The way forward to achieve high COVID-19 vaccination and revaccination coverage in a city amid a period of tranquility

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Background: Amid the current COVID-19 pandemic, there is an urgent need for both vaccination and revaccination ("boosting"). This study aims to identify factors associated with the intention to receive a booster dose of the coronavirus (COVID-19) vaccine among individuals vaccinated with two doses and characterize their profiles in Hong Kong, a city with a low COVID-19 incidence in the initial epidemic waves. Among the unvaccinated, vaccination intention is also explored and their profiles are investigated.

Methods: From December 2021 - January 2022, an online survey was employed to recruit 856 Hong Kong residents aged 18 years or over from an established population-based cohort. Latent class analysis and multivariate logistic regression modeling approaches were used to characterize boosting intentions.

Results: Of 638 (74.5%) vaccinated among 856 eligible subjects, 42.2% intended to receive the booster dose. Four distinct profiles emerged with believers having the highest intention, followed by apathetics, fence-sitters and skeptics. Believers were older and more likely to have been vaccinated against influenza. Older age, smoking, experiencing no adverse effects from a previous COVID-19 vaccination, greater confidence in vaccines and collective responsibility, and fewer barriers in accessing vaccination services were associated with higher intentions to receive the booster dose. Of 218 unvaccinated, most were fence-sitters followed by apathetics, skeptics, and believers.

Conclusion: This study foretells the booster intended uptake lagging initial vaccination across different age groups and can help refine the current or...
future booster vaccination campaign. Given the fourth COVID-19 vaccine dose may be offered to all adults, strategies for improving boosting uptake include policies targeting young adults, individuals who experienced adverse effects from previous doses, fence-sitters, apathetics, and the general public with low trust in the health authorities.

**KEYWORDS**
boosting uptake coverage, COVID-19, Hong Kong, latent profile analysis, vaccine hesitancy

### Introduction

Following the first detection of the SARS-CoV-2 (B.1.1.529) variant in Gauteng Province, South Africa, Omicron has replaced Delta to become the most dominant COVID-19 variant in many populations globally. Given its high transmissibility and vaccine breakthrough infection nature (1), the substantial infection posed a threat to the unvaccinated, a particularly vulnerable group. Vaccination is still considered to effectively protect vulnerable groups against severe illness, hospitalization and mortality associated with infection triggered by Omicron (2). A recent study revealed that 20% of those receiving two doses of BNT162b2 had detectable neutralizing antibodies against Omicron at 56 days after the first dose (3). Receiving a three-dose short course of BNT162b2 vaccine can strengthen the vaccine effectiveness (VE) against symptomatic infection and severe outcomes (hospitalization or death) due to both the Omicron and Delta variants (4). This supports the urgent need for both vaccination and revaccination (“boosting”).

Hong Kong, a densely populated city with frequent daily social contacts and an important travel hub for foreign multinationals, has experienced 3 major epidemic waves with a low cumulative number of confirmed cases of under 12,000 from January 2020 to November 2021 (5). A territory-wide vaccination campaign began in February 2021 in which two choices of vaccine, namely BNT162b2 (BioNTech hereafter) and CoronaVac (Sinovac hereafter), were provided (6). In terms of speed, it took 9 months to get 70% of the eligible population vaccinated with the first dose (7), which was longer than the United Kingdom and Israel (7) while mainland China fully vaccinated its entire population within 3 months (8). The persistence of vaccine hesitancy, a phenomenon whereby people are reluctant to receive the vaccine or delay their decision to accept it despite the availability of vaccine services (9), among the unvaccinated, and receipt of a booster dose lagging the initial vaccination (10), increased the difficulties in administering the next phase of the vaccination campaign. Given that more than 6 months have passed since the majority of Hong Kong citizens had received their first vaccine dose (6), an unprecedented revaccination campaign in both speed and scale should be implemented as soon as possible.

Different types of vaccine hesitancy may be sensitive to different promotional strategies. To enhance the community protection against infection and severe outcomes with the Omicron variant and a potential transition period before the establishment of regular infection seasonality, unraveling the vaccine hesitancy profiles of the general population and identifying determinants of intention to be revaccinated is essential for refining the overall strategy of current and future booster vaccination campaigns. In this study, we report a cross-sectional analysis of a representative population survey of adults residing in Hong Kong to first determine, among those who have received or will receive their second COVID-19 vaccine dose, the proportion who intend to receive a third (booster) dose. Second, we determine factors associated with the intention to receive a booster dose and present the profiles among them. Third, we explore the proportion of unvaccinated and identify their profiles.

### Methods

**Subject recruitment**

A community cohort was set up within 36h after the first reported COVID-19 case in Hong Kong in January 2020 to longitudinally assess the risk perception toward COVID-19 among the general population (11). District councilors distributed an online survey link via the routes in which they normally disseminate information to their target residents. Our cohort comprised citizens from all administrative districts in Hong Kong, and thus was representative of the Hong Kong population. The cohort was maintained with 9 follow-up rounds and all subjects in the existing cohort were invited to join the study. Additional subjects were recruited with the same sampling methodology from December 2021 - January 2022.

**Eligibility criteria**

Eligibility criteria included being aged 18 years or more and a resident of Hong Kong, defined as living in Hong Kong for at least 5 days per week on average during the past
month. We included two groups of people: those who were unvaccinated (hereafter unvaccinated) and those who had received or intended to receive two doses (hereafter vaccinated). Thus, we excluded those who received only one dose and had no intention to receive further doses.

Outcome

The primary outcome was the intention to receive a third (booster) dose among the vaccinated, which was assessed with the question: “How likely will you receive the third dose of the COVID-19 vaccine?” Responses were rated on an 11-point Likert scale ranging from 0 (absolutely unlikely) to 10 (absolutely likely). Those who had already received their third dose were given a score of 10. The secondary outcome, intention to receive the first vaccine dose among the unvaccinated, was evaluated by rating: “How likely will you receive the COVID-19 vaccine?” and rated on the same 11-point Likert scale described above.

Covariates

Independent variables included socio-demographic characteristics such as age, sex, and employment status; health-related information such as smoking status, long-term illnesses, influenza vaccination history, history of organ transplant, and treatment for immunosuppression; and adverse effects experienced from any of their previous COVID-19 vaccine doses. The 15-item scale of 5C psychological antecedents to vaccination (12) was used as a measurement of the indicators in the latent profile analysis, which covered five different domains of psychological factors determining vaccine hesitancy, namely confidence (trust in vaccine effectiveness, safety, and necessity and the system that delivers it), complacency (perceived the disease as low risk), constraints (perceived low vaccine availability, affordability, and accessibility), calculation (engagement in information searching), and collective responsibility (willingness to protect others via herd immunity). Responses to the items ranged from 1 (strongly disagree) to 7 (strongly agree) with 4 representing a neutral viewpoint.

Statistical analysis

To examine profiles and factors associated with the intention to receive the COVID-19 vaccine, two frameworks were adopted. We first analyzed vaccination intention as a continuous variable in a latent profile analysis (LPA) framework. Second, we defined those expressing a level of intention >6 as having an intention to receive the third vaccine dose in a multivariate logistic regression framework.

(i) Person-centered approach

LPA was employed to identify latent subgroups within the full sample based on the 5C psychological antecedents of vaccine hesitancy (13). The number of subgroups was determined based on prior findings (14) and several statistics for model comparison and interpretability (15). We modeled the predictors and vaccination intentions for two subgroups - one each for the vaccinated and unvaccinated subgroups. The profile structure of the full sample was adopted to each subgroup by fixing the profile means for each of the 5C indicators.

(ii) Variable-centered approach

To determine factors independently associated with the intention to receive the third COVID-19 vaccine dose among the vaccinated subgroup, we fitted an initial multivariate logistic regression model to the data in which mildly significant (p-value < 0.1) variables from the univariate analysis were included. A stepwise backward elimination technique was then used to reduce the complexity of the model based on the AIC value. Variables with a p-value < 0.05 were included in the final multivariate model. The strength of association for each risk factor in the final model was presented as an adjusted odds ratio (OR) with 95% confidence interval (CI). We also performed a sensitivity analysis to determine whether including participants who gave invalid utility scores changed the results.

All analyses were conducted in R v4.1.0 (16) and Mplus v7.4 (17).

Ethics

The study was approved by the Survey Behavioral Research Ethics Committee of The Chinese University of Hong Kong (reference number: SBRE-20-037).

Results

Respondent characteristics

Of the 862 eligible respondents, 644 (74.7%) had received at least one COVID-19 vaccine dose (611 (70.9%) received two doses) and the remaining 218 (25.3%) had not received any. Of the 33 who had received only one dose, six were excluded from the analysis because they indicated they would not receive a second dose (two gave multiple reasons; two stated their doctors did not recommend it; one stated they had already been infected with COVID-19; one thought a single dose was sufficient). Therefore, 856 eligible responses were analyzed. The median (IQR) survey completion time among all eligible participants was 43 (interquartile range: 30–65) min. A summary of the variables and comparison of vaccination intention within the
### TABLE 1  Characteristics of 856 respondents by vaccinated (n = 638) and unvaccinated groups (n = 218).

| Factors                                | Total (N = 856) | Vaccinated (n = 638) | Unvaccinated (n = 218) |
|----------------------------------------|----------------|----------------------|------------------------|
|                                        |                | No intention (n = 369) | Intention (n = 269) | P-value<sup>2</sup> | No intention (n = 199) | Intention (n = 19) | P-value<sup>2</sup> |
| Age group                              |                |                      |                       |                       |                        |                      |                       |
| 18–24                                  |                | 61 (9.6)             | 44 (72.1)             | 17 (27.9)             | 20 (90.9)             | 2 (9.1)              |                       |
| 25–34                                  |                | 199 (31.2)           | 136 (68.3)            | 63 (31.7)             | 68 (89.5)             | 8 (10.5)             |                       |
| 35–44                                  |                | 194 (30.4)           | 108 (55.7)            | 86 (44.3)             | 57 (91.9)             | 5 (8.1)              |                       |
| 45–54                                  |                | 105 (16.5)           | 49 (46.7)             | 56 (53.3)             | 27 (100.0)            | 0 (0.0)              |                       |
| 55–64                                  |                | 58 (9.1)             | 27 (46.6)             | 31 (53.4)             | 19 (86.4)             | 3 (13.6)             |                       |
| 65+                                    |                | 21 (3.3)             | 5 (23.8)              | 16 (76.2)             | 8 (88.9)              | 1 (11.1)             |                       |
| Sex                                    |                | 238 (37.3)           | 132 (55.5)            | 106 (44.5)            | 72 (90.0)             | 8 (10.0)             |                       |
| Female                                 |                | 400 (62.7)           | 237 (59.2)            | 163 (40.8)            | 127 (92.0)            | 11 (8.0)             |                       |
| Male                                   |                |                      |                       |                       |                        |                      |                       |
| Cohort                                 |                | 199 (31.2)           | 136 (68.3)            | 63 (31.7)             | 70 (93.3)             | 5 (6.7)              |                       |
| First (original)                       |                | 439 (68.8)           | 233 (53.1)            | 206 (46.9)            | 129 (90.2)            | 14 (9.8)             |                       |
| Second (top-up)                        |                |                      |                       |                       |                        |                      |                       |
| Employed full-time                     |                | 259 (40.6)           | 137 (52.9)            | 122 (47.1)            | 85 (91.4)             | 8 (8.6)              |                       |
| Yes                                    |                | 379 (59.4)           | 232 (61.2)            | 147 (38.8)            | 114 (91.2)            | 11 (8.8)             |                       |
| Smoking status                         |                | 30 (4.7)             | 13 (43.3)             | 17 (56.7)             | 11 (100.0)            | 0 (0.0)              |                       |
| Regular                                |                | 18 (2.8)             | 9 (50.0)              | 9 (50.0)              | 4 (100.0)             | 0 (0.0)              |                       |
| Occasional                             |                | 14 (2.2)             | 7 (50.0)              | 7 (50.0)              | 4 (66.7)              | 2 (33.3)             |                       |
| Former                                 |                | 576 (90.3)           | 340 (59.0)            | 236 (41.0)            | 180 (91.4)            | 17 (8.6)             |                       |
| Non-smoker                             |                | 0.292                |                        |                       |                        |                      |                       |
| Smoking status                         |                |                       |                       |                       |                        |                      |                       |
| Regular                                |                | 7 (1.1)              | 7 (100.0)             | 0 (0.0)               | 5 (100.0)             | 0 (0.0)              |                       |
| Occasional                             |                | 18 (2.8)             | 10 (55.6)             | 8 (44.4)              | 6 (100.0)             | 0 (0.0)              |                       |
| Former                                 |                | 154 (24.1)           | 95 (61.7)             | 59 (38.3)             | 59 (92.2)             | 5 (7.8)              |                       |
| Good                                   |                | 367 (57.5)           | 209 (56.9)            | 158 (43.1)            | 100 (90.1)            | 11 (9.9)             |                       |
| Very good                              |                | 576 (90.3)           | 340 (59.0)            | 236 (41.0)            | 180 (91.4)            | 17 (8.6)             |                       |
| Perceived health                       |                |                      |                       |                       |                        |                      |                       |
| Very bad                               |                | 94 (14.7)            | 54 (57.4)             | 40 (42.6)             | 43 (89.6)             | 5 (10.4)             |                       |
| No                                     |                | 544 (85.3)           | 315 (57.9)            | 229 (42.1)            | 156 (91.8)            | 14 (8.2)             |                       |
| Food/drug allergies                    |                | 0.575                |                        |                       |                        |                      |                       |
| Yes                                    |                | 275 (43.1)           | 150 (54.5)            | 125 (45.5)            | 95 (90.5)             | 10 (9.5)             |                       |
| No                                     |                | 363 (56.9)           | 219 (60.3)            | 144 (39.7)            | 104 (92.0)            | 9 (8.0)              |                       |
| Long-term illnesses<sup>1</sup>        |                | 0.166                |                        |                       |                        |                      |                       |
| Yes                                    |                | 10 (1.6)             | 5 (50.0)              | 5 (50.0)              | 7 (100.0)             | 0 (0.0)              |                       |
| No                                     |                | 628 (98.4)           | 364 (58.0)            | 264 (42.0)            | 192 (91.0)            | 19 (9.0)             |                       |
| Received immunosuppressant treatment   |                | 0.75                 |                        |                       |                        |                      |                       |
| Yes                                    |                | 59 (9.2)             | 36 (61.0)             | 23 (39.0)             | 20 (90.9)             | 2 (9.1)              |                       |
| No                                     |                | 579 (90.8)           | 333 (57.5)            | 246 (42.5)            | 179 (91.3)            | 17 (8.7)             |                       |

(Continued)
Among the 638 vaccinated, 42.2% (95% CI: 38.3–46.1) expressed an intention to receive the booster dose. The most important reasons given by the participants to receive it included self-protection (51.2%), protecting others (47.5%), and to prevent the next wave (40.1%). In contrast, the most common reasons for not receiving the booster dose included an unwillingness to be forced into taking it (31.2%), a worry that the vaccine would trigger hidden problems in the body (25.7%), and concerns about adverse effects (23.3%).

**Table 1** (Continued)

| Factors | Total (N = 856) | Vaccinated (n = 638) | Unvaccinated (n = 218) |
|---------|----------------|----------------------|------------------------|
|         | No intention (n = 369) | Intention (n = 269) | P-value | No intention (n = 199) | Intention (n = 19) | P-value |
| Influenza vaccination (previous season) | | | | | | |
| Yes | 198 (31.0) | 93 (47.0) | 105 (53.0) | < 0.001 | 26 (76.5) | 8 (23.5) | 0.003 |
| No | 440 (69.0) | 276 (62.7) | 164 (37.3) | | 173 (94.0) | 11 (6.0) | |
| Influenza vaccination (current season) | | | | | | |
| Yes | 115 (18.0) | 44 (38.3) | 71 (61.7) | < 0.001 | 14 (66.7) | 7 (33.3) | <0.001 |
| No | 523 (82.0) | 325 (62.1) | 198 (37.9) | | 185 (93.9) | 12 (6.1) | |
| Experienced adverse effects from the 1st COVID dose | | | | | | |
| Yes | 354 (55.5) | 235 (66.4) | 119 (33.6) | < 0.001 | | |
| No | 284 (44.5) | 134 (47.2) | 150 (52.8) | | | |
| Experienced adverse effects from the 2nd COVID dose | | | | | | |
| Yes | 379 (62.0) | 242 (63.9) | 137 (36.1) | < 0.001 | 3.7 (2.0–4.7) | 4.3 (3.0–5.2) | 0.027 |
| No/not applicable | 232 (38.0) | 104 (44.8) | 128 (55.2) | | 3.0 (2.0–4.2) | 3.3 (2.0–4.2) | 0.35 |
| Vaccine hesitancy constructs^1 | | | | | | |
| Confidence | 4.3 (3.3–5.3) | 4.0 (3.3–5.0) | 5.3 (4.0–6.0) | < 0.001 | 3.7 (2.0–4.7) | 4.3 (3.0–5.2) | 0.027 |
| Complacency | 4.0 (3.0–4.3) | 4.0 (3.0–4.3) | 3.3 (2.3–4.0) | < 0.001 | 4.0 (3.3–4.7) | 3.7 (2.2–4.0) | 0.002 |
| Constraint | 3.3 (2.0–4.0) | 3.7 (2.7–4.0) | 2.7 (2.0–4.0) | < 0.001 | 3.7 (2.7–4.0) | 3.3 (2.0–4.2) | 0.35 |
| Calculation | 5.7 (4.7–6.0) | 5.3 (4.3–6.0) | 5.7 (4.7–6.0) | 0.173 | 6.0 (5.0–6.7) | 6.0 (5.0–6.3) | 0.981 |
| Collective | 4.7 (4.0–6.0) | 4.7 (4.0–5.7) | 5.7 (4.7–6.3) | < 0.001 | 4.0 (3.3–4.7) | 4.7 (3.7–5.3) | 0.215 |

^1 Includes ear/nose/throat conditions such as rhinitis, hay fever, and tinnitus; hypertension; kidney disease; skin conditions such as eczema and psoriasis; depression; tuberculosis; inherited blood disorders (e.g., thalassemia, hemophilia); eye diseases (e.g., glaucoma, cataract, vision loss/blindness); hypercholesterolemia; diabetes mellitus; and other miscellaneous illnesses.

^2 The level of agreement to each statement of the 5C vaccine hesitancy scale ranged from 1 to 7. The chi-squared or Fisher’s exact test was used to assess the crude association between categorical covariates and the outcomes as appropriate while the Wilcoxon rank-sum test was used for continuous variables.

Bold figures indicate p-values smaller than 0.05.

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Vaccinated and unvaccinated subgroups are presented in Table 1. Descriptive results are reported in the Appendix.

(i) Full sample

In the LPA on 856 eligible participants, we arrived at a 4-profile solution (Table 2, Figure 1, and Supplementary Table 1). These profiles were labeled “believers” (30.1%), “fence-sitters” (34.0%), “apathetics” (26.3%), and “skeptics” (9.6%). Based on mean standardized (z) scores, believers exhibited high confidence (z = 0.84), high collective responsibility (z = 1.08), low complacency (z = −0.78), and low constraint (z = −0.76). Fence-sitters had average scores in all constructs while apathetics scored low in calculation (z = −1.19) but high in complacency (z = 0.25) and constraint (z = 0.52). In contrast, skeptics were characterized by having low confidence (z = −1.58), low collective responsibility (z = −1.57), high complacency (z = 0.84), and high constraint (z = 0.19) (Supplementary Table 2).

(ii) Vaccinated subgroup

Among the 638 vaccinated, 42.2% (95% CI: 38.3–46.1) expressed an intention to receive the booster dose. The most important reasons given by the participants to receive it included self-protection (51.2%), protecting others (47.5%), and to prevent the next wave (40.1%). In contrast, the most common reasons for not receiving the booster dose included an unwillingness to be forced into taking it (31.2%), a worry that the vaccine would trigger hidden problems in the body (25.7%), and concerns about adverse effects (23.3%) (Supplementary Table 3). From the LPA, believers (36.8%) predominated followed by fence-sitters (33.5%), apathetics (25.9%), and skeptics (3.8%). Demographic characteristics varied across the profiles (Table 3). Believers were older than fence-sitters and apathetics, and reported better perceived health than apathetics. They were also more likely to have been vaccinated against the seasonal flu than the others. The profiles significantly differed in their mean intention to take the booster dose (p < 0.001) with believers having the highest intention (7.64), followed by apathetics (4.98), fence-sitters (4.56), and skeptics (1.58).
TABLE 2 Descriptive information of the four latent profiles (N = 856).

| Profile  | Constructs | 5C Constructs |
|----------|-------------|---------------|
|          | Confidence | Complacency | Constraint | Calculation | Collective responsibility |
|          | Mean 95% CI| Mean 95% CI | Mean 95% CI| Mean 95% CI | Mean 95% CI |
| Skeptic  | 82 (9.6)  | 1.94 (1.65, 2.23) | 4.59 (4.17, 5.01) | 3.32 (3.11, 3.92) | 6.42 (6.26, 6.57) | 2.97 (2.65, 3.29) |
| Believer | 258 (30.1)| 5.47 (5.18, 5.77) | 2.60 (2.25, 3.11) | 2.03 (1.97, 2.09) | 5.61 (5.50, 5.72) | 6.04 (5.88, 6.21) |
| Fence-sitter | 291 (34.0) | 4.27 (3.91, 4.64) | 3.89 (3.68, 4.10) | 3.13 (3.00, 3.26) | 5.72 (5.56, 5.88) | 4.91 (4.52, 5.30) |
| Apathetic | 225 (26.3)| 3.81 (3.64, 3.97) | 3.91 (3.80, 4.02) | 3.73 (3.60, 3.86) | 4.26 (4.06, 4.46) | 4.04 (3.94, 4.13) |

Numbers in the brackets represent the Z-scores.

As a regression analysis on the intention for the first dose was not statistically powered enough to keep more than two parameters in any model to remain close to 1 parameter per 8–10 positive guidelines, only the highest intention (7, 43%) followed by the second highest intention (27, 40%) were included for this analysis. The majority of the unvaccinated participants were fence-sitters and apathetics, only 15% (17) of those who had received or intended to receive only 1 dose had an intention to receive a second dose. The current four profile pattern in the full sample was very similar to the one found in a survey conducted among nurses during the “contracting” phase in March 2020 (1). The “middle” except that the “contradictor” profile was no longer applicable to the general population sample at the time of the survey as the respondents who thought the disease was not as severe as claimed in the earlier wave had a higher risk perception toward Omicron. The “outsider” profile defined in our previous work was classified as fence-sitters and apathetics, respectively in this study. The “contradictor” profile was missing (1). The “middle” except that the “contradictor” profile was no longer applicable to the general population sample at the time of the survey as the respondents who thought the disease was not as severe as claimed in the earlier wave had a higher risk perception toward Omicron.
Believers were shown to have the highest intention to have the booster dose, followed by apathetics, fence-sitters and skeptics.

Factors associated with a person’s decision to receive the booster dose included older age, being a smoker, having confidence in vaccines and the authorities who procure and distribute them, and having a sense of collective responsibility. In contrast, having a history of experiencing an adverse effect from previous doses of the vaccine and structural and psychological barriers in accessing vaccination services were associated with a low willingness to receive the booster dose.

**Result implications**

Our study has several implications. First, the proportion of participants having an intention to receive the third vaccine dose remained low across vulnerable sub-groups. A recent study revealed that the effectiveness of the vaccine against hospitalization waned among persons aged 65 years or above in a clinically vulnerable group (19) and in persons aged 40 to 64 years with underlying medical conditions than in healthy adults (20). This highlighted the need for a booster dose among these subpopulations. However, the proportion intending to receive a booster dose among individuals aged 45–64, with long-term illnesses, receiving immunosuppressant treatment, and with bad self-perceived health ranged from 44.4 to 53.3%. The latest co-circulation of both Omicron and Delta in Hong Kong will likely result in a substantial hospital burden attributed to a large number of infections from these subgroups if the epidemic is not controlled.

Second, factors associated with COVID-19 vaccination may no longer be associated with the intention to receive the booster dose. Influenza vaccination history was considered an associated factor with increased acceptance of the COVID-19 vaccine. However, it was not associated with COVID-19 revaccination (21). More evidence on the number of booster doses required in the future, rather than their influenza vaccination history, might affect people’s current perceptions. The co-administration of both influenza vaccination and a COVID-19 booster dose may not be an option in the short term. Compared to adults aged 18 to 34 years, adults aged 55 years or over were the most willing group followed by individuals aged 35–44 years for receiving a booster dose. This relationship was reversed in a previous study from our group for a different outcome on the intention to receive a COVID-19 vaccine in the same study sample (22). Older people were less likely to receive the COVID-19 vaccine. And when they did, they might be more determined (more likely to be believers) and thus more accepting of the booster dose.

Smoking status was associated with the COVID vaccination intention in this study, unlike in our previous study. Taking off their protective mask for smoking (23) and the increased infection risk attributed to smoking (24) may explain why smokers were more likely to receive a booster dose than non-smokers. To escape from the restrictions imposed by the
FIGURE 2
Distributions in the level of agreement to each statement of the 5C vaccine hesitancy scale.

vaccine bubble policies for unvaccinated individuals, smokers, who are usually lower in health awareness (25), might tend to disregard the risk of potential adverse effects of the booster and could be more motivated to take the booster. The association between smoking and vaccination intention is equivocal in the literature. While the current findings echoed with two other studies conducted in Japan (26) and Egypt (27) in the COVID-19 context, other studies conducted in Western countries (28) and in a non-COVID-19 (29–31) context suggested the opposite. Cultural factors [e.g., power distance (32) and individualism (33)] and contextual factors [e.g., pandemic versus non-pandemic period, trust and psychological reactance in the society (34, 35)] could be potential moderators in the smoking-vaccination linkage. Other psychological factors, including future time perspective (36) and the risk perception of the poorer prognosis (27) brought by smoking, could also be possible candidates to explore.

Future endeavors are needed to debunk the equivocality in the association between smoking and vaccination intention. Among the 5Cs, compared with our previous work among local nurses, greater confidence and collective responsibility were similarly independently associated with an increased booster uptake intention. However, unlike in our previous work, complacency was not significant in this study. Instead, having less constraint was a newly found associated antecedent for higher booster intention. Experiencing an adverse effect in previous doses, which was not available in the previous study, was found to impede the intention for the booster. Helping the public to have a greater understanding and management of the potential adverse effects after COVID-19 vaccination may therefore promote a greater acceptance of a booster dose. Delivering free door-to-door vaccination services could be especially beneficial to people with impaired mobility by alleviating the constraints to access the vaccines.
TABLE 3  Three-step results for predictors (4 profiles).

| Predictors | Vaccinated (n = 638) | Unvaccinated (n = 218) |
|------------|----------------------|------------------------|
|            | C1: skeptic (n = 24) | C2: believer (n = 235) | C3: fence-sitter (n = 214) | C4: apathetic (n = 165) | C1: skeptic (n = 58) | C2: believer (n = 23) | C3: Fence-sitter (n = 77) | C4: Apathetic (n = 60) |
| Age (years) |                     |                        |                        |                         |                        |                        |                           |                         |
|            | > C3, < C4 | < C2 | < C2 | < C2 | > C1, > C3, > C4 | < C2 | < C2 | < C2 |
| 18–34      | 50.0%    | 34.0% | 46.3% | 41.8% | 51.7%    | 30.4% | 34.8% | 41.6% |
| 35–54      | 33.3%    | 49.8% | 43.5% | 49.1% | 39.7%    | 34.8% | 41.6% | 43.3% |
| 55+        | 16.7%    | 16.2% | 10.3% | 9.1%  | 8.6%     | 34.8% | 41.6% | 10.0% |
| Sex        | < C3     | < C1, > C2, > C4 | < C3 |
| Male       | 54.2%    | 40.0% | 29.9% | 40.6% | 41.4%    | 30.4% | 34.8% | 45.0% |
| Female     | 45.8%    | 60.0% | 70.1% | 59.4% | 58.6%    | 69.6% | 55.0% |
| Health     | > C4     | < C2 | > C3 | < C1 |
| Below average | 4 16.7% | 3 1.4% | 11 6.7% | 3 1.4% | 1 4.3% | 3 5.0% |
| Average    | 4 16.7% | 45 19.1% | 47 28.5% | 9 15.5% | 10 43.5% | 29 37.7% | 16 26.7% |
| Above average | 16 66.7% | 153 71.5% | 107 64.8% | 47 81.0% | 12 52.2% | 43 55.8% | 41 68.3% |
| Respiratory symptoms in recent 2 weeks | > C4 | < C2 | > C2 | < C1, < C3, < C4 | > C2 |
| No         | 83.3%    | 88.5% | 92.1% | 93.3% | 89.7%    | 91.3% | 89.6% | 54 90.0% |
| Yes        | 16.7%    | 11.5% | 7.9%  | 6.7%  | 10.3%    | 8.7%  | 10.4% | 6 10.0% |
| Smoking status | > C2 | < C1, < C3, < C4 | > C2 | > C2 |
| Non-smoker | 91.7%    | 93.6% | 93.0% | 90.3% | 93.1%    | 95.7% | 93.5% | 55 91.7% |
| Smoker     | 8.3%     | 6.4%  | 7.0%  | 9.7%  | 6.9%     | 4.3%  | 6.5%  | 5 8.3% |
| Allergies  | < C2     | > C1, > C4 | < C2 |
| No         | 91.7%    | 86.4% | 84.1% | 84.2% | 81.0%    | 73.9% | 70.1% | 86.7% |
| Yes        | 8.3%     | 13.6% | 15.9% | 15.8% | 19.0%    | 26.1% | 29.9% | 13.3% |
| Long-term illness | > C2 | < C1, < C3, < C4 | > C2 | > C2 |
| No         | 54.2%    | 56.2% | 54.7% | 61.2% | 53.4%    | 48.1% | 60.0% |
| Yes        | 45.8%    | 43.8% | 45.3% | 38.8% | 46.6%    | 60.9% | 51.9% | 40.0% |
| Full-time job | > C2 | < C1, < C3, < C4 | > C2 | > C2 |
| No         | 45.8%    | 43.4% | 39.3% | 37.6% | 36.2%    | 40.9% | 40.3% | 27 45.0% |
| Yes        | 54.2%    | 56.6% | 60.7% | 62.4% | 63.8%    | 39.1% | 59.7% | 33 55.0% |

(Continued)
TABLE 3 (Continued)

| Predictors | Vaccinated (n = 638) | Unvaccinated (n = 218) |
|------------|----------------------|------------------------|
|            | C1: skeptic (n = 24) | C2: believer (n = 235) | C3: fence-sitter (n = 214) | C4: apathetic (n = 58) | C2: believer (n = 23) | C3: Fence-sitter (n = 77) | C4: Apathetic (n = 60) |
| N          | %                    | n                      | %                        | n                       | %                        | n                        | %                        |
| Adverse effect | No                           | Yes                      |                           | No                           | Yes                      |                           |                           |
| Flu vaccination last season | <C2, <C4 | >C1, >C3, (>C4) | <C2, <C4 | >C1, (<C2), >C3 | <C2, <C4 | >C1, >C3, >C4 | <C2 | >C1, <C2 |
| No | 22 | 91.7% | 138 | 58.7% | 169 | 79.0% | 111 | 67.3% | 56 | 96.6% | 14 | 60.9% | 65 | 84.4% | 49 | 81.7% |
| Yes | 2 | 8.3% | 97 | 41.3% | 45 | 21.0% | 54 | 32.7% | 2 | 3.4% | 9 | 39.1% | 12 | 15.6% | 11 | 18.3% |

Values in the table are estimates from the R3STEP logistic regression analyses using Mplus. We adopted the profile structure of the full sample to the split samples. The resultant profile sizes were slightly different from the full sample. Profile sizes shown in this table are from the full sample. *The direction indicates the difference in the proportion of women. () p < 0.10.

Our study has some limitations. First, the major outcome was the revaccination intention, although several studies have suggested a positive correlation between intention and behavior (47). Given the inherent limitations of cross-sectional studies, our study was not able to identify associated factors and profiles of COVID-19 vaccination through the association between intention and behavior (47). Given the inherent limitations of cross-sectional studies, our study was not able to identify associated factors and profiles of COVID-19 vaccination through the association between intention and behavior (47).

Limitations

Third, an improvement in vaccination coverage for the first and third doses seems possible in this population, among the unvaccinated, “skeptics” accounted for about 10% of this subpopulation. Although it is challenging to persuade “skeptics” who have not received the first dose, fence-sitters and apathetics accounted for 70% of the unvaccinated. “Skeptics” and individuals who have received the first and third doses are more likely to be vaccinated (5). However, these individuals did not form a critical mass. To improve vaccination coverage, the government could adopt strategies to help the fence-sitters (<C2) and apathetics (<C4) to adopt vaccination. Finally, discussing both a person-centered and variable-centered approach together may provide a more thorough understanding of each (41). To our best knowledge, although many studies related to vaccine hesitancy (or intention), this is the first study to identify vaccine hesitancy (or intention). This is the first study to identify vaccine hesitancy (or intention). This is the first study to identify vaccine hesitancy (or intention). This is the first study to identify vaccine hesitancy (or intention). This is the first study to identify vaccine hesitancy (or intention). This is the first study to identify vaccine hesitancy (or intention).
TABLE 4 Factors associated with the intention to receive a third COVID-19 vaccine dose (n = 638).

| Factor                      | Intention to receive a third COVID-19 dose | Adjusted OR (95% CI) | p-value  |
|-----------------------------|-------------------------------------------|----------------------|----------|
|                             | Yes (n = 269)                             | No (n = 369)         |          |
| Age group (years)           |                                           |                      |          |
| 18–34 (reference group)     | 80 (30.8)                                 | 180 (69.2)           |          |
| 35–44                       | 142 (47.5)                                | 157 (52.5)           | 1.61 (1.09–2.38) | 0.017    |
| 55+                         | 47 (59.5)                                 | 32 (40.5)            | 1.92 (1.06–3.49) | 0.032    |
| Sex                         |                                           |                      |          |
| Female (reference group)    | 163 (40.8)                                | 237 (59.2)           |          |
| Male                        | 106 (44.5)                                | 132 (55.5)           | 1.04 (0.71–1.53) | 0.822    |
| Cohort                      |                                           |                      |          |
| First (R1-R10)              | 63 (31.7)                                 | 136 (68.3)           |          |
| Second (R10 "top-up”)       | 206 (46.9)                                | 233 (53.1)           | 2.04 (1.36–3.10) | 0.001    |
| Smoking status              |                                           |                      |          |
| Non-smoker (reference group)| 236 (41.0)                                | 340 (59.0)           |          |
| Smoker                      | 33 (33.2)                                 | 29 (46.8)            | 2.21 (1.22–4.03) | 0.009    |
| Experienced any adverse effects1 |                                      |                      |          |
| No (reference group)        | 109 (55.3)                                | 88 (44.7)            |          |
| Yes                         | 160 (36.3)                                | 281 (63.7)           | 0.52 (0.35–0.77) | 0.001    |
| Constructs of vaccine hesitancy2 (median, IQR) |                                    |                      |          |
| Confidence                  | 5.3 (4.0–6.0)                             | 4.0 (3.3–5.0)        | 1.54 (1.30–1.84) | <0.001   |
| Complacency                 | 3.3 (2.3–4.0)                             | 4.0 (3.0–4.3)        | 0.85 (0.71–1.01) | 0.070    |
| Constraint                  | 2.7 (2.0–4.0)                             | 3.7 (2.7–4.0)        | 0.82 (0.69–0.98) | 0.027    |
| Calculation                 | 5.7 (4.7–6.0)                             | 5.3 (4.3–6.0)        | 0.94 (0.77–1.14) | 0.536    |
| Collective                  | 5.7 (4.7–6.3)                             | 4.7 (4.0–5.7)        | 1.30 (1.04–1.64) | 0.023    |

1From the first and/or second COVID-19 vaccine dose. 2Average scores of items within each construct were computed, with higher scores indicating higher levels of the constructs. Cronbach's alpha values for the 5 constructs ranged from 0.72 - 0.87. OR, Odds ratio; CI, Confidence interval. Bold figures indicate p-values smaller than 0.05.

Conclusions

Given the fourth COVID-19 vaccine dose may offer to all adults, this study helps to refine existing and future strategies in vaccination campaigns. Strategies for improving boosting uptake include targeting the younger adults, providing additional information to alleviate concerns about the vaccine's adverse effects, improving confidence in vaccines by the general public, rebuilding the trust of fence-sitters in the health authorities (40, 41) and providing apathetics additional information to drive personal benefits and costs.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Survey Behavioral Research Ethics Committee of the Chinese University of Hong Kong (reference number: SBRE-20-037). The patients/participants provided their written informed consent to participate in this study.

Author contributions

Conceptualization: KK, KL, and SW. Formal analysis: KK, KL, CL, and EM. Methodology: KK, KL, CI, EM, AT, EC, and WW. Writing-original draft: KK. Data collection:
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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.935243/full#supplementary-material

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