

1 **Full title: Work-related Covid-19 transmission**

2 Short title: Work-related Covid-19

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24

## 1 **Abstract**

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

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

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

18 **Results:** We identified 103 possible work-related cases (14.9%) among a  
19 total of 690 local transmissions. The five occupation groups with the most  
20 cases were healthcare workers (HCWs) (22%), drivers and transport workers  
21 (18%), services and sales workers (18%), cleaning and domestic workers  
22 (9%) and public safety workers (7%). Possible work-related transmission  
23 played a substantial role in early outbreak (47.7% of early cases).  
24 Occupations at risk varied from early outbreak (predominantly services and  
25 sales workers, drivers, construction laborers, and religious professionals) to

- 1 late outbreak (predominantly HCWs, drivers, cleaning and domestic workers,
- 2 police officers, and religious professionals).
- 3 **Conclusions:** Work-related transmission is considerable in early Covid-19
- 4 outbreaks, and the elevated risk of infection was not limited to HCW.
- 5 Implementing preventive/surveillance strategies for high-risk working
- 6 populations is warranted.
- 7

## 1 Introduction

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

7

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

21

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

1 Asian countries, and around 43.5% of Middle East respiratory syndrome  
2 (MERS) cases [9-11]. There was high prevalence of infection among HCWs  
3 despite the introduction of precautions against nosocomial transmission  
4 [12,13].

5

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

10

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

14

## 15 **Methods**

### 16 Study population selection

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

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

4

#### 5 Categorization of work-related cases

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

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

16

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

25 All differences between the occupation physicians were reviewed by the third

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

2

### 3 Statistical analysis

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

6

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

20

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

1 mechanisms and case information across prefectures could potentially bias  
2 the results. The descriptive analysis was performed by R software (version  
3 3.6.2). The figures were plotted by Microsoft® EXCEL™.

4  
5

## 6 **Results**

7 We identified 2,002 officially confirmed Covid-19 cases within the designated  
8 40-day interval among the six countries/areas. We excluded 1,312 imported  
9 cases and included 690 locally transmitted cases in the final analysis. The  
10 cases included in this study were reported between January 23, 2020 and  
11 March 14, 2020 (Supplement table).

12

13 103 possible work-related cases were included for analysis (including 37  
14 cases from Category 1 and 66 from Category 2), accounting for 15% of local  
15 transmissions. Among the possible work-related cases, 22% were HCW. In  
16 addition to HCWs, we identified other occupations that were at higher risk of  
17 work-related transmission. The high-risk occupations included car, taxi and  
18 van drivers (N=15), shop salesperson (N=7), domestic housekeepers (N=7),  
19 religious professionals (N=6), construction laborers (N=5), tour guides (N=5),  
20 and so on. In terms of occupation grouping, the groups with the most cases  
21 were HCWs, drivers and transport workers, services and sales workers,  
22 cleaning and domestic workers, and public safety workers. (Table 1)

23



1 **Table 1. Possible work-related Covid-19 cases categorized by**  
 2 **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)

3  
 4 ISCO-08: International Standard Classification of Occupations, 2008  
 5 \* Mainly from workplace clusters without detailed occupational description of  
 6 each case

7

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

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

Occupation (ISCO-08)	Early transmission period, N=31	Late transmission period, N=72	<i>P</i> -value <sup>a</sup>
	<i>Count, N (%)</i>	<i>Count, N (%)</i>	
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

11  
 12 ISCO-08: International Standard Classification of Occupations, 2008

13 <sup>a</sup>*P*-values were calculated with Fisher exact test.

14

15

1 Notably, there were different composition of high-risk occupations across  
2 transmission periods. Car, taxi and van driver and religious professionals  
3 were the most common occupations in both early and late transmission  
4 periods. Retail salespersons and tour guides were predominant in the early  
5 transmission period, while HCWs, domestic housekeepers, and police officers  
6 were the leading high-risk occupations in the late transmission period.  
7 Furthermore, while the proportion of work-related transmission decreased for  
8 shop salespersons, construction laborers and receptionists, there was a  
9 discernable increase in proportion of HCWs in the late period ( $P < 0.001$ ,  
10 Table 2)  
11  
12 Fig. 2A illustrates new daily confirmed local transmission, possible work-  
13 related transmission, and HCW cases over time in the six countries/areas.  
14 While the number of daily confirmed local transmission increased, the number  
15 of work-related cases reported in each day remained relatively steady  
16 throughout the follow-up period. We found 48% of locally transmitted cases in  
17 the early transmission period were due to possible work-related transmission,  
18 compared to 11% in the late transmission period (Chi-squared statistic =  
19 61.84,  $P < 0.0001$ ).  
20  
21 In further sensitivity analysis excluding Japan because of its different case  
22 reporting system, the daily confirmed local transmissions became relatively  
23 constant (Fig. 2B). After excluding Japan, possible work-related cases  
24 comprised 44% of the locally transmitted cases in the early period, while only  
25 18% in the late period (Chi-squared statistic=18.8,  $P$ -value<0.0001).

1

2 HCW comprised 22% of the possible work-related cases. Moreover, we found  
3 the occurrence of Covid-19 transmission among the HCW was relatively late  
4 compared to the non-HCW population. Fig. 2(A) and Fig. 2(B) showed a two-  
5 week lag of the first HCW case after the local Covid-19 outbreak (median lag:  
6 15 days, IQR 13-20 days). The median time lag from the report of the first  
7 possible work-related case to the first HCW case was 13.5 days (IQR: 12.3-  
8 14.5 days) among the study population. Furthermore, nearly all the HCWs  
9 (95%) had clear and traceable contact history with a confirmed case  
10 (Category 1); while only 43.2% of the non-HCW cases could trace back the  
11 infection source ( $P$ -value<0.001).

12

13

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

19

## 20 **Discussion**

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

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

3

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

17

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

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

4

5 This study raises the importance of protecting high-risk non-HCWs for several  
6 reasons. First, the work-related risks of respiratory infection, including Covid-  
7 19 infection, among the occupations are often neglected, and the workers are  
8 less likely to have PPEs or proper infection control in their workplaces.

9 Second, it is much challenging to trace back the infection source of the non-  
10 HCW cases compared to the HCW cases, indicating the urging need of  
11 precautions for the high-risk population. Third, many of these occupations are  
12 impossible to work remotely and the workers may not benefit from the  
13 measures of worker-protection, such as government-imposed shutdown or  
14 work-from-home order. Fourth, many of the high-risk workers are in relatively  
15 lower socioeconomic status (SES), which is a risk factor of having Covid-19  
16 infection and worse disease outcomes [23]. People from the lower ends of the  
17 society are more susceptible to infectious outbreaks due to poorer living and  
18 working conditions [24,25]. They are more likely to have chronic health  
19 conditions which could lead to more severe consequences after being  
20 infected [26]. Protecting the high-risk workers could provide an opportunity to  
21 prevent the spread of the disease and to mitigate the deepening of health  
22 disparities.

23

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

1 in the non-healthcare workplaces to protect the workers in this pandemic [27].

2 Early delivery of infection control knowledge and health concepts to workers,

3 as well as providing adequate PPE are crucial in protecting workers and the

4 whole society.

5

6 Our study has some strengths. First, the data were extracted from the

7 investigation reports published by the government of six countries/areas,

8 which should be valid [28,29], and pooling of multi-county sources prevented

9 the results from being skewed by single-country experience. Regarding the

10 different case reporting system in Japan, we did further sensitivity analysis

11 using the data from other five countries/areas and found similar temporal

12 distribution patterns, which strengthened our conclusions. Second, every

13 eligible case was reviewed by two occupational physicians and a physician

14 epidemiologist with agreements on work-relatedness after thorough inspection

15 of case reports. Moreover, we followed each country/area for 40 days, which

16 allowed us to obtain comparable data for pooled analysis and illustrate trends

17 of transmission in early stages of Covid-19 outbreak.

18

19 Nonetheless, there are limitations of this study. First, there were

20 discrepancies in reporting and investigation across the countries/areas. Cases

21 without reported occupational history could potentially lead to underestimation

22 in the analysis. Second, the report date of a case could be different to the

23 date of getting infected and having symptoms. However, the information bias

24 should be non-differential as the official reports were not different between

25 whether a case was work-related or not. Third, the criteria of deciding whom

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

14

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

20



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Figure 1. Study population selection process

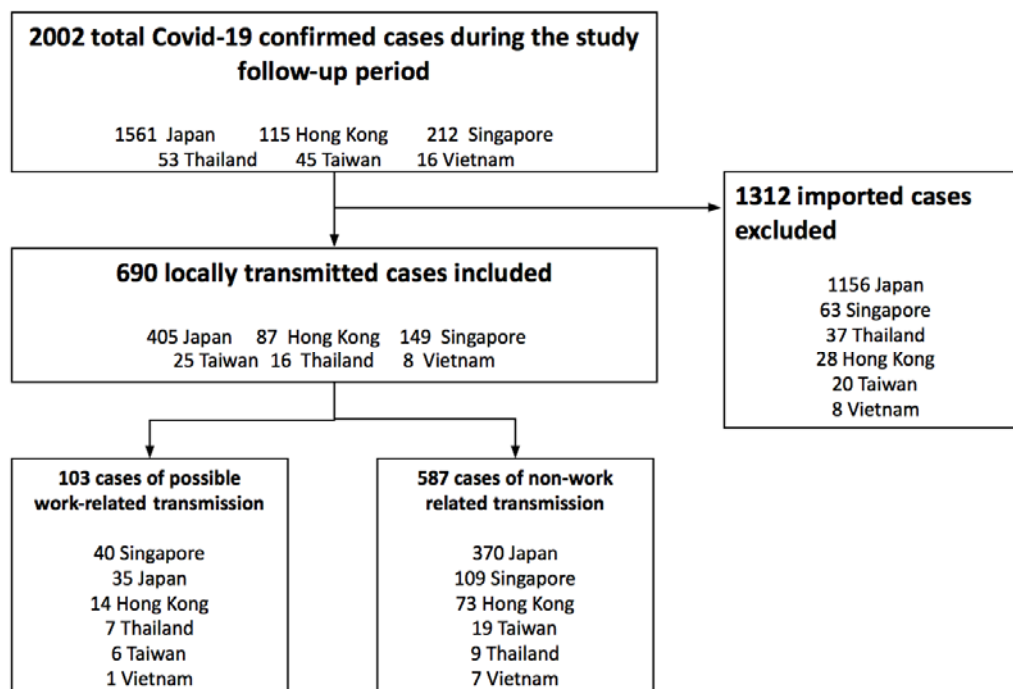
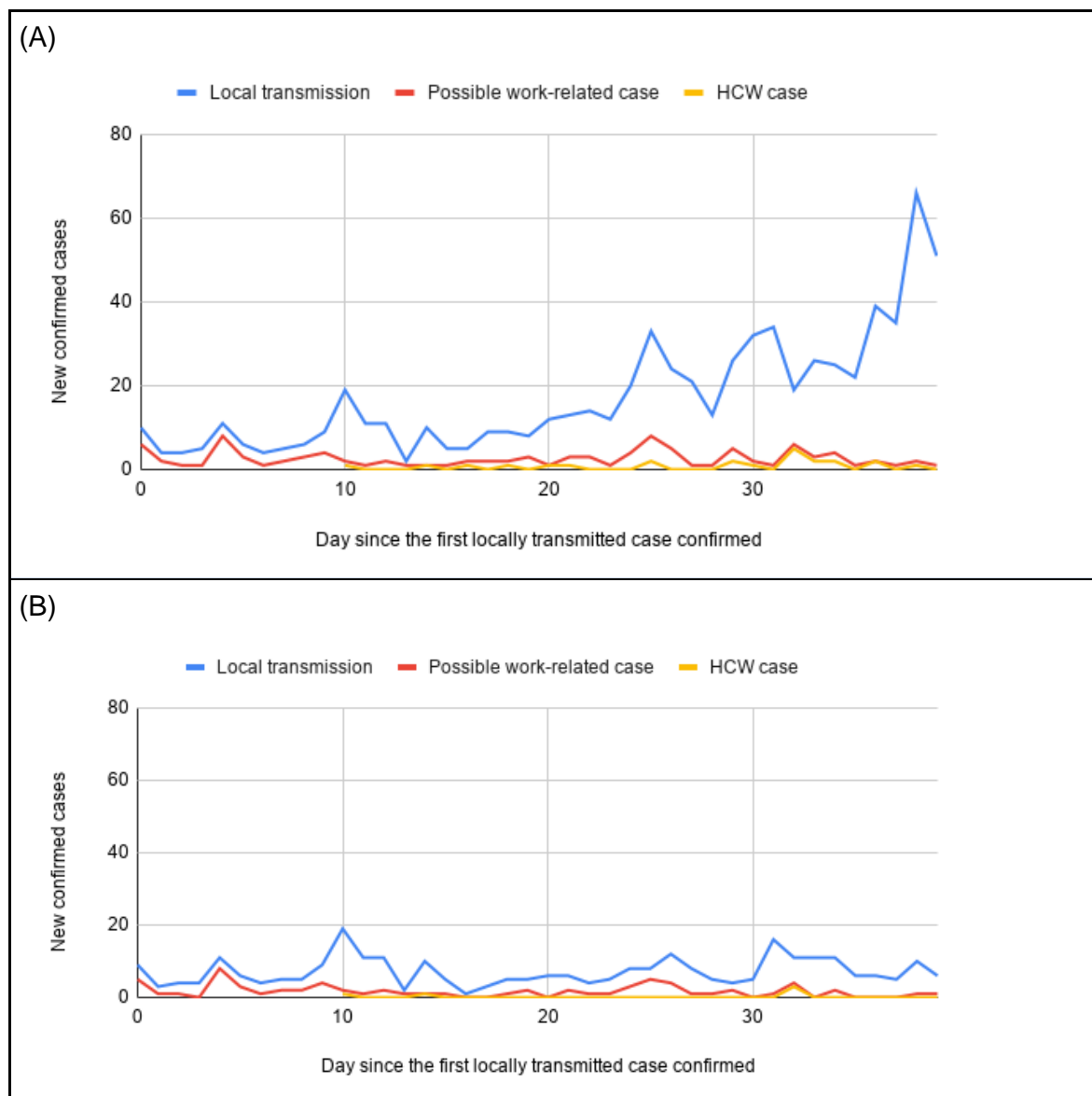


Figure 2. New daily confirmed Covid-19 cases within 40-day followup periods across countries/areas.



(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