

## Factors associated with acceptance of a digital contact tracing application for COVID-19 in the Japanese working-age population

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### ABSTRACT

The working-age population is at the epicenter of coronavirus disease 2019 (COVID-19) infections. Therefore, it is important to increase the acceptance of digital contact tracing apps in this population. Contact-Confirming Application (COCOA) is the only digital contact tracing app in Japan. This study aimed to determine factors associated with acceptance of the COCOA for COVID-19 in the Japanese working-age population. A cross-sectional study was performed for 27,036 full-time workers registered with an internet survey company during December 2020 in Japan. Factors associated with COCOA adoption were evaluated by multivariate logistic regression analysis. The rate of downloading the COCOA was 25.1%. The COCOA was more likely to be accepted by people with married status, university graduation or above, higher income, and occupations involving desk work. Fear of COVID-19 transmission, wearing a mask, using hand disinfection, willingness to be vaccinated against COVID-19, and presence of an acquaintance infected with COVID-19 were also associated with a greater likelihood of adopting the app. The rate of downloading the COCOA in Japan was not very high. The present findings have important implications for widespread adoption of digital contact tracing apps in working-age populations in Japan and elsewhere.

Keywords: contact tracing, COVID-19, SARS-CoV-2, smartphone, worksite

Abbreviations:

CI: confidence interval

COCOA: Contact-Confirming Application

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COVID-19: coronavirus disease 2019

DCT: digital contact tracing

OR: odds ratio

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## INTRODUCTION

Digital contact tracing (DCT) has been used in many countries in response to the coronavirus disease 2019 (COVID-19) pandemic. DCT apps implemented in mobile devices (eg smartphones) can be employed to detect close contact with infected individuals and prevent the spread of COVID-19.<sup>1</sup> Although the method of contact tracing has been used for a long time, traditional paper-based surveys are complicated and time-consuming, and are affected by loss of questionnaires and huge amounts of data entry.<sup>2</sup> With the recent development of digital technology and the widespread use of mobile devices, DCT has overcome the shortcomings of traditional paper-based surveys and made it possible to conduct surveys more quickly. In recent years, DCT has been associated with effective control of Ebola hemorrhagic fever in Sierra Leone, tuberculosis in Botswana, and whooping cough in the United States.<sup>3</sup>

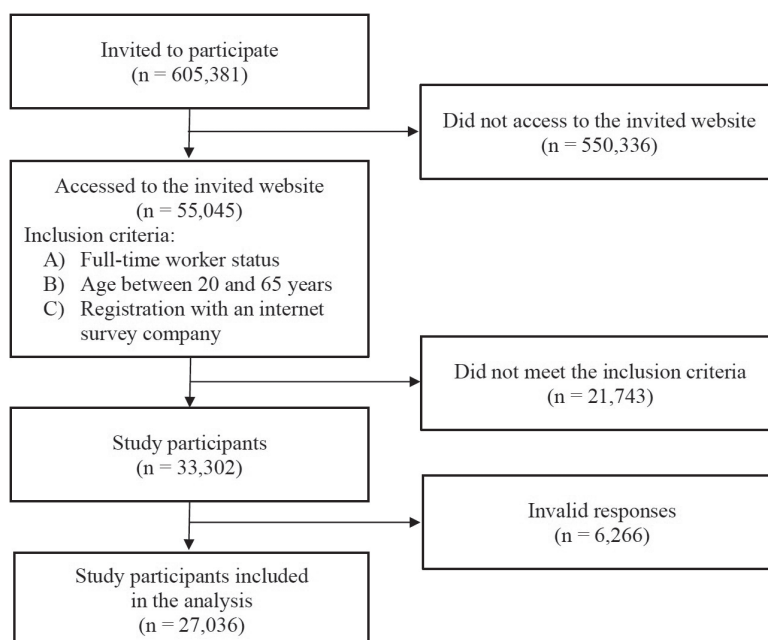
Ensuring that large numbers of people install DCT apps is essential for effective operation of DCT against COVID-19.<sup>4-6</sup> Previous studies revealed that demographic, behavioral, psychological, and COVID-19-related factors all influence the installation of DCT apps.<sup>1,3,7-9</sup> From the demographic aspect, ethnic minorities, migrants, low-income people, and elderly people were less likely to install the apps.<sup>3</sup> From the behavioral aspect, non-smoking status was associated with high app acceptance, while lack of information technology skills and not having a smartphone were associated with low app acceptance.<sup>1,8</sup> From the psychological aspect, low app acceptance was associated with doubts about the effectiveness of DCT apps, anxiety about the collection of personal information, and distrust of the government and app developers.<sup>8,9</sup> From the COVID-19-related aspect, acceptance of new lifestyles under the COVID-19 epidemic such as use of hand sanitizers, avoidance of public transportation, and wearing masks was associated with app use.<sup>7,8</sup>

Because the working-age population is at the epicenter of COVID-19 infections, it is important to increase the acceptance of DCT apps in this population.<sup>10</sup> In other words, the public health benefits of adopting these apps need to be particularly recognized by the working-age population.<sup>9,11</sup> In countries where installation of DCT apps is optional, such as North America, Europe, Oceania, and Japan, the installation rates tend to be lower compared with countries where it is mandatory.<sup>1,7,12</sup> However, few studies have evaluated the factors associated with acceptance of DCT apps using sufficient sample sizes of workers.<sup>13</sup> The purpose of the present study was to evaluate the factors associated with acceptance of a DCT app for COVID-19 in the working-age population of Japan, where app installation is optional. The findings provide insights that can help to facilitate the adoption of DCT apps among workers.

## MATERIALS AND METHODS

### *Study design and participants*

The present study had a cross-sectional design and used baseline questionnaire data from a prospective cohort research project in Japan, the Collaborative Online Research on the Novel-coronavirus and Work (CORoNaWork), between 22 and 26 December 2020.<sup>14</sup> The study supplements another study from the CORoNaWork project that evaluated occupational factors



**Fig. 1** Flow chart of the study participants

associated with DCT adoption.<sup>10</sup> During the research period, COVID-19 vaccines had not yet been introduced in Japan and the third wave of infection was at its peak, with more than 3,000 new infections per day.<sup>15</sup> The inclusion criteria for the study were: full-time worker status, age between 20 and 65 years, and registration with an internet survey company. A flow chart of the study participants is shown in Figure 1. Invitations were sent by e-mail to 605,381 people registered with an internet survey company, of whom 55,045 people accessed the linked website. Of these, 33,302 participants who met the inclusion criteria provided informed consent and completed the baseline survey in an online format. After excluding 6,266 participants who gave incorrect answers to questions designed to identify inappropriate responses, 27,036 participants were eligible for the analysis. This study was approved by the Ethics Committee of the University of Occupational and Environmental Health, Japan (R2-079).

#### *The Contact-Confirming Application (COCOA) DCT app in Japan*

The COCOA is the only DCT app in Japan and was released by the Ministry of Health, Labour and Welfare in June 2020. The COCOA uses a decentralized approach through Bluetooth and is designed not to store personal information on a central server controlled by the government or the developer. Furthermore, downloading and deleting the COCOA is optional. If a person comes into contact with a COVID-19-positive person within a 1-m radius for more than 15 minutes, the person is notified as a close contact.<sup>6</sup>

#### *Dependent variable*

The dependent variable in the study was the following question about adoption of the COCOA: “Have you downloaded the COCOA?” The response options were “yes” and “no”.

#### *Independent variables*

Based on relevant studies, the independent variables were divided into four aspects: demo-

graphic, behavioral, psychological, and COVID-19 transmission-related variables.<sup>1,3,7-9</sup> Demographic variables included sex, age, marital status, education, annual household income (in Japanese yen), occupation (desk work, work with interpersonal communication, manual work), and family members living together. Behavioral variables included smoking status, alcohol consumption, and regular doctor's visits for chronic diseases. Psychological variables included fear of COVID-19 transmission. Variables related to COVID-19 transmission included wearing a mask, using hand sanitizer, willingness to be vaccinated against COVID-19, and presence of an acquaintance infected with COVID-19.

### Statistical analysis

Factors associated with COCOA adoption were evaluated by univariate and multivariate logistic regression analyses, and the results were presented as odds ratios [ORs] and 95% confidence interval [CIs]. The multivariate analyses were adjusted for sex, age, marital status, education, and annual household income, based on relevant studies.<sup>1,3,7-9</sup> The *P*-values were two-sided, and statistical significance was set at  $P < 0.05$ . All statistical analyses were performed using Stata/SE 16.1 software (StataCorp, College Station, TX, USA).

## RESULTS

Table 1 shows the general characteristics of the study participants. Of the 27,036 participants, around half were men (51.1%), married (55.6%), educated at university or graduate school (48.7%), and engaged in desk work (49.8%). Regarding acceptance of the DCT app for COVID-19, 6,786 respondents (25.1%) reported that they had downloaded the COCOA.

**Table 1** General characteristics of the study participants

	Total N=27,036 n (%)	Acceptance of digital contact tracing application for COVID-19	
		Yes n=6,786 n (%)	No n=20,250 n (%)
Sex			
Women	13,222 (48.9)	3,181 (46.9)	10,041 (49.6)
Men	13,814 (51.1)	3,605 (53.1)	10,209 (50.4)
Age			
20–39 years	6,763 (25.0)	1,669 (24.6)	5,094 (25.2)
40–49 years	8,011 (29.6)	1,886 (27.8)	6,125 (30.2)
50–59 years	9,012 (33.4)	2,359 (34.8)	6,653 (32.9)
60–65 years	3,250 (12.0)	872 (12.8)	2,378 (11.7)
Marital status			
Single	9,164 (33.9)	1,991 (29.4)	7,173 (35.4)
Divorced or widowed	2,843 (10.5)	722 (10.6)	2,121 (10.5)
Married	15,029 (55.6)	4,073 (60.0)	10,956 (54.1)
Education			
Junior high or high school	7,321 (27.1)	1,647 (24.3)	5,674 (28.0)
Vocational school or college	6,544 (24.2)	1,552 (22.9)	4,992 (24.7)
University or graduate school	13,171 (48.7)	3,587 (52.8)	9,584 (47.3)

Annual household income			
< 2,000,000 yen	1,709 (6.3)	277 (4.1)	1,432 (7.1)
2,000,000–3,999,999 yen	5,548 (20.5)	1,188 (17.5)	4,360 (21.5)
4,000,000–7,999,999 yen	11,927 (44.1)	2,925 (43.1)	9,002 (44.5)
≥ 8,000,000 yen	7,852 (29.1)	2,396 (35.3)	5,456 (26.9)
Job type			
Manual work	6,641 (24.6)	1,283 (18.9)	5,358 (26.5)
Desk work	13,468 (49.8)	3,736 (55.1)	9,732 (48.1)
Work involving interpersonal communication	6,927 (25.6)	1,767 (26.0)	5,160 (25.5)
Family living together			
No	5,807 (21.5)	1,400 (20.6)	4,407 (21.8)
Yes	21,229 (78.5)	5,386 (79.4)	15,843 (78.2)
Smoking			
Never	14,587 (54.0)	3,495 (51.5)	11,092 (54.8)
Past	5,445 (20.1)	1,551 (22.9)	3,894 (19.2)
Current	7,004 (25.9)	1,740 (25.6)	5,264 (26.0)
Alcohol intake			
Never	11,472 (42.4)	2,699 (39.8)	8,773 (43.3)
Occasionally	4,547 (16.8)	1,186 (17.5)	3,361 (16.6)
Regular	11,017 (40.8)	2,901 (42.7)	8,116 (40.1)
Regular doctor's visits for chronic diseases			
No	17,526 (64.8)	4,008 (59.1)	13,518 (66.8)
Yes	9,510 (35.2)	2,778 (40.9)	6,732 (33.2)
Fear of COVID-19 transmission			
No	7,019 (26.0)	1,049 (15.5)	5,970 (29.5)
Yes	20,017 (74.0)	5,737 (84.5)	14,280 (70.5)
Wearing a mask			
Rarely/never	682 (2.5)	84 (1.2)	598 (3.0)
Often	3,046 (11.3)	570 (8.4)	2,476 (12.2)
Always	23,308 (86.2)	6,132 (90.4)	17,176 (84.8)
Using hand sanitizer			
Rarely/never	3,740 (13.8)	633 (9.3)	3,107 (15.3)
Often	8,282 (30.6)	1,965 (29.0)	6,317 (31.2)
Always	15,014 (55.4)	4,188 (61.7)	10,826 (53.5)
Willing to receive the COVID-19 vaccine			
No	16,889 (62.5)	3,467 (51.1)	13,422 (66.3)
Yes	10,147 (37.5)	3,319 (48.9)	6,828 (33.7)
Presence of an acquaintance infected with COVID-19			
No	24,760 (91.6)	5,947 (87.6)	18,813 (92.9)
Yes	2,276 (8.4)	839 (12.4)	1,437 (7.1)

COVID-19: coronavirus disease 2019

Table 2 presents the factors associated with acceptance of the DCT app for COVID-19. In the multivariate analyses, married (adjusted OR: 1.29; 95% CI: 1.17–1.43) and divorced/widowed (adjusted OR: 1.16; 95% CI: 1.09–1.25) individuals had significantly higher acceptance of the DCT app than single individuals. Similarly, people with a university or graduate school degree had higher acceptance of the DCT app than people with a junior high school or high school degree (adjusted OR: 1.19; 95% CI: 1.11–1.28). Higher annual income was associated with higher acceptance of the app ( $\geq 8,000,000$  yen: adjusted OR: 2.08; 95% CI: 1.80–2.39). In contrast, acceptance of the app was lower among people living with family members (adjusted OR: 0.82; 95% CI: 0.76–0.89).

From the behavioral aspect, past smokers were more accepting of the app than non-smokers (adjusted OR: 1.24; 95% CI: 1.15–1.34), but there was no significant difference for smokers. Patients who regularly visited the hospital for chronic diseases were more likely to accept the app than patients who did not (adjusted OR: 1.39; 95% CI: 1.32–1.48). From the psychological aspect, the odds of accepting the app were 2.29 times (95% CI: 2.13–2.47) higher in people who feared COVID-19 transmission. From the COVID-19-related aspect, people who always wore a mask (adjusted OR: 2.44; 95% CI: 1.94–3.08) or used hand sanitizer (adjusted OR: 1.88; 95% CI: 1.71–2.07) were more likely to accept the app than people who rarely or never performed these actions. Acceptance of the app had 1.83 times higher odds (95% CI: 1.73–1.94) among people who were willing to receive the COVID-19 vaccine than among people who were not. Similarly, people who had an acquaintance infected with COVID-19 had 1.76 times higher odds (95% CI: 1.61–1.93) of accepting the app than people who did not.

**Table 2** Factors associated with acceptance of the digital contact tracing application for COVID-19

	Univariate			Multivariate*		
	OR	(95% CI)	P	OR	(95% CI)	P
Sex						
Women	1.00	–	–	1.00	–	–
Men	1.12	(1.06–1.18)	<0.001	1.03	(0.96–1.10)	0.402
Age						
20–39 years	1.00	–	–	1.00	–	–
40–49 years	0.94	(0.87–1.01)	0.108	0.90	(0.83–0.98)	0.011
50–59 years	1.08	(1.01–1.16)	0.033	0.99	(0.91–1.07)	0.752
60–65 years	1.12	(1.02–1.23)	0.020	1.01	(0.91–1.12)	0.873
Marital status						
Single	1.00	–	–	1.00	–	–
Divorced or widowed	1.23	(1.11–1.35)	<0.001	1.16	(1.09–1.25)	<0.001
Married	1.34	(1.26–1.42)	<0.001	1.29	(1.17–1.43)	<0.001
Education						
Junior high or high school	1.00	–	–	1.00	–	–
Vocational school or college	1.07	(0.99–1.16)	0.089	1.08	(0.99–1.17)	0.078
University or graduate school	1.29	(1.21–1.38)	<0.001	1.19	(1.11–1.28)	<0.001
Annual household income						
< 2,000,000 yen	1.00	–	–	1.00	–	–
2,000,000–3,999,999 yen	1.41	(1.22–1.63)	<0.001	1.40	(1.21–1.61)	<0.001
4,000,000–7,999,999 yen	1.68	(1.47–1.92)	<0.001	1.60	(1.39–1.83)	<0.001
$\geq 8,000,000$ yen	2.27	(1.98–2.60)	<0.001	2.08	(1.80–2.39)	<0.001

Acceptance of the COCOA in Japan

Job type						
Manual work	1.00	–	–	1.00	–	–
Desk work	1.60	(1.49–1.72)	<0.001	1.49	(1.38–1.60)	<0.001
Work involving interpersonal communication	1.43	(1.32–1.55)	<0.001	1.36	(1.25–1.48)	<0.001
Family living together						
No	1.00	–	–	1.00	–	–
Yes	1.07	(1.00–1.15)	0.049	0.82	(0.76–0.89)	<0.001
Smoking						
Never smoking	1.00	–	–	1.00	–	–
Past smoking	1.26	(1.18–1.36)	<0.001	1.24	(1.15–1.34)	<0.001
Current smoking	1.05	(0.98–1.12)	0.156	1.05	(0.98–1.12)	0.212
Alcohol intake						
Never	1.00	–	–	1.00	–	–
Occasionally	1.15	(1.06–1.24)	0.001	1.12	(1.03–1.21)	0.006
Regular	1.16	(1.09–1.23)	<0.001	1.08	(1.02–1.15)	0.014
Regular doctor's visits for chronic diseases						
No	1.00	–	–	1.00	–	–
Yes	1.39	(1.32–1.47)	<0.001	1.39	(1.32–1.48)	<0.001
Fear of COVID-19 transmission						
No	1.00	–	–	1.00	–	–
Yes	2.29	(2.13–2.46)	<0.001	2.29	(2.13–2.47)	<0.001
Wearing a mask						
Rarely/never	1.00	–	–	1.00	–	–
Often	1.64	(1.28–2.10)	<0.001	1.57	(1.23–2.01)	<0.001
Always	2.54	(2.02–3.20)	<0.001	2.44	(1.94–3.08)	<0.001
Using hand sanitizer						
Rarely/never	1.00	–	–	1.00	–	–
Often	1.53	(1.38–1.69)	<0.001	1.50	(1.36–1.66)	<0.001
Always	1.90	(1.73–2.08)	<0.001	1.88	(1.71–2.07)	<0.001
Willing to receive the COVID-19 vaccine						
No	1.00	–	–	1.00	–	–
Yes	1.88	(1.78–1.99)	<0.001	1.83	(1.73–1.94)	<0.001
Presence of an acquaintance infected with COVID-19						
No	1.00	–	–	1.00	–	–
Yes	1.85	(1.69–2.02)	<0.001	1.76	(1.61–1.93)	<0.001

COVID-19: coronavirus disease 2019

OR: odds ratio

CI: confidence interval

*P*: *P* value

\*Adjusted for sex, age, income, marital status, education, and annual household income.

## DISCUSSION

In the present study, the rate of downloading the COCOA in Japan was not very high at 25.1%. The results revealed that there were several factors associated with downloading of the DCT app for each of the demographic, behavioral, psychological, and COVID-19-related variables. Although different countries have differing policies toward DCT apps, the present results suggest that adoption of DCT apps may be influenced by individual characteristics. The findings of the present study have important implications for the widespread adoption of DCT apps in working-age populations in Japan and elsewhere.

From the demographic aspect, the present study showed that the DCT app was more likely to be accepted by people with married status, university graduation or above, higher income, and desk work. These findings suggest that relatively wealthy people in society are more likely to use DCT apps, consistent with previous studies conducted in many countries including the United States, the United Kingdom, Switzerland, and Japan.<sup>8,16-18</sup> In contrast, the present study found that living with family members tended to reduce the use of the DCT app, which was inconsistent with a previous study.<sup>19</sup> Although the reason for the discrepancy remains unclear, it is possible that family interactions reduced anxiety about COVID-19, which in turn reduced the need for the DCT app. Conflicting results were also reported in another study. Specifically, Tomczyk et al<sup>20</sup> pointed out that greater perceived usefulness of DCT apps was associated with greater fear of COVID-19 infection and lower adoption of the apps. Therefore, people who are afraid of letting their families know that they are infected with COVID-19 may tend to avoid DCT apps.

From the behavioral aspect, individuals with regular doctor's visits for chronic diseases and past smokers were more willing to adopt the DCT app, while current smokers showed no association in the present study. The severity of COVID-19 was reported to be higher in people with regular doctor's visits for chronic diseases such as hypertension and respiratory disease, and in smokers.<sup>21</sup> Therefore, the present results suggest that people with a greater risk of severe COVID-19 are more positive about adopting DCT apps. On the contrary, current smokers generally have limited access to health information, which may have attenuated the result.<sup>22</sup> Measures are needed to facilitate adoption of DCT apps by these people. For example, it may be useful for family physicians to encourage their patients to adopt DCT apps.

From the psychological aspect, fear of COVID-19 transmission was strongly associated with higher acceptance of the DCT app, consistent with a previous study in the United Kingdom that found a positive association between risk perception for COVID-19 infection and acceptance of DCT apps.<sup>17</sup> Kawakami et al<sup>19</sup> found that installation of a DCT app mitigated the psychological distress associated with the risk of COVID-19 infection. Taken together, the findings suggest that fear of COVID-19 transmission increases the adoption of DCT apps and that appropriate adoption of DCT apps may reduce anxiety about COVID-19.

From the COVID-19-related aspect, wearing a mask, using hand disinfection, willingness to be vaccinated against COVID-19, and presence of an acquaintance infected with COVID-19 led to greater likelihood of adopting the DCT app. A previous study in Singapore demonstrated similar findings for mask wearing and hand sanitizer use.<sup>7</sup> A similar trend was also observed in a study conducted in the United States, wherein people infected with COVID-19 had a higher acceptance rate of DCT apps.<sup>18</sup> Based on these findings, posting Quick Response codes for DCT apps on the packages of masks and hand sanitizers and at vaccination sites may be an effective measure. A function for inviting friends within the apps may also be effective.<sup>9</sup>

There are several limitations to this study. First, we recruited participants who were registered with an internet research company. Therefore, we may have selected people who actively used the internet, smartphones, and apps. However, we consider this potential selection bias to be negligible



because the COCOA downloading rate announced by the Ministry of Health, Labour and Welfare in December 2020 was 20.8%,<sup>23</sup> and thus close to the rate in the present study (25.1%). Second, the present study used cross-sectional data for a single period of time. Therefore, the findings can only suggest associations between factors for this given period of time, and cannot capture changes over time within individuals. Third, in the multivariate logistic regression analyses, there was a possibility of unmeasured confounding. Unmeasured personal habits and behavioral patterns may have influenced the adoption of the DCT app.

## CONCLUSION

The present study revealed factors associated with adoption of a DCT app among the working-age population in Japan. Use of the COCOA among Japanese workers was not sufficient, and it is important to develop an approach based on the present findings. We found that relatively wealthy people in society were more likely to use the DCT app. In addition, people with a greater risk of severe COVID-19 were more positive about adopting the DCT app. Fear of COVID-19 transmission increased adoption of the DCT app, suggesting that appropriate adoption of DCT apps can reduce anxiety about COVID-19. Because wearing a mask, using hand disinfection, and willingness to be vaccinated against COVID-19 were associated with greater likelihood of adopting the DCT app, posting Quick Response codes for DCT apps on the packages of masks and hand sanitizers and at vaccination sites may be an effective measure.

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

## CONFLICT OF INTEREST

The authors and the project members listed in the Acknowledgements declare no conflict of interest.

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