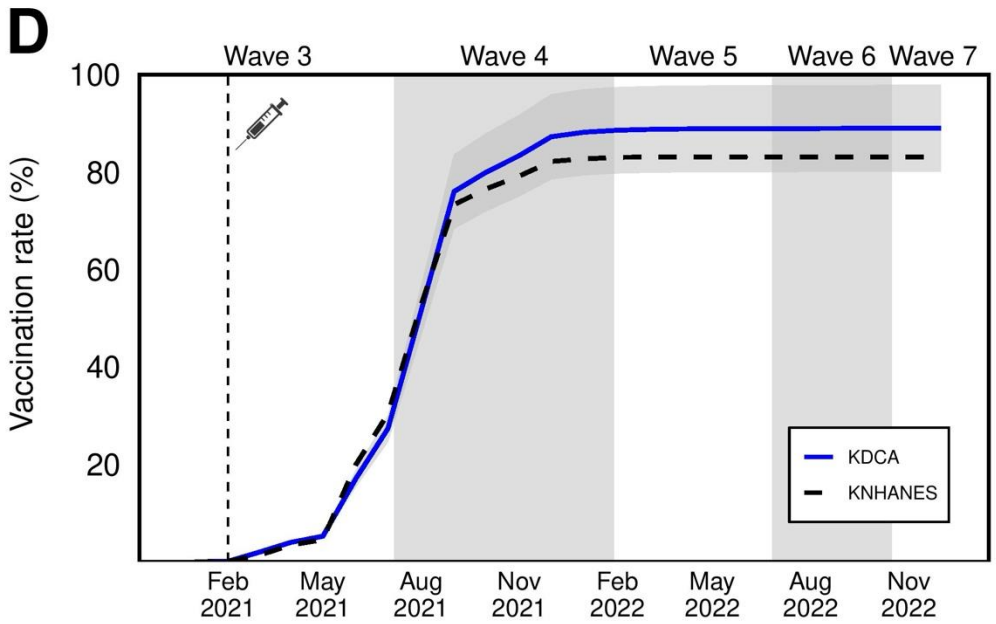

Kim A, et al. Under review. 2025

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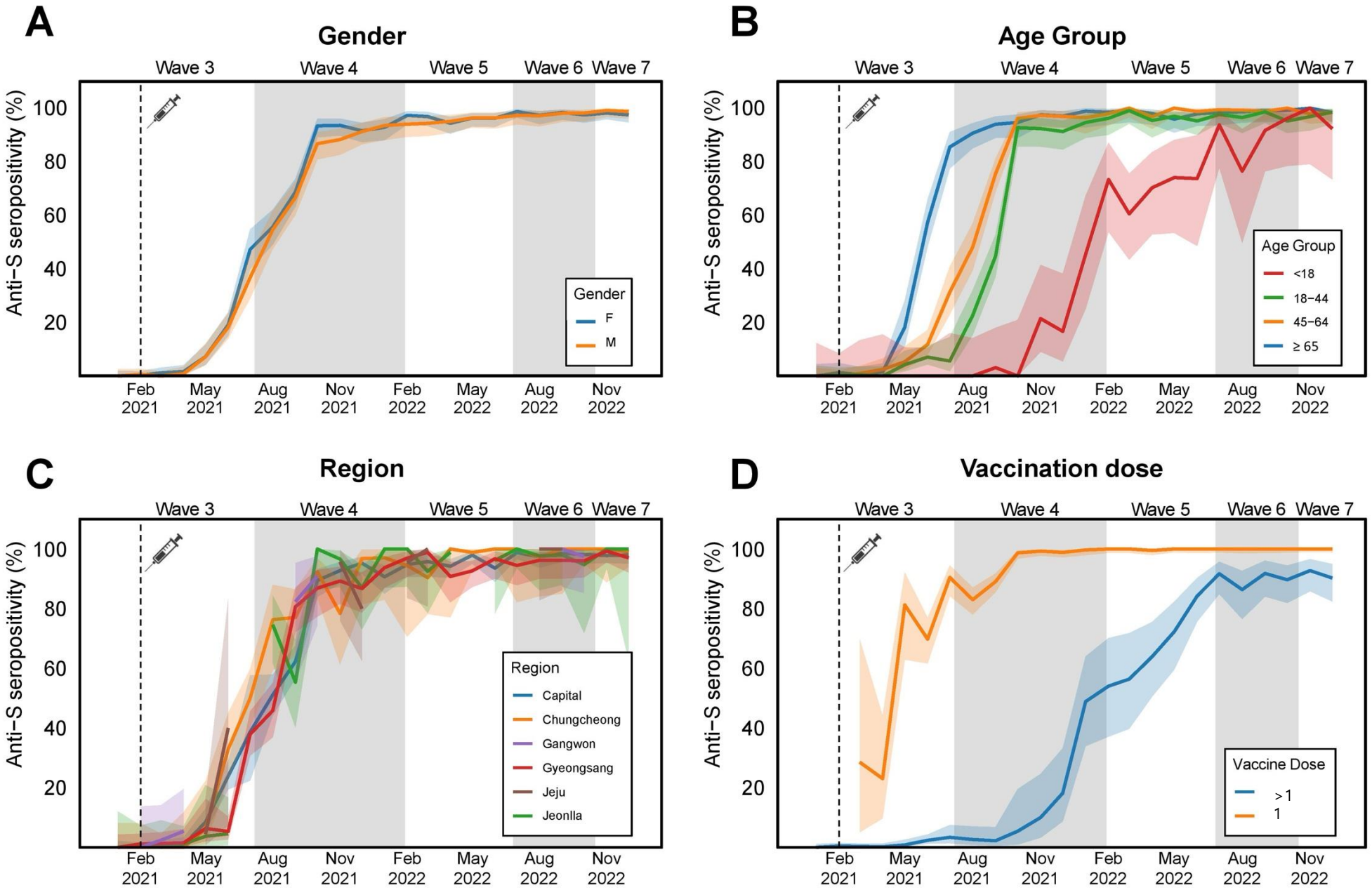

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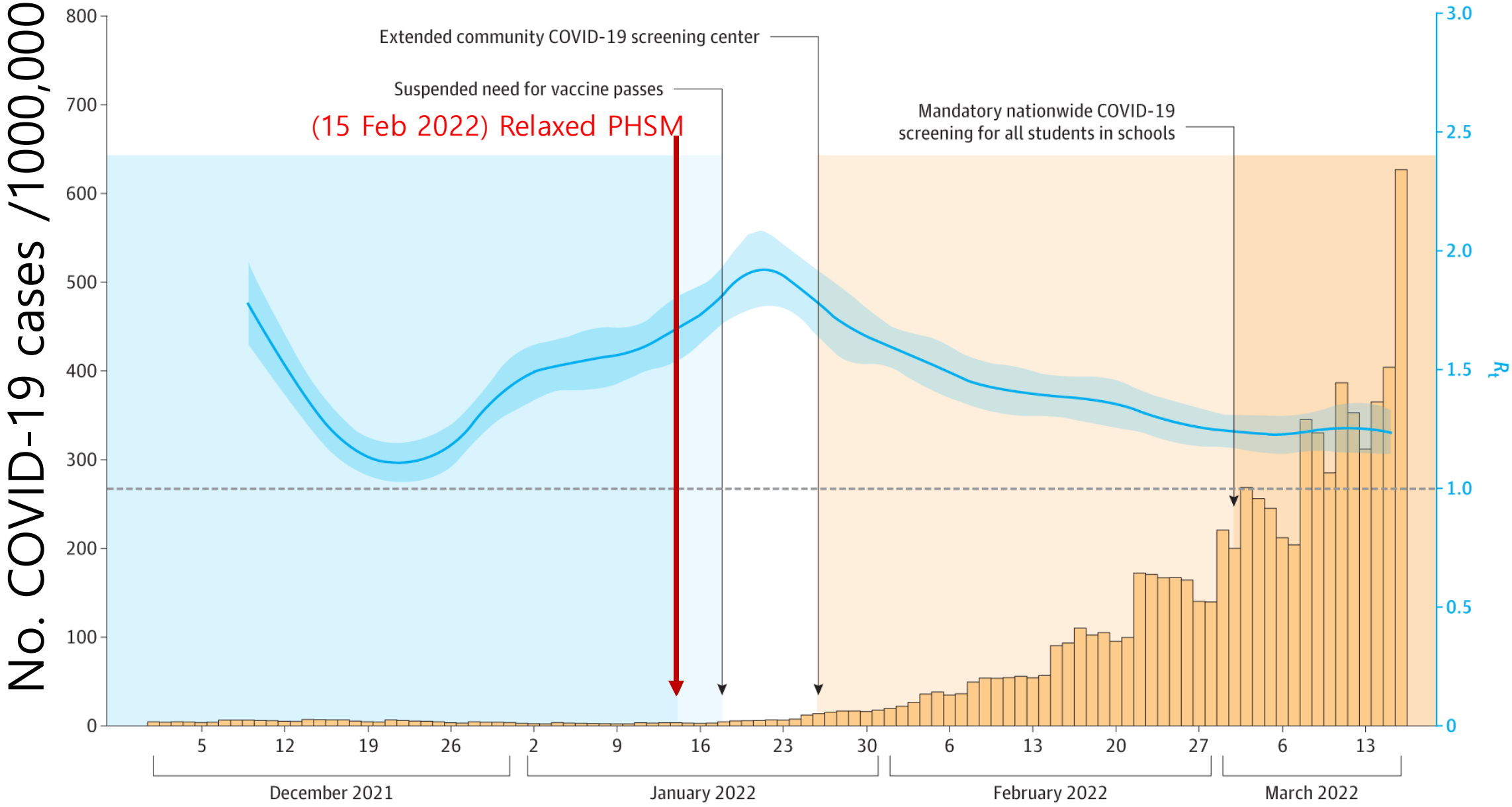
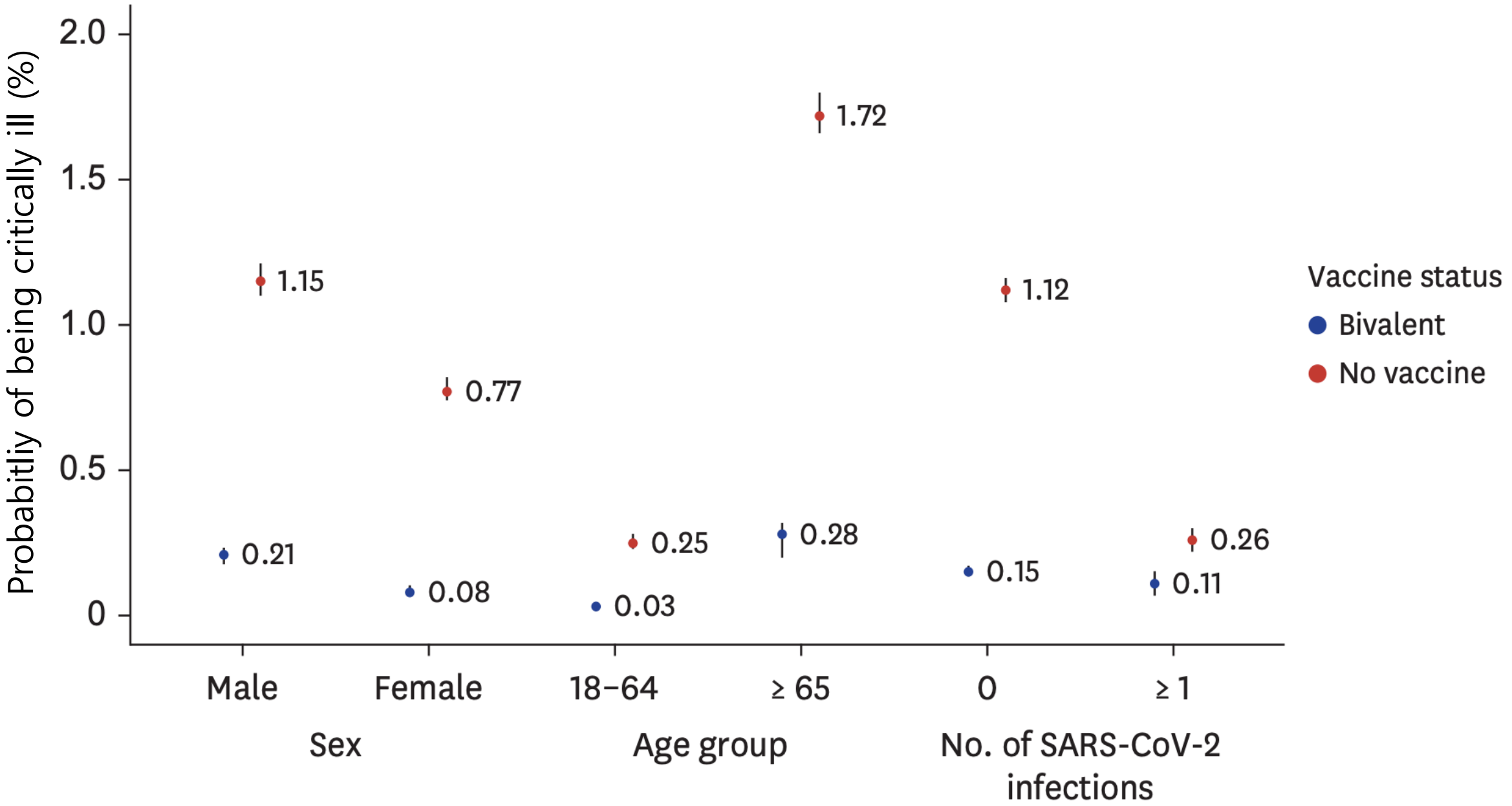
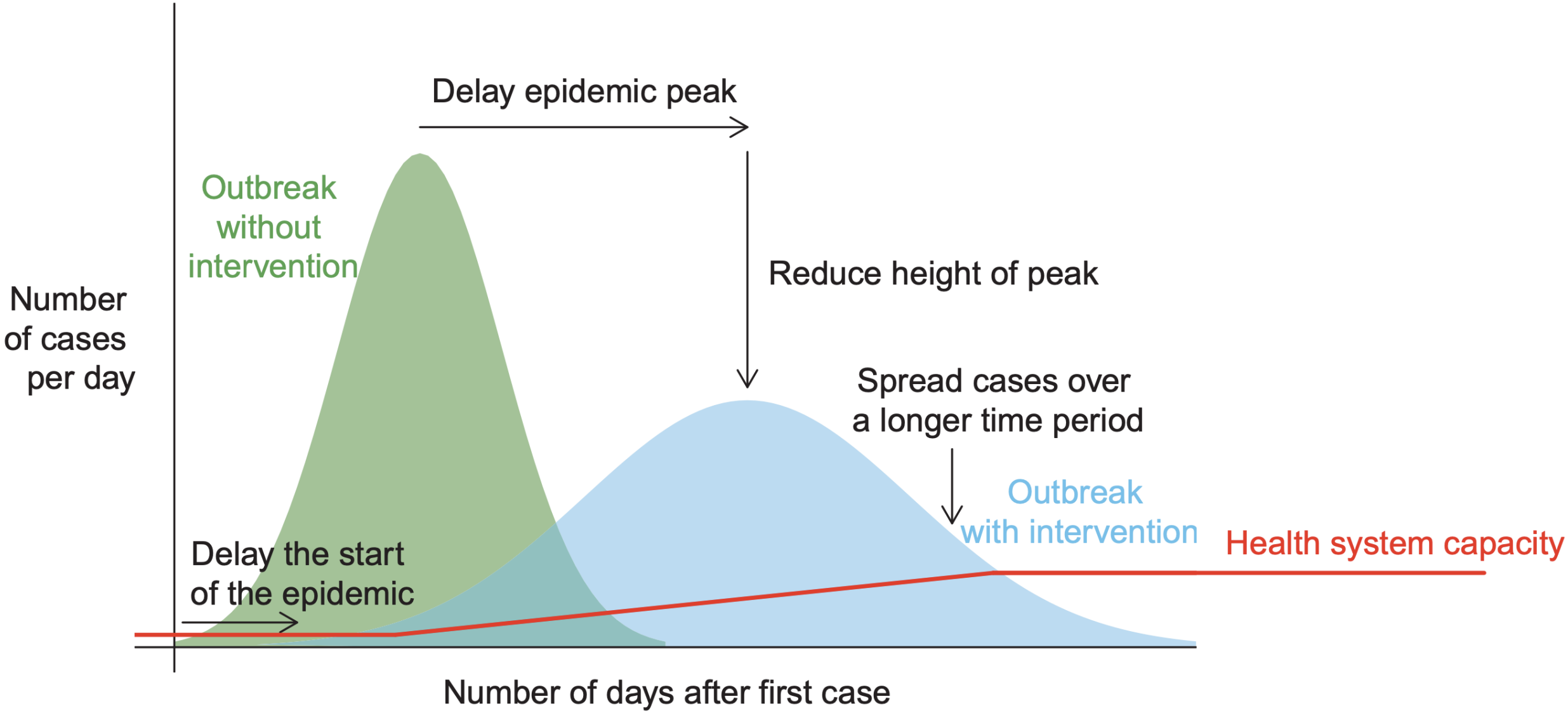


Ryu S, et al. JAMA Netw Open. 2022



Choi YS, et al. JKMS. 2024



Ryu S, et al. Cold Spring Harb Perspect Med. 2020

Summary +

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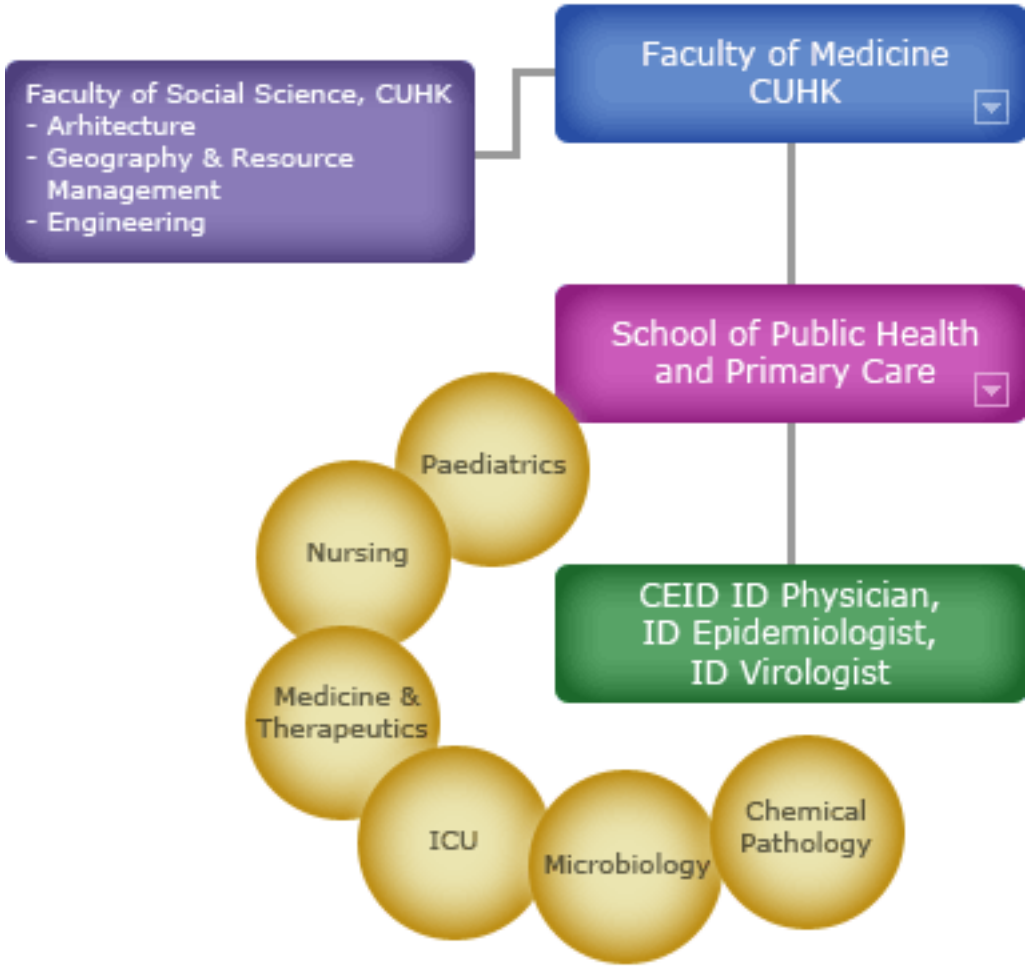
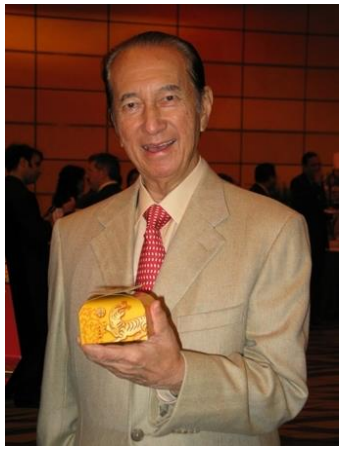
Li Ka Shing
(1928 – 1990)

지역사회 기반 감염병연구

https://sph.hku.hk/





Stanley Ho Hung-sun
(1921 –2020)

CEID
Community Research
CUHK

지역사회 기반 감염병연구

https://www.cuhk.edu.hk/med/ceid/

Lee Kun-hee
(1942 –2020)

Q&A

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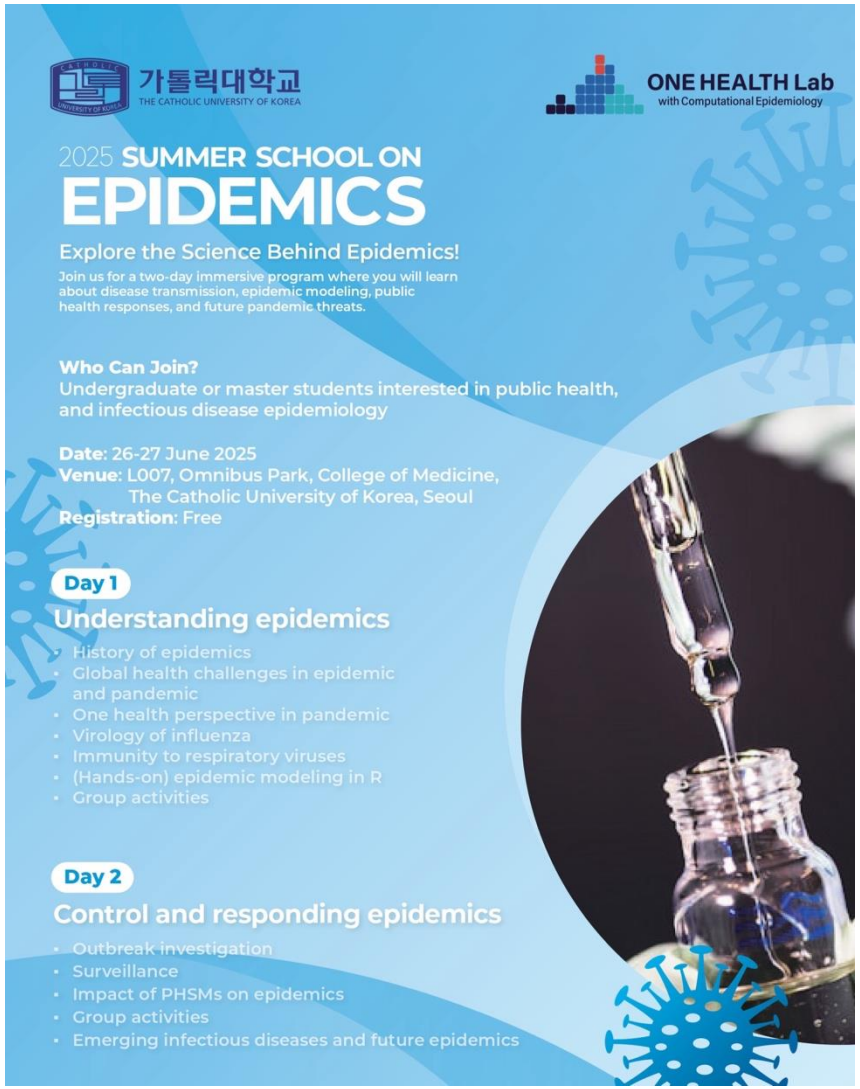
ONE HEALTH Lab
with Computational Epidemiology



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