Full title: Work-related Covid-19 transmission

Short title: Work-related Covid-19

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Manuscript word count: 286 (the abstract); 2,773 (the full article).

Abstract

Importance: Our study helps fill the knowledge gap related to work-related transmission in the emerging coronaviral pandemic.

Objective: To demonstrate high-risk occupations for early coronavirus disease 2019 (Covid-19) local transmission.

Methods: In this observational study, we extracted confirmed Covid-19 cases from governmental investigation reports in Hong Kong, Japan, Singapore, Taiwan, Thailand, and Vietnam. We followed each country/area for 40 days after its first locally transmitted case, and excluded all imported cases. We defined a possible work-related case as a worker with evidence of close contact with another confirmed case due to work, or an unknown contact history but likely to be infected in the working environment (e.g. an airport taxi driver). We calculated the case number for each occupation, and illustrated the temporal distribution of all possible work-related cases and healthcare worker (HCW) cases. The temporal distribution was further defined as early outbreak (the earliest 10 days of the following period) and late outbreak (11^{th} to 40^{th} days of the following period).

Results: We identified 103 possible work-related cases (14.9%) among a total of 690 local transmissions. The five occupation groups with the most cases were healthcare workers (HCWs) (22%), drivers and transport workers (18%), services and sales workers (18%), cleaning and domestic workers (9%) and public safety workers (7%). Possible work-related transmission played a substantial role in early outbreak (47.7% of early cases). Occupations at risk varied from early outbreak (predominantly services and sales workers, drivers, construction laborers, and religious professionals) to

late outbreak (predominantly HCWs, drivers, cleaning and domestic workers, police officers, and religious professionals).

Conclusions: Work-related transmission is considerable in early Covid-19 outbreaks, and the elevated risk of infection was not limited to HCW. Implementing preventive/surveillance strategies for high-risk working populations is warranted.

Introduction

Coronavirus disease 2019 (Covid-19) was declared by the World Health Organization (WHO) as a pandemic on March 11, 2020 and its local transmission has been reported in many countries [1]. The transmission pathways and the related risk factors are of vital interest in efforts to control the outbreak [2-4].

Work-related transmission is a crucial contributor to infectious disease outbreaks. The characteristics of SARS-CoV-2 virus and its transmission patterns could lead to high transmission rates among workers. For example, cases of Covid-19 largely present with mild or no symptoms [5]. Also, some studies have found similar transmissibility from asymptomatic and symptomatic patients [6-8]. These characteristics could lead to a higher probability of work-related transmission as people with mild symptoms could continue to work, travel or otherwise conduct business and spread the disease to others during work or commuting. Furthermore, the infected workers can subsequently transmit the virus to other people in their households and communities. Therefore, it is contingent to better understand the epidemiology of work-related transmission of Covid-19 to implement evidence-based prevention and protection strategies in workplaces.

Most of the studies to date focus on occupational exposure among healthcare workers (HCWs). Work-related transmission among HCWs constituted a large proportion in previous coronavirus outbreaks. HCWs comprised 37-63% of suspected severe acute respiratory syndrome (SARS) cases in highly affected

Asian countries, and around 43.5% of Middle East respiratory syndrome (MERS) cases [9-11]. There was high prevalence of infection among HCWs despite the introduction of precautions against nosocomial transmission [12,13].

In contrast, there is limited discussion on the work-related risks among workers such as taxi drivers, tour guides, cleaners and janitors, and civil servants, who have frequent contact with the public in their daily routines or have workplaces with higher risks of virus exposure [14].

In this study, we aimed to identify the occupations at higher risk of Covid-19 transmission, and to explore the temporal distribution of work-related cases among local transmission.

Methods

Study population selection

We extracted and included all locally transmitted Covid-19 confirmed cases from the publicized government investigation reports from six Asian countries/areas, including Hong Kong, Japan, Singapore, Taiwan, Thailand, and Vietnam. These countries/areas were selected since they shared some common temporo-spatial characteristics. First, they are proximal to Mainland China, where the first outbreak of Covid-19 was reported. Second, the first cases of these countries/areas were imported cases from Mainland China in mid-January. Third, the first locally transmitted cases in these countries/areas were identified around late January to early February. We followed each

country/area for forty days since the report of the first locally transmitted case and excluded the imported cases. The study population selection process is presented in Fig. 1.

Categorization of work-related cases

Each case report was reviewed by two occupational physicians and categorized by the work-relatedness. Subsequently, the possible work-related cases were grouped into two categories based on whether the transmission source was known:

1. *Category 1: had clear close contact with a confirmed case due to work*, such as a registered nurse having a history of directly caring for a patient who is an index confirmed case; and
2. *Category 2: unknown transmission source; no apparent contact history but likely to be infected in the working environment*, such as an airport taxi driver without clear contact history to any confirmed case.

The cases with occupations and contact histories were coded according to the International Standard Classification of Occupations, 2008 (ISCO-08) [15]. We defined health professionals, medical doctors, and nursing professionals as healthcare workers (HCWs) regarding the high risk of infection due to the work. We further grouped the occupations into drivers and transport workers, services and sales workers, cleaning and domestic workers, public safety workers, religious workers, construction workers, and other groups according to the jobs similarity.

All differences between the occupation physicians were reviewed by the third

investigator, who is a physician-epidemiologist to reach a consensus.

Statistical analysis

Descriptive analysis was performed to compare the trends of daily reported cases in the locally transmitted cases, work-related cases, and HCW groups.

For each country/area, we calculated the intervals between the first reported locally transmitted case and the first reported work-related case, as well as the interval between the first reported locally transmitted case and the first reported HCW case. We also summarized the number of cases for each occupation across country/area and stratified the cases into early and late transmission periods. We defined early transmission period as the first 10 days from when the first locally transmitted case was reported, and late transmission period as the 11th to 40th day of the study period. We enlisted the most common occupations in each period and compared the distribution of occupations in order to examine the temporal difference. We performed Chi-squared tests or Fisher exact tests to compare the proportions of work-related cases and HCW cases among all local transmissions between early and late transmission periods.

We also conducted sensitivity analysis comparing the results between the six countries/areas and five countries/areas excluding Japan. We excluded Japan due to its different case reporting system from other countries/areas. Unlike other countries/areas that have central reporting systems, Japan had cases reported from each prefecture separately. Differences in reporting

mechanisms and case information across prefectures could potentially bias the results. The descriptive analysis was performed by R software (version 3.6.2). The figures were plotted by Microsoft® **EXCEL**™.

Results

We identified 2,002 officially confirmed Covid-19 cases within the designated 40-day interval among the six countries/areas. We excluded 1,312 imported cases and included 690 locally transmitted cases in the final analysis. The cases included in this study were reported between January 23, 2020 and March 14, 2020 (Supplement table).

103 possible work-related cases were included for analysis (including 37 cases from Category 1 and 66 from Category 2), accounting for 15% of local transmissions. Among the possible work-related cases, 22% were HCW. In addition to HCWs, we identified other occupations that were at higher risk of work-related transmission. The high-risk occupations included car, taxi and van drivers (N=15), shop salesperson (N=7), domestic housekeepers (N=7), religious professionals (N=6), construction laborers (N=5), tour guides (N=5), and so on. In terms of occupation grouping, the groups with the most cases were HCWs, drivers and transport workers, services and sales workers, cleaning and domestic workers, and public safety workers. (Table 1)

Table 1. Possible work-related Covid-19 cases categorized by occupation.

Occupation group	N (%)	Occupation (ISCO-08)	N (%)
Health professional (Healthcare workers)	23 (22)	Other health professionals	10 (10)
		Nursing professionals	10 (10)
		Medical doctors	3 (3)
Drivers and Transport workers	19 (18)	Car, taxi and van drivers	15 (15)
		Locomotive engine drivers and related workers	2 (2)
		Bus and tram drivers	2 (2)
Services and sales workers	19 (18)	Shop salespersons	7 (7)
		Travel attendants, conductors and guides	5 (5)
		Receptionists	3 (3)
		Waiter or bartenders	2 (2)
		Cooks	1 (1)
		Personal care workers in health services	1 (1)
Cleaning and domestic workers	9 (9)	Domestic housekeepers	7 (7)
		Domestic cleaners and helpers	2 (2)
Public safety workers	7 (7)	Police officers	3 (3)
		Fire fighter	2 (2)
		Security guards	2 (2)
Religious workers	6 (6)	Religious professionals	6 (6)
Construction workers	5 (5)	Construction laborers	5 (5)
Other groups	15 (15)	Unspecified*	15 (15)
Summary			103 (100)

ISCO-08: International Standard Classification of Occupations, 2008

* Mainly from workplace clusters without detailed occupational description of each case

There were 31 incident confirmed cases during early transmission period, while there were 72 incident cases occurring in late transmission period. The most common occupations during early transmission were shop salesperson (N=6), car, taxi and van drivers (N=5), construction laborer (N=4), religious professionals (N=3), tour guides (N=3), and receptionist (N=3). Meanwhile, most common occupations during late transmission were health professionals (N=23), car, taxi and van drivers (N=10), domestic housekeepers (N=6), police officers (N=3), and religious professionals (N=3) (Table 2).

Table 2. Occupation distribution of possible work-related Covid-19 cases in early and late transmission.

Occupation (ISCO-08)	Early transmission period, N=31	Late transmission period, N=72	*P*-value[a]
	Count, N (%)	*Count, N (%)*	
Health professionals	0 (0)	23 (32)	<0.001
Shop salespersons	6 (19)	1 (1)	0.003
Car, taxi and van drivers	5 (16)	10 (14)	0.767
Domestic housekeepers	1 (3)	6 (8)	0.672
Construction laborers	4 (13)	1 (1)	0.028
Religious professionals	3 (10)	3 (4)	0.362
Police officers	0 (0)	3 (4)	0.552
Travel attendants, conductors and guides	3 (10)	2 (3)	0.159
Receptionists	3 (10)	0 (0)	0.025

ISCO-08: International Standard Classification of Occupations, 2008

[a]*P*-values were calculated with Fisher exact test.

Notably, there were different composition of high-risk occupations across transmission periods. Car, taxi and van driver and religious professionals were the most common occupations in both early and late transmission periods. Retail salespersons and tour guides were predominant in the early transmission period, while HCWs, domestic housekeepers, and police officers were the leading high-risk occupations in the late transmission period. Furthermore, while the proportion of work-related transmission decreased for shop salespersons, construction laborers and receptionists, there was a discernable increase in proportion of HCWs in the late period (*P* <0.001, Table 2)

Fig. *2A* illustrates new daily confirmed local transmission, possible work-related transmission, and HCW cases over time in the six countries/areas. While the number of daily confirmed local transmission increased, the number of work-related cases reported in each day remained relatively steady throughout the follow-up period. We found 48% of locally transmitted cases in the early transmission period were due to possible work-related transmission, compared to 11% in the late transmission period (Chi-squared statistic = 61.84, *P* <0.0001).

In further sensitivity analysis excluding Japan because of its different case reporting system, the daily confirmed local transmissions became relatively constant (Fig. *2B*). After excluding Japan, possible work-related cases comprised 44% of the locally transmitted cases in the early period, while only 18% in the late period (Chi-squared statistic=18.8, *P*-value<0.0001).

HCW comprised 22% of the possible work-related cases. Moreover, we found the occurrence of Covid-19 transmission among the HCW was relatively late compared to the non-HCW population. Fig. 2(A) and Fig. 2(B) showed a two-week lag of the first HCW case after the local Covid-19 outbreak (median lag: 15 days, IQR 13-20 days). The median time lag from the report of the first possible work-related case to the first HCW case was 13.5 days (IQR: 12.3-14.5 days) among the study population. Furthermore, nearly all the HCWs (95%) had clear and traceable contact history with a confirmed case (Category 1); while only 43.2% of the non-HCW cases could trace back the infection source (*P*-value<0.001).

In further sensitivity analysis excluding Japan, non-HCW accounted for 93% possible work-related cases. The median lag of HCW transmissions after the local Covid-19 outbreak was 14 days (range: 10-32 days), and the median lag from the first possible work-related case to the first HCW case was 13 days (range: 10-14 days).

Discussion

In this study, we identified several high-risk occupations for Covid-19 infection that are rarely discussed [16]. These high-risk occupations comprised almost a half of local transmission during the early period of outbreak. In terms of the occupational risks of Covid-19 infection among the HCW, we found a median of two-week lag of HCW case after local transmission outbreaks. Moreover,

non-HCW comprised the majority of the possible work-related cases and most of the cases were not able to trace back the infection sources.

Our results indicate the importance of work-related transmission in the local Covid-19 outbreak. One novel finding of this study is that the early transmissions were highly related to some occupations beyond healthcare settings, including taxi driver, salesperson, tour guide, and housekeeper and cleaner. Taxi drivers, salespersons and tour guides are at higher risk because of frequent contact with travelers. In fact, one of the earliest locally transmitted cases in Taiwan was a taxi driver who took a passenger returning from mainland China. This case led to a family cluster of Covid-19 with four more locally transmitted cases [17]. Another example was an infected worker involved in a reported cluster leading to three more local cases within a household in Singapore [4]. On the other hand, housekeepers and cleaners are more likely to be exposed to contaminated surfaces than direct contact with Covid-19 patients [18].

In this study, the proportion of HCWs among locally transmitted cases was smaller than non-HCWs in the included countries/areas, 3% versus 12% respectively. The first cases HCWs appeared much later than the first non-HCW cases in all the study countries. The lower rate of HCW and the occurrence time lags among HCWs likely reflects improved triage, screening and isolation of Covid-19 patients in the healthcare setting, as well as better personal protective equipment (PPE) and hygiene among HCWs once knowledge and experience with outbreaks increase [19-21]. Health

professionals are more equipped with infection control knowledge and concepts, are more aware of self-hygiene and more informed regarding new outbreaks compared to non-HCWs [22].

This study raises the importance of protecting high-risk non-HCWs for several reasons. First, the work-related risks of respiratory infection, including Covid-19 infection, among the occupations are often neglected, and the workers are less likely to have PPEs or proper infection control in their workplaces. Second, it is much challenging to trace back the infection source of the non-HCW cases compared to the HCW cases, indicating the urging need of precautions for the high-risk population. Third, many of these occupations are impossible to work remotely and the workers may not benefit from the measures of worker-protection, such as government-imposed shutdown or work-from-home order. Fourth, many of the high-risk workers are in relatively lower socioeconomic status (SES), which is a risk factor of having Covid-19 infection and worse disease outcomes [23]. People from the lower ends of the society are more susceptible to infectious outbreaks due to poorer living and working conditions [24,25]. They are more likely to have chronic health conditions which could lead to more severe consequences after being infected [26]. Protecting the high-risk workers could provide an opportunity to prevent the spread of the disease and to mitigate the deepening of health disparities.

The substantial contribution of non-HCW to the Covid-19 locally transmitted cases emphasizes the importance of implementing effective infection control

in the non-healthcare workplaces to protect the workers in this pandemic [27]. Early delivery of infection control knowledge and health concepts to workers, as well as providing adequate PPE are crucial in protecting workers and the whole society.

Our study has some strengths. First, the data were extracted from the investigation reports published by the government of six countries/areas, which should be valid [28,29], and pooling of multi-county sources prevented the results from being skewed by single-country experience. Regarding the different case reporting system in Japan, we did further sensitivity analysis using the data from other five countries/areas and found similar temporal distribution patterns, which strengthened our conclusions. Second, every eligible case was reviewed by two occupational physicians and a physician epidemiologist with agreements on work-relatedness after thorough inspection of case reports. Moreover, we followed each country/area for 40 days, which allowed us to obtain comparable data for pooled analysis and illustrate trends of transmission in early stages of Covid-19 outbreak.

Nonetheless, there are limitations of this study. First, there were discrepancies in reporting and investigation across the countries/areas. Cases without reported occupational history could potentially lead to underestimation in the analysis. Second, the report date of a case could be different to the date of getting infected and having symptoms. However, the information bias should be non-differential as the official reports were not different between whether a case was work-related or not. Third, the criteria of deciding whom

to be tested varied between countries/areas, especially during early outbreaks when testing capacities were limited. Therefore, high risk populations, including high risk occupations, might tend to be tested. However, we believe the bias was non-differential, as health authorities should not decide whom to be tested differently based on whether the suspected case was a worker or not. In fact, most of the early cases were tested because of the symptoms or obvious contact histories, instead of occupations [30]. Finally, we excluded all imported cases in the analysis. Travelers, however, could actually be business travelers, or other workers in travel-related industries, such as flight attendants, tour managers, and so on. Although workers of these occupations do have frequent contact with the public and have higher probability to be infected, our results could not demonstrate their risks and thus further studies on business travelers are warranted.

In conclusion, our study demonstrates that occupational infections are considerable in early Covid-19 local transmission. Second, several specific professional groups were at higher risk during early domestic outbreaks. We urge authorities to implement preventive strategies for each of these high-risk working populations.

References:

1. Ebrahim SH, Ahmed QA, Gozzer E, Schlagenhauf P, Memish ZA. Covid-19 and community mitigation strategies in a pandemic. BMJ. 2020;368:m1066.

2. Burke RM, Midgley CM, Dratch A, Fenstersheib M, Haupt T, Holshue M, et al. Active Monitoring of Persons Exposed to Patients with Confirmed COVID-19 - United States, January-February 2020. MMWR Morb Mortal Wkly Rep. 2020;69(9):245-6.

3. Ghinai I, McPherson TD, Hunter JC, Kirking HL, Christiansen D, Joshi K, et al. First known person-to-person transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in the USA. Lancet. 2020.

4. Pung R, Chiew CJ, Young BE, Chin S, Chen MIC, Clapham HE, et al. Investigation of three clusters of COVID-19 in Singapore: implications for surveillance and response measures. The Lancet. 2020.

5. Guan WJ, Ni ZY, Hu Y, Liang WH, Ou CQ, He JX, et al. Clinical Characteristics of Coronavirus Disease 2019 in China. N Engl J Med. 2020.

6. Rothe C, Schunk M, Sothmann P, Bretzel G, Froeschl G, Wallrauch C, et al. Transmission of 2019-nCoV Infection from an Asymptomatic Contact in Germany. N Engl J Med. 2020;382(10):970-1.

7. Bai Y, Yao L, Wei T, Tian F, Jin DY, Chen L, et al. Presumed Asymptomatic Carrier Transmission of COVID-19. JAMA. 2020.

8. Zou L, Ruan F, Huang M, Liang L, Huang H, Hong Z, et al. SARS-CoV-2 Viral Load in Upper Respiratory Specimens of Infected Patients. N Engl J Med. 2020;382(12):1177-9.

9. Chowell G, Abdirizak F, Lee S, Lee J, Jung E, Nishiura H, et al. Transmission characteristics of MERS and SARS in the healthcare setting: a comparative study. BMC Med. 2015;13:210.

10. Twu SJ, Chen TJ, Chen CJ, Olsen SJ, Lee LT, Fisk T, et al. Control measures for severe acute respiratory syndrome (SARS) in Taiwan. Emerg Infect Dis.

2003;9(6):718-20.

11. Peck AJ, Newbern EC, Feikin DR, Issakbaeva ET, Park BJ, Fehr J, et al. Lack of SARS transmission and U.S. SARS case-patient. Emerg Infect Dis. 2004;10(2):217-24.

12. Lipsitch M, Cohen T, Cooper B, Robins JM, Ma S, James L, et al. Transmission dynamics and control of severe acute respiratory syndrome. Science. 2003;300(5627):1966-70.

13. Seto WH, Tsang D, Yung RW, Ching TY, Ng TK, Ho M, et al. Effectiveness of precautions against droplets and contact in prevention of nosocomial transmission of severe acute respiratory syndrome (SARS). Lancet. 2003;361(9368):1519-20.

14. Quinn SC, Kumar S. Health inequalities and infectious disease epidemics: a challenge for global health security. Biosecur Bioterror. 2014;12(5):263-73.

15. International Labour Organization. International Standard Classification of Occupations 2008 (ISCO-08): Structure, group definitions and correspondence tables: The Organization; 2012 May 10.

16. Occupational Safety and Health Administration [Internet]. Safety and Health Topics / COVID-19; c2020 [cited 2020 March 19]. [Available from: https://www.osha.gov/SLTC/covid-19/controlprevention.html]

17. Taiwan Centers for Disease Control [Internet]; c2020 [cited 2020 March 19]. [Available from: https://www.cdc.gov.tw/Bulletin]

18. van Doremalen N, Bushmaker T, Morris DH, Holbrook MG, Gamble A, Williamson BN, et al. Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1. New England Journal of Medicine. 2020.

19. Wong TW, Tam WW. Handwashing practice and the use of personal protective equipment among medical students after the SARS epidemic in Hong Kong. Am J Infect Control. 2005;33(10):580-6.

20. Magill SS, O'Leary E, Janelle SJ, Thompson DL, Dumyati G, Nadle J, et al. Changes in Prevalence of Health Care-Associated Infections in U.S. Hospitals. N

Engl J Med. 2018;379(18):1732-44.

21. Vaughn VM, Saint S, Greene MT, Ratz D, Fowler KE, Patel PK, et al. Trends in Health Care-Associated Infection Prevention Practices in US Veterans Affairs Hospitals From 2005 to 2017. JAMA Netw Open. 2020;3(2):e1920464.

22. Parmeggiani C, Abbate R, Marinelli P, Angelillo IF. Healthcare workers and health care-associated infections: knowledge, attitudes, and behavior in emergency departments in Italy. BMC Infect Dis. 2010;10:35.

23. Pini A, Stenbeck M, Galanis I, Kallberg H, Danis K, Tegnell A, et al. Socioeconomic disparities associated with 29 common infectious diseases in Sweden, 2005-14: an individually matched case-control study. Lancet Infect Dis. 2019;19(2):165-76.

24. Wheeler BW, Ben-Shlomo Y. Environmental equity, air quality, socioeconomic status, and respiratory health: a linkage analysis of routine data from the Health Survey for England. J Epidemiol Community Health. 2005;59(11):948-54.

25. Stanbury M, Rosenman KD. Occupational health disparities: a state public health-based approach. Am J Ind Med. 2014;57(5):596-604.

26. Elo IT. Social Class Differentials in Health and Mortality: Patterns and Explanations in Comparative Perspective. Annual Review of Sociology. 2009;35(1):553-72.

27. Fadel M, Salomon J, Descatha A. Coronavirus outbreak: the role of companies in preparedness and responses. Lancet Public Health. 2020.

28. Jung SM, Akhmetzhanov AR, Hayashi K, Linton NM, Yang Y, Yuan B, et al. Real-Time Estimation of the Risk of Death from Novel Coronavirus (COVID-19) Infection: Inference Using Exported Cases. J Clin Med. 2020;9(2).

29. Wu Z, McGoogan JM. Characteristics of and Important Lessons From the Coronavirus Disease 2019 (COVID-19) Outbreak in China: Summary of a Report of 72314 Cases From the Chinese Center for Disease Control and Prevention. JAMA. 2020.

30. Pongpirul WA, Pongpirul K, Ratnarathon AC, Prasithsirikul W. Journey of a Thai Taxi Driver and Novel Coronavirus. N Engl J Med. 2020;382(11):1067-8.

Figure 1. Study population selection process

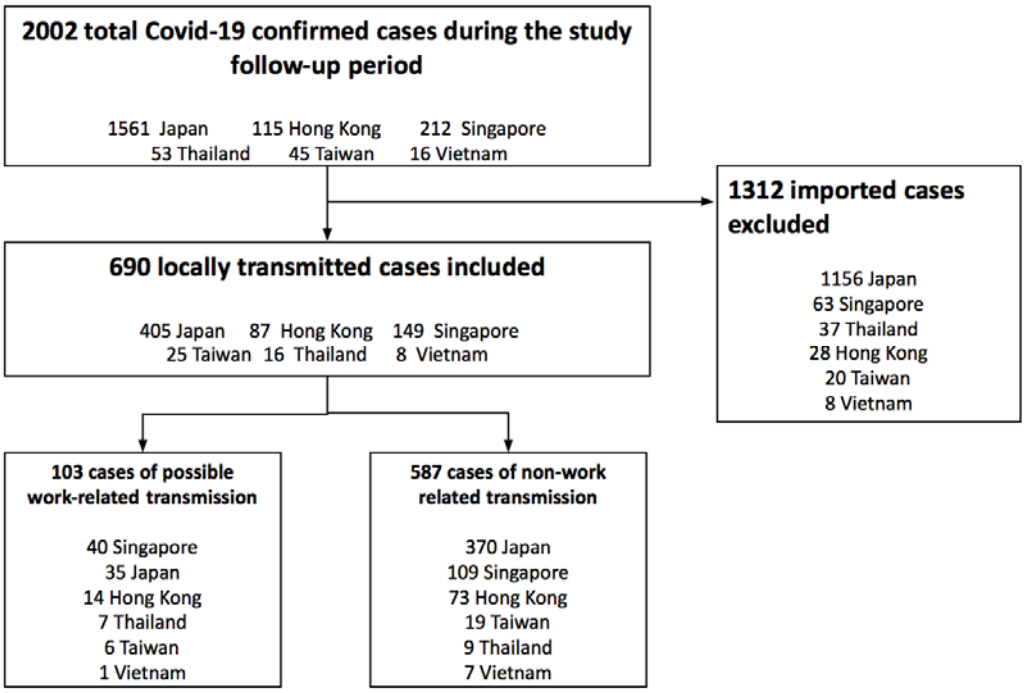
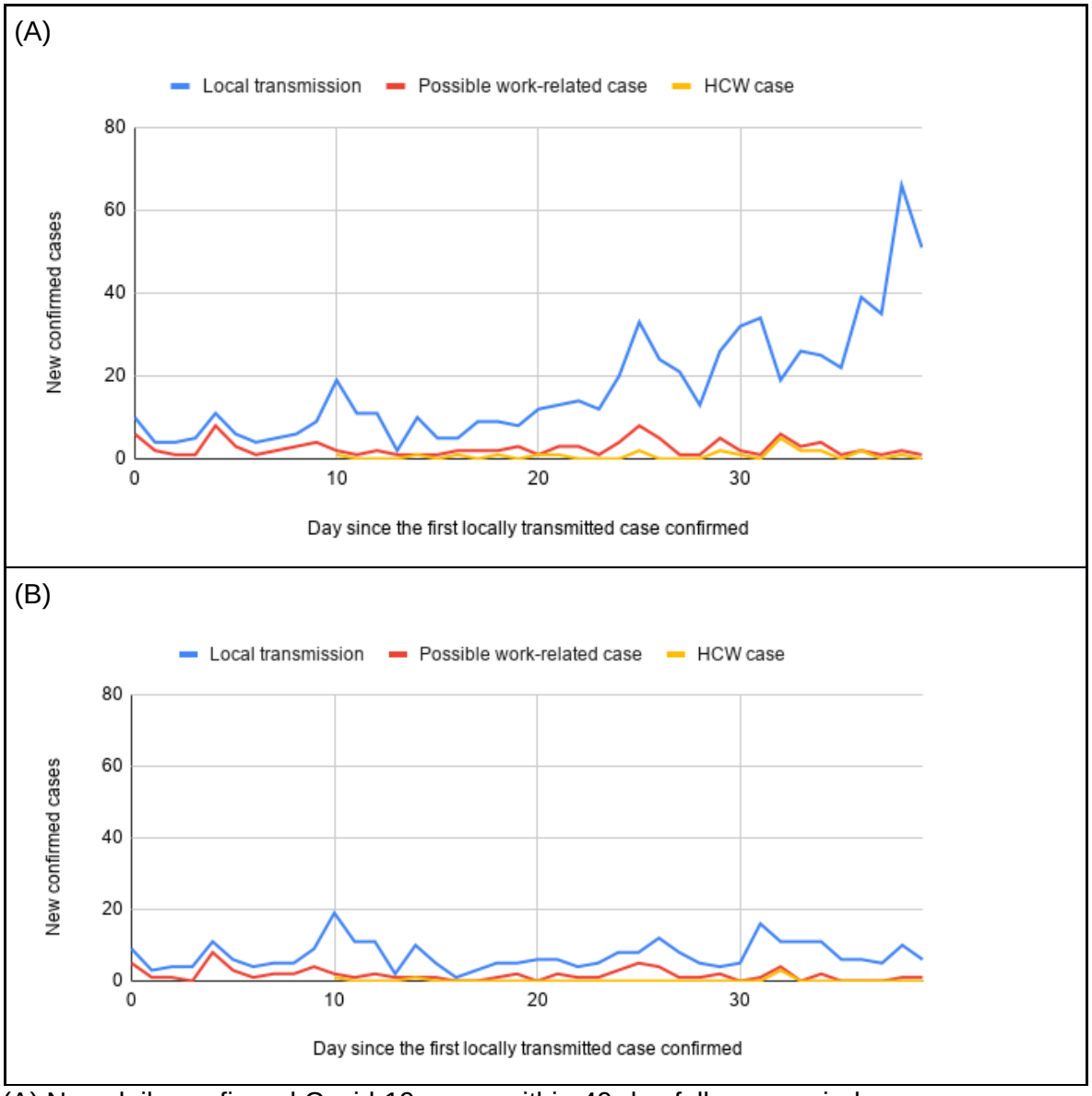


Figure 2. New daily confirmed Covid-19 cases within 40-day followup periods across countries/areas.



(A) New daily confirmed Covid-19 cases within 40-day followup periods among the six countries/areas. (B) New daily confirmed Covid-19 cases within 40-day followup periods among the five countries/areas excluding Japan.
HCW: Healthcare worker