Case-Control Study of Use of Personal Protective Measures and Risk for SARS Coronavirus 2 Infection, Thailand

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We evaluated effectiveness of personal protective measures against severe acute respiratory disease coronavirus 2 (SARS-CoV-2) infection. Our case-control study included 211 cases of coronavirus disease (COVID-19) and 839 controls in Thailand. Cases were defined as asymptomatic contacts of COVID-19 patients who later tested positive for SARS-CoV-2; controls were asymptomatic contacts who never tested positive. Wearing masks all the time during contact was independently associated with lower risk for SARS-CoV-2 infection compared with not wearing masks; wearing a mask sometimes during contact did not lower infection risk. We found the type of mask worn was not independently associated with infection and that contacts who always wore masks were more likely to practice social distancing. Maintaining ≥1 m distance from a person with COVID-19, having close contact for ≤15 minutes, and frequent handwashing were independently associated with lower risk for infection. Our findings support consistent wearing of masks, handwashing, and social distancing to protect against COVID-19.

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Evaluation of the effectiveness of mask-wearing to protect healthy persons in the general public from infection with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the causative agent of coronavirus disease (COVID-19), is urgently needed (*1*,*2*). On February 27, 2020, during the early stages of the COVID-19 outbreak, the World Health Organization (WHO) announced that wearing a mask of any type was not recommended for asymptomatic persons (*3*). The rationale at that time was to avoid unnecessary cost, procurement burden, and a false sense of security (*3*). Several systematic reviews found no conclusive evidence to support widespread use of masks in public settings to protect against respiratory infectious diseases, such as influenza and severe acute respiratory syndrome (SARS) (*4*–*6*). However, China, South Korea, Japan, Thailand, and other countries in Asia have recommended the use of face masks among the general public since early in the COVID-19 pandemic (*7*). Evidence suggests that persons with COVID-19 can have a presymptomatic period, during which they can be contagious and transmit SARS-CoV-2 to others before symptoms develop (*8*). These findings led to a change in recommendations from the US Centers for Disease Control and Prevention on April 4, 2020, that advised all persons wear a cloth face covering when in public (*9*). On April 6 and June 5, 2020, WHO updated its advice on the use of masks for the general public and encouraged countries that issue the recommendations to conduct research on this topic (*8*).

Thailand has been implementing multiple measures against transmission of SARS-CoV-2 since the beginning of the outbreak (*10*,*11*). The country established thermal screening at airports on January 3, 2020, and detected an early case of COVID-19 outside China in a traveler from Wuhan, China, arriving at Bangkok Suvarnabhumi airport on January 8, 2020 (*10*). Thailand uses Surveillance and Rapid Response Teams (SRRTs), together with village health volunteers, to conduct contact tracing, educate the public about COVID-19, and monitor close contacts of persons with COVID-19 in quarantine (*11*). SRRTs are epidemiologic teams trained to conduct surveillance, investigations, and initial control of communicable diseases, such as SARS and influenza (*12*,*13*). More than 1,000 district-, provincial-, and regional-level SRRTs are working on COVID-19 contact tracing in Thailand.

By February 2020, public pressure to wear masks in Thailand was high. However, medical masks became difficult for the public to procure, and the government categorized medical masks as price-controlled goods. When the Ministry of Public Health (MoPH) designated COVID-19 a dangerous communicable disease, according to the Communicable Disease Act of 2015, government officials were empowered to quarantine case-contacts and close venues (*14*,*15*). On March 3, MoPH recommended public use of cloth face masks (*16*). On March 18, schools, universities, bars, nightclubs, and entertainment venues were closed (*17*). On March 26, when the country was reporting ≈100–150 new COVID-19 cases per day, the government declared a national state of emergency, prohibited public gatherings, and enforced wearing of face masks by all persons on public transport (*18*). On April 21, MoPH announced 19 new PCR-confirmed COVID-19 cases, bringing the total number of cases to 2,811 (*18*). Given the lack of evidence, we sought to evaluate the effectiveness of mask-wearing, handwashing, social distancing, and other personal protective measures against SARS-CoV-2 infection in public in Thailand.

Methods

Study Design

We conducted a retrospective case-control study by drawing persons with COVID-19 cases and noninfected controls from a cohort of contact tracing records of the central SRRT team at the Department of Disease Control (DDC), MoPH, Thailand. We included contact investigations of 3 large COVID-19 clusters in nightclubs, boxing stadiums, and a state enterprise office in Thailand.

Contacts were defined by DDC as persons who had activities with or were in the same location as a person with confirmed COVID-19 (*19*,*20*). The main aim of contact tracing was to identify and evaluate contacts, perform reverse transcription PCR (RT-PCR) diagnostic tests, and quarantine high-risk contacts, as defined by the MoPH (Appendix, https://wwwnc.cdc.gov/EID/article/26/11/20-3003-App1.pdf). RT-PCR was performed at laboratories certified for COVID-19 testing by the National Institute of Health of Thailand (*19*,*20*). Data on risk factors associated with SARS-CoV-2 infection, such as type of contact and use of mask, were recorded during contact investigations, but data sometimes were incomplete.

The central SRRT performed contact investigations for clusters of ≥5 PCR-confirmed COVID-19 cases from the same location within a 1-week period (*19*,*20*). We used these data to identify contacts who were asymptomatic during March 1–31, 2020. We used all available contact tracing records of the central SRRT in the study.

We telephoned contacts during April 30–May 27, 2020, and asked details about their contact with a COVID-19 index patient, such as dates, locations, duration, and distance of contact. We asked whether contacts wore a mask during the contact with the index patient, the type of mask, and the frequency of wearing a mask, which we defined as compliance with mask-wearing. We asked whether and how frequently contacts washed their hands while with the index patient. We asked whether contacts performed social distancing and whether they had physical contact with the COVID-19 index patient. If they did not know, or could not remember, contact with the index patient, we asked whether they had contact with other persons at the location. We asked whether the contact shared a cup or a cigarette with other persons in the place they had contact or had highest risk for contact with the index patient and whether the COVID-19 index patient, if known to the respondent, had worn a mask (Appendix, Additional Methods). We also asked, and verified by using DDC records, whether and when the contacts had symptoms and when COVID-19 was diagnosed.

For our study, we defined cases as asymptomatic contacts who later tested positive for SARS-CoV-2, on the basis of RT-PCR results available by April 21, 2020. We defined controls as asymptomatic contacts who did not have positive test results for SARS-CoV-2 by April 21, including those who tested negative and those who were not tested. We defined asymptomatic contacts as persons who had contact with or were in

the same location as a symptomatic COVID-19 patient and had no symptoms of COVID-19 on the first day of contact. We defined index patients as persons identified from contact tracing data as the potential source of SARS-CoV-2 infection; cases (as defined above) also could be index patients. We defined primary index patients as persons whose probable sources of infection were before the study period, March 1–31; for whom we were not able to identify the source of infection; or whose probable sources of infection were outside the contact tracing data included in the study. We defined high-risk exposure as that which occurred when persons lived in the same household as a COVID-19 patient; had a direct physical contact with a COVID-19 patient; were ≤1 m from a COVID-19 patient for >15 minutes; or were in the same closed environment, such as a room, nightclub, stadium, or vehicle, ≤1 m from a COVID-19 patient for >15 minutes.

We used 21 days after March 31 as a cutoff date based on evidence that most persons with COVID-19 likely would develop symptoms within 14 days (*21*) and that it could take ≤7 additional days for symptomatic persons under contact investigation to go to a healthcare facility and be tested for COVID-19. Our study follows the STROBE guidelines (*22*).

Statistical Analysis

To include only initially asymptomatic contacts in the study, we excluded persons who reported having symptoms of COVID-19 at the time of initial contact with an index patient. Because our study focused on the risk for infection in the community, we excluded contacts whose contact locations were healthcare facilities. We also excluded primary index patients if they were the first to have symptoms at the contact investigation location, had symptoms since the first day of visiting the location, or were the origin of infection based on the contact investigation.

We estimated secondary attack rates by using the percentage of new cases among asymptomatic contacts with high-risk exposure to enable comparison with other studies. We estimated odds ratios (ORs) and 95% CIs for associations between developing COVID-19 and factors evaluated. We used logistic regression with random effects for location and for index patients nested in the same location. If an asymptomatic contact had contact with ≥1 symptomatic COVID-19 index patient, the interviewer identified the index patient as the symptomatic COVID-19 patient with the closest contact. The percentage of missing values for the variable indicating whether the index patients wore a mask was 27%; thus, we did not include this variable in our analyses. For other variables, we assumed that missing values were missing at random and used imputation by chained equations (*23*,*24*). We created 10 imputed datasets and the imputation model included the case-control indicator and variables used in the multivariable models, including sex, age group, contact place, shortest distance of contact, duration of contact at ≤1 m, sharing dishes or cups, sharing cigarettes, handwashing, mask-wearing, and compliance with mask-wearing. We developed the final multilevel mixed-effect logistic regression models on the basis of previous knowledge and a purposeful selection method (*25*; Appendix, Additional Analyses). Because of collinearity between mask use and mask type, we conducted a separate analysis including mask type in the multilevel mixed-effects logistic regression model for SARS-CoV-2 infection. We also tested a predefined interaction between mask type and compliance with mask-wearing (Appendix, Additional Analyses).

To clarify patterns of behavior and factors related to compliance with mask-wearing, we used multinomial logistic regression models and the imputed dataset to estimated OR and 95% CI for associations between 3 mask-wearing compliance categories, never, sometimes, or all the time; and for other practices, including handwashing and social distancing during the contact period. We used logistic regression to estimate p values for pairwise comparisons.

To estimate the proportional reduction in cases that would occur if exposure to risk factors was reduced, we estimated the population attributable fraction by using the imputed dataset and a direct method based on logistic regression, as described previously (*26*,*27*; Appendix, Additional Analyses). We performed all analyses by using Stata version 14.2 (StataCorp, https://www.stata.com) and R version 4.0.0 (R Foundation for Statistical Computing, https://www.r-project.org).

Results

Characteristics of the Cohort Data

The contact tracing records of the central SRRT included 1,716 persons who had contact with or were in the same location as a person with diagnosed COVID-19 in an investigation of 3 large clusters (Figure 1). Overall, 18 primary index patients were identified: 11 from the nightclub cluster, 5 from the boxing stadiums cluster, and 2 from the state enterprise office cluster. Timelines of primary index patients from the 3 clusters varied (Appendix Figures

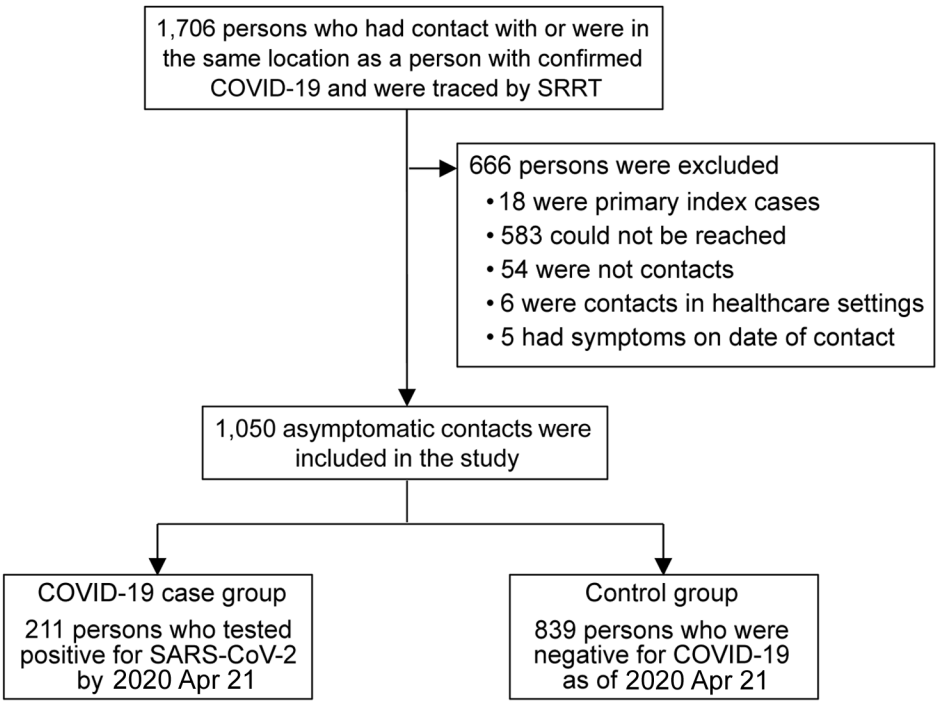

Figure 1. Flow diagram in case-control study of severe acute respiratory syndrome coronavirus 2 infections and contacts, Thailand, March–April 2020. COVID-19, coronavirus disease; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; SRRT, Surveillance and Rapid Response Team of Ministry of Public Health.

1–3); we excluded the 18 primary index patients from our analyses.

Characteristics of Cases and Controls

After interviewing each contact by phone and applying the exclusion criteria (Figure 1), our analysis included 1,050 asymptomatic persons who had contact with or were in the same location as a symptomatic COVID-19 index patient during March 1–31, 2020. The median age of persons included was 38 years (IQR 28–51 years); 55% were male, and 45% were female (Table 1). Most (61%; n = 645) asymptomatic contacts included in the study were associated with the boxing stadiums cluster, 36% (n = 374) were related to the nightclub cluster, and 3% (n = 31) were related to the state enterprise office cluster. Overall, 890 (84.8%) contacts were considered to have high-risk exposure.

Among 1,050 asymptomatic contacts included in our analysis, 211 (20.1%) tested positive for SARS-CoV-2 by April 21, 2020, and were classified as cases; 839 (79.9%) never tested positive and were controls. Of the 211 cases, 195 (92.4%) had high-risk exposures and 150 (71.1%) had symptoms before COVID-19 diagnosis by RT-PCR (Appendix). The last date that a COVID-19 case was detected was April 9, 2020. Among the 839 controls, 695 (82.8%) had high-risk exposures and 719 (85.7%) were tested by PCR at least once.

Among asymptomatic contacts included in the study, 228 had contact with a COVID-19 index patient at nightclubs, 144 at boxing stadiums, and 20 at the state enterprise office (Figure 2). The others had contacts with a COVID-19 index patient at workplaces (n = 277), households (n = 230), and other places (n = 151). Among 890 asymptomatic contacts with high-risk exposures included in the study, the secondary attack rate from boxing stadiums was 86% (111/129), the secondary attack rate for nightclubs was 18.2% (34/187), the household secondary attack rate was 16.5% (38/230), the workplace secondary attack rate was 4.9% (10/205), and the secondary attack rate at other places was 1.4% (2/139).

Bivariate Analyses

Our analysis showed risk for SARS-CoV-2 infection was negatively associated with personal protective measures (Table 1). Crude odds ratio (OR) for infection was 0.08 (95% CI 0.02–0.31) for those maintaining a distance of ≥1 m from a COVID-19 patient; 0.13 (95% CI 0.04–0.46) for those whose duration of contact was ≤15 minutes; 0.41 (95% CI 0.18–0.91) for those who performed handwashing sometimes; 0.19 (95% CI 0.08–0.46) for those who washed hands often; and 0.16 (95% CI 0.07–0.36) for those wearing a mask all the time during contact with a COVID-19 patient. We noted a higher risk for SARS-CoV-2 infection among persons sharing dishes or cups (OR 2.71; 95% CI 1.48–4.94) and sharing cigarettes (OR 6.12; 95% CI 2.12–17.72) with other persons in general, not necessarily including a COVID-19 patient. In the bivariate model, type of mask was associated with risk for infection (p = 0.003).

Multivariable Analyses

We found a negative association between risk for SARS-CoV-2 infection and maintaining a distance of ≥1 m from a COVID-19 patient (adjusted odds ratio [aOR] 0.15; 95% CI 0.04–0.63); duration of contact ≤15 minutes (aOR 0.24; 95% CI 0.07–0.90); handwashing often (aOR 0.33; 95% CI 0.13–0.87); and wearing a mask all the time during contact with a COVID-19 patient (aOR 0.23; 95% CI 0.09–0.60) (Table 1). Wearing masks sometimes during contact with a COVID-19 patient was not statistically significantly associated with lower risk for infection (aOR 0.87; 95% CI 0.41–1.84). Sharing cigarettes with other persons was associated with higher risk for infection (aOR 3.47; 95% CI 1.09–11.02).

Compliance with mask-wearing during contact with a COVID-19 patient was strongly associated

Table 1. Factors associated with coronavirus disease among persons followed through contract tracing, Thailand, March–April 2020*

Factors	COVID-19 cases, no. (%), N = 211†	Controls, no. (%), N = 839†	Crude odds ratio (95% CI)‡	p value	Adjusted odds ratio (95% CI)‡	p value
Sex	n = 211	n = 838				
F	65 (30.8)	404 (48.2)	Referent	0.52	Referent	0.37
M	146 (69.2)	434 (51.8)	0.83 (0.47–1.46)		0.76 (0.41–1.41)	
Age group, y	n =211	n = 829				
≤15	6 (2.8)	49 (5.9)	0.65 (0.17–2.48)	0.29	0.57 (0.15–2.21)	0.21
>15–40	94 (44.5)	435 (52.5)	Referent		Referent	
>40–65	98 (46.4)	302 (36.4)	1.65 (0.91–2.97)		1.77 (0.94–3.32)	
>65	13 (6.2)	43 (5.0)	1.29 (0.33–5.07)		0.97 (0.22–4.24)	
Contact place§	n = 211	n = 839				
Nightclub	35 (16.6)	193 (23.0)	NA	NA	NA	NA
Boxing stadium	125 (59.2)	19 (2.3)				
Workplace	11 (5.2)	286 (34.0)				
Household	38 (18.0)	192 (22.9)				
Others	2 (0.9)	149 (17.8)				
Shortest distance of contact	n = 197	n = 809				
Physical contact	132 (67.0)	292 (36.1)	Referent	0.001	Referent	0.02
≤1 m without physical contact	61 (30.9)	335 (41.4)	0.76 (0.43–1.35)		1.09 (0.58–2.07)	
>1 m	4 (2.0)	182 (22.5)	0.08 (0.02–0.31)		0.15 (0.04–0.63)	
Duration of contact within 1 m	n = 199	n = 801				
>60 min	180 (90.4)	487 (60.8)	Referent	0.003	Referent	0.09
>15–60 min	14 (7.0)	162 (20.2)	0.53 (0.24–1.17)		0.67 (0.29–1.55)	
≤15 min	5 (2.5)	152 (19.0)	0.13 (0.04–0.46)		0.24 (0.07–0.90)	
Sharing dishes or cups¶	n = 210	n = 837				
N	125 (59.5)	576 (68.8)	Referent	0.001	Referent	0.39
Y	85 (40.5)	261 (31.2)	2.71 (1.48–4.94)		1.33 (0.70–2.54)	
Sharing cigarettes#	n = 209	n = 836				
N	196 (93.8)	824 (98.6)	Referent	0.001	Referent	0.03
Y	13 (6.2)	12 (1.4)	6.12 (2.12–17.72)		3.47 (1.09–11.02)	
Handwashing**	n = 210	n = 826				
None	44 (20.9)	121 (14.6)	Referent	<0.001	Referent	0.045
Sometimes	114 (54.3)	333 (40.3)	0.41 (0.18–0.91)		0.34 (0.14–0.81)	
Often	52 (24.8)	372 (45.0)	0.19 (0.08–0.46)		0.33 (0.13–0.87)	
Type of mask††	n = 211	n = 834				
None	102 (48.3)	500 (60.0)	Referent	0.003	–	–
Nonmedical masks only	25 (11.8)	77 (9.2)	0.78 (0.32–1.90)			
Nonmedical and medical	12 (5.7)	48 (5.8)	0.46 (0.13–1.64)			
Medical mask only	72 (34.1)	209 (25.0)	0.25 (0.12–0.53)			
Compliance with mask-wearing††	n = 210	n = 823				
Not wearing a mask	102 (48.6)	500 (60.7)	Referent	<0.001	Referent	0.006
Wearing a mask sometimes	79 (37.6)	125 (15.2)	0.75 (0.37–1.52)		0.87 (0.41–1.84)	
Always wearing a mask	29 (13.8)	198 (24.1)	0.16 (0.07–0.36)		0.23 (0.09–0.60)	

*NA, not applicable; COVID-19, coronavirus disease.
†Data not available for all cases and controls for all factors.
‡Crude and adjusted odds ratios were estimated using logistic regression with random effects for location and for index patient nested within the same location.
§The state enterprise office was included as a workplace. Others included restaurants, markets, malls, religious places, and households of index patients or other persons in persons not living in that household. Location was included in the model as a random effect variable.
¶Sharing multiserving dishes and using communal serving utensils to portion food individually was not categorized as sharing dishes.
#Included sharing electronic cigarettes and any vaping devices.
**Included washing with soap and water, and by using alcohol-based solutions.
††Wearing masks incorrectly, such as not covering both nose and mouth, was considered the same as not wearing a mask for analyses. Crude odds ratios of wearing mask and of each factor evaluated were estimated using logistic regression with random effects for location and for index patient nested within the same location to take into account clustering; therefore, the crude odds ratios are not equal to dividing of the odds in the case group by the odds in the control group.

with lower risk for infection in the multivariable model. Because of collinearity with mask-wearing compliance, we did not include mask type in the final model. We included mask type in a separate multivariable model and found type of mask was not independently associated with infection (p = 0.54) (Appendix Table 1). We found no evidence of effect modification between mask type and mask-wearing compliance.

Association Between Mask-Wearing Compliance and Other Social Distancing Practices

Because mask-wearing throughout the contact period was negatively associated with COVID-19, we

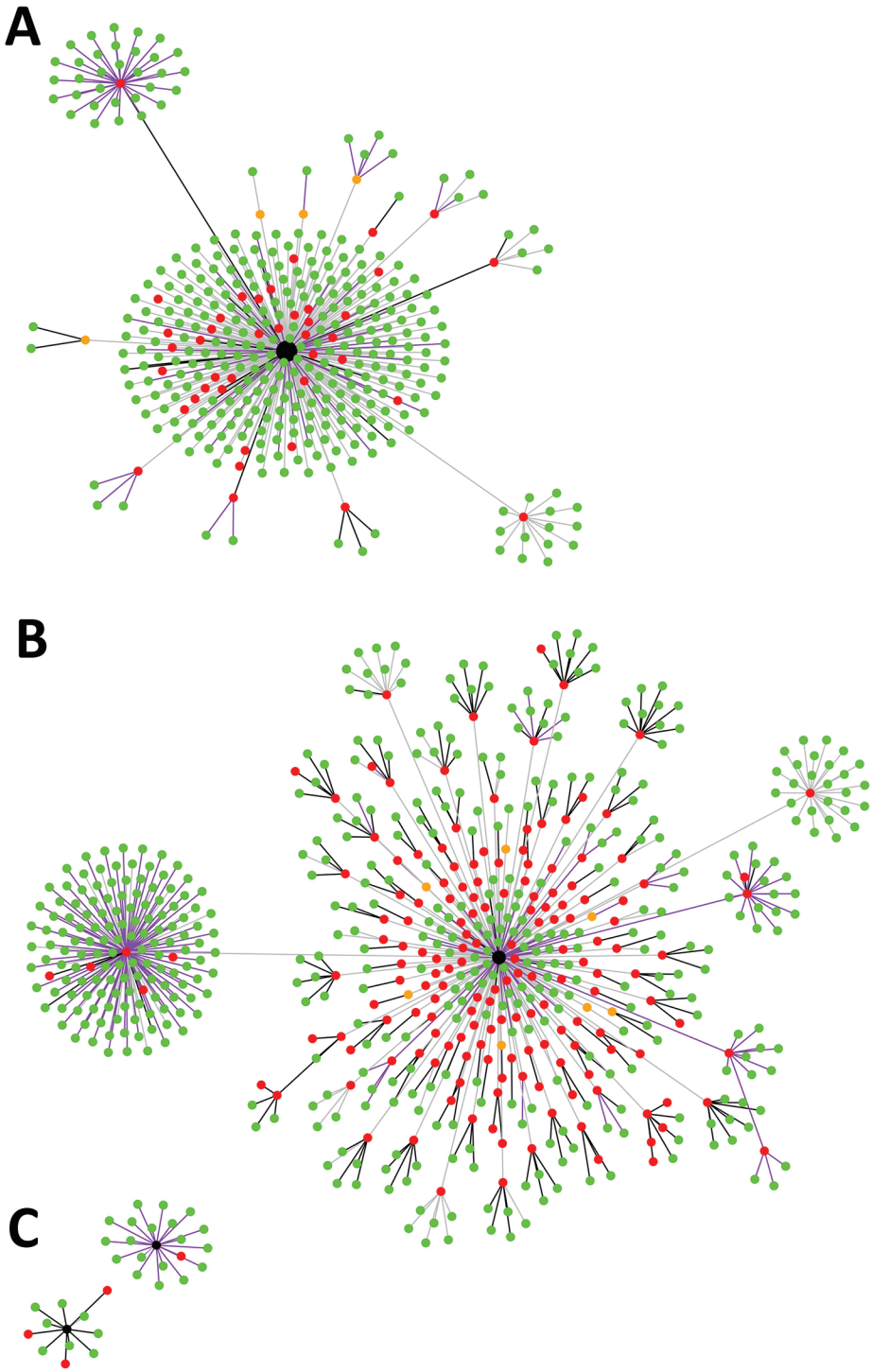

Figure 2. Development and transmission of severe acute respiratory syndrome coronavirus 2 among asymptomatic contacts, Thailand, March–April 2020. Clusters indicate coronavirus disease (COVID-19) contacts from nightclubs (A); boxing stadiums (B), and the state enterprise office (C). Black nodes represent primary index patients, red dots cases (contacts of primary index patients who had COVID-19), green dots noninfected controls, and orange dots patients with confirmed COVID-19 who could not be contacted by the study team. Black lines represent household contacts, purple lines contacts at workplaces, and gray lines contacts at other locations.

further explored characteristics of participants to ascertain whether wearing a mask produced a potential false sense of security. We found that during the contact period, 25% of persons who wore masks all the time reported maintaining ≥1 m distance from contacts compared with 18% of persons who did not wear a mask (pairwise p = 0.03). In addition, persons who wore masks all the time were more likely to report duration of contact ≤15 minutes (26% vs. 13% for those who did not wear a mask; pairwise p<0.001) and washing hands often (79% vs. 26% for those who did not wear a mask; pairwise p<0.001) (Table 2). We found that 43% of persons who wore masks sometimes were likely to wash their hands often compared with those who did not wear masks (26%; pairwise p<0.001), but they were more likely to have physical contact (50% vs. 42%; pairwise p = 0.03) and report duration of contact >60 minutes (75% vs. 67%; pairwise p = 0.04) compared with those who did not wear masks.

Discussion

Our findings provide evidence that mask-wearing, handwashing, and social distancing are independently associated with lower risk for SARS-CoV-2 infection in the general public in community settings in Thailand. We observed that wearing masks throughout the period of exposure to someone infected with SARS-CoV-2 was associated with lower risk for infection, but wearing masks only sometimes during the period was not. This evidence supports recommendations to wear masks consistently and correctly at all times in public (*2,7–9*).

The effectiveness of mask-wearing we observed is consistent with previous studies, including a randomized-controlled trial showing that consistent face

Table 2. Factors associated with compliance of mask wearing among coronavirus disease cases and controls, Thailand, March–April 2020*

Factors	Not wearing masks, no. (%), n = 602	Sometimes wearing masks, no. (%), n = 204	Always wearing masks, no. (%), n = 227	p value†
Sex	n = 601	n = 204	n = 227	
F	277 (46.1)	75 (36.8)	112 (49.3)	0.03
M	324 (53.9)	129 (63.2)	115 (50.7)	
Age group, y	n = 594	n = 204	n = 225	
≤15	45 (7.6)	5/204 (2%)	3/225 (1%)	<0.001
>15–40	269 (45.3)	117/204 (57%)	132/225 (59%)	
>40–65	236 (39.7)	76/204 (37%)	84/225 (37%)	
>65	44 (7.4)	6/204 (3%)	6/225 (3%)	
Contact places‡	n = 602	n = 204	n = 227	
Nightclub	84 (14.0)	51 (25.0)	91 (40.1)	<0.001
Boxing stadium	48 (8.0)	66 (32.4)	29 (12.8)	
Workplace	178 (29.6)	46 (22.5)	64 (28.2)	
Household	167 (27.7)	27 (13.2)	33 (14.5)	
Others	125 (20.7)	14 (6.9)	10 (4.4)	
Shortest distance of contact	n = 588	n = 191	n = 212	
Physical contact	246 (41.8)	96 (50.3)	76 (35.8)	0.005
≤1 m without physical contact	238 (40.5)	70 (36.6)	83 (39.1)	
>1 m	104 (17.7)	25 (13.1)	53 (25.0)	
Duration of contact within 1 m	n = 590	n = 190	n = 205	
>60 min	396 (67.1)	143 (75.3)	121 (59.0)	<0.001
>15–60 min	120 (20.3)	23 (12.1)	30 (14.6)	
≤15 min	74 (12.5)	24 (12.6)	54 (26.3)	
Sharing dishes or cups§	n = 601	n = 203	n = 226	
N	361 (60.1)	130 (64.0)	200 (88.5)	<0.001
Y	240 (39.9)	73 (36.0)	26 (11.5)	
Sharing cigarettes¶	n = 600	n = 202	n = 226	
N	586 (97.7)	194 (96.0)	223 (98.7)	0.29
Y	14 (2.3)	8 (4.0)	3 (1.3)	
Handwashing#	n = 594	n = 203	n = 224	
None	142 (23.9)	16 (7.9)	6 (2.7)	<0.001
Sometimes	298 (50.2)	99 (48.8)	42 (18.8)	
Often	154 (25.9)	88 (43.3)	176 (78.6)	

*Data not available for all cases and controls for all factors. Wearing masks incorrectly, such as not covering both nose and mouth, was considered the same as not wearing a mask for analyses.
†p values were estimated by using univariable multinomial logistic regression models. Missing values were imputed using the imputation model.
‡The state enterprise office was included as a workplace. Others included restaurants, markets, malls, religious places, and households of index patients or other persons but not living together (e.g., persons not living in that household).
§Sharing multiserving dishes and using communal serving utensils to portion food individually was not categorized as sharing dishes.
¶Included sharing electronic cigarettes and any vaping devices.
#Included washing with soap and water, and by using alcohol-based solutions.

mask use reduced risk for influenza-like illness (*28*), 2 case-control studies that found that mask-wearing was associated with lower risk for SARS infection (*29*,*30*), and a retrospective cohort study that found that mask-wearing by index patients or family members at home was associated with lower risk for SARS-CoV-2 infection (*31*). Previous studies found use of surgical masks or similar 12–16-layer cotton reusable masks demonstrated protection against coronavirus infection in the community (*32*), but we did not observe a difference between wearing nonmedical and medical masks in the general population. Our results suggest that wearing nonmedical masks in public can potentially reduce transmission of SARS-CoV-2. Another study found perception of risk of developing COVID-19 can increase a person's likelihood of wearing a medical mask in nonmedical settings (T.D. Huynh, unpub. data, https://www.medrxiv.org/content/10.1101/2020.03.26.20044388v1). However, given supply shortages, medical masks should be reserved for use by healthcare workers.

We found a negative association between risk for SARS-CoV-2 infection and social distancing, consistent with previous studies that found that ≥1 m physical distancing was associated with a large protective effect and distances of >2 m could be more effective (*32*). Our findings on effectiveness of hand hygiene also were consistent with reports in previous studies (*33*).

In this study, secondary attack rates at different venues varied widely. The household secondary attack rate in our study (16.5%) is comparable with ranges reported previously (11%–23%) (*34*,*35*), and relatively high compared with workplaces (4.9%) and other settings (1.4%). Although quarantine measures can be challenging and sometimes impractical, household members should immediately separate a person who develops symptoms of COVID-19; the sick person should stay in a specific room; use a separate bathroom, if possible; and not share dishes, cups, and other utensils (*36*). All household members should wear masks, frequently wash their hands, and perform social distancing to the extent possible (*37*).

The high number of COVID-19 cases associated with nightclub exposures in Bangkok is comparable to a COVID-19 outbreak associated with the Itaewon nightclub cluster in Seoul, South Korea, during May 2020 (*38*), in which persons visited several nightclubs in the same area during a short period of time. The secondary attack rate in boxing stadiums was high (86%) but similar to a cluster of COVID-19 cases associated with a football match in Italy during February 2020 (*39*). The secondary attack rate of COVID-19 at a choir practice in the United States was reported to be 53.3%–86.7% (*40*). Secondary attack rates in public gathering places with high densities of persons shouting and cheering, such as football and boxing stadiums, are still uncertain but appear to be high.

Clear and consistent public messaging from policy makers likely can prevent a false sense of security and promote compliance with social distancing in Thailand. We found that those who wore masks throughout the time they were exposed to a COVID-19 patient also were more likely to wash their hands and perform social distancing. Traditional and social media outlets can support public health responses by working with governments to provide consistent, simple, and clear messages (*41*). In Thailand, daily briefings from the Centre for COVID-19 Situation Administration provided clear, consistent messages on social distancing, how to put on a mask, and how to wash hands, which might have improved public confidence with the recommendations. Consistent public messages on how to wear masks correctly also are needed, particularly for those who wear masks sometimes or incorrectly, such as not covering both nose and mouth. We found that persons who only intermittently wore masks during exposure also did not practice social distancing adequately.

Our study has several limitations. First, because our findings were based on contacts related to 3 major COVID-19 clusters in Thailand during March 2020, they might not be generalizable to all settings. Second, estimated ORs were conditioned on reported contact with index patients; our study did not evaluate or consider the probability of having contact with other infected persons in the community, which could have occurred. Third, because only 89% of controls were tested, those not tested could have been infected; therefore, cases might have been missed in persons with mild or no symptoms or who did not report symptoms or seek care or testing. Nonetheless, we believe that misclassification likely was minimal because those who were not tested with RT-PCR were low-risk contacts; the small number likely would not change our main findings and recommendations on personal protective measures. Fourth, identifying every potential contact can be nearly impossible because some persons might have had contact with >1 COVID-19 patient. Hence, our estimated secondary attack rates among contacts with high-risk exposure could be overestimated or underestimated. Fifth, population attributable fraction is based on several assumptions, including causality, and should be interpreted with caution (*42*,*43*). Finally, findings were subject to

common biases of retrospective case-control studies, including memory bias, observer bias, and information bias (*44*). To reduce potential biases, we used structured interviews in which each participant was asked the same set of defined questions.

As many countries begin to relax social distancing measures, our findings provide evidence supporting consistent mask-wearing, handwashing, and adhering to social distancing recommendations to reduce SARS-CoV-2 transmission in public gatherings. Wearing nonmedical masks in public could help slow the spread of COVID-19. Complying with all measures could be highly effective; however, in places with a high population density, additional measures might be required.

Clear and consistent public messaging on personal protective recommendations is essential, particularly for targeting those who wear masks intermittently or incorrectly. Our data showed that no single protective measure was associated with complete protection from COVID-19. All measures, including mask-wearing, handwashing, and social distancing, can increase protection against COVID-19 in public settings.

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Case-Control Study of Use of Personal Protective Measures and Risk for SARS-CoV-2 Infection, Thailand

Appendix

Additional Methods

Study Design

Contacts were defined by the Department of Disease Control (DDC), Ministry of Public Health (MoPH), Thailand as persons who had activities with or were in the same location as a COVID-19 patient (*1*,*2*). All high-risk contacts with any symptoms were tested with a reverse transcription PCR (RT-PCR) assay and quarantined in a hospital or a quarantine site. High-risk contacts defined by the MoPH included family members or persons who lived in the same household as a COVID-19 patient; persons ≤1 m distance of a COVID-19 patient for >15 minutes; persons exposed to coughs, sneezes, or secretions of a COVID-19 patient and were not wearing protective gear, such as a mask; and persons in the same closed environment, such as a room, nightclub, stadium, or vehicle, ≤1 m from a COVID-19 patient for >15 minutes, and they were not wearing protective gear, such as a mask (*1*,*2*). All high-risk contacts without any symptoms were self-quarantined at home. Before March 23, 2020, all high-risk contacts without any symptoms were tested by using RT-PCR assays on day 5 after the last date of exposure to a COVID-19 patient (*1*,*2*). As of March 23, 2020, all household contacts were tested by using RT-PCR assays regardless of their symptoms (*1*,*2*). Other high-risk contacts were tested only if COVID-19 symptoms developed. All low-risk contacts were recommended to perform self-monitoring for 14 days and visit healthcare facilities immediately for RT-PCR assays if COVID-19 symptoms developed (*1*,*2*). All RT-PCR assays targeting open read frame 1b (ORF1b) and N gene regions were performed at laboratories certified for COVID-19 testing by the National Institute of Health of Thailand (*3*) based on the protocols recommended by the World Health Organization (WHO; *4*). RT-PCR assays required a detection limit of <25 copies/reaction and no

cross-reactivity with a panel of other respiratory viruses including SARS-CoV, MERS-CoV, and hCoV (NL63, OC43, 229E, and HKU1) (*3*). When an RT-PCR assay result was negative, the result was reported immediately. When a RT-PCR assay result was positive for either or both ORF1b and N gene regions, a confirmation test was conducted by using either a PCR assay targeting different regions or targeting ORF1b and N gene regions with different targets, or nucleotide sequencing of ORF1b or N gene regions.

We telephoned contacts during April 30–May 27, 2020 and asked details about their contact with a COVID-19 index patient, such as date, location, duration, and distance of contact. We asked whether contacts wore a mask during the contact period with the following possible responses: never; yes, non-medical mask; yes, medical mask; yes, alternately nonmedical and medical masks; unknown or cannot remember. If contacts reported wearing a mask, we asked the frequency of mask-wearing during the contact period with the following possible responses: sometimes; all the time; unknown or cannot remember. We asked if and how frequently they washed their hands during the contact period with the following possible responses: no washing with soap or alcohol-based solutions; yes, sometimes; yes, all the time after any contact (defined below as 'often'); unknown or cannot remember. We asked if they performed social distancing, including type of contact with the COVID-19 index patient or other persons at place of contact, if unable to remember who the patient was with the following possible responses: had physical contact; shortest distance $\leq$1 m and no physical contact; shortest distance >1 m and no physical contact; unknown or cannot remember. We asked about the total duration of contact with the following possible responses: >1 hour; at least 15 minutes but not >1 hour; <15 minutes; unknown or cannot remember. We asked whether contacts shared a cup or a cigarette with other persons in the place they had contact or had highest risk for contact with the index patient with the following possible responses: no, yes, unknown or cannot remember. We asked whether the COVID-19 index patient, if known to the respondent, had worn a mask with the following possible responses: never; yes, nonmedical mask; yes, medical mask; yes, alternately nonmedical and medical masks; unknown or cannot remember. We asked if the COVID-19 index patient wore a mask and the frequency of mask-wearing with the following possible responses: sometimes; all the time; unknown or cannot remember. We also asked, and verified using DDC records, whether and when the contacts had symptoms or COVID-19 was diagnosed. The reporting of this study follows the STROBE guidelines (*5*).

Statistical Analysis

We developed the final multilevel mixed-effect logistic regression models on the basis of previous knowledge and a purposeful selection method (*6*). In short, we performed the following: 1) fit a multilevel mixed-effect univariable model with each covariate; 2) selected candidate variables with the α level of <0.25; 3) evaluated variables that were not statistically significant in the multivariate model at an α level of 0.10; 4) fit a reduced model and evaluated confounding by change in log odds ratios of any remaining variables compared with the full model; 5) repeated steps 3 and 4 until the model contained statistically significant covariates or confounders; and 6) added back in the model, 1 at a time, any variable not originally selected, kept any that were statistically significant, and reduced the model following steps 3 and 4. We kept sex, age group, and sharing dishes or cups in the mixed-effect multivariable model on the basis of previous knowledge that sex, age group, and sharing dishes or cups were associated with COVID-19 development.

We estimated the direct population attributable fraction (PAF) by using the imputed dataset and the direct method, as previously described (*7*,*8*). Direct PAF can be obtained by calculating PAFs directly from subjects' data by using logistic regression (*7*,*8*). First, we modified our final logistic regression model by considering each risk factor dichotomously. Then, irrespective of exposure to each risk factor for each subject, that factor was removed from the population by calculating probability based on all observations as unexposed. The predicted probability of developing COVID-19 for each asymptomatic contact, with the assumption that no exposure to a certain risk factor occurred, was defined by:

$$P_{ki} = \frac{1}{1 + \exp\left[-(\beta_0 + \sum_{j \neq i} \beta_j x_j)\right]}$$

P_{ki} is representative of predicted probability of COVID-19 in an asymptomatic contact, k, assuming no exposure to a specific risk factor (x_i); β_j indicates the regression coefficient of risk factor (x_j), except risk factor number i (x_i). Subsequently, the sum of all predicted probabilities for all subjects in the study would be equal to the adjusted estimate of total cases, which is anticipated in the absence of that specific risk factor (x_i).

Then, PAF was estimated by subtraction of the total number of predicted cases from total number of observed cases, divided by the total number of observed cases:

$$\mathrm{PAF} = \frac{\text{Total number of observed cases} - \text{total number of predicted cases}}{\text{total number of observed cases}}$$

Additional Results

Characteristics of the Cohort Data

For the nightclub cluster, we identified 11 primary index patients who started having symptoms during March 4–8 and had a COVID-19 diagnosis and began isolation during March 3–10 (Appendix Figure 1). Primary index patients visited multiple nightclubs included in the analysis during the study period, and 35/228 (15.4%) asymptomatic contacts at nightclubs had PCR-confirmed SARS-CoV-2 infections after the contact (Figure 2, panel A).

For the boxing stadium cluster, we identified 5 primary index patients who started having symptoms during March 6–12 and had diagnosed COVID-19 and began isolation during March 11–21 (Appendix Figure 2). Primary index patients visited multiple boxing stadiums included in the analysis during the study period, and 125/144 (86.8%) asymptomatic contacts at the boxing stadiums had RT-PCR–confirmed SARS-CoV-2 infections after the contact (Figure 2, panel B).

Among the 2 primary index patients for the office cluster (Appendix Figure 3), 1 had symptoms that began on March 15, 2020 (primary index patient C1) and was considered the source of infection for 1 new case in the office during the study period. The other primary index patient (primary index patient C2) was a household member of a staffer at the office and was considered the source of infection for the staffer via household contact.

Characteristics of Cases and Controls

Because all household contacts were tested with RT-PCR assays, we further explored characteristics of household contacts. Among 38 household contacts who later had diagnosed COVID-19, 20 (52.6%) reported having symptoms before diagnosis by RT-PCR. Among 192 household contacts who did not have diagnosed COVID-19, 9 (4.6%) reported having symptoms ($p<0.001$). The median time from exposure to a COVID-19 index patient and testing by RT-PCR did not differ between household contacts who later had COVID-19 (9 days [IQR 6–14 days]) and household contacts who did not have COVID-19 (9 days [IQR 6–12 days]; $p = 0.65$).

Multivariable Analyses

Wearing masks all the time during contact was independently associated with lower risk for SARS-CoV-2 infection compared with not wearing masks (aOR 0.23; 95% CI 0.09–0.60) (Appendix Table 1), but wearing masks sometimes during contact was not (aOR 0.87; 95%CI 0.41–1.84). We further explored whether the risk for infection was different between those who wore masks all the time and those who wore masks sometimes. We found a negative association between risk for SARS-CoV-2 infection and wearing masks all the time compared with wearing masks sometimes (aOR 0.27; 95% CI 0.11–0.70; p = 0.007).

PAF

We estimated that the proportional reduction in cases that might occur if everyone wore a mask all the time during contact with COVID-19 patients was 0.28; that is, the PAF of not wearing masks all the time (Appendix Table 2). Among modifiable risk factors evaluated, PAF of shortest distance of contact <1 m was highest (0.40). Based on our data, if everyone wore a mask all the time; washed hands often; did not share a dish, cup, or cigarette; had shortest distance of contact >1 m; and had duration of contact <15 min, COVID-19 cases might have been reduced by 84%.

Additional Discussion

We also quantified the effectiveness of different measures that could be implemented to prevent transmission in nightclubs, stadiums, workplaces, and other public gathering places. We estimated that adopting all recommendations (mask-wearing all the time; handwashing often; not sharing dishes, cups, or cigarettes; maintaining a distance of >1 m and, if this distance cannot be maintained, limiting contact duration to <15 minutes) might prevent ≥84% of COVID-19 infections in the study settings during the study period. However, PAF is based on several assumptions, including causality, and should be interpreted with caution (*9,10*). Nonetheless, public gathering places could consider multiple measures to protect against COVID-19 and new pandemic diseases in the future.

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Appendix Table 1. Factors associated with severe acute respiratory syndrome coronavirus 2 infection in a multivariable model, including type of mask, among persons followed through contract tracing, March–April 2020, Thailand

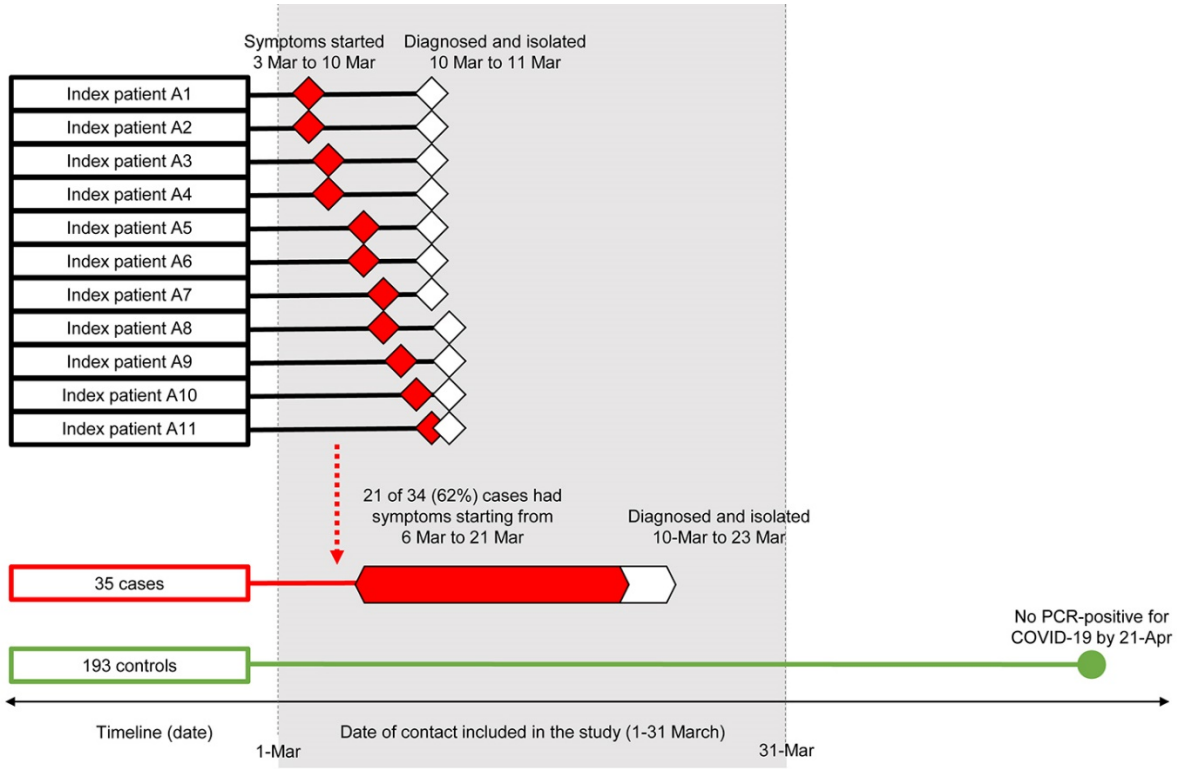
Factors	Adjusted odds ratio (95% CI)†	p value
Sex		
F	Referent	0.35
M	0.75 (0.40–1.38)	
Age group, y		
≤15	0.56 (0.14–2.18)	0.19
>15–40	1.0 (referent)	
>40–65	1.77 (0.94–3.35)	
>65	1.00 (0.23–4.34)	
Contact place‡		
Nightclub	NA	–
Boxing stadium		
Workplace		
Household		
Others		
Shortest distance of contact		
Physical contact	Referent	0.02
≤1 m without physical contact	1.08 (0.57–2.03)	
>1 m	0.15 (0.04–0.66)	
Duration of contact within 1 m		
>60 min	Referent	0.10
>15–60 min	0.67 (0.29–1.56)	
≤15 min	0.25 (0.07–0.94)	
Sharing dishes or cups§		
N	Referent	0.39
Y	1.32 (0.69–2.53)	
Sharing cigarettes¶		
N	Referent	0.03
Y	3.48 (1.09–11.05)	
Handwashing#		
None	Referent	0.04
Sometimes	0.33 (0.14–0.79)	
Often	0.33 (0.12–0.87)	
Type of masks worn**		
None	Referent	0.54
Nonmedical masks only	1.29 (0.48–3.45)	
Nonmedical and medical	1.03 (0.26–4.07)	
Medical masks only	0.61 (0.25–1.49)	
Wearing masks all the time**		
N	Referent	0.02
Y	0.32 (0.12–0.82)	

*NA, not applicable; –, not available.
†Crude and adjusted odds ratios were estimated by using logistic regression with random effects for location and for index patient nested within the same location. Missing values were imputed using the imputation model.
‡The state enterprise office was included as a workplace. Others included restaurants, markets, malls, religious places, and households of index patients or other persons but not living together. Location was included in the model as a random effect variable.
§Sharing multiserving dishes and using communal serving utensils to portion food individually was not categorized as sharing dishes.
¶Included sharing electronic cigarettes and any vaping devices.
#Included washing with soap and water, and by using alcohol-based solutions.
**Wearing masks during the contact period. Wearing masks incorrectly, such as not covering both nose and mouth, was considered the same as not wearing a mask for analyses.

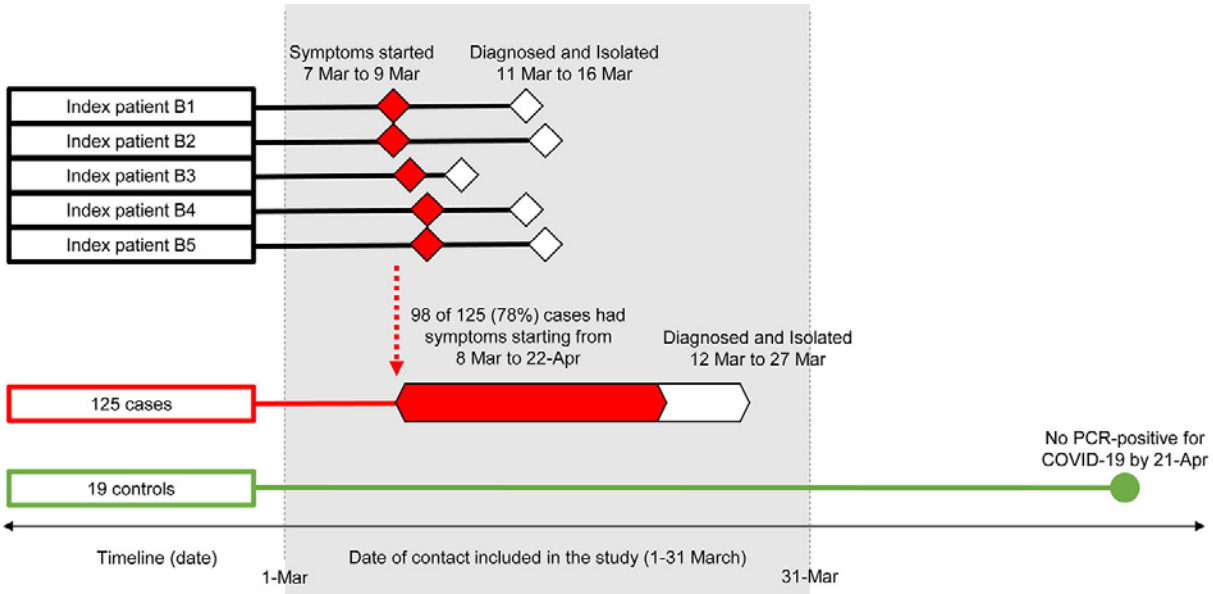
Appendix Table 2. Population attributable fraction of risk factors for severe acute respiratory syndrome coronavirus 2 infection in various locations based on contact tracing data, March–April 2020, Thailand*

	Nightclub		Boxing stadium		Workplace		Household		Other places		Overall	
Risk factors	Prev	PAF	Prev	PAF	Prev	PAF	Prev	PAF	Prev	PAF	Prev	PAF
Non-modifiable												
Female sex	0.51	0.08	0.13	0.002	0.40	0.03	0.68	0.09	0.40	0.08	0.45	0.03
Age group >15 y	1.00	0.32	0.98	0.05	0.99	0.37	0.82	0.26	0.96	0.37	0.95	0.15
Modifiable during the contact period												
Distance of contact <1 m	0.88	0.71	0.98	0.19	0.65	0.72	0.87	0.68	0.85	0.76	0.82	0.40
Duration of contact within 1 m >15 min	0.86	0.55	0.99	0.11	0.70	0.57	0.91	0.53	0.91	0.64	0.85	0.29
Sharing dishes or cups†	0.34	0.10	0.30	0.01	0.19	0.06	0.57	0.11	0.26	0.13	0.33	0.04
Sharing cigarettes‡	0.08	0.12	0.02	0.001	0.01	0.06	0	0	0.01	0.007	0.02	0.02
Not washing hands§	0.05	0.06	0.21	0.01	0.20	0.17	0.10	0.08	0.28	0.29	0.16	0.04
Not wearing masks all the time¶	0.60	0.52	0.80	0.08	0.78	0.65	0.86	0.55	0.94	0.68	0.78	0.28
Sum of all modifiable risk factors#		0.98		0.75		0.98		0.97		0.99		0.84

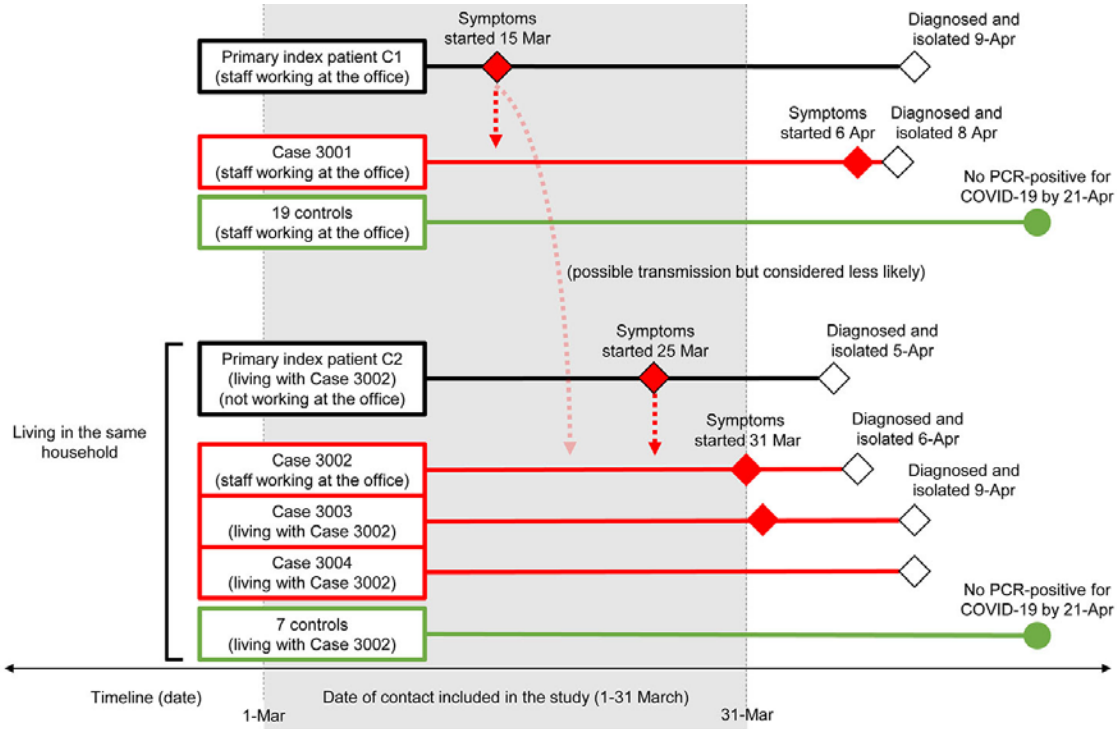
*Prevalence was estimated by using the imputed dataset. Population attributable fraction was estimated by using the direct method (*7,8*). PAF, population attributable fraction; Prev, prevalence.
†Sharing multiserving dishes and using communal serving utensils to portion food individually was not categorized as sharing dishes.
‡Included sharing electronic cigarettes and any vaping devices.
§Included washing with soap and water, and by using alcohol-based solutions.
¶Wearing masks incorrectly, such as not covering both nose and mouth, was considered the same as not wearing a mask for analyses.
#Age and gender were considered nonmodifiable risk factors; other risk factors were considered modifiable. Total PAF was directly estimated by using logistic regression in the form of natural logarithm; therefore, total PAF was not equal to the direct summation of PAF of each risk factor.



Appendix Figure 1. Timeline and possible transmission of severe acute respiratory syndrome coronavirus 2 from primary index patients of the nightclub cluster, March–April 2020, Thailand.



Appendix Figure 2. Timeline and possible transmission of severe acute respiratory syndrome coronavirus 2 from primary index patients of the boxing stadium state enterprise office cluster, March–April 2020, Thailand.



Appendix Figure 3. Timeline and possible transmission of severe acute respiratory syndrome coronavirus 2 from primary index patients of the state enterprise office cluster, March–April 2020, Thailand.