Temporal changes in factors associated with COVID-19 vaccine hesitancy and uptake among adults in Hong Kong: Serial cross-sectional surveys

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Summary

Background COVID-19 vaccine hesitancy can lead to reduced vaccine uptake and hinder the safe relaxation of other public health measures. This study aims to explore the factors associated with vaccine hesitancy and uptake among adults before and after the implementation of the COVID-19 vaccination program in Hong Kong.

Methods Cross-sectional telephone surveys were conducted every four weeks over a nine-month period from November 2020 through July 2021. Target respondents were Hong Kong resident aged 18 or above and recruited by random-digit dialling. In each survey, responses on COVID-19 vaccine hesitancy and COVID-19 vaccine uptake were collected as primary and secondary outcomes, respectively. Data of potentially associated factors, including socio-demographics, chronic medical conditions, perceived risk of COVID-19, perceived personal efficacy in self-protection, confidence in the government's ability to control the pandemic, compliance with social distancing measures, and confidence in COVID-19 vaccines, were also collected. Multivariable logistic regression models were used to examine the factors associated with COVID-19 vaccine hesitancy at different time points.

Findings Ten cross-sectional surveys were conducted, including 7411 respondents. The levels of vaccine hesitancy fluctuated over time. From December 2020 to May 2021, the age group with the highest vaccine hesitancy was young adults 18–34y, while the vaccine hesitancy was highest among adults ≥ 65y in June-July 2021 (Fig. 2C). Our regression analyses (Fig. 3) showed that before and at the beginning of the rollout of the mass vaccination program, there was no statistically significant association between chronic medical conditions and vaccine hesitancy. However, two-five months after the program implementation respondents with chronic medical conditions were more likely to be hesitant. From January to June 2021, higher confidence in the government was associated with lower vaccine hesitancy (Fig. 3). Confidence in COVID-19 vaccines was consistently associated with lower vaccine hesitancy at different stages of the program.

Interpretation The factors associated with COVID-19 vaccine hesitancy changed over time. This study highlighted the importance to monitor temporal changes in COVID-19 vaccine hesitancy and associated factors, and adjust promotion strategies correspondingly to boost vaccination uptake.

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Introduction

There is strong evidence that COVID-19 vaccines are effective for preventing symptomatic SARS-CoV-2 infections and reducing COVID-19-related hospitalizations and complications,[1–3] despite having lower efficacy against mild-to-moderate infections and disease

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Research in context

Evidence before this study

Vaccine hesitancy is one of the 10 threats to global health according to the World Health Organization. In the era of COVID-19, vaccine hesitancy affects vaccination coverage in many parts of the world. Some studies have explored the factors associated with COVID-19 vaccine hesitancy at single points in time, but relatively few studies have explored factors associated with changing hesitancy over time at different phases of the COVID-19 pandemic and different stages of COVID-19 vaccination programs. We searched PubMed on 4 December 2021 for cross-sectional studies assessing the temporal changes of potential factors associated with COVID-19 vaccination intention and vaccine hesitancy with the following search terms ((COVID-19 OR SARS-CoV-2) AND (vaccine hesitancy OR vaccine uptake OR vaccination intention) AND (factors OR predictors OR determinants OR reasons OR drivers OR barriers) AND (changes OR change OR trend OR overtime OR over time OR temporal)). We found two studies examining the potential factors associated with the changing vaccination intention or vaccine hesitancy at different time points before the rollout of the mass COVID-19 vaccination programs and five studies examining the potential factors at different time points at the beginning and after the program rollout. None of them comprehensively studied the temporal changes of potential factors associated with COVID-19 vaccination intention or vaccine hesitancy before and after the rollout of the mass COVID-19 vaccination program.

Added value of this study

From ten monthly cross-sectional surveys before and after the implementation of the mass COVID-19 vaccination program in Hong Kong, we found that the age group with the highest vaccine hesitancy has changed from young adults aged 18-34 years before and at the beginning of the vaccination program (December 2020-May 2021) to older adults aged ≥65 years 4-5 months after the program implementation (June-July 2021). Before and at the beginning of the rollout of the mass vaccination program (November 2020-March 2021), the association between chronic medical conditions and vaccine hesitancy was insignificant, however, 2-5 months after the program implementation (April-July 2021) respondents with chronic medical conditions were more likely to be hesitant. Higher confidence in the government was not significantly associated with vaccine hesitancy in November-December 2020, but was associated with a lower risk of vaccine hesitancy from January to June 2021. We also discussed how the temporal changes in the factors associated with vaccine hesitancy could be associated with a set of contextual changes, including changes in risk of COVID-19, widespread reports about potential vaccine adverse effects from the media, and changes in vaccine-related policy.

Implications of the available evidence

Our study suggests that vaccine hesitant groups and the factors associated with vaccine hesitancy could change during the implementation of the COVID-19 vaccination programs. Continuous monitoring of COVID-19 vaccine hesitancy and its associated factors, and evaluating and adjusting the vaccination program are essential for the success of the vaccination program.

transmission.[4,5] Therefore, high population uptake rates of COVID-19 vaccination can provide protection against severe disease for vaccinated individuals and limit the public health impact of COVID-19 epidemics. COVID-19 vaccination campaigns have been launched in many countries since late 2020 and early 2021. However, a major challenge to reaching high vaccination coverage is vaccine hesitancy.

Vaccine hesitancy refers to delaying or refusing a vaccine even if the vaccination services are available.[6] Despite the increasing availability of COVID-19 vaccines worldwide, COVID-19 vaccine hesitancy was widely reported.[7–9] Some studies reported that the prevalence of vaccine hesitancy would change from time to time before and after the rollout of the mass COVID-19 vaccination campaigns.[7,10,11] Understanding the factor associated with vaccine hesitancy is essential to identify major hesitant groups and design effective vaccine risk communication strategies for promoting vaccination acceptance at different stages of a vaccination program. Vaccine hesitancy could be influenced by a set of individual psychological and contextual factors as well as their interactions. Contextual factors may involve increasing availability of COVID-19 vaccines, changes in risk of COVID-19, widespread reports about potential vaccine adverse effects from the media, and changes in vaccine-related policy. These contextual changes would influence individual perceptions of COVID-19 risk and confidence in COVID-19 vaccines and hence affect their vaccination intention.[12,13] In view of the unstable situation of the global pandemic, the emerge of SARS-CoV-2 Variants of Concern, and the development of new COVID-19 vaccines, the major vaccine hesitant groups and factors associated with vaccine hesitancy could also change over time. However, few studies monitored the temporal changes of the factors associated with COVID-19 vaccine hesitancy and uptake at different stages before and after the implementation of a vaccination program.

Based on repeated cross-sectional population-based surveys, this study aimed (i) to monitor the changes of COVID-19 vaccine hesitancy over time, (ii) to examine the potential factors associated with COVID-19 vaccine hesitancy among adults before and after the launch of the COVID-19 vaccination program in Hong Kong and (iii) to examine the differences in sociodemographic characteristics and other factors between vaccinated and

unvaccinated respondents over the five months after the implementation of the program. The potential influencing factors included in our study were sociodemographic factors, such as gender, age, education level, and occupation, and perception factors, e.g., perceived risks of COVID-19, perceived benefits and risks of COVID-19 vaccines, confidence in the authorities proving the vaccines, etc., which were potential factors associated with COVID-19 vaccine hesitancy and/or vaccination intention reported in previous studies.[7,14–17]

Methods

Study design

This was a repeated cross-sectional survey conducted using random-digit dialling of both land-based telephone and mobile numbers roughly in the ratio of 1:1. The telephone numbers were randomly generated using known prefixes assigned to telecommunication services providers. The surveys were implemented by a survey company and all the phone calls were scheduled at different times of a day covering both working hours and non-working hours in order to recruit a more representative sample. Experienced interviewers were deployed by the survey company to conduct the telephone interviews. The interviewers were trained prior to the fieldwork and monitored by experienced supervisors. Each sampled telephone number were called up to five times at different times and on different days before being dropped. For land-based samples, if there was more than one eligible and available members, "next birthday rule" was adopted. The one who will have his/her birthday next was invited to participate in the survey. All survey data were collected by a Web-based Computer Assisted Telephone Interviewing system which allows real-time data entry by interviewers and consolidation.

A total of ten survey rounds were involved in this study. Four rounds were conducted before the implementation of the COVID-19 vaccination program in Hong Kong from early November 2020 to late January 2021, while the remaining six rounds were conducted from the first week of the program rollout (22–26 February 2021) and thereafter once every month till the fifth months after the COVID-19 vaccination program was launched. The sample size of each survey round was around 500 for the first five rounds and increased to approximately 1000 for the other rounds. For each survey round, a sample size of around 500 (n) was sufficient to estimate population characteristics (p = 0.5) with a margin of error 0.04 (m = 0.04) and 95% confidence interval (t = 1.96) using the following formula.

$$n = \frac{t^2 \times p(1-p)}{m^2}$$

Using the same formula, a sample size of around 1000 (n) was sufficient to estimate population characteristics (p = 0.5) with a margin of error 0.03 (m = 0.03) and 95% confidence interval (t = 1.96). Target respondents were Cantonese-speaking Hong Kong resident aged 18 or above and have land-based or mobile telephone lines. Visitors who travel to Hong Kong were excluded. Each telephone interview lasted for ~ten minutes based on a standardized questionnaire. Major study measures were described below.

Outcome measures

Before the COVID-19 vaccination program, we assessed respondents' intention to receive a COVID-19 vaccine if it was available. The response scale was 7-point categorical ranging from "never" to "certain". Respondents were classified as having vaccine hesitancy if they responded "never", "very unlikely", "unlikely", or "evens" to take a COVID-19 vaccine, while the respondents answered "likely", "very likely", or "certain" were classified as having no/low vaccine hesitancy. From February 2021 after COVID-19 vaccines were provided in Hong Kong, respondents were first asked about their actual uptake of COVID-19 vaccination. For those who were yet to take the COVID-19 vaccines, we assessed their vaccination intention. The primary outcome of this study is vaccine hesitancy defined as never, very unlikely, unlikely, or evens to get vaccinated, rather than likely, very likely, or certain to vaccinate or already vaccinated in all survey rounds (Fig. S1a). The secondary outcome is self-reported COVID-19 vaccine uptake in the six rounds of surveys from February to July 2021 (Fig. S1b).

Potential factors associated with COVID-19 vaccine uptake and hesitancy

In each survey round, we collected data on socio-demographics, perceived risk of COVID-19, perceived internal, and external control over COVID-19 pandemic, compliance to social distancing measures and confidence in COVID-19 vaccines (see Supplementary Table S1 for details). For socio-demographics, we recorded age, gender, educational attainment, and occupation of the respondents. Their chronic medical conditions were also recorded. Measures of the perceived risk of COVID-19 included perceived susceptibility to COVID-19, perceived severity of COVID-19, and worry about being infected with COVID-19. Perceived internal and external controls were perceived personal efficacy in self-protection and confidence in the government's ability to control the pandemic, respectively. We assessed compliance to social distancing measures by the compliance to avoiding crowded places, avoiding going out, and avoiding social gathering. Noting the high collinearity of these three factors, and given that compliance with avoiding social gathering was found to be a better predictor for modeling local COVID-19 transmission in our

previous study,[18] we only included the measure of compliance with avoiding social gathering in the analysis. These measures were similar to those used in our previous surveys in 2003 SARS outbreak and 2009–10 influenza A (H1N1) pandemic.[19,20] All respondents were also assessed on their confidence in COVID-19 vaccines with a standard vaccine confidence scale in vaccination importance, effectiveness, safety, and religious and personal belief compatibility.[21]

Local epidemic curve of COVID-19

To demonstrate the temporal changes of COVID-19 vaccine hesitancy along with changes in the local epidemic situation, we collected official data on the number of daily reported laboratory-confirmed COVID-19 cases in Hong Kong to draw the epidemic curve from 18 January 2020 to 31 August 2021. The data were classified as numbers of local (infected in Hong Kong) or imported (infected outside Hong Kong) cases and the data were obtained from the Hong Kong Centre for Health Protection.[22]

Statistical analysis

The data analysis mainly included three parts. First, the temporal changes of COVID-19 vaccine hesitancy were assessed. The proportion of COVID-19 vaccine hesitancy in each survey was calculated as the number of respondents reported never, very unlikely, unlikely, or evens to the COVID-19 vaccination intention question over the number of respondents, and the proportions were rim-weighted by age, sex, education level, and occupation status distributions to the adult population in Hong Kong (census data in 2019) and the 95% confidence intervals (CIs) were also calculated with the normal approximation. The temporal changes of COVID-19 vaccine confidence against vaccine hesitancy were assessed. The weighted proportions of COVID-19 vaccine confidence and the corresponding 95% CIs for each item were calculated for each survey. Second, the unweighted factor-stratified proportions of vaccine hesitancy in each survey were calculated. Vaccine hesitancy and its associated factors were compared with chi-square tests. Multivariable logistic regression models were used to examine the factors that may have an impact on COVID-19 vaccine hesitancy at different time points. Third, factors potentially associated with COVID-19 vaccine uptake (self-report vaccine uptake from the surveys) were assessed by running multivariable logistic regression models using data from each survey round conducted from March to July 2021. Multiple imputation was used to replace a small proportion of missing values (no more than 6% on any factor) in the regression models. Multiple imputation was done with R package mice (Multivariate Imputation by Chained Equations) version 3.13.0, using predictive mean matching for included variables, with 20 imputations for five iterations. Additional data analyses were conducted to explore the temporal changes of COVID-19 vaccine hesitancy by factors. Please see Supplementary Table S9 for details. All data analyses were done with R version 4.0.2 (R Foundation for Statistical Computing, Vienna, Austria).

Ethical approval

This study was approved by the Institutional Review Board of The University of Hong Kong (Reference No.: UW 20-095). Verbal informed consents were provided by respondents before data collection. All data were anonymised when entered into the electronic database. Original identities (landline phone numbers or mobile numbers) were kept in a separate file accessible only to authorised persons. No incentive was provided for the participation in the cross-sectional surveys.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

In total, 7411 respondents were recruited for the ten rounds of telephone surveys. The recruitment process is shown in Figure 1 and the detail recruitment process for each survey is shown in Supplementary Fig. S2. The detailed implementation date, sample size in each round, and distributions of gender, age, educational attainment, occupation, chronic medical conditions, and trust in the government of respondents in each round of surveys are shown in Table 1.

Hong Kong had experienced four epidemic waves of COVID-19 and we categorised the first wave from 23 January to 29 February 2020, the second wave from 1 March to 30 April 2020, the third wave from 1 May to 31 October 2020, and the fourth wave from 1 November 2020 to 31 May 2021 (Figure 2A). The survey timeline covered the fourth wave and post-fourth wave periods from November 2020 to July 2021. From early November to early December 2020, around 34–41% of the respondents reported that they were having COVID-19 vaccine hesitancy, but the rate increased to 51.5% (95% CI: 46.6–56.3%) in late January 2021 (Figure 2B and Supplementary Table S4). Since the launch of the program, the vaccine hesitancy rate declined to 43.0% (95% CI: 38.0–48.0%) in late February, but the rate increased again to around 49–55% 1–3 months later (late March to late May 2021). Then, the vaccine hesitancy rate decreased significantly in June and July 2021 to 26.5% (95% CI: 23.4–29.6%). Figure 2C shows the unweighted vaccine hesitancy rate by age groups. The

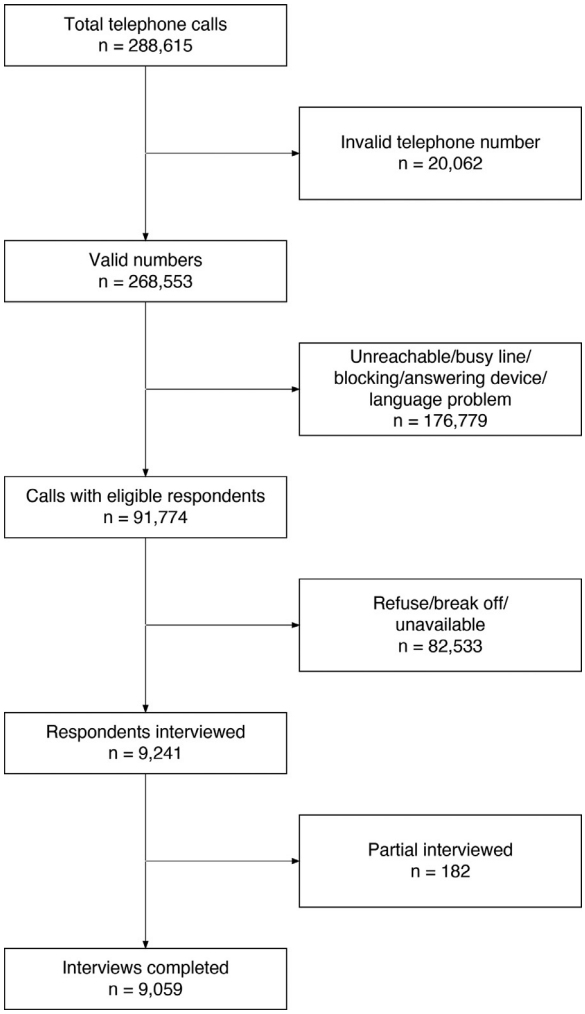

Figure 1. Flow chart of respondent recruitment and interview. There were 1004, 1004 and 1010 respondents in the first three rounds of surveys (2–5 November 2020, 30 November -3 December 2020 and 28–30 December 2020), respectively. But only 504, 537 and 329 respondents in these surveys were invited to answer the vaccination intention question. Therefore, there were 7,411 respondents included in the analysis.

rates (58–83%) were highest among young adults aged 18–34 years old from December 2020 to May 2021. Nonetheless, the vaccine hesitancy rates decreased to around 22–30% in this age group in July 2021. For older adults aged 65 or above, the proportions of COVID-19 vaccine hesitancy were around 31–40% from early November 2020 to late February 2021. But the rates remained at higher levels (45–54%) from March to June 2021. In the last survey conducted in July 2021, the vaccine hesitancy rate was highest in the age group 65 years or above.

The temporal changes in COVID-19 vaccine confidence are shown in Figure 2D and Supplementary Table S4. The confidence in vaccine safety and efficacy decreased from November 2020 to January 2021 and increased gradually in the subsequent months from February to July 2021. The confidence in vaccine safety and efficacy reached the highest levels of 54.6% (95% CI: 50.9–58.3%) and 63.7% (95% CI: 59.9–67.4%), respectively in late July 2021. Most respondents (70.6%) believed that COVID-19 vaccines would be important for children to have in late November to early December 2020. However, this proportion dropped significantly to 38.2% (95% CI: 34.6–41.8%) in April and May 2021 and remained at around 50% in June and July 2021. The proportions of respondents who reported COVID-19 vaccines were compatible with their religious beliefs and personal values were higher from early November to early December 2020 (33–36% and 59–64%, respectively) and remained at low levels of around 22–28% and 45–55% separately from late December 2020 to late July 2021. The reliability coefficient of the five items for measuring COVID-19 confidence was 0.82 (95% CI: 0.81–0.83) (value of Cronbach's alpha). Thus, we calculated the mean of respondents' answers to the five items on COVID-19 vaccine confidence which was then categorized into low vaccine confidence (mean score≤ 3) and high vaccine confidence (mean score> 3) for subsequent logistic regression analyses.

Supplementary Table S5 shows the unweighted factor-stratified COVID-19 vaccine hesitancy in each survey and Figure 3 shows the adjusted odds ratios of factors of multivariable regression analyses. Females were more likely to be hesitant to take the vaccines before and at the beginning of the vaccination program (November-December 2020 and March 2021), but three months after the implementation (May-July 2021) of the program, gender was no longer a statistically significant factor associated with vaccine hesitancy. The analyses showed that age group was not a statistically significant factor associated with vaccine hesitancy from December 2020 to February 2021. However, younger adults and older adults were statistically significantly more hesitant to take the vaccine compared to mid-aged adults from March to July 2021. There was no obvious pattern in vaccine hesitancy in respondents with different occupations or educational attainment. Before the launch of the vaccination program, having chronic medical conditions was not statistically significantly associated with vaccine hesitancy but was associated with a greater risk of vaccine hesitancy after the vaccination program started from April to July 2021, with the adjusted odds ratios ranging from 1.57 (95%CI: 1.10–2.23) to 2.15 (95%CI: 1.50–3.08) (Table S6). Higher confidence in the government was not statistically significantly associated with vaccine hesitancy in November-December 2020, but was associated with a lower risk of vaccine hesitancy from January to June 2021. Worry about being infected with SARS-CoV-2 and belief in self-efficacy in preventing COVID-19 were not statistically

Characteristics	Total	3–4 months before the vaccination program		1–2 months before the vaccination program		0–1 months after the vaccination program was implemented		2–3 months after the vaccination program was implemented		4–5 months after the vaccination program was implemented	
		2–5 Nov 2020 *N* (%)	30 Nov–3 Dec 2020 *N* (%)	28–30 Dec 2020 *N* (%)	25–27 Jan 2021 *N* (%)	22–23 Feb 2021 *N* (%)	29–31 Mar 2021 *N* (%)	27–30 Apr 2021 *N* (%)	24–28 May 2021 *N* (%)	21–25 Jun 2021 *N*(%)	19–24 Jul 2021 *N*(%)
Total number of respondents	7411	504	537	329	509	509	1001	1010	1003	1004	1005
Received at least 1st dose		-	-	-	-	0 (0)	106 (10.6)	170 (16.8)	234 (23.3)	381 (37.9)	516 (51.3)
Sex											
Male	3017 (40.7)	212 (42.1)	252 (46.9)	137 (41.6)	207 (40.7)	235 (46.2)	439 (43.9)	422 (41.8)	397 (39.6)	368 (36.7)	348 (34.6)
Female	4394 (59.3)	292 (57.9)	285 (53.1)	192 (58.4)	302 (59.3)	274 (53.8)	562 (56.1)	588 (58.2)	606 (60.4)	636 (63.3)	657 (65.4)
Age, median (interquartile range)	52 (36-68)	50 (33-67)	51 (35-67)	54 (38-70)	49 (34-65)	52 (38-67)	55 (35-70)	52 (35-69)	52 (36-67)	53 (37-68)	55 (39-70)
Age group											
18–24	588 (7.9)	59 (11.7)	35 (6.5)	23 (7.0)	49 (9.6)	45 (8.8)	84 (8.4)	77 (7.6)	75 (7.5)	72 (7.2)	69 (6.9)
25–34	968 (13.1)	69 (13.7)	85 (15.8)	41 (12.5)	64 (12.6)	55 (10.8)	128 (12.8)	156 (15.4)	133 (13.3)	126 (12.5)	111 (11.0)
35–44	1109 (15.0)	73 (14.5)	87 (16.2)	55 (16.7)	90 (17.7)	80 (15.7)	137 (13.7)	152 (15.0)	141 (14.1)	158 (15.7)	136 (13.5)
45–54	1134 (15.3)	58 (11.5)	81 (15.1)	56 (17.0)	87 (17.1)	83 (16.3)	128 (12.8)	144 (14.3)	167 (16.7)	161 (16.0)	169 (16.8)
55–64	1222 (16.5)	77 (15.3)	96 (17.9)	54 (16.4)	83 (16.3)	88 (17.3)	180 (18.0)	148 (14.7)	177 (17.6)	161 (16.0)	158 (15.7)
65 or above	2245 (30.3)	157 (31.2)	145 (27.0)	96 (29.2)	128 (25.1)	147 (28.9)	325 (32.5)	309 (30.6)	292 (29.1)	310 (30.9)	336 (33.4)
Education											
Primary or below	1255 (16.9)	76 (15.1)	86 (16.0)	67 (20.4)	65 (12.8)	61 (12.0)	169 (16.9)	179 (17.7)	188 (18.7)	181 (18.0)	183 (18.2)
Secondary	3285 (44.3)	221 (43.8)	228 (42.5)	140 (42.6)	243 (47.7)	244 (47.9)	438 (43.8)	425 (42.1)	442 (44.1)	440 (43.8)	464 (46.2)
Tertiary or above	2777 (37.5)	202 (40.1)	220 (41.0)	112 (34.0)	195 (38.3)	194 (38.1)	387 (38.7)	393 (38.9)	356 (35.5)	370 (36.9)	348 (34.6)
Occupation											
Professional	1148 (15.5)	77 (15.3)	79 (14.7)	56 (17.0)	80 (15.7)	95 (18.7)	156 (15.6)	159 (15.7)	163 (16.3)	128 (12.7)	155 (15.4)
Clerical and service worker	1369 (18.5)	90 (17.9)	113 (21.0)	68 (20.7)	132 (25.9)	86 (16.9)	166 (16.6)	176 (17.4)	174 (17.3)	181 (18.0)	183 (18.2)
Production worker	717 (9.7)	53 (10.5)	46 (8.6)	36 (10.9)	40 (7.9)	58 (11.4)	104 (10.4)	85 (8.4)	109 (10.9)	99 (9.9)	87 (8.7)
Schooling	359 (4.8)	37 (7.3)	24 (4.5)	10 (3.0)	22 (4.3)	26 (5.1)	59 (5.9)	48 (4.8)	47 (4.7)	47 (4.7)	39 (3.9)
Home maker	1341 (18.1)	79 (15.7)	77 (14.3)	57 (17.3)	80 (15.7)	70 (13.8)	154 (15.4)	200 (19.8)	199 (19.8)	227 (22.6)	198 (19.7)
Retired	2052 (27.7)	141 (28.0)	166 (30.9)	79 (24.0)	116 (22.8)	142 (27.9)	318 (31.8)	284 (28.1)	253 (25.2)	266 (26.5)	287 (28.6)
Not employed nor schooling	308 (4.2)	17 (3.4)	22 (4.1)	11 (3.3)	30 (5.9)	23 (4.5)	30 (3.0)	43 (4.3)	42 (4.2)	44 (4.4)	46 (4.6)
With chronic medical condition	2361 (31.9)	166 (32.9)	168 (31.3)	104 (31.6)	138 (27.1)	142 (27.9)	337 (33.7)	324 (32.1)	326 (32.5)	318 (31.7)	338 (33.6)
Higher trust in the government	2730 (36.8)	178 (35.3)	159 (29.6)	101 (30.7)	144 (28.3)	170 (33.4)	364 (36.4)	346 (34.3)	371 (37.0)	416 (41.4)	481 (47.9)

***Table 1*: Respondent characteristics.**

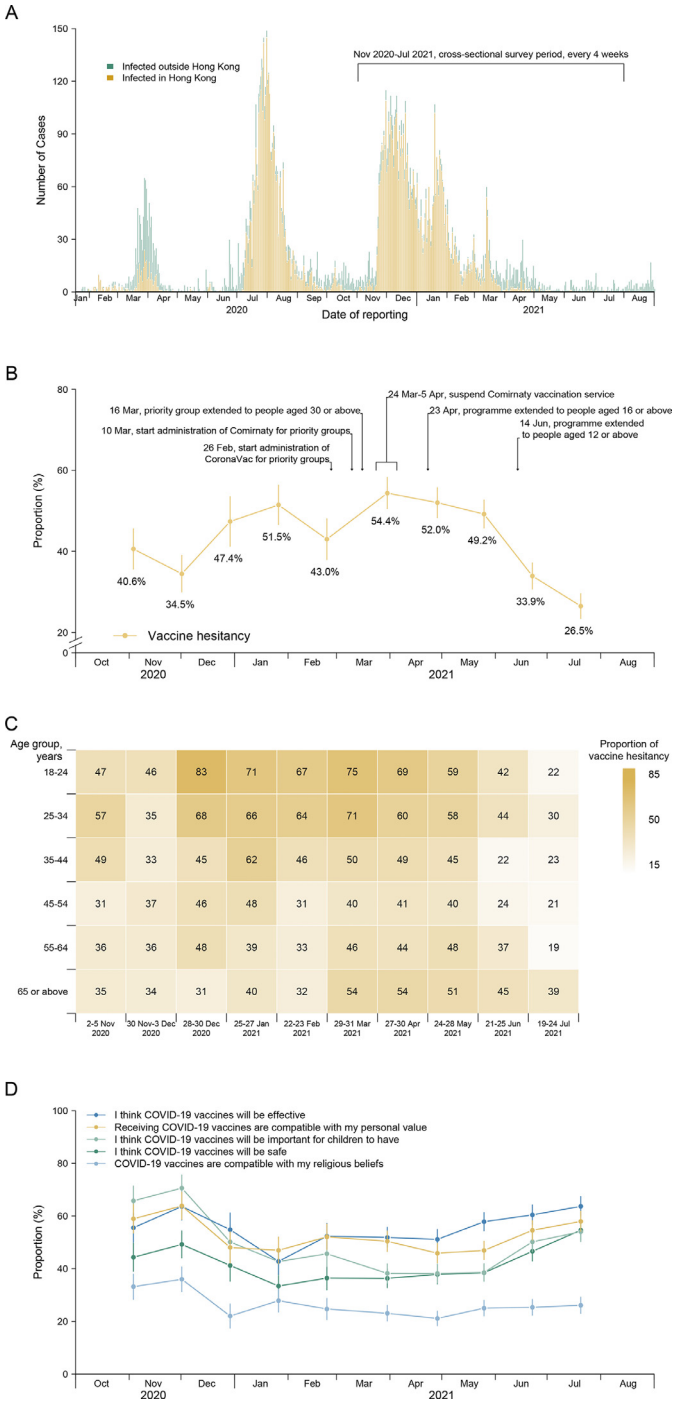

Figure 2. Panel A. COVID-19 cases by date of reporting. The reporting period is from 18 January 2020 to 31 August 2021. Panel B. COVID-19 vaccine hesitancy. COVID−19 vaccine hesitancy was defined as never, very unlikely, unlikely, or evens to get vaccinated, rather than likely, very likely or certain to vaccinate or already vaccinated. The proportions of COVID-19 vaccine hesitancy were weighted to the Hong Kong census data in 2019, with 95% CI +/- about 3%. Panel C. COVID-19 vaccine hesitancy stratified by age. Proportions shown in Panel C are unweighted age-stratified vaccine hesitancy rates. Panel D. COVID-19 vaccine confidence. Vaccine confidence was defined as agree or strongly agree to statements rather than neutral, disagree or strongly disagree. The proportions of vaccine confidence were weighted to the Hong Kong census data in 2019, with 95% CI +/- about 3%.

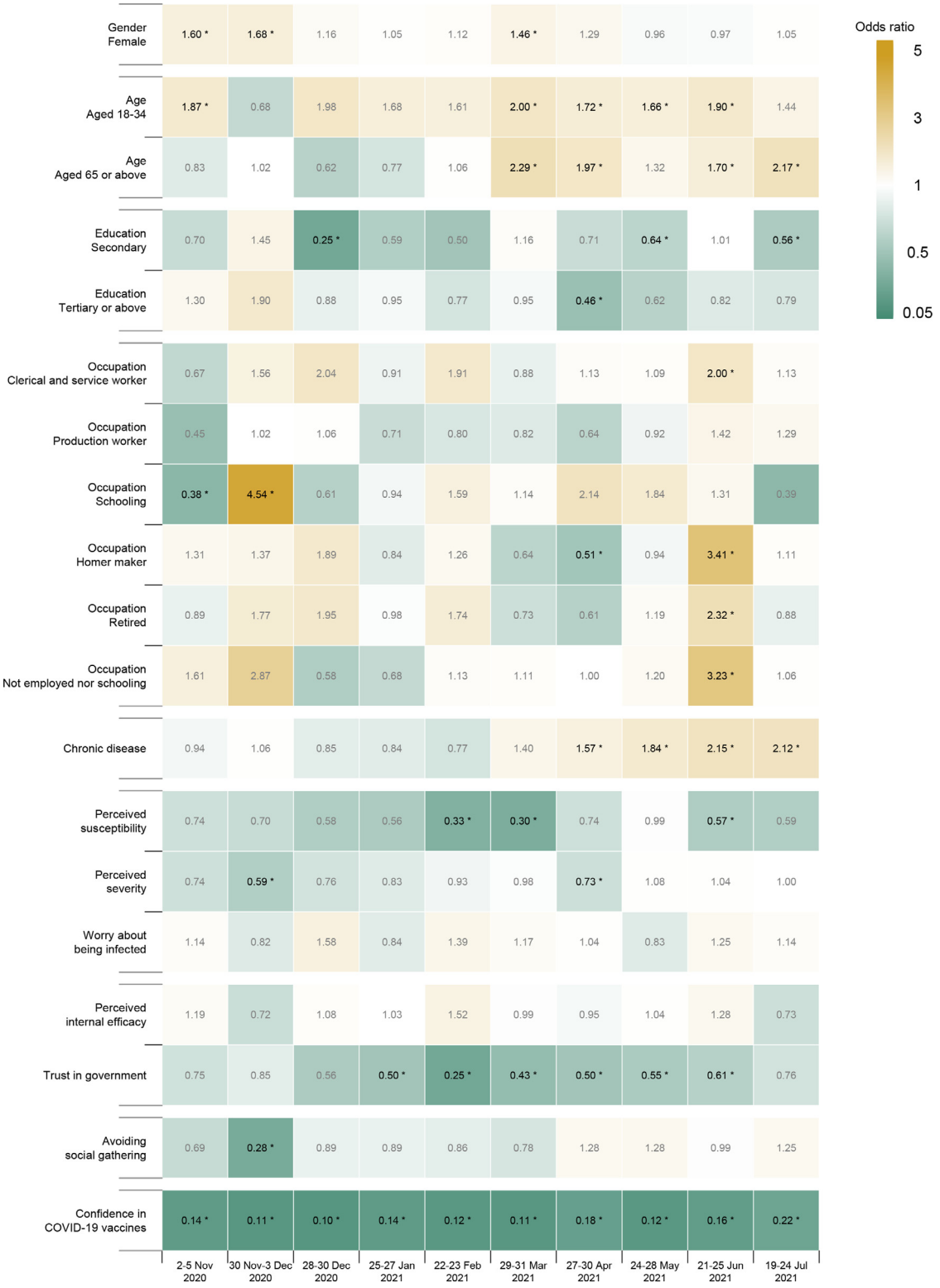

Figure 3. Multivariable logistic regression analysis of potential factors associated with COVID-19 vaccine hesitancy. Numbers in the boxes are odds ratios. Numbers in black and with "*" indicate statistically significant. Green color indicates less likely to be hesitant and orange indicates more likely to be hesitant.

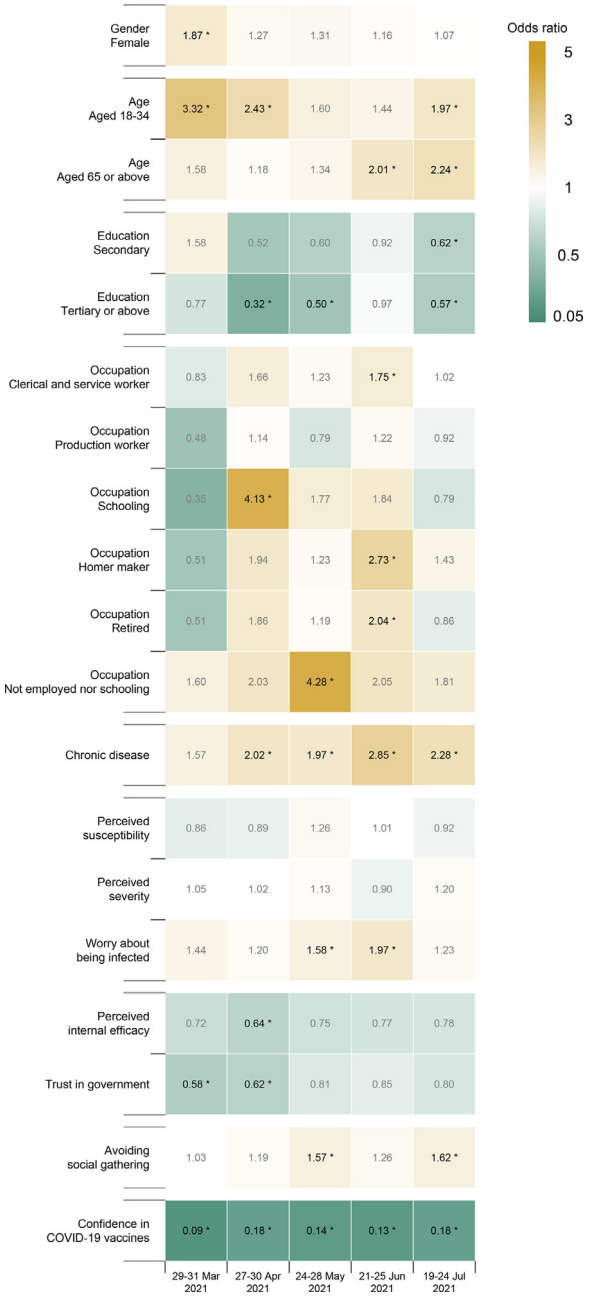

Figure 4. Multivariable logistic regression analysis of potential factors associated with COVID-19 vaccine uptake. Numbers in the boxes are odds ratios. Numbers in black and with "*" indicate statistically significant. Green color indicates more likely to be already vaccinated and orange indicates less likely to be already vaccinated.

significantly associated with vaccine hesitancy throughout the ten survey rounds. In addition, greater confidence in COVID-19 vaccines was associated with lower vaccine hesitancy in all survey rounds.

The self-reported COVID-19 vaccine uptake rate was 0% (0/509) in February 2021, 10.6% (106/1001) in March 2021, 16.8% (170/1010) in April 2021, 23.3% (234/1003) in May 2021, 37.9% (381/1004) in June 2021 and 51.3% (516/1005) in July 2021 (Table 1). Supplementary Table S7 shows the unweighted factor-stratified COVID-19 vaccine uptake in each survey and Figure 4 presents the adjusted odds ratios of potential factors that were associated with COVID-19 vaccine uptake from March to July 2021. Vaccinated respondents were less likely to be female (adjusted odds ratios> 1) in late March 2021, but the gender difference was not statistically significant from April to July 2021. In the last survey, vaccinated respondents were more likely to be mid-aged adults and attended secondary, tertiary or above education (adjusted odds ratios< 1). People with chronic medical conditions were less likely to report having received COVID-19 vaccines from April to July 2021. Vaccinated respondents tended to trust in their ability to prevent themselves from SARS-CoV-2 infections and have confidence in the government to control the pandemic in March/April 2021. In addition, vaccinated respondents reported lower compliance to social distancing measures compared to unvaccinated respondents in May and July 2021. Higher confidence in COVID-19 vaccines was statistically significantly associated with vaccine uptake in all survey rounds.

Discussion

Our study was conducted from November 2020 to July 2021 to monitor the changes in COVID-19 vaccine hesitancy before and after the implementation of the mass COVID-19 vaccination program in Hong Kong covering the fourth wave and post-fourth wave period. When COVID-19 vaccines were under development and testing, Wang and colleagues conducted two cross-sectional online surveys in February 2020 (the first wave) and August–September 2020 (the third wave), respectively, among the working population in Hong Kong.[11] Their study found that rates of COVID-19 vaccine hesitancy (defined as refuse or undecided rather than accept COVID-19 vaccines) increased from 55.8% in the first wave to 65.2% in the third wave.[11] Our study found that vaccine hesitancy during the fourth wave and post-fourth wave period was generally lower compared to the vaccine hesitancy rates in the first and third waves reported by Wang et al.[11] Our study findings were somewhat different from that conducted in the United States which reported that COVID-19 vaccine hesitancy (similar definition to ours) decreased from 46.0% in October 2020 before the implementation of COVID-19 vaccination campaign there to 35.2% in March 2021 after the program had been implemented for three months.[10] Our study provides important insights into the changes in factors that influenced COVID-19 vaccine hesitancy

as the vaccines became increasingly available for the population.

First, we found that the vaccine hesitancy increased one month before the start of the mass COVID-19 vaccination program. Many contextual changes could possibly contribute to the increase, e.g. recent reports about the potential adverse effects following COVID-19 vaccination in the countries where mass COVID-19 vaccination campaigns started in December 2020 and January 2021. In late February 2021, COVID-19 vaccines were primarily provided for five priority groups in Hong Kong, including adults aged 60 years old or above, healthcare workers, residents and staff of residential care homes, personnel maintaining critical public services, and personnel performing cross-boundary related work.[23] And the top government officials took the lead to receive the first few doses of COVID-19 vaccines in Hong Kong. Our survey conducted in the first week of the program showed that the rate of COVID-19 vaccine hesitancy nevertheless decreased to 43.0%. From 16 March 2021, the priority groups of COVID-19 vaccination were expanded to all adults aged 30 or above in Hong Kong. However, Comirnaty vaccination services were suspended from 24 March to 5 April 2021 due to the packaging defects of the Comirnaty vaccine, one of the two types of COVID-19 vaccines available in Hong Kong.[24] This could be a potential major contributor to the temporary increase in COVID-19 vaccine hesitancy detected in the survey round conducted in late March 2021. Starting from 23 April 2021, the COVID-19 vaccination program was expanded to cover all Hong Kong residence aged 16 years or above. In May 2021, incentives such as paid leaves due to COVID-19 vaccination and some relaxation of social distancing measures for vaccinated individuals were announced by the government of Hong Kong to encourage COVID-19 vaccine uptake. In addition, some private sectors in Hong Kong also introduced tangible incentives such as lotteries to encourage people to take the vaccines. These contextual changes might have contributed to the decrease in COVID-19 vaccine hesitancy since May 2021 which reached a rate of 26.5% in late July 2021.

The temporal changes in associations of age and chronic medical condition with COVID-19 vaccine hesitancy and uptake also provided important insights. We found that young adults aged 18–34 had the highest COVID-19 vaccine hesitancy in late 2020 – early 2021 but their vaccine hesitancy became comparable to that of the mid-age group in July 2021. The incentives from the government and private sectors and the exemption from frequent compulsory COVID-19 testing among certain working groups might possibly contribute to the change among young adults. Older adults aged 65 or above who had the least vaccine hesitancy in late 2020 became the most hesitant age group in mid-2021 and the COVID-19 vaccine uptake rate was lowest among older adults in June-July 2021. The results from the regression analyses suggested that chronic disease was not associated with COVID-19 vaccine hesitancy from late 2020 to early 2021. However, the chronic medical condition became a statistically significant factor associated with vaccine hesitancy and uptake from April to July 2021. The temporal changes of these associations of older age and chronic medical condition with COVID-19 vaccine hesitancy and uptake could possibly be explained by the changes of risk and benefit perception of COVID-19 vaccination. There were also several reports of fatalities in older adults following COVID-19 vaccination and the changes in medical recommendations for the COVID-19 vaccination of people with underlying medical conditions.[25] These contextual changes have greatly influenced vaccine hesitancy among older people and people with underlying medical conditions. In addition, Hong Kong adopts the "zero-COVID" strategy and COVID-19 local transmission has been maintained at a low level since April 2021. This has contributed to low perceived risks from infections with SARS-CoV-2, which means that perceived risks from the adverse events associated with the vaccination could outweigh the perceived risk from the disease.

Compared to other countries/territories following the "zero-COVID" strategy, the prevalence of vaccine hesitancy was higher among the Hong Kong population compared to that in Mainland China and New Zealand.[26,27] As the natural infection rate of COVID-19 is low in Hong Kong, a high uptake rate is crucial to achieve a high level of population immunity. Hong Kong's current COVID-19 first dose vaccine uptake rate was only 61.4% among the population aged 12 or above by 31 August 2021. Older adults and individuals with chronic diseases who are at high risk of severe consequences after SARS-CoV-2 infection[28,29] had the highest hesitancy to take COVID-19 vaccines. This can be a potential challenge to the healthcare system if the pandemic resurges in Hong Kong. Public communication on the safety profile of COVID-19 vaccines among older adults and people with chronic medical conditions[2] is critical to dispel their misconceptions and promote population-wide vaccination uptake.

Trust in the government's ability to control the pandemic could be used as a proxy of confidence in the government. From January to June 2021, those having confidence in the government were less likely to be vaccine hesitant. Other studies also found that greater vaccine hesitancy was associated with lower confidence in the government or lower public trust in authorities who provided the vaccination services.[7,14,30] Since the social unrest in 2019 in Hong Kong,[31] the trust in the government among people of different political orientations has become extremely low, which can be a challenge to encourage their uptake of COVID-19 vaccines in Hong Kong.

There were some limitations in this study. First, the data were collected using telephone surveys. Although efforts were made to improve the representativeness of samples to the population including making phone calls during and beyond working hours and generating phone numbers for landline and mobile at a 1:1 ratio, volunteer bias was unavoidable. Self-reported vaccination uptake rates were generally higher compared to the actual uptake rates during the survey periods (the actual COVID-19 first dose uptake rates among adults aged 18 or above on the end dates of the last 5 surveys were 7.2%, 14.3%, 20.5%, 32.6%, and 46.8%, respectively). This may possibly because vaccinated individuals were more willing to participate in the telephone surveys. Second, the vaccine hesitancy responses were self-reported. Respondents reported having vaccine hesitancy may not necessarily translate to no vaccine uptake, while respondents reported likely, very likely, or certain to take COVID-19 vaccines may still delay taking the vaccines.[6] Third, we did not record the reasons for vaccine hesitancy in the surveys. Fourth, we could not provide evidence about the causal associations between contextual changes including changes in the news reports about COVID-19 vaccines and policies and the changes in public risk perceptions and their vaccine hesitancy. It limited us from providing more specific recommendations to boost vaccine uptake among hesitant groups. In addition, the findings of this study were limited by the cross-sectional design. No causal relationship could be inferred.

In conclusion, the prevalence of COVID-19 vaccine hesitancy, and the associated factors would change over time. As the COVID-19 pandemic transitioning to the endemicity phase, high vaccination coverage is essential to ensure the sustainability of that transition. In addition, the third dose has been administered in some countries and booster shots might be administered to the general population ultimately.[32] Regular monitoring of vaccine hesitancy and its predictors should be implemented to guide policy-making to boost vaccine uptake.

Declaration of interests

BJC consults for AstraZeneca, GSK, Moderna, Pfizer, Roche and Sanofi Pasteur. The authors report no other potential conflicts of interest.

Contributors

The study was designed by JX, BJC and QL. The survey tools were developed by JX, BJC and QL. Funding was obtained by MYN, BJC and QL. Data analyses were done by JX and JC. JX wrote the first draft of the manuscript and all authors interpreted data, provided critical review and revision of the text and approved the submitted manuscript.

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Data sharing statement

Survey data are available from the corresponding author on request.

Editor note

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.lanwpc.2022.100441.

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