Association between COVID-19 infection rates by region and implementation of non-pharmaceutical interventions: a cross-sectional study in Japan

Tomomi Anan[1], Tomohiro Ishimaru[2], Ayako Hino[3], Tomohisa Nagata[1], Seiichiro Tateishi[4], Mayumi Tsuji[5], Akira Ogami[6], Shinya Matsuda[7], Yoshihisa Fujino[2], for the CORoNaWork project

[1]Department of Occupational Health Practice and Management, Institute of Industrial Ecological Sciences, University of Occupational and Environmental Health Japan, Kitakyushu, 807-8555, Japan
[2]Department of Environmental Epidemiology, Institute of Industrial Ecological Sciences, University of Occupational and Environmental Health Japan, Kitakyushu, 807-8555, Japan
[3]Department of Mental Health, Institute of Industrial Ecological Sciences, University of Occupational and Environmental Health Japan Kitakyushu, 807-8555, Japan
[4]Department of Occupational Medicine, School of Medicine, University of Occupational and Environmental Health Japan Kitakyushu, 807-8555, Japan
[5]Department of Environmental Health, School of Medicine, University of Occupational and Environmental Health Japan, Kitakyushu, 807-8555, Japan
[6]Department of Work Systems and Health, Institute of Industrial Ecological Sciences, University of Occupational and Environmental Health Japan, Kitakyushu, 807-8555, Japan
[7]Department of Preventive Medicine and Community Health, School of Medicine, University of Occupational and Environmental Health Japan, Kitakyushu, 807-8555, Japan
Address correspondence to Yoshihisa Fujino, E-mail: zenq@med.uoeh-u.ac.jp.

ABSTRACT

Background During a pandemic, non-pharmaceutical interventions (NPIs) play an important role in protecting oneself and others from infection. There are large regional differences in COVID-19 infection rates in Japan. We hypothesized that the local infection incidence may affect adherence to individual NPIs.

Methods This cross-sectional study was conducted online among full-time workers in Japan in December 2020. The questionnaire asked the respondents to identify their habits regarding seven common NPIs (wearing masks, washing hands after the bathroom, disinfecting hands when entering indoors, gargling when returning home, ventilating the room, disinfecting or washing hands after touching frequently touched surfaces, carrying alcohol sanitizers when outdoors).

Results A total of 27 036 participants were analyzed. Compared with the region with the lowest infection rate, five of the seven NPIs showed statistically significant trends across regional infection levels, the two exceptions being wearing masks and washing hands after the bathroom. Multivariate adjustment did not change these trends.

Conclusions This study found that NPIs were more prevalent in regions with higher incidence rates of COVID-19 in Japanese workers. The findings suggest that the implementation of NPIs was influenced not only by personal attributes but also by contextual effects of the local infection level.

Keywords COVID-19, public health, non-pharmaceutical interventions

Introduction

COVID-19 has spread rapidly all around the world since December 2019. The World Health Organization declared COVID-19 a pandemic on 11 March 2020.[1] Various efforts have been made at a policy level in many countries to prevent the spread of infection during the pandemic, which is ongoing. Many countries have implemented lockdowns, curfews of restaurants and bars, physical distancing, bans on social gatherings and school closures. By the end of 2020, vaccines against COVID-19 had been developed and their roll out had commenced. The Japanese government declared a 'state of emergency' in response to record numbers of cases and

Tomomi Anan, M.D., Assistant Professor
Tomohiro Ishimaru, M.D., M.P.H., Ph.D., Associate Professor
Ayako Hino, M.D., Ph.D., Assistant Professor
Tomohisa Nagata, M.D., Ph.D., Associate Professor
Mayumi Tsuji, M.D., Ph.D., Professor
Akira Ogami, M.D., Ph.D., Professor
Shinya Matsuda, M.D., Ph.D., Professor
Yoshihisa Fujino, M.D., M.P.H., Ph.D., Professor

asked the public to refrain from going out, close restaurants or restrict their opening times, work remotely, and limit or cancel events.[2]

During a pandemic, non-pharmaceutical interventions (NPIs) play an important role in protecting oneself from infection and preventing the spread of infection to others. NPIs are defined as behaviors or actions that individuals or communities can take to slow the spread of pathogens, such as washing hands, wearing masks and physical distancing; they do not include taking medication or receiving vaccines.[3] Centers for disease control and prevention (CDCs) recommend wearing a mask, staying at least 6 feet away from others, avoiding crowds and poorly ventilated spaces, washing hands frequently, cleaning and disinfecting frequently touched surfaces, and monitoring one's health daily.[4] The Japanese government has called on the public to focus on avoiding the 'three Cs': closed spaces, crowded places and close-contact settings and has reminded people to wash their hands, wear masks, ventilate their houses and avoid eating out with others.[5]

Although the implementation of NPIs is important for preventing the spread of infection, some people do not follow the recommended interventions, and some even oppose them. It is already known that adherence to individual NPIs is influenced by demographic factors such as gender, age and place of residence;[6] social factors such as education, income[7,8] and sources of information[9] and psychological factors such as anxiety, fear, political ideology and health beliefs.[7,8,10,11] In the USA, many people in urban areas resist wearing masks, partly due to political ideology.[6,12] Unlike in other countries, the Japanese government's infection control actions do not include mandatory measures such as lockdowns, but mostly request cooperation from the public. Therefore, individuals' attitudes toward the NPIs are a key issue for combatting the spread of infection.

There are large regional differences in COVID-19 infection rates in Japan, which may lead to differences in people's risk perception. The risk perception regarding COVID-19 differs widely among places and individuals and can affect the spread of the virus.[13] One study reported that Japanese people placed most trust in local information[9] about infection status and hospital bed occupancy rates. As the infection rate in a region rises, people start to hear about cases close to them, and infection prevention measures are strengthened in workplaces and public places. We assume that people's risk perceptions are influenced by contextual and environmental factors.

We hypothesized that the local infection incidence rate may affect adherence to individual NPIs. We considered that the incidence rate of COVID-19 in a given region is related to the implementation of such interventions through people's risk perception. To our knowledge, however, very few reports have examined the rate of implementation of NPIs in relation to local infection rates. Here, to test this hypothesis, we examined the association between regional differences in COVID-19 infection levels in Japan and individual NPIs.

Methods

Study design

We conducted a survey from 22 to 26 December 2020, during the third wave of the COVID-19 pandemic, as a part of the Collaborative Online Research on the Novel-coronavirus and Work (CORoNaWork) Project.[14] This cross-sectional study was conducted online among full-time workers in Japan.

The study was approved by the ethics committee of the University of Occupational and Environmental Health, Japan (reference No. R2-079 and R3-006). Participants provided informed consent by completing a form on the survey website.

Study population

A total of 33 087 participants answered an online, self-administered questionnaire. After excluding invalid responses, 27 036 were eligible for analysis. The age-range of the target population was 20–65 years. To take account of regional characteristics, the 47 Japanese prefectures were classified into four levels based on the level of infection. Completed questionnaire samples were extracted from these four regions to obtain equal sample sizes.

Region 1 consisted of Fukushima, Yamaguchi, Aomori, Ehime, Yamagata, Nagasaki, Iwate, Tokushima, Shimane, Kagawa, Niigata, Tottori and Akita prefectures; region 2 of Nagano, Saga, Tochigi, Oita, Toyama, Okayama and Fukui prefectures; region 3 of Gunma, Ishikawa, Gifu, Kumamoto, Ibaraki, Miyagi, Hiroshima, Shiga, Mie, Kochi, Shizuoka, Wakayama, Miyazaki, Yamanashi and Kagoshima prefectures and region 4 of Tokyo, Kanagawa, Saitama, Chiba, Okinawa, Osaka, Hokkaido, Aichi, Hyogo, Fukuoka, Kyoto and Nara prefectures.

Assessment of non-pharmaceutical interventions

The questionnaire asked respondents to report on their habits regarding seven types of NPIs in the last month, namely wearing a mask in public, washing hands after using the bathroom, disinfecting hands with alcohol sanitizers when going inside, gargling when returning home, opening windows or doors to ventilate the room, disinfecting or washing hands after touching frequently touched surfaces such as doorknobs or railings and carrying alcohol sanitizers when going out. Participants answered from the following options: 'always do', 'mostly do', 'not often' or 'almost never'.

Measurement of regional infection level of COVID-19

The infection level in the region where participants lived was measured by the incidence rate for the entire period since the pandemic was declared (per 1000 population), the number of people infected for the entire period, the incidence rate for one month before the survey (per 1000 population) and the number of people infected over the one month.

Assessment of other covariates

Covariates included demographic and socioeconomic factors including age, sex, marital status, household income, educational background, job type, smoking status and the number of employees in the workplace. Age was used as a continuous variable. Marital status was categorized in three groups: currently married, divorced or widowed and never married. Annual equivalent household income was categorized into three groups: 4 70 000–26 50 000 Japanese yen (JPY), 26 50 000–45 00 000 JPY and 45 90 000–1 05 00 000 JPY. Educational background was categorized in three groups: graduated from junior high school; high school and university, graduate school, vocational school or junior college. Job type was categorized in three groups: mainly desk work (clerical or computer work), mainly work involving interpersonal communication (customer service, sales, selling, etc.) and mainly labor (physical work, nursing care, etc.). The number of employees in the workplace was classified into four categories: 1–29, 30–99, 100–999 and ≤1000.

Statistical analysis

We show the participants' demographic information using counts and percentages (Table 1). We compared seven representative NPIs by the four regions using one-way analysis of variance (Table 2).

Age-sex and multivariate adjusted odds ratios (ORs) of incidence rate of COVID-19 in areas associated with each NPI, defined by those who answered 'always do', were estimated with a multilevel logistic model and nested by area of residence (cities, towns and villages). In the multilevel model, the incidence rate of COVID-19 in an area was used as an area-level factor. The multivariate model was adjusted for age, sex, marital status, education, job type, annual equivalent household income, smoking status and number of employees in the workplace. A P-value less than 0.05 was considered statistically significant. All analyses were conducted using Stata (Stata Statistical Software: Release 16; StataCorp LLC, TX, USA).

Results

Table 1 shows basic characteristics of the participants. Regions are classified by the incidence of COVID-19 for the entire period since the pandemic was declared (per 1000). Region 4 had the highest infection rate, at 1.91, followed by region 3 (0.79), region 2 (0.51) and region 1 (0.28). Region 4 includes the Tokyo metropolitan area, which has more urban lifestyle characteristics than the other three regions, such as more single people, higher household incomes, higher education levels, more hospitality workers, fewer manual laborers and more workers in large companies.

Table 2 shows the implementation status of the seven NPIs by region according to the incidence rate of COVID-19. Among the interventions, wearing masks in public places had the highest overall implementation rate, at 86.2%, followed in decreasing order by washing hands after using the bathroom (85.3%), disinfecting hands with alcohol sanitizers when going indoors (55.5%), gargling when returning home (50.9%), opening windows and doors for ventilation (45.0%), disinfecting or washing hands after touching frequently touched surfaces (37.2%) and carrying alcohol sanitizers when going out (31.0%). Six of the NPIs showed a trend in implementation according to area incidence rate of COVID-19 (all Ps < 0.001); the exception was handwashing after using the bathroom.

Table 3 shows the multivariate analyses of the implementation of the seven NPI items. Compared with the region with the lowest infection rate (region 1), the OR for the region with the highest rate (region 4) was 1.24 (95%CI: 1.10–1.40, $P < 0.001$) for wearing a mask in public, 1.08 (95%CI: 0.97–1.20, $P = 0.157$) for washing hands after using the bathroom, 1.17 (95%CI: 1.01–1.35, $P = 0.031$) for disinfecting hands with alcohol sanitizers when going indoors, 1.54 (95%CI: 1.31–1.82, $P < 0.001$) for gargling when returning home, 1.45 (95%CI: 1.20–1.75, $P < 0.001$) for opening windows and doors for ventilation, 1.33 (95%CI: 1.18–1.51, $P < 0.001$) for disinfecting or washing hands after touching frequently touched surfaces and 1.32 (95%CI: 1.17–1.49, $P < 0.001$) for carrying alcohol sanitizers when going out. Five items showed statistically significant trends with regional infection levels: disinfecting hands with alcohol sanitizers when going indoors (P for trend $= 0.030$), gargling when returning home ($P < 0.001$), opening windows and doors for ventilation ($P < 0.001$), disinfecting or washing hands after touching

Table 1 Characteristics of the subjects by area according to incidence rate of COVID-19

	Area according to incidence rate of COVID-19[a]			
	Region 1 (n = 5342)	*Region 2 (n = 5450)*	*Region 3 (n = 5334)*	*Region 4 (n = 10910)*
Age, mean	46.5 (10.7)	45.8 (10.8)	47.1 (10.5)	47.8 (10.3)
Sex, male (%)	2709 (50.7%)	2766 (50.8%)	2725 (51.1%)	5614 (51.5%)
Marriage status				
Currently married	3022 (56.6%)	3211 (58.9%)	2999 (56.2%)	5797 (53.1%)
Divorced or widowed	586 (11.0%)	588 (10.8%)	575 (10.8%)	1094 (10.0%)
Never married	1734 (32.5%)	1651 (30.3%)	1760 (33.0%)	4019 (36.8%)
Annual equivalent household income (JPY)				
4 70 000–26 50 000	1996 (37.4%)	1764 (32.4%)	1893 (35.5%)	3341 (30.6%)
26 50 000–45 00 000	1786 (33.4%)	1927 (35.4%)	1774 (33.3%)	3195 (29.3%)
45 90 000–1 05 00 000	1560 (29.2%)	1759 (32.3%)	1667 (31.3%)	4374 (40.1%)
Educational background				
Junior high	62 (1.2%)	83 (1.5%)	77 (1.4%)	146 (1.3%)
High school	1796 (33.6%)	1450 (26.6%)	1483 (27.8%)	2224 (20.4%)
University, graduate school, vocational school, junior college	3484 (65.2%)	3917 (71.9%)	3774 (70.8%)	8540 (78.3%)
Job type				
Mainly desk work (clerical or computer work)	2689 (50.3%)	2684 (49.2%)	2626 (49.2%)	5469 (50.1%)
Jobs mainly involving interpersonal communication (customer service, sales, selling, etc.)	1287 (24.1%)	1315 (24.1%)	1304 (24.4%)	3021 (27.7%)
Mainly labor (physical work, nursing care, etc.)	1366 (25.6%)	1451 (26.6%)	1404 (26.3%)	2420 (22.2%)
Current smoker, %	1410 (26.4%)	1302 (23.9%)	1386 (26.0%)	2906 (26.6%)
Number of employees in the workplace				
1–29	1209 (22.6%)	1138 (20.9%)	1257 (23.6%)	2561 (23.5%)
30–99	1613 (30.2%)	1444 (26.5%)	1377 (25.8%)	2506 (23.0%)
100–999	1403 (26.3%)	1574 (28.9%)	1424 (26.7%)	2752 (25.2%)
≤1000	1117 (20.9%)	1294 (23.7%)	1276 (23.9%)	3091 (28.3%)
Incidence of COVID-19 for the whole period (per 1000), median (IQR)	0.28 (0.20–0.34)	0.51 (0.51–0.55)	0.79 (0.66–0.88)	1.91 (1.54–3.12)
Number of people infected with COVID-19 for the whole period, median (IQR)	396 (211, 448)	1053 (507, 1073)	1822 (974, 2413)	14 427 (9309, 27 500)
Incidence of COVID-19 in the month before the survey (per1000), median (IQR)	0.89 (0.67–0.14)	0.26 (0.15–0.32)	0.32 (0.25–0.44)	0.74 (0.59–1.06)
Number of people infected with COVID-19 in the month before the survey, median (IQR)	148 (79, 184)	447 (124, 501)	865 (403, 1193)	5596 (3664, 9851)

[a]Region 1: Fukushima, Yamaguchi, Aomori, Ehime, Yamagata, Nagasaki, Iwate, Tokushima, Shimane, Kagawa, Niigata, Tottori and Akita prefectures. Region 2: Nagano, Saga, Tochigi, Oita, Toyama, Okayama and Fukui prefectures. Region 3: Gunma, Ishikawa, Gifu, Kumamoto, Ibaraki, Miyagi, Hiroshima, Shiga, Mie, Kochi, Sizuoka, Wakayama, Miyazaki, Yamanashi and Kagoshima prefectures. Region 4: Tokyo, Kanagawa, Saitama, Chiba, Okinawa, Osaka, Hokkaido, Aichi, Hyogo, Fukuoka, Kyoto and Nara prefectures.

frequently touched surfaces ($P < 0.001$) and carrying alcohol sanitizers when going out ($P < 0.001$). The two NPI items showing no significant trend with regional infection level were wearing a mask in public and washing hands after using the bathroom. Multivariate adjustment did not change any trends.

Discussion

Main finding of this study

This study revealed that people living in areas with higher levels of infection were more likely to engage in various non-pharmaceutical interventions.

What is already known on this topic

Non-pharmaceutical interventions have been recommended as a measure to prevent or slow the spread of COVID-19, along with organizational efforts such as emergency declarations and lockdowns. It has been reported that individual characteristics, such as sociodemographic factors,[6–8] sources of information[9] and psychological factors,[7,8,10,11] are associated with non-pharmaceutical behaviors.

What this study adds

In this study, the association between community infection level and preventive behaviors remained robust even after

Table 2 Non-pharmaceutical interventions by area according to incidence rate of COVID-19

		Area according to incidence rate of COVID-19[a]				
	Total (n = 27036)	*Region 1 (n = 5342)*	*Region 2 (n = 5450)*	*Region 3 (n = 5334)*	*Region 4 (n = 10910)*	*P for trend* [b]
Wearing a mask in public	23 308 (86.2%)	4483 (83.9%)	4736 (86.9%)	4624 (86.7%)	9465 (86.8%)	<0.001
Washing hands after using the bathroom	23 065 (85.3%)	4513 (84.5%)	4661 (85.5%)	4569 (85.7%)	9322 (85.4%)	0.176
Disinfecting hands with alcohol sanitizers when going indoors	15 014 (55.5%)	2850 (53.4%)	2968 (54.5%)	2950 (55.3%)	6246 (57.3%)	<0.001
Gargling when returning home	13 767 (50.9%)	2393 (44.8%)	2462 (45.2%)	2718 (51.0%)	6194 (56.8%)	<0.001
Opening windows and doors for ventilation	12 155 (45.0%)	2107 (39.4%)	2259 (41.4%)	2462 (46.2%)	5327 (48.8%)	<0.001
Disinfecting or washing hands after touching frequently touched surfaces such as doorknobs or railings	10 048 (37.2%)	1759 (32.9%)	1975 (36.2%)	1991 (37.3%)	4323 (39.6%)	<0.001
Carrying alcohol sanitizers when going out	8389 (31.0%)	1464 (27.4%)	1655 (30.4%)	1664 (31.2%)	3606 (33.1%)	<0.001

[a]Area was divided according to incidence rate of COVID-19 for the whole period (per 1000). Median of incidence rates was 0.28 for region 1, 0.51 for region 2, 0.79 for region 3 and 1.91 for region 4.
[b]*P*-values were derived from the nonparametric test for trend.

adjusting for individual factors. The results suggest that the implementation of NPIs is influenced by the regional context.

There are at least three possible reasons why the regional infection level may affect the implementation of NPIs. First, the higher the level of infection in a region, the more people's fear of infection and their risk perception is likely to be affected, which in turn will lead to greater engagement with NPIs. Japanese people trust local government information more than other sources of information[9] and are relatively knowledgeable about the status of infection in their communities. Second, people living in areas with higher levels of infection will encounter more social situations that require NPIs, such as workplaces, restaurants and public facilities. Third, majority synching bias[15] may impact people's implementation of NPIs; this bias is the idea that it is safe to act in the way that people around you are acting and has been demonstrated in a study of factors associated with decision-making regarding evacuation during a disaster.[15] Moreover, a recent report found that the predominant reason for wearing a mask during a pandemic among Japanese people was that wearing a mask was a social norm, whereas the original purpose—preventing personal infection and transmitting it to others—was less important.[16] Majority synching bias is likely to be enhanced as the number of people performing NPIs increases in areas with high infection levels.

Among the NPIs studied here, some showed a dose–response relationship with the local infection level, whereas others—specifically, wearing masks and hand-washing after using the bathroom—did not. We assume that the latter two were not associated with the local infection level because their implementation levels were high, at ~85%, regardless of infection level. In Japan, wearing masks has been widely practiced during epidemics of common colds, influenza, seasonal allergies and infectious gastroenteritis, even since before the current global pandemic.[17] A 2015 survey by the Consumer Affairs Agency, a Japanese government agency, reported that ~85% of respondents said that they washed their hands after using the bathroom.[18] It is likely that the lack of a dose–response relationship in relation to COVID-19 and community infection levels is due to Japanese people being accustomed to wearing masks and washing their hands after using the bathroom, which start with hygiene education in childhood.

In contrast, disinfecting hands with alcohol sanitizers when going indoors, gargling when returning home, opening windows and doors for ventilation, disinfecting or washing hands after touching frequently touched surfaces and carrying alcohol sanitizers when going out were found to have a dose–response relationship with community infection levels. These were newly recommended approaches for helping to prevent

Table 3 ORs of area incidence rate of COVID-19 associated with non-pharmaceutical interventions

	Area according to incidence rate of COVID-19[a]									
	Region 2 (n = 5450)			*Region 3 (n = 5334))*			*Region 4 (n = 10 910)*			*P for trend*
	OR[b]	*95%CI*	*P*	*OR*[b]	*95%CI*	*p*	*OR*[b]	*95%CI*	*P*	
Wearing a mask in public										
model 1[c]	1.26	1.10–1.45	0.001	1.25	1.09–1.42	0.001	1.24	1.10–1.40	<0.001	0.090
model 2[d]	1.23	1.07–1.41	0.004	1.23	1.08–1.40	0.002	1.17	1.03–1.32	0.013	0.334
Washing hands after the bathroom										
model 1[c]	1.09	0.97–1.24	0.143	1.10	0.98–1.24	0.103	1.08	0.97–1.20	0.157	0.385
model 2[d]	1.08	0.96–1.22	0.236	1.09	0.97–1.23	0.158	1.01	0.91–1.13	0.775	0.718
Disinfecting hands with alcohol sanitizers when going indoors										
model 1[c]	1.03	0.87–1.22	0.715	1.11	0.96–1.28	0.147	1.17	1.01–1.35	0.031	0.030
model 2[d]	1.01	0.85–1.19	0.940	1.10	0.95–1.28	0.194	1.14	0.98–1.33	0.081	0.059
Gargling when returning home										
model 1[c]	0.96	0.80–1.17	0.714	1.29	1.10–1.52	0.002	1.54	1.31–1.82	<0.001	<0.001
model 2[d]	0.94	0.78–1.15	0.564	1.28	1.09–1.51	0.003	1.49	1.26–1.76	<0.001	<0.001
Opening windows and doors for ventilation										
model 1[c]	1.05	0.85–1.31	0.633	1.32	1.1–1.59	0.003	1.45	1.2–1.75	<0.001	<0.001
model 2[d]	1.04	0.83–1.29	0.741	1.32	1.1–1.58	0.003	1.41	1.17–1.70	<0.001	0.001
Disinfecting or washing hands after touching frequently touched surfaces such as doorknobs or railings										
model 1[c]	1.14	0.99–1.31	0.069	1.23	1.09–1.40	0.001	1.33	1.18–1.51	<0.001	<0.001
model 2[d]	1.12	0.97–1.29	0.123	1.22	1.08–1.39	0.002	1.30	1.15–1.48	<0.001	<0.001
Carrying alcohol sanitizers when going out										
model 1[c]	1.12	0.98–1.29	0.106	1.21	1.06–1.37	0.003	1.32	1.17–1.49	<0.001	<0.001
model 2[d]	1.11	0.96–1.27	0.163	1.20	1.06–1.37	0.004	1.30	1.15–1.48	<0.001	<0.001

[a]Area was divided according to the incidence rate of COVID-19 for the whole period (per 1000). Median incidence rates were 0.28 for region 1, 0.51 for region 2, 0.79 for region 3 and 1.91 for region 4.

[b]The reference group is region 1 (*n* = 5342).

[c]Model 1 adjusted for age and sex.

[d]Model 2 adjusted for age, sex, marital status, education, job type, annual equivalent household income, smoking status and number of employees in the workplace.

the spread of COVID-19. In previous infectious disease epidemics, carrying alcohol-based disinfectant and washing or disinfecting hands after touching frequently handled doorknobs and handrails were not common prevention behaviors. In view of the widespread recognition that alcohol disinfection is effective against SARS-Cov2[19,20] and that COVID-19 is contact-transmissible,[21] it is likely that such behaviors were reinforced as the infection spread, especially in regions with higher infection rates.

Although ventilating rooms is also widely acknowledged as a measure for preventing infection, it has not been routinely adopted because it causes the room temperature to drop during the winter, and many work environments cannot be ventilated appropriately due to the structure of buildings. During this pandemic, avoiding the 'Three Cs'—closed spaces with poor ventilation, crowded places and close-contact settings—has been strongly recommended, especially in Japan.[5] As many people are aware that ventilation is highly effective in preventing COVID-19 infection, it is not surprising that this NPI is more commonly performed in regions with higher infection rates.

In Japan, people are taught from a young age that gargling is a preventive measure against infectious diseases, starting in schools and households. Gargling is practiced by many people during infectious disease epidemics. However, in the present survey, it emerged that gargling was not so widespread, with a practice prevalence of ∼50%. Although gargling may be effective in preventing upper respiratory tract infections in healthy adults,[22] it is not recommended in the CDC guidelines for infection prevention[4] or even in the Japanese guidelines for preventive measures against COVID-19.[5] Because of their belief in gargling's effectiveness, people in areas with higher levels of community infection may be more concerned about possible infection while away from home and, therefore, practice more proactive gargling behavior.

The present results suggest that individual adherence to NPIs depends not only on individual characteristics but also on the contextual effect of local infection level. Considering that the waxing and waning of infection will be repeated in the future, it is important for people to actively implement NPIs even in areas with low infection levels, where organized campaigns to promote awareness of NPIs may be effective.

Limitation

There are several limitations in this study. First, we conducted a survey of full-time workers only; we did not include part-time workers, housewives, the elderly or people under 15 years of age. Accordingly, the results do not present a complete picture of NPI practices in the community; some reports show different rates of implementation of preventive measures in different age groups.[6] Second, given the cross-sectional nature of the study, it is not possible to assign causation. In other words, it is not possible to compare rates of NPI implementation before and after the increase in COVID-19 infection rate in a given region. Therefore, we cannot conclude that the rate of implementation has increased because of the increase in infectious rate. Third, we used a simple question to measure NPI adherence; details about frequency and timing remain unknown.

Acknowledgements

The current members of the CORoNaWork Project, in alphabetical order, are Yoshihisa Fujino (present chairperson of the study group), Akira Ogami, Arisa Harada, Ayako Hino, Hajime Ando, Hisashi Eguchi, Kazunori Ikegami, Kei Tokutsu, Keiji Muramatsu, Koji Mori, Kosuke Mafune, Kyoko Kitagawa, Masako Nagata, Mayumi Tsuji, Ning Liu, Rie Tanaka, Ryutaro Matsugaki, Seiichiro Tateishi, Shinya Matsuda, Tomohiro Ishimaru and Tomohisa Nagata. All members are affiliated with the University of Occupational and Environmental Health, Japan.

Conflict of interest

The authors declare no conflicts of interest associated with this manuscript.

Ethical approval

This study was approved by the ethics committee of the University of Occupational and Environmental Health, Japan (reference No. R2-079 and R3-006).

Funding

This study was supported and partly funded by the research grant from the University of Occupational and Environmental Health, Japan (no grant number); Japanese Ministry of Health, Labour and Welfare (H30-josei-ippan-002, H30-roudou-ippan-007, 19JA1004, 20JA1006, 210301-1 and 20HB1004); Anshin Zaidan (no grant number); Collabo-Health Study Group (no grant number) and Hitachi Systems, Ltd. (no grant number), and scholarship donations from Chugai Pharmaceutical Co., Ltd. (no grant number).

Informed consent

Informed consent was obtained in the form of the website.

References

1 World Health Organization. Archived: WHO timeline - COVID-19 [Internet]. 2020. https://www.who.int/news/item/27-04-2020-who-timeline---covid-19 (20 July 2021, date last accessed).

2 Office for Novel Coronavirus Disease Control, Cabinet Secretariat, Government of Japan. COVID-19 information and resources [Internet. *Cabinet Secretariat*]. https://corona.go.jp/en/emergency/ (20 July 2021, date last accessed).

3 Centers for Disease Control and Prevention. Nonpharmaceutical interventions (NPIs) [Internet]. https://www.cdc.gov/nonpharmaceutical-interventions/index.html (20 July 2021, date last accessed).

4 Centers for Disease Control and Prevention. COVID-19 how to protect yourself & others [Internet]. https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/prevention.html (20 July 2021, date last accessed).

5 Ministry of Health, Labour, and Welfare. Information on health and medical consultation [Internet]. https://www.mhlw.go.jp/stf/covid-19/kenkou-iryousoudan_00006.html#1-1 (20 July 2021, date last accessed).

6 Haischer MH, Beilfuss R, Hart MR *et al.* Who is wearing a mask? Gender-, age-, and location-related differences during the COVID-19 pandemic. *PLoS One* [Internet]. 2020;**15**(**10**): e0240785.

7 Seale H, Dyer CEF, Abdi I *et al.* Improving the impact of non-pharmaceutical interventions during COVID-19: examining the factors that influence engagement and the impact on individuals. *BMC Infect Dis* [Internet]. 2020;**20**(**1**):607.

8 Sim SW, Moey KSP, Tan NC. The use of facemasks to prevent respiratory infection: a literature review in the context of the health belief model. *Singapore Med J [Internet]* 2014;**55**(**3**):160–7

9 Muto K, Yamamoto I, Nagasu M *et al*. Japanese citizens' behavioral changes and preparedness against COVID-19: an online survey during the early phase of the pandemic. *PLoS One* [Internet] 2020;**15**(**6**): e0234292.

10 Rosenstock IM, Strecher VJ, Becker MH. Social learning theory and the health belief model. *Health Educ Q* [Internet] 1988;**15**(**2**):175–83.

11 Costa MF. Health belief model for coronavirus infection risk determinants. *Rev Saude Publica [Internet]* 2020;**54**:47.

12 Atske S. Republicans, democrats move even further apart in coronavirus concerns [Internet]. https://www.pewresearch.org/politics/2020/06/25/republicans-democrats-move-even-further-apart-in-coronavirus-concerns/ (20 July 2021, date last accessed).

13 Cori L, Bianchi F, Cadum E, Anthonj C. Risk perception and COVID-19. *Int J Environ Res Public Health* [Internet] 2020;**17**(**9**): 3–4.

14 Fujino Y, Ishimaru T, Eguchi H *et al*. Protocol for a Nationwide Internet-based Health Survey of Workers During the COVID-19 Pandemic in 2020. *J UOEH*. 2021;**43**(2):217–225.

15 Ito K, Sato Y. Evacuation support system to control emotional level of crowd: simulation-based evaluation under various scales and ratios of guide robots for evacuees. *Artif Life Robot* [Internet] 2021;**26**(**1**): 61–5.

16 Nakayachi K, Ozaki T, Shibata Y, Yokoi R. Why do Japanese people use masks against COVID-19, even though masks are unlikely to offer protection from infection. *Front Psychol* [Internet] 2020;**11**:1918. http://dx.doi.org/10.3389/fpsyg.2020.01918.

17 weathernews. *About half of all respondents wore masks, up 23 points in two months*! (written in Japanese) [Internet]. 2018. https://weathernews.jp/s/topics/201801/260055/ (1 June 2021, date last accessed).

18 Consumers Affairs Agency, Government of Japan. The survey on consumers' hand washing [internet]. Ministry of Health Labour, and Welfare. 2015. https://www.mhlw.go.jp/file/06-Seisakujouhou-11130500-Shokuhinanzenbu/0000104951.pdf (1 June 2021, date last accessed).

19 Golin AP, Choi D, Ghahary A. Hand sanitizers: a review of ingredients, mechanisms of action, modes of delivery, and efficacy against coronaviruses. *Am J Infect Control [Internet]*. 2020;**48**(**9**):1062–7.

20 Jairoun AA, Al-Hemyari SS, Shahwan M. The pandemic of COVID-19 and its implications for the purity and authenticity of alcohol-based hand sanitizers: the health risks associated with falsified sanitizers and recommendations for regulatory and public health bodies. *Res Social Adm Pharm [Internet]* 2021;**17**(**1**):2050–1.

21 Wiersinga WJ, Rhodes A, Cheng AC *et al*. Pathophysiology, transmission, diagnosis, and treatment of coronavirus disease 2019 (COVID-19): a review. *JAMA [Internet]* 2020;**324**(**8**):782–93..

22 Satomura K, Kitamura T, Kawamura T *et al*. Prevention of upper respiratory tract infections by gargling: a randomized trial. *Am J Prev Med [Internet]* 2005;**29**(**4**):302–7.