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Effect of commuting on the risk of COVID-19 and COVID-19-induced anxiety in Japan, December 2020

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Abstract

Background: To prevent the spread of coronavirus disease (COVID-19), it is important to avoid 3Cs (closed spaces, crowded places, and close-contact settings). However, the risk of contact with an unspecified number of people is inevitable while commuting to and from work. In this study, we investigated the relationship between commuting, and the risk of COVID-19 and COVID-19-induced anxiety.

Methods: An internet-based questionnaire survey was conducted to obtain a dataset from 27,036 respondents. One-way commuting time was evaluated using a five-case method. The commuting distance was estimated using zip codes of the home and workplace. Logistic regression analysis was performed with the following outcomes: COVID-19 risk, close contact, infection anxiety, and infection anxiety due to commuting. Commuting distance and commuting time were analyzed separately in the model. We excluded participants with incalculable commuting distance, commuting distance exceeding 300 km, commuting distance of 0 km, or who telecommuted at least once a week.

Results: The total number of participants included in the analysis was 14,038. The adjusted odds ratios (aORs) of using public transportation for severe acute respiratory syndrome coronavirus 2 infection were 4.17 (95% confidence interval [CI]: 2.51–6.93) (commuting time) and 5.18 (95% CI: 3.06–8.78) (commuting distance). The aOR of COVID-19 diagnosis decreased significantly with increasing commuting distance. The aORs of using public transportation to infection anxiety were 1.44 (95% CI: 1.31–1.59) (commuting time) and 1.45 (95% CI: 1.32–1.60) (commuting distance). The longer the commuting time, the more the aOR increased.

Conclusions: COVID-19 risk, close contact, and infection anxiety were all associated with the use of public transportation during commuting. Both commuting distance and time were associated with infection anxiety due to commuting, and the strength of the association increased with increase in commuting time distance. Since transportation by commuting is associated with COVID-19 risk and anxiety, we recommend the use of telecommuting and other means of work.

Keywords: COVID-19, Commute, Public transportation, Commuting distance, Commuting time

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Background

Coronavirus disease (COVID-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was first discovered in Wuhan, China in December 2019 [1]. In Japan, COVID-19 has had a considerable social impact, starting from the infection transmission in the Diamond Princess ship; moreover, in April 2020, the Japanese government declared a state of emergency in some prefectures, which later became nationwide. The state of emergency required a 70% reduction in the amount of human contact, which accelerated the adoption of telework initiatives by companies. In Japan, the number of infected people has gradually decreased, although no enforceable restrictions are on-going as in other countries. As a result, the state of emergency was undeclared in non-urban areas on May 14, and in all areas by May 25. According to a survey by the Tokyo Metropolitan Government, the telework adoption rate rose from 24% in March 2020 to 62.7% in April 2020 [2]. Notwithstanding, approximately 40% of companies continued to work at the office. Although there are regional differences in the means of commuting, in urban areas such as the Tokyo metropolitan area, people mainly use public transportation such as trains. To prevent COVID-19, it is important to avoid 3Cs (closed spaces, crowded places, and close-contact settings). However, the 3Cs are not easy to avoid in public transportation. A report examining the risk of SARS-CoV-2 infection in high-speed trains conducted on patients with COVID-19 and their close contacts in China found that the closer the seats and longer the contact time, the greater the risk of COVID-19 transmission [3]. Although there are no reports on the relationship between commuting and SARS-CoV-2 infection, commuter trains are generally shorter in duration than high-speed trains, with a considerable number of passengers, which can potentially predispose to COVID-19 transmission. In particular, trains are often extremely crowded during commuting hours in Japan, with the number of passengers sometimes reaching twice the train capacity [4]. Although no clusters have been reportedly caused by commuting using public transportation, it is difficult to strictly perform contact tracing on public transportation, which is used daily by an unspecified number of people.

In addition to the direct risk of COVID-19 transmission, commuting may cause anxiety among users due to the lack of adequate infection control measures. Many studies have reported mental health problems caused by COVID-19 [5–8]. In a survey conducted in Japan, Sasaki et al. found that the fear of infection and anxiety tended to increase with stronger corporate infection prevention measures, whereas psychological distress and work performance tended to decrease with stronger corporate infection prevention measures [9]. Commuting is an

essential part of working; however, companies face severe limitations in implementing infection prevention measures during commuting. Although it is possible to grant special permission for workers to commute using private cars, which is not normally permitted, or to shift commuting times, the risk of infection during the commuting process is expected to remain somewhat high.

We aimed to clarify the relationship between commuting and the risk of COVID-19 and anxiety about infection, using a large-scale, internet-based cross-sectional survey.

Methods

Participants

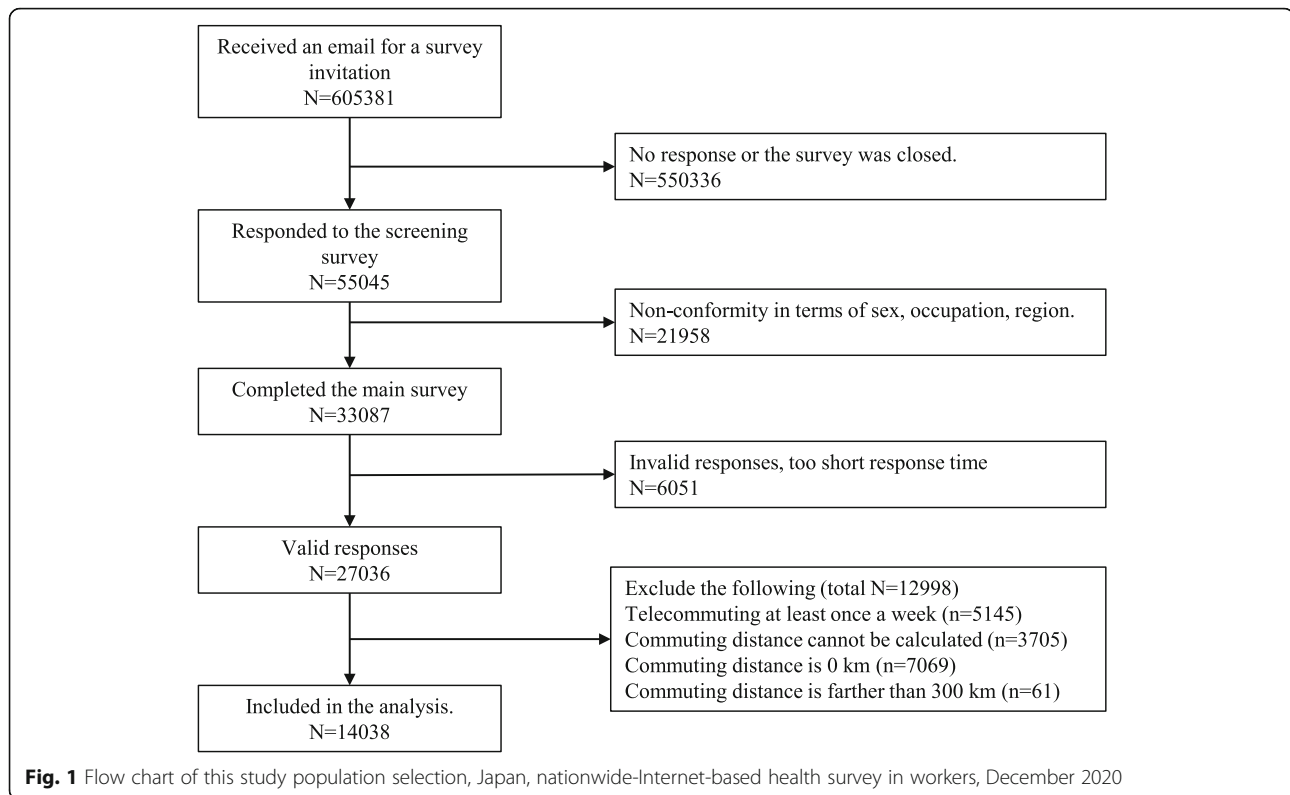
This survey was conducted online among Internet monitors registered with Cross Marketing Inc. (Tokyo, Japan), which is the Japanese Internet research contractor with 4.7 million registered monitors. Information was sent to 605,381 registered monitors, of which 55,045 participated in the screening. Workers between the ages 20 and 65 years were then sampled among the 55,045, taking into account sex, region, and occupation. Of the 33,087 participants who completed the main survey, 6051 participants were excluded based on the following exclusion criteria: response time was too short (≤ 6 min), height was too short (< 140 cm), and the weight was too light (< 30 kg), inconsistencies in the combination of responses (i.e., inconsistent answers to similar questions throughout the survey, such as responses to marital status and living area), answered a general question (Please choose the third largest number among the following: 231, 245, 323, 252, 312) incorrectly. Finally, of the remaining 27,036 participants, we excluded 5145 who telecommuted for more than 1 day per week and those whose commuting distance could not be calculated or was either 0 km ($n = 7069$) or > 300 km ($n = 61$) (see Fig. 1 for the flow of the study). Finally, the total number of subjects analyzed in this study was 14,038. Details of this survey protocol are reported separately [10]. The specification of the survey according to the CHERRIES statement [11] is also reported separately [12].

Questionnaire

The questionnaire items used in this study are described in detail by Fujino et al. [10]. We used questionnaire data on sex, age, educational background, job type, telecommuting frequency, the use of public transportation for commuting, one-way commuting time, home zip code, and workplace zip code.

Calculation of commuting distance

We used HeartRails Geo API (HeartRails Inc. Sagami-hara, Kanagawa, Japan) [13] to obtain the longitude and latitude of the representative points corresponding to



the postal code in the questionnaire. Regarding home addresses, for three participants, the Application Programming Interface (API) could not be used to obtain the longitude and latitude of the area where a new postal code was added in 2020; consequently, these were obtained using the postal code that existed prior to the designation of the new postal code. Addresses with no regular postal codes, such as postal codes for offices alone, or those that were entered with fictitious numbers, which resulted in errors in the API, were excluded. The longitude and latitude of the workplace could not be obtained for 3705 participants. The commuting distance was calculated by determining the straight-line distance using the longitude and latitude of the home and workplace. The commuting distance was calculated for 23,331 (86.3%) of the 27,036 participants.

In addition, 61 participants who had commuting distances > 300 km were excluded because the data were unreliable. We also excluded 7069 participants with a commuting distance of 0 km.

Outcome variable

The outcome was the response to the following four questions in the questionnaire: “Q38. The following questions are related to novel coronavirus infections”; “Q38.1 Have you had COVID-19? (Yes/No)”; “Q38.2 Have you come in close contact with a person infected with COVID-19? (Yes/No)”; “Q38.5 Do you feel anxious

about being infected with COVID-19? (Yes/No)”; and “Q38.7 Do you feel anxious about getting infected when you commute to work? (Yes/No).”

Predictor variable

Based on approximate quartiles, the commuting distances were divided into four groups: 3 km or less, 6 km or less, 15 km or less, and longer.

The commuting time was confirmed by the question “Q45. On average, how much time do you spend on the following activities? (more than 2 hours/more than 1 hour/more than 30 minutes/less than 30 minutes/almost never)” and “Q45.8. Time spent on one-way commute (excluding time spent at home)”. In the analysis, the results of this question were used as-is. As for the use of public transportation for commuting, we used the answer to the question “Q38.8 Do you use public transportation to go to work? (Yes/No).”

Potential confounders

The following items, surveyed using a questionnaire, were included as confounding factors. Sex, age (20–29, 30–39, 40–49, 50–59, and ≥ 60 years), and education level (junior or senior high school, junior college or vocational school, and university or graduate school), which were considered as personal factors while occupation (regular employees, managers, executives, public

service workers, temporary workers, freelancers, or professionals) was considered as a work-related factor.

Statistical analyses

Logistic regression analysis was performed for the statistical analysis. For each of the above objective variables, we calculated the odds ratios for commuting time and public transportation use; moreover, commuting distance and public transportation use were considered as explanatory variables, with and without correction for confounding factors. In addition, the p -values of logistic regression analysis were calculated by considering each category scale of commuting distance and commuting time as continuous variables (p for trend). The analysis was conducted using STATA/SE version 15 (StataCorp LLC). The significance level was set at $p < 0.05$.

Results

Participant baseline characteristics are shown in Table 1. The total number of participants in the final analysis was 14,038. In this study, 64 (0.5%) participants had COVID-19, 136 (1.0%) were close contacts, 10,627 (75.7%) were anxious about infection, and 4302 (30.6%) were anxious about infection during commuting. Public transportation was used for commuting by 3676 participants (26.2%).

Results of the logistic regression analysis of the relationship between COVID-19 risk, close contact as an outcome, and commuting time are shown in Table 2. Multiple regression analysis showed that the adjusted odds ratio (aOR) of using public transportation was 4.17 (95% confidence interval [CI]: 2.51–6.93) in the analysis with COVID-19 risk as the outcome, and the trend in commuting time was not significant ($p = 0.131$). In the analysis with close contact as the outcome, the aOR of using public transportation was 1.99 (95% CI: 1.40–2.82) and the trend in commuting time was significant ($p = 0.048$, aOR = 1.13, 95% CI: 1.00–1.28).

The results of the logistic regression analysis of the relationship between COVID-19 risk, close contact as the outcome, and commuting distance are shown in Table 3. In the analysis with COVID-19 risk as the outcome, the aOR of using public transportation was 5.18 (95% CI: 3.06–8.78), and the trend was significant ($p = 0.003$, aOR = 0.70, 95% CI: 0.55–0.88). In the analysis with close contact as the outcome, the aOR for using public transportation use was 2.15 (95% CI: 1.49–3.10), and the trend for commuting time was not significant ($p = 0.109$).

Results of the logistic regression analysis of the relationship between infection anxiety about COVID-19 and commuting time, with infection anxiety about commuting as the outcome are shown in Table 4. In the analysis of infection anxiety as the outcome, the aOR of using

public transportation was 1.44 (95% CI: 1.31–1.59), and the trend in commuting time was significant ($p = 0.004$, aOR = 1.04, 95% CI: 1.01–1.07). In the analysis of infection anxiety related to commuting as an outcome, the aOR of using public transportation was 15.80 (95% CI: 14.39–17.35) and the trend in commuting time was significant ($p = 0.003$, aOR = 1.05, 95% CI: 1.02–1.09).

Results of the logistic regression analysis of the relationship between infection anxiety about COVID-19 and commuting distance, with infection anxiety about commuting as the outcome are shown in Table 5. In the analysis with infection anxiety as the outcome, the aOR of using public transportation was 1.45 (95% CI: 1.32–1.60), and the trend in commuting distance was not significant ($p = 0.744$). In the analysis of infection anxiety related to commuting as an outcome, the aOR for using public transportation was 15.17 (95% CI: 13.78–16.70) and the trend in commuting distance was significant ($p = 0.004$, aOR = 1.06, 95% CI: 1.020–1.11).

Discussion

This study examined the impact of commuting on COVID-19 risk and infection anxiety using an online survey. We analyzed the relationship between the number of persons with COVID-19 and the use of public transportation in commuting, commuting time, and commuting distance. The use of public transportation in commuting has been reported to be associated with COVID-19 risk. Trains and buses are the most common forms of public transportation used for commuting. According to the 2010 census, 24.8% of commuters use the train, and 7.4% use the bus to get to work or school [14]. Furuya et al. reported a mathematical model simulation of influenza virus infection in trains [15]. They showed that the median of the estimated probability distribution of reproduction number (RA) increased linearly with increasing exposure time in the train; when the number of people in the train car was 150, the RA was less than 1 at an exposure time of less than 30 min. The capacity of a typical rail car in Japan is approximately 150 people; however, according to the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), the average congestion rate during commuting hours in the Tokyo metropolitan area is 163%, and 11 of the 31 major sections have congestion rates exceeding 180% [4, 16]. The number of passengers was high compared to that in the previous simulation. In Tokyo, approximately 2.9 million people typically commute by train from surrounding cities [17].

Regarding infection in bus vehicles (another major form of public transportation), mathematical simulations for influenza viruses were reported by Zhu et al. [18]. They found that the infection rate was higher when there were infected people on the air supply

Table 1 Participant baseline characteristics, Japan, nationwide-Internet-based health survey in workers, December 2020

Items	COVID-19		Close contact		Anxiety of infection		Anxiety about infection due to commuting	
	Y	N	Y	N	Y	N	Y	N
Using public transportation								
Y	37	3639	55	3621	2958	718	2719	957
N	27	10,335	81	10,281	7669	2693	1583	8779
Commuting time								
Almost never	16	6256	46	6226	4693	1579	1854	4418
< 30 min	13	2020	24	2009	1571	462	627	1406
< 1 h	16	2272	27	2261	1776	512	730	1558
< 2 h	12	2183	21	2174	1664	531	697	1498
≥ 2 h	7	1243	18	1232	923	327	394	856
Commuting distance								
≤ 3 km	25	4132	46	4111	3149	1008	971	3186
≤ 6 km	12	3035	26	3021	2296	751	818	2229
≤ 15 km	15	4097	37	4075	3133	979	1300	2812
> 15 km	12	2710	27	2695	2049	673	1213	1509
Sex								
Male	36	6639	75	6600	4778	1897	1843	4832
Female	28	7335	61	7302	5849	1514	2459	4904
Age								
20–29 yr	11	1045	16	1040	802	254	380	676
30–39 yr	9	2729	31	2707	2117	621	945	1793
40–49 yr	17	4346	35	4328	3211	1152	1293	3070
50–59 yr	21	4395	37	4379	3360	1056	1256	3160
≥ 60 yr	6	1459	17	1448	1137	328	428	1037
Education								
Junior or senior high school	16	4017	27	4006	3004	1029	1023	3010
Junior college or vocational school	14	3558	39	3533	2787	785	1132	2440
University or graduate school	34	6399	70	6363	4836	1597	2147	4286
Occupation								
Regular employees	32	7368	59	7341	5524	1876	2324	5076
Managers	10	1328	11	1327	1007	331	401	937
Executives	2	329	4	327	253	78	84	247
Public service workers	9	1670	19	1660	1279	400	409	1270
Temporary workers	1	1673	13	1661	1274	400	640	1034
Freelancers or professionals	8	1425	26	1407	1144	289	388	1045
Others	2	181	4	179	146	37	56	127

and exhaust routes, and that the infection rate was higher in areas with mixed ventilation. According to a report by the MLIT, the ventilation capacity of major buses in Japan is approximately 5 min with the windows closed for sightseeing buses, and approximately 3 min for route buses [19]. While several cluster infections have been reported in sightseeing buses, there are no reports of clusters in route buses. This may be due to factors such as the difficulty in tracing

the use of route buses and limited duration of the ride.

We analyzed the relationship between COVID-19 risk, commuting time, and commuting distance. The commuting time did not show a significant trend in COVID-19 risk. There was a significant association between commuting distance and fewer COVID-19 risk with increasing distance. This suggests that the use of public transportation has a greater effect on COVID-19 risk

Table 2 Odds ratios of COVID-19 infection and exposure to close contact in function of commuting time, Japan, nationwide-Internet-based health survey in workers, December 2020

	Unadjusted OR					Adjusted OR				
	OR	95% CI		p	p for trend	OR	95% CI		p	p for trend
		Lower	Upper				Lower	Upper		
COVID-19										
Using public transportation	3.89	2.37	6.40	<.001		4.17	2.51	6.93	<.001	
Commuting time					0.021					0.131
Almost never	1					1				
< 30 min	2.52	1.21	5.24	0.014		2.38	1.13	4.98	0.022	
< 1 h	2.75	1.37	5.52	0.004		2.45	1.21	4.96	0.012	
< 2 h	2.15	1.02	4.55	0.046		1.76	0.82	3.79	0.146	
≥ 2 h	2.21	0.90	5.36	0.082		1.72	0.69	4.29	0.247	
Close contact										
Using public transportation	1.93	1.37	2.72	<.001		1.988	1.399	2.824	<.001	
Commuting time					0.024					0.048
Almost never	1					1				
< 30 min	1.62	0.98	2.66	0.058		1.56	0.94	2.57	0.083	
< 1 h	1.62	1.00	2.61	0.049		1.51	0.93	2.46	0.093	
< 2 h	1.31	0.78	2.20	0.311		1.25	0.74	2.13	0.402	
≥ 2 h	1.98	1.14	3.42	0.015		1.92	1.09	3.40	0.024	

OR odds ratio, CI confidence interval

Adjusted odds ratios are adjusted for sex, age, education, and occupation

Table 3 Odds ratios of COVID-19 infection and exposure to close contact in function of commuting distance, Japan, nationwide-Internet-based health survey in workers, December 2020

	Unadjusted OR					Adjusted OR				
	OR	95% CI		p	p for trend	OR	95% CI		p	p for trend
		Lower	Upper				Lower	Upper		
COVID-19										
Using public transportation	3.89	2.37	6.40	<.001		5.18	3.06	8.78	<.001	
Commuting Distance					0.229					0.003
≤ 3 km	1					1				
≤ 6 km	0.65	0.33	1.30	0.277		0.55	0.27	1.10	0.090	
≤ 15 km	0.61	0.32	1.15	0.125		0.42	0.22	0.82	0.011	
> 15 km	0.73	0.37	1.46	0.375		0.36	0.17	0.75	0.006	
Close contact										
Using public transportation	1.93	1.37	2.72	<.001		2.15	1.49	3.10	<.001	
Commuting Distance					0.568					0.109
≤ 3 km	1					1				
≤ 6 km	0.77	0.47	1.25	0.287		0.74	0.46	1.21	0.229	
≤ 15 km	0.81	0.53	1.25	0.347		0.72	0.46	1.13	0.151	
> 15 km	0.890	0.56	1.44	0.650		0.68	0.41	1.12	0.131	

OR odds ratio, CI confidence interval

The mono-regression analysis of "Using public transportation" is a reiteration of Table 2

Adjusted odds ratios are adjusted for sex, age, education, and occupation

Table 4 Odds ratios of COVID-19 anxiety and for infection anxiety in function of commuting time, Japan, nationwide-Internet-based health survey in workers, December 2020

	Unadjusted OR					Adjusted OR				
	OR	95% CI		p	p for trend	OR	95% CI		p	p for trend
		Lower	Upper				Lower	Upper		
Infection anxiety										
Using public transportation	1.45	1.32	1.59	<.001		1.44	1.31	1.59	<.001	
Commuting time					0.633					0.004
Almost never	1					1				
< 30 min	1.14	1.02	1.29	0.026		1.18	1.05	1.33	0.007	
< 1 h	1.17	1.04	1.31	0.008		1.24	1.11	1.40	<.001	
< 2 h	1.05	0.94	1.18	0.359		1.17	1.04	1.31	0.009	
≥ 2 h	0.95	0.83	1.09	0.465		1.11	0.96	1.28	0.163	
Anxiety about infection due to commuting										
Using public transportation	15.76	14.39	17.26	<.001		15.80	14.39	17.35	<.001	
Commuting time					0.019					0.003
Almost never	1					1				
< 30 min	1.06	0.95	1.19	0.273		1.11	0.97	1.27	0.127	
< 1 h	1.12	1.01	1.24	0.036		1.17	1.03	1.33	0.015	
< 2 h	1.11	1.00	1.23	0.054		1.12	0.98	1.27	0.101	
≥ 2 h	1.10	0.96	1.25	0.167		1.25	1.06	1.48	0.007	

OR odds ratio, CI confidence interval

Adjusted odds ratios are adjusted for sex, age, education, and occupation

Table 5 Odds ratios of COVID-19 anxiety and for infection anxiety in function of commuting distance, Japan, nationwide-Internet-based health survey in workers, December 2020

	Unadjusted OR					Adjusted OR				
	OR	95% CI		p	p for trend	OR	95% CI		p	p for trend
		Lower	Upper				Lower	Upper		
Infection anxiety										
Using public transportation	1.45	1.32	1.59	<.001		1.45	1.32	1.60	<.001	
Commuting distance					0.927					0.744
≤ 3 km	1					1				
≤ 6 km	0.98	0.88	1.09	0.697		0.98	0.88	1.10	0.734	
≤ 15 km	1.02	0.93	1.13	0.640		1.01	0.92	1.12	0.793	
> 15 km	0.98	0.87	1.09	0.653		0.96	0.86	1.08	0.531	
Anxiety about infection due to commuting										
Using public transportation	15.76	14.39	17.26	<.001		15.17	13.78	16.70	<.001	
Commuting distance					<.001					0.004
≤ 3 km	1					1				
≤ 6 km	1.20	1.08	1.34	0.001		0.97	0.86	1.10	0.637	
≤ 15 km	1.52	1.38	1.67	<.001		0.99	0.88	1.11	0.826	
> 15 km	2.64	2.38	2.93	<.001		1.26	1.10	1.43	0.001	

OR odds ratio, CI confidence interval

The mono-regression analysis of "Using public transportation" is a reiteration of Table 4

Adjusted odds ratios are adjusted for sex, age, education, and occupation

than commuting time. Although the generation of drop-lets is limited because most passengers wear masks and there is little conversation on the train during commuting, it is assumed that there is a risk of infection. Moreover, it is assumed that the longer the commuting distance, the more contact opportunities there are, and the higher the likelihood of SARS-CoV-2 infection; nonetheless, the opposite was true. One reason for this might be that the method of transportation changes as the commuting distance increases, even if it is by the same train. The type of trains used could be regular, limited express, or bullet trains. In general, the type of train depends on the distance. During commuting hours, limited express and bullet trains are less likely to be full, unlike regular trains; hence, it is thought that the latter provides more opportunities for human contact.

There was a significant trend in commuting time and the use of public transportation for close contacts. However, there was no significant trend in commuting distance. In Japan, the criterion for close contact is 15 min or more of contact within 1 m without wearing a mask. Since contact time is an important factor in the above criterion, we thought that the relationship of close contact with commuting time may have been stronger than that with commuting distance.

Two types of infection anxiety were analyzed: general infection anxiety and commuting-related infection anxiety. In terms of general infection anxiety, the use of public transportation was significantly associated with increased anxiety with regards to both commuting time and commuting distance. There was no significant trend for commuting distance, although there was a significant trend for commuting time, and the relationship between commuting time and general infection anxiety became stronger as commuting time increased. No significant results were found for infection anxiety and commuting time of more than 2 h. Cases where the commuting time exceeded 2 h are assumed to be cases where people commuted from the suburbs to urban areas, whereas a commuting distance of more than 15 km is possible in both rural and urban areas. In the suburbs, the risk of daily infection is assumed to be lower than in urban areas. The infection anxiety caused by the increased commuting time may have been counterbalanced by the daily low infection risk. Therefore, it is possible that infection anxiety is no longer significant. On the other hand, since the commuting time is long, the infection anxiety due to commuting may have been significant. There was a significant trend both in commuting time and commuting distance with infection anxiety. Several studies have reported that anxiety causes people to apply infection prevention measures [20, 21]. The use of public transportation, commuting time, and commuting distance were all associated with anxiety about infection

due to commuting; the longer the commuting time and distance, the more likely people are to voluntarily intensify infection prevention measures. This may be related to the finding of an inverse relationship between commuting distance and COVID-19 risk. Because of the increased anxiety caused by long-distance commuting, people may voluntarily strengthen their infection control measures during commuting, and the risk of COVID-19 may reduce. A larger number of users share the same space while using public transportation. It is very difficult to avoid the 3Cs (closed spaces, crowded places, and close-contact settings) [22], which are considered to be high risk infection transmission situations. This survey was conducted during the third wave of COVID-19 in Japan, and afterward, a second state of emergency declaration was issued for the Tokyo and other metropolitan areas on January 8, 2021, and on January 14, 2021, respectively. This survey was conducted at a time when the infection was spreading, which may have affected the anxiety about infection; hence, further research is required to clarify our study findings.

The use of public transportation was significantly related to both COVID-19 spread and infection anxiety. To avoid contact with unspecified people, it is important to reduce the frequency of commuting, use non-public transportation for commuting, and resort to telecommuting. In a simulation by Karako et al. [17], it was reported that teleworking by 55% of the workforce may be effective in controlling COVID-19 spread in urban areas. In addition, there are many cases where teleworking is impossible in some industries, such as manufacturing industries. In addition to infection prevention measures, such as ventilation and wearing masks, it is important to track contacts to prevent the spread of COVID-19 through commuting. Contact-tracing applications using the Bluetooth function of smartphones have been developed worldwide [23]. In Japan, a software called COCOA is being used, and it is thought to be useful for this purpose.

This study has some limitations. First, this was a cross-sectional study; thus, causality could not be addressed. Due to the constantly changing social situation surrounding the COVID-19 pandemic, longitudinal follow-up is required. Second, this study was an internet-based questionnaire survey, which may not necessarily contain accurate information. The participants were limited to registered members of the research company. The email to the participants contained the brief theme of the questionnaire, which may have led to a selection bias. In order to minimize bias as much as possible, a sampling plan was designed and conducted according to sex, region, and occupation. Third, the commuting distances used in this study were estimated from the zip codes, which limits the accuracy of the

data. Moreover, because we used a straight line distance between home and work, the overall commuting distance is likely to be underestimated. Commuting is not necessarily limited to a straight line distance between home and work, but may include a variety of activities such as traveling to and from the station and picking up children. This may be one of the reasons for the discrepancy between the results for commuting distance and commuting time; thus, a more detailed survey is required.

Conclusions

COVID-19 risk, close contact, and infection anxiety were all associated with the use of public transportation during commuting. The longer the commute, the greater the chances of having close contacts. Overall infection anxiety was associated with commuting time, but not with commuting distance. Both commuting distance and commuting time were associated with infection anxiety due to commuting; the strength of this association increased with increasing commuting time and distance. To reduce COVID-19 infection and anxiety, it may be helpful to refrain from using public transportation for commuting.

Abbreviations

aOR: Adjusted odds ratio CI: Confidence interval COVID-19: Coronavirus disease 2019 MLIT: Ministry of land, infrastructure, transport, and tourism SARS-CoV-2: Severe acute respiratory syndrome coronavirus 2

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Authors' contributions

HA, manuscript writing and data analysis; KI, data analysis, manuscript review, and advice on interpretation; ST, TN, HE, MT, SM, and AO, manuscript review, advice on interpretation, and funding for research; YF, overall survey planning, questionnaire creation, data analysis, and manuscript drafting. The authors read and approved the final manuscript.

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Availability of data and materials

Data are not available due to ethical restrictions.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the University of Occupational and Environmental Health, Japan (reference No. R2-079). The survey was conducted after an online confirmation of the participants' consent.

Consent for publication

All authors have read and agreed to the publication of the final version of the manuscript.

Competing interests

The authors have no conflicts of interest to declare regarding this study.

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References

- 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;382(18):1708–20. <https://doi.org/10.1056/NEJMoa2002032>.
- Tokyo Metropolitan Government. Report on the results of our telework adoption rate survey! (Report No. 1737). (Retrieved from: <https://www.metro.tokyo.lg.jp/osei/hodohappyo/press/2021/03/06/14.html>) Survey results for the second half of February during the emergency measures period; 2021 (in Japanese). Accessed 14 Mar 2021.
- Hu M, Lin H, Wang J, Xu C, Tatem AJ, Meng B, et al. Risk of coronavirus disease 2019 transmission in train passengers: an epidemiological and modeling study. *Clin Infect Dis*. 2021;72(4):604–10. <https://doi.org/10.1093/cid/ciaa1057>.
- Ministry of Land, Infrastructure, Transport and Tourism. Japan. Crowding rates for major sections in the three major metropolitan areas 2018. (Retrieved from: <https://www.mlit.go.jp/common/001245347.pdf>) (in Japanese). Accessed 14 Mar 2021.
- Qiu J, Shen B, Zhao M, Wang Z, Xie B, Xu Y. A nationwide survey of psychological distress among Chinese people in the COVID-19 epidemic: implications and policy recommendations. *Gen Psychiatr*. 2020;33(2):e100213. <https://doi.org/10.1136/gpsych-2020-100213>.
- Li S, Wang Y, Xue J, Zhao N, Zhu T. The impact of COVID-19 epidemic declaration on psychological consequences: a study on active Weibo users. *IJERPH*. 2020;17(6):2032. <https://doi.org/10.3390/ijerph17062032>.
- Varatharaj A, Thomas N, Ellul MA, Davies NWS, Pollak TA, Tenorio EL, et al. Neurological and neuropsychiatric complications of COVID-19 in 153 patients: a UK-wide surveillance study. *Lancet Psychiatr*. 2020;7(10):875–82. [https://doi.org/10.1016/S2215-0366\(20\)30287-X](https://doi.org/10.1016/S2215-0366(20)30287-X).
- Serafini G, Parmigiani B, Amerio A, Aguglia A, Sher L, Amore M. The psychological impact of COVID-19 on the mental health in the general population. *QJM An Int J Med*. 2020;113(8):531–7. <https://doi.org/10.1093/qjmed/hcaa201>.
- Sasaki N, Kuroda R, Tsuno K, Kawakami N. Workplace responses to COVID-19 associated with mental health and work performance of employees in Japan. *J Occup Health*. 2020;62(1):e12134. <https://doi.org/10.1002/1348-9585.12134>.

10. Fujino Y, Ishimaru T, Eguchi H, Tsuji M, Tateishi S, Ogami A, et al. Protocol for a nationwide internet-based health survey of workers during the COVID-19 pandemic in 2020. *J UOEH*. 2021;43(2):217–25. <https://doi.org/10.7888/juoeh.43.217>.
11. Eysenbach G. Improving the quality of web surveys: the checklist for reporting results of internet E-surveys (CHERRIES). *J Med Internet Res*. 2004; 6(3):e34. <https://doi.org/10.2196/jmir.6.3.e34>.
12. Kawasumi M, Nagata T, Ando H, Hino A, Tateishi S, Tsuji M, et al. Association between preventive measures against workplace infection and preventive behavior against personal infection. *Ind Health*. 2021; (in press).
13. HeartRails Inc. HeartRails geo API. (Retrieved from: <https://geoapi.heartrails.com/>). Accessed 14 Mar 2021.
14. Statistics Bureau. Ministry of Internal affairs and communications. National Census/2010 Census/Aggregate data of population and industries by place of employment and place of commuting (Male and female population, age, and industries of workers (major categories)); 2015. (Retrieved from: https://www.e-stat.go.jp/stat-search/files?page=1&layout=datalist&toukei=00200521&tstat=000001039448&cycle=0&tclass1=000001049567&tclass2=000001051128&stat_infid=000013171990&tclass3val=0 (in Japanese). Accessed 1 Apr 2021.
15. Furuya H. Risk of transmission of airborne infection during train commute based on mathematical model. *Environ Health Prev Med*. 2007;12(2):78–83. <https://doi.org/10.1007/BF02898153>.
16. Ministry of Land, Infrastructure, Transport and Tourism. Japan. Average traffic congestion rate, transport capacity, and number of passengers on major routes in the three major metropolitan areas 2018. (Retrieved from: <https://www.mlit.go.jp/common/001245346.pdf> (in Japanese). Accessed 14 Mar 2021.
17. Karako K, Song P, Chen Y, Tang W. Shifting workstyle to teleworking as a new normal in face of COVID-19: analysis with the model introducing intercity movement and behavioral pattern. *Ann Transl Med*. 2020;8(17): 1056. <https://doi.org/10.21037/atm-20-5334>.
18. Zhu S, Srebric J, Spengler JD, Demokritou P. An advanced numerical model for the assessment of airborne transmission of influenza in bus microenvironments. *Build Environ*. 2012;47:67–75. <https://doi.org/10.1016/j.buildenv.2011.05.003>.
19. Ministry of Land, Infrastructure, Transport and Tourism. Interior ventilation capacity of sightseeing buses and route buses 2020. (Retrieved from: https://www.mlit.go.jp/jidosha/anken/top/data/covid19_info_shyanaikanki.pdf (in Japanese). Accessed 14 Mar 2021.
20. Kwok KO, Li KK, Chan HHH, Yi YY, Tang A, Wei W, et al. Community responses during early phase of COVID-19 epidemic. *Hong Kong Emerg Infect Dis*. 2020;26(7):1575–9. <https://doi.org/10.3201/eid2607.200500>.
21. Magdy D, Metwally A, Magdy O. Assessment of Community Psycho-behavioral Responses during the outbreak of novel coronavirus. 2019–nCoV: a cross-sectional study. 2020. <https://doi.org/10.21203/rs.3.rs-40112/v1>.
22. Ministry of Health, Labour and Welfare, Japan. Important notice for preventing COVID-19 outbreaks. Avoid the “three Cs”; 2020. (Retrieved from: <https://www.mhlw.go.jp/content/3CS.pdf>). Accessed 20 Mar 2021.
23. Nakamoto I, Jiang M, Zhang J, Zhuang W, Guo Y, Jin MH, et al. Evaluation of the design and implementation of a peer-to-peer COVID-19 contact tracing mobile app (COCOA) in Japan. *JMIR mHealth uHealth*. 2020;8(12):e22098. <https://doi.org/10.2196/22098>.

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