BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-064468
Article Type:	Original research
Date Submitted by the Author:	12-May-2022
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Keywords:	COVID-19, EPIDEMIOLOGY, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Public health < INFECTIOUS DISEASES

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COVID-19 vaccine acceptance in rural Bangladesh is very high: implications for the journey towards herd immunity

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Abstract

Objective: To evaluate coronavirus disease 2019 (COVID-19) vaccine acceptance and uptake in rural Bangladesh.

Design: Cross-sectional.

Setting: Rural Bangladesh.

Participants: Age ≥18 years, not pregnant, no history of surgery for the last three months.

Primary and secondary outcomes: The primary outcomes were proportions of COVID-19 vaccine acceptance and roll-out participation among the rural population. The secondary outcome was identification of correlates which contributed to COVID-19 vaccine acceptance and roll-out participation. Chi-square tests and multivariable logistic regression analyses were performed to identify relevant correlates such as sociodemographic factors, clinical conditions, and COVID-19 related factors.

Results: A total of 1,603 participants was enrolled. The overall COVID-19 vaccine acceptance was very high (1,521/1,601, 95%), and half of the participants have received at least one dose of the COVID-19 vaccine. Majority of participants wanted to keep others safe (89%) and agreed to the benefits of COVID-19 vaccines (88%). Most participants received information from television (56%) or friends and family (33%), and 62% had to visit an internet café to

register for the vaccines. Increased age, being housewives, underweight and an undergraduate education level were associated with vaccine acceptance, while being female, increased age and being overweight/obese were associated with vaccine uptake. Trust in the health department and practical knowledge regarding COVID-19 vaccines were associated with both vaccine acceptance and uptake.

Conclusion: COVID-19 vaccine acceptance is very high in rural Bangladesh. Policymakers should ensure an ongoing and effective communication regarding vaccines, increase vaccine literacy in the population, and improve supply and distribution of vaccines across the country.

Keywords: COVID-19, vaccine acceptance, vaccine roll-out, Bangladesh, rural

Word count: 4,348

Article summary (strengths and limitations of this study)

- This study has a large sample size and utilised offline data collection methods suitable for the assessment of rural population
- The sampling methods used are well-established (multi-stage cluster random approach and the 'Kish-Grid' protocol)
- Utilisation of cross-sectional design means inference cannot be made and incidence cannot be calculated

Introduction

Mass vaccinations have been demonstrated to effectively curb the spread of the coronavirus disease 2019 (COVID-19) pandemic in many countries, allowing livelihoods to return to a new normal [1]. However, vaccine hesitancy has resulted in delay of acceptance or complete refusal of safe and efficacious COVID-19 vaccines across the globe [2, 3]. In early 2021, a study of low-to-middle income countries (LMICs) across Asia, Africa and South America reported an overall COVID-19 vaccine acceptance rate of 80.3% [4]. Acceptance rates in Bangladesh, India, Pakistan, and Nepal at the same period of time were lower, at 65%, 66%, 72% and 74% respectively [5]. In many countries, including LMICs, the risk of potential vaccine hesitancy remains significant due to complex political, geographical, social, and other determinants [6].

The developed world has vaccinated the majority of their population and are continuing to roll-out booster programs [7]. This contrasts the reality in most LMICs, which remain behind in the roll-out progress due to vaccine inequity and a lack of supply [8, 9]. As observed in many LMICs, Bangladesh has been struggling to curb its COVID-19 infections and meet vaccination ambitions. As at 24 March 2022, only 57% of the entire Bangladeshi population have received two doses of the COVID-19 vaccines and 4% have received a booster vaccine [10], among the slowest in Asia and globally [8]. The estimated herd immunity threshold for COVID-19 is estimated to be at 85% or higher [11], and boosters will remain critical to combat current and future variants of COVID-19. While currently available COVID-19 vaccines do not necessarily prevent COVID-19 infection, it is highly effective at preventing hospital systems from being overwhelmed by COVID-19 patients (due to reduced hospitalisation) [12].

During the initial phase of the vaccine roll-out in Bangladesh (January - February 2021), four studies indicated a moderate-to-high prevalence of vaccine acceptance (59% to 68%) [5, 13-15]. These studies included mostly young to middle aged people from urban areas and utilised online data collection methods, which cannot fully capture the perspective of underprivileged people living in rural/remote areas. A study prior to the roll-out, which included 52% rural participants, reported 75% were willing to vaccinate against COVID-19 if a safe and effective vaccine was available without a fee [16]. Currently, no studies have been conducted solely on the rural population in Bangladesh, which represent 62.2% of population in the country [17] and are often underrepresented in COVID-19 related studies. Additionally, given the data collection period of these studies was prior to or during the initial phase of the vaccine roll-out, it is unknown whether vaccine acceptance has changed overtime [8]. Critically, during this initial roll-out period, an online registration process for those seeking to get vaccinated was made compulsory [8], and 46% of rural communities in Bangladesh do not have access to the internet [18]. The effects of other potentially critical determinants on COVID-19 vaccine acceptance in the rural population, such as the effect of misinformation of vaccine safety and efficacy, social media and previous COVID-19 diagnosis, and barriers to receiving vaccines, are also unknown. Therefore, the aim of the study was to evaluate vaccine acceptance and participation rates during an ongoing COVID-19 vaccination roll-out in rural Bangladesh.

Methods

Study design and population

We conducted a cross-sectional study in rural Bangladesh from June to November 2021. For sampling, a multi-stage cluster random approach was used. Households were selected from 17 villages in rural Bangladesh and data was collected from an eligible member in the selected household using the 'Kish Grid' method [19]. Sample size calculation is provided in Supplementary Appendix 1.

Patient and public involvement

Patients or the public were not involved in the design, reporting, or dissemination plans of our research.

Sampling method

A multi-stage cluster random sampling method was used. Randomness was maintained in all selection processes. Geographically, Bangladesh is divided into eight divisions/regions, the first level of administrative hierarchy (Figure 1). One division was randomly selected from these eight divisions, followed by a further random selection of one district from all districts (the second level of administrative hierarchy) of the selected division. Thereafter, an upazila (third level of administrative hierarchy) was selected from the selected district. Finally, a union parishad (the fourth and final level of administrative hierarchy) was selected from this upazila.

The interviewers firstly identified a household closest to the centre point of the union parishad as the first household for enrolment. Then, using a predefined inclusion criteria (age ≥18 years, not pregnant, no history of surgery for the last three months) a household member was interviewed [20]. The 'Kish Grid' method was used to collect data from an eligible member in

the selected household [19]. This method required interviewing only a single eligible member of the selected household. If the selected household member was unavailable (e.g., household shutdown or decline to participate), the next eligible household was approached (Figure 1). The second eligible household was selected by skipping the next household, and choosing the subsequent household (i.e., every alternate household). This process was repeated until the expected sample size of 1,553 participants was reached (Supplementary Appendix 1). A total of 17 villages were covered in this survey. Throughout the data collection period, gender and age group proportion was maintained. Training was provided for data collectors, including COVID-safe practice (see Supplementary Appendix 2 for more information).

Participants' consent

Prior to commencement of the interview, the data collector informed the participants regarding the details of the study, including freedom to participate and how the information will be used. If the participant agreed to participate, an explanatory statement was provided and any queries from participants were addressed. The participants were asked to sign a consent form after which they were interviewed.

Data collection

A structured questionnaire was developed for this study based on published literature and validated questionnaires. The questions were written in plain, simple English, which was translated into Bengali, the local language. To ensure consistency, the Bengali version was again converted to English. The questionnaire took approximately 40 minutes to complete per participant. Research Electronic Data Capture (REDCap), a secure web-based application, was

used to create the survey, pool and manage data. REDCap ensures validated data entry, helps track data manipulation, and enables easy and automated data export into common statistical software packages. Supplementary Appendix 3 and 4 provide details on quality control of data collection, and data access and storage, respectively.

We collected participants' socio-demographic information (age, gender, marital status, education level, and employment status), lifestyle factors (smoking status and consumption of chewing tobacco alone or with betel leaf), anthropometric measures (height, weight, waist and hip size), and clinical conditions (hypertension, coronary artery disease, kidney disease, cancer, asthma, stroke, anxiety and depression). Vaccine acceptance was determined using a close-ended question inquiring participants' willingness to get vaccinated as the main outcome variable. It has two categorical responses: yes (indicating acceptance) and maybe/no (hesitance). Vaccine hesitancy was defined as a delay in acceptance or downright refusal of vaccines albeit readiness of vaccine services, as per World Health Organisation's definition [21]. Vaccine roll-out participation was determined using a close-ended question inquiring whether participants have received at least the first dose of COVID-19 vaccine. The question had two categorical responses (yes and no). Non-demographic correlates which may have contributed to vaccine acceptance and roll-out participation were determined. This included questions surrounding participants' general knowledge regarding vaccinations prior to the pandemic, knowledge and/or experience regarding the COVID-19 vaccine (including availability, accessibility, perceptions of risk and benefits, scheduling and compliance) and factors which may contribute to hesitancy such as political and religious factors, previous COVID-19 status, trust (or a lack thereof) in health systems or pharmaceutical industries, and

potential source of vaccine misinformation such as use of social media. We also explored willingness-to-pay perceptions if the COVID-19 vaccine was no longer available for free in Bangladesh.

Measures of anthropometric and clinical variables

Participants' heights were collected using a portable stadiometer. They were instructed to stand straight against a wall while barefoot, head facing forward and arms on their sides. A head plate was placed on the crown of the head and their height was measured to the nearest 0.5 cm. The measurement was repeated at least twice, and an average was recorded. A digital weighing machine was used to measure body weight. Participants were instructed to stand barefoot on the machine with arms on their sides and head facing forward. Weight was recorded to the nearest 0.1 kg. Blood pressure measurement was taken using a digital sphygmomanometer. Participants were asked to avoid drinking caffeine or smoking at least 30 minutes, and to lean back on their seat, legs uncrossed, feet flat on the floor and rest for at least five minutes prior to measurement. The arm was placed at the heart level and freed of any excess clothing. Blood pressure was measured three times in 5-minute intervals for every participant. History of chronic disease including coronary artery disease (CAD), kidney disease, diabetes, asthma, cancer, arthritis and stroke were validated through a documented diagnosis or medication history (verified by a medical doctor) or any past clinical procedures. Anxiety and depression were assessed using the Generalized Anxiety Disorder-7 (GAD-7) scale [22] and Patient Health Questionnaire (PHQ-9) [23] respectively. Operational definitions are provided in Supplementary Appendix 5.

Outcome measures

The main outcomes of interest were rate of acceptance and uptake of the COVID-19 vaccine. Vaccine acceptance was defined as the individual decision to accept or refuse vaccines when presented with the opportunity to vaccinate [24]. Vaccine uptake was defined as having received at least one dose of the COVID-19 vaccine.

Statistical analysis

Descriptive statistics of demographic, lifestyle and clinical variables of vaccine acceptance and roll-out participation were presented as frequencies and percentages for categorical variables and means and standard deviations for continuous variables. Chi-square test was performed to assess the association between vaccine acceptance and roll-out participation with all potential correlates. Multivariable logistic regression analyses along with stepwise variable selection were performed for two main outcome variables: COVID-19 vaccine acceptance (yes/no) and if one has received at least one dose of COVID-19 vaccine (yes/no). Adjusted odds ratio (OR) and 95% confidence intervals (CIs) were presented from stepwise multivariable logistic regression analysis. A two-tailed p-value of 0.05 was considered statistically significant. All the statistical analyses were performed in the statistical software Stata version 17.0.

Results

Characteristics of study participants

A total of 1,603 participants were included in this study, wherein 51% were male. The mean age of participants was 42.3±14.2 years. Majority of participants were married (87.8%) and

attended secondary school as their highest level of education (42.2%). The proportion of participants who were married or employed was identical (44.5%). Of all participants, nearly a fifth (19.8%) were active smokers and 24.0% were regular users of chewing tobacco. The mean BMI of participants was 24.2±6.2 kg/m^2. Almost a third (30.7%) of study participants presented with a chronic disease.

Table 1 provides a summary finding of key practical and behavioural questions. Among our study participants, only 21.1% had a smartphone and 18.6% were social media users. Television and relatives/friends were the main source of information. Participants had a good understanding of vaccine benefits and side effects in general, but only 49.9% have been previously vaccinated with other vaccines prior to COVID (e.g., influenza vaccine).

Table 1. Distribution of COVID-19 vaccine acceptance and roll-out in rural Bangladesh, according to sociodemographic, lifestyle and clinical factors (n=1,603)

Variables	Vaccine acceptance			Received COVID-19 vaccine		
	Yes, n (%)	No, n (%)	p-value	Yes, n (%)	No, n (%)	p-value
All participants	1521 (95.0%)	82 (5.1%)		801 (50.0%)	802 (50.0%)	
SOCIODEMOGRAPHIC FACTORS						
Gender						
Male	761 (93.1)	57 (6.9)	**0.001**	411 (50.2)	407 (49.8)	0.822
Female	760 (96.8)	25 (3.2)		390 (49.7)	395 (50.3)	
Age groups						
<30 years	333 (88.3)	44 (11.7)	**<0.001**	99 (26.3)	278 (73.7)	**<0.001**
30 - 50 years	777 (97.3)	22 (2.8)		430 (53.8)	369 (46.2)	

>50 years	411 (96.3)	16 (3.8)		272 (63.7)	155 (36.3)	
Marital status						
Married	1347 (95.6)	61 (4.3)		725 (51.5)	683 (48.5)	
Not married	76 (81.7)	17 (18.3)	**<0.001**	17 (18.3)	76 (81.7)	**<0.001**
Others	98 (96.1)	4 (3.9)		59 (57.8)	43 (42.2)	
Education level						
Illiterate/never went to school	422 (96.1)	17 (3.9)		234 (53.3)	205 (46.7)	
Primary school	392 (95.8)	17 (4.2)	0.181	217 (53.1)	192 (46.9)	**0.026**
Secondary	632 (93.5)	44 (6.5)		319 (47.2)	357 (52.8)	
Undergraduate & above	75 (94.9)	4 (5.1)		31 (39.2)	48 (60.8)	
Employment status						
Unemployed	100 (93.5)	7 (7.5)		72 (67.3)	35 (32.7)	
Employed/self-employed	673 (94.3)	41 (5.7)	**<0.001**	367 (51.4)	347 (48.6)	**<0.001**
Housewife	692 (97.1)	21 (2.9)		352 (49.4)	361 (50.6)	
Students or retirees	56 (81.2)	13 (18.8)		10 (14.5)	59 (85.5)	
LIFESTYLE-RELATED FACTORS						
Body mass index (kg/m^2)						
Normal (18.5 - 22.9 kg/m^2)	511 (91.9)	45 (8.1)		247 (44.4)	309 (55.6)	
Underweight (<18.5 kg/m^2)	129 (96.2)	5 (3.7)	**0.001**	60 (44.8)	74 (55.2)	**0.002**
Overweight (23.0 - 27.5 kg/m^2)	569 (96.2)	22 (3.7)		317 (53.6)	274 (46.4)	
Obese (>27.5 kg/m^2)	312 (96.8)	10 (3.1)		177 (54.9)	145 (45.1)	
Smoking history						
Current smoker	288 (91.1)	28 (8.9)		150 (47.5)	166 (52.5)	
Former smoker	85 (92.4)	7 (7.6)	**0.001**	56 (60.9)	36 (39.2)	0.076
Non smoker	1140 (96.0)	47 (3.9)		593 (49.9)	594 (50.1)	

Chewing tobacco or betel leaf users						
Current user	362 (94.0)	23 (6.0)	0.318	212 (55.1)	173 (44.9)	0.053
Former user	28 (90.3)	3 (9.7)		17 (54.8)	14 (45.2)	
Non user	1130 (95.3)	56 (4.7)		571 (48.2)	615 (51.8)	
Use of social media						
Yes	267 (89.6)	31 (10.4)	**<0.001**	108 (36.2)	190 (63.8)	**<0.001**
No	1254 (96.1)	51 (3.91)		693 (53.1)	612 (46.9)	
Chronic disease						
No conditions	965 (93.8)	64 (6.2)	0.124	483 (46.9)	546 (53.1)	**0.022**
Hypertension	134 (95.1)	7 (4.9)		77 (54.6)	64 (45.4)	
Diabetes	204 (97.1)	6 (2.9)		123 (58.6)	87 (41.4)	
Heart disease	51 (98.1)	1 (1.9)		25 (48.1)	27 (51.9)	
Asthma	72 (97.3)	2 (2.7)		38 (51.4)	36 (48.6)	
Others*	95 (97.9)	2 (2.1)		55 (56.7)	42 (43.3)	
Anxiety						
Have anxiety	239 (92.3)	20 (7.7)	**0.038**	677 (50.4)	667 (49.6)	0.462
Do not have anxiety	1282 (95.4)	62 (4.6)		124 (47.8)	135 (52.1)	
Depression						
Have depression	285 (95.6)	13 (4.4)	0.513	650 (49.8)	655 (50.2)	0.788
Do not have depression	1236 (94.7)	69 (5.3)		151 (50.6)	147 (49.3)	

*Stroke, arthritis, cancer, kidney disease and others.

Table 2 outlines the distribution and results of chi-square tests of COVID-19 vaccine acceptance and roll-out according to different sociodemographic, lifestyle and clinical factors. Overall vaccine acceptance among study participants was very high (1,521/1,601, 95.0%). Acceptance was higher in female compared to male (96.8% vs. 93.1% respectively, p = 0.001), but lowest in the youngest age group (<30 years, 88.3%) compared to older age groups (30-50 years and >50 years, 97.3% and 96.3% respectively) (p < 0.001). Vaccine acceptance appeared to be lowest in those who were not married (81.7%, p < 0.001). The prevalence of acceptance was similar across different education levels. In terms of employment status, acceptance was lowest in students or retirees (81.2%) compared to unemployed (93.5%) and employed/self-employed (94.3%) participants, and highest among housewives (97.1%). Higher BMI was positively associated with higher proportion of COVID-19 vaccine acceptance (normal: 91.9% vs. obese: 96.8%, p = 0.001). Non-smokers had the highest proportion of acceptance compared to former or current smokers (96.0%, 92.4% and 91.1% respectively, p = 0.001), while the prevalence was not significantly different among chewing tobacco users and non-users. In terms of clinical conditions, acceptance was lower among those with anxiety compared to those without (92.3% vs. 95.4%, p = 0.038), and similar trends was observed across different types of chronic diseases or depression status.

Table 2. Key practical and behavioural questions regarding COVID-19 vaccination in rural Bangladesh

Questions	Response		
	Yes, n (%)	No, n (%)	Unsure/others, n (%)
Attitude towards vaccination (in general terms) prior to COVID-19 pandemic			
Are you aware of the benefits of vaccines?	1451 (90.6)	151 (9.4)	N/A

Are you aware of potential side effects of vaccines?	1178 (73.5)	424 (26.5)	N/A
Have you been vaccinated previously e.g., for influenza?	794 (49.9)	796 (50.1)	N/A
Previous experience with vaccination prior to COVID-19 pandemic			
Was the place you had your vaccination in clean?	773 (97.7)	18 (2.3)	N/A
Did you consider the delivery of the vaccine safe?	655 (82.9)	135 (17.1)	N/A
Did you experience any side effects after getting vaccinated?	125 (15.9)	659 (84.1)	N/A
Knowledge of COVID-19 vaccination			
Have you heard about the COVID-19 vaccine?	1597 (99.7)	5 (0.3)	N/A
Do you understand the dosage?	1525 (95.2)	77 (4.8)	N/A
Are you familiar with the brands?	1484 (92.9)	113 (7.1)	N/A
Are you aware of the potential side-effects?	1341 (83.7)	261 (16.3)	1 (0.1)
Source of information for COVID-19 vaccination			
What is your main source of COVID-19 information?	-	-	-
Television	895 (55.8)	N/A	N/A
Social media	166 (10.4)	N/A	N/A
Relatives or friends	534 (33.3)	N/A	N/A
Others	8 (0.5)	N/A	N/A
Do you trust your main source of information?	1253 (78.2)	6 (0.4)	343 (21.4)
Do you use social media?	298 (18.6)	1305 (81.4)	N/A
If yes, which platform do you use?	-	-	-
Facebook messenger	288 (96.6)	N/A	N/A
Instagram or others	10 (3.4)	N/A	N/A
If yes, do you always believe everything you find there?	22 (7.4)	12 (4.0)	264 (88.6)
If yes, do you think all the information is from a trusted source?	21 (7.1)	18 (6.0)	259 (86.9)
Availability and potential barriers of getting the COVID-19 vaccine			

Do you have smartphones?	338 (21.1)	1265 (78.9)	N/A
Do you understand how to register for the COVID-19 vaccine?	1439 (89.8)	164 (10.2)	N/A
Have you registered for the COVID-19 vaccine?	1242 (77.9)	353 (22.1)	N/A
If yes, did you find the overall registration process easy?	1016 (87.2)	149 (12.8)	N/A
If yes, was the app easy to download and use?	73 (31.2)	1 (0.4)	160 (68.4)*
Any out-of-pocket costs associated with the registration?	1019 (71.4)	241 (16.9)	167 (11.7)
Do you know where to get the COVID-19 vaccine?	1587 (99.1)	15 (0.9)	N/A
Is it easy to travel there?	1518 (95.7)	37 (2.3)	31 (2.0)
Influence of previous COVID-19 status			
Have you been tested for COVID-19 before?	25 (1.6)	1578 (98.4)	N/A
Have you been diagnosed with COVID-19 before?	6 (0.4)	1597 (99.6)	N/A
Has a close relative or friend been previously diagnosed with COVID-19?	31 (1.9)	1571 (98.1)	N/A
Influence of personal beliefs			
Do you trust the government information related to COVID-19 vaccine?	1550 (96.8)	11 (0.7)	41 (2.6)
Should the government make the COVID-19 vaccine compulsory?	1541 (96.1)	32 (2.0)	30 (1.9)
Is the government doing a good job with the roll-out?	1452 (90.6)	77 (4.8)	73 (4.6)
Do you trust the health department related to COVID-19 vaccine?	1566 (97.8)	15 (0.9)	20 (1.3)
Is the health department is doing a good job with the roll-out?	1479 (92.6)	56 (3.5)	63 (3.9)
Do you think pharmaceutical companies developed the vaccine to help society?	626 (39.1)	827 (51.8)$	146 (9.1)
Does your religion have any restrictions on getting vaccinated?	3 (0.2)	1513 (94.4)	87 (5.4)
Which country do you trust to produce the COVID-19 vaccine?	-	-	-
India	45 (2.8)	N/A	N/A
China	461 (28.8)	N/A	N/A
Russia	15 (0.9)	N/A	N/A
UK	19 (1.2)	N/A	N/A

USA	135 (8.4)	N/A	N/A
Others	924 (57.8)	N/A	N/A
If you had to pay for the vaccine (i.e., no longer free), would you pay for it?	911 (56.9)	514 (32.1)	176 (11.0)

*Neither easy nor difficult or have not tried yet; $To help society and for profit, or only for profit; N/A: not applicable

The reasons for acceptance among participants were primarily due to wanting to keep others safe (88.6%), followed by feeling socially pressured to get vaccinated (7.7%). The reasons for not wanting to get vaccinated among those who are hesitant included falling into an ineligible age category (27.5%), confident that their bodies could fight the virus naturally (23.8%) and wanting to see others take the vaccine first (20%). In terms of personal beliefs/attitude, 88.3% believed that there are benefits associated with being vaccinated from COVID-19 (Table 1). These included being protected from catching COVID-19 (82%), reaching herd immunity for the community to be safe (9.7%), and ability to travel domestically (5.2%).

The results from the stepwise multivariable logistic regression analysis (Table 3) revealed that increased age (OR 4.4, 95 % CI 2.4 - 8.2, $p < 0.001$ to 5.2, 95% CI 2.5 - 10.7, $p < 0.001$), being a housewife (OR 2.9, 95% CI 1.6 - 5.2, $p = 0.001$) or underweight (OR: 3.2, 95% CI 1.0 - 9.7, $p = 0.043$) were associated with higher COVID-19 vaccine acceptance. Participants with at least undergraduate qualifications were more likely to accept the vaccine (OR: 3.6, 95% CI 1.0 - 12.7, $p = 0.045$), while being a student or retiree reduced the likelihood by 60% (95% CI 0.1 – 0.9, $p = 0.029$). Presence of anxiety or depression is associated with 50% reduced likelihood of vaccine acceptance. In terms of COVID-19 related factors, knowledge of the dosage (OR 3.2, 95% CI 1.5 – 6.9, $p = 0.003$), where to register for the vaccine (OR 3.4, 95% CI 1.7 – 6.7,

p = 0.001) and where to get the vaccine (OR 5.0, 95% CI 1.2 – 20.5, p = 0.026), as well as willingness to pay if the vaccine was no longer free (OR 3.1, 95% CI 1.8 – 5.4, p < 0.001) were strongly related to vaccine acceptance. For personal belief, trust in the health department was crucial (OR 4.9, 95% CI 2.0 – 12.0, p = 0.001). The results of simple logistic regression of vaccine acceptance are presented in Supplementary Appendix 5, Table S1.

Table 3. Stepwise multivariable logistic regression of demographic, lifestyle, clinical and COVID-19 related correlates and COVID-19 vaccine acceptance and uptake in rural Bangladesh

Variable	Vaccine acceptance		Received COVID-19 vaccine	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Demographics				
Gender (ref: Male)				
Female	-	-	**1.3 (1.1 - 1.7)**	**0.027**
Age groups (ref: <30 years)				
30 - 50 years	**4.4 (2.4 - 8.2)**	**<0.001**	**2.7 (2.1 - 3.8)**	**<0.001**
>50 years	**5.2 (2.5 - 10.7)**	**<0.001**	**4.7 (3.3 - 6.7)**	**<0.001**
Education level (ref: Illiterate)				
Primary	-	-	-	-
Secondary	-	-	-	-
Undergraduate and above	**3.6 (1.0 - 12.7)**	**0.045**	-	-
Employment status (ref: Unemployed)				
Employed	-	-	-	-
Housewife	**2.9 (1.6 - 5.2)**	**0.001**	-	-
Students or retirees	**0.4 (0.1 - 0.9)**	**0.029**	**0.5 (0.2 - 0.9)**	**0.040**

Anthropometric and lifestyle behaviour				
BMI (kg/m²) (ref: Normal)				
Underweight	3.2 (1.0 - 9.7)	0.043	-	-
Overweight	-	-	1.3 (1.0 - 1.7)	0.021
Obese	-	-	1.4 (1.1 - 1.8)	0.037
Clinical conditions				
Have anxiety or depression (ref: No)				
Yes	0.5 (0.3 - 0.9)	0.003	-	-
Attitude towards vaccination (in general terms) prior to COVID-19 pandemic				
Have been vaccinated previously e.g., for influenza (ref: No)				
Yes	-	-	0.7 (0.5 - 0.9)	0.007
Knowledge of COVID-19 vaccination				
Understood COVID-19 dosage (ref: No)				
Yes	3.2 (1.5 - 6.9)	0.003	17.0 (6.1 - 47.9)	<0.001
Availability and potential barriers of getting COVID-19 vaccine				
Understood how to register for COVID-19 vaccine (ref: No)				
Yes	3.4 (1.7 - 6.7)	0.001	3.7 (2.4 - 5.6)	<0.001
Understood where to get the vaccine (ref: No)				
Yes	5.0 (1.2 - 20.5)	0.026	-	-
Would you take the vaccine if it is no longer free? (ref: No)				
Yes	3.1 (1.8 - 5.4)	<0.001	-	-
Influence of personal beliefs				
Do you trust the health department regarding information related to COVID-19 vaccine? (ref: No)				
Yes	4.9 (2.0 - 12.0)	0.001	-	-

The following covariates were introduced into the model but were not statistically significant for both vaccine acceptance and uptake: *marital status, smoking history, use of chewing tobacco, chronic disease, aware of benefits of vaccines, familiar with COVID-19 vaccine brands, trust in government.*

Vaccine roll-out participation in rural Bangladesh

Half of the study participants have had at least one dose of the COVID-19 vaccine (Table 2). The roll-out participation rate (i.e., proportion of those who have received the vaccine) was similar across gender, but there was a clear upward trend in roll-out participation when stratified by age groups (26.3% to 63.7%, $p < 0.001$). Just over half (51.5%) of those who are married have received the vaccine, while 76.1% of unmarried participants have received it. Participation rate appeared to have decreased as education level increases (illiterate: 53.3% vs. undergraduate and above: 39.2%, $p = 0.026$). The proportion of those who have received the vaccine was similar according to smoking status, including among users/non-users of chewing tobacco or betel leaf. The prevalence of those who have been vaccinated was generally higher in those with comorbid conditions (48.1%-58.6%) than without (46.9%, $p = 0.022$), but not significantly different when stratified by mental health conditions.

Out of 803 participants who have taken the first dose, 79.2% reported no side effects. Among these first-dose takers, 99.8% were planning to or already took their second vaccination dose. Of those who have taken the second dose (n=263), 99.6% were compliant (i.e., were vaccinated according to the scheduled time), and 88.1% reported having no side effects. Most participants received the vaccines in district hospitals (76.3%) or government registered clinics (22.5%).

Most common reasons of those who have not received the vaccine were a lack of interest (25.1%) and not within the eligible age category (18.9%). For those who have registered (or were intending to register) for the vaccine, participants either visited (or will be visiting) an internet café (61.6%), used their own or someone else's smartphone (15.8%) or directly visited a government hospital (12.8%).

According to the stepwise multivariable logistic regression analysis (Table 3), sociodemographic correlates of roll-out participation were female (OR 1.3, 95% CI 1.1 – 1.7, p = 0.027), increased age (OR 2.7, 95% CI 2.1 – 3.8, p<0.001 to 4.7, 95% CI 3.3 – 6.7, p<0.001), and being overweight or obese (OR 1.3, 95% CI 1.0 – 1.7 and 1.4, 95% CI 1.0-1.8, respectively). Students and retirees were 50% less likely to have been vaccinated than unemployed participants (95% CI 0.2 - 0.9, p = 0.040). Interestingly, previous vaccination (prior to COVID) were associated with reduced likelihood of having received the vaccine (OR 0.7, 95% CI 0.5-0.9, p = 0.007), while knowledge of the dosage (OR 17.0, 95% CI 6.1-47.9, p < 0.001) and how to register for the vaccine (OR 3.7, 95% CI 2.4-5.6, p < 0.001) were related to vaccine uptake. The results of simple logistic regression of vaccine uptake are presented in Supplementary Appendix 5, Table S1.

Discussion

This study is a first to exclusively assess vaccine acceptance among people living in rural Bangladesh. Offline data collection methods were employed to counter a low digital literacy and/or access among the rural population. We found a high COVID-19 acceptance rate of 95% in this population eleven months since start of the roll-out program in January 2021. This

acceptance rate is substantially higher than findings from the general Bangladeshi population (59%-68%) at the initial phase of the roll-out [5, 13-15]. Our observed acceptance rate is further supported by a higher rate of COVID-19 vaccine uptake for at least one dose in rural Bangladesh compared to national data at the end of the data collection period (50% vs. 36% in November 2021). Therefore, our findings may either reflect an improvement in acceptance over time, or an already high acceptance among rural residents since the very start.

Our finding of an exceptionally high COVID-19 vaccine acceptance in rural Bangladesh contrasts a previous sub-analysis of the general Bangladeshi population [16] and countries with similar demographic profile such as India [25], wherein rural residents were more likely to mistrust vaccines. However, vaccine decisions are highly multifactorial and can change over time [26, 27]. A previous study in sub-Saharan African countries also found that hesitancy is higher in urban areas and in richer households [26]. Furthermore, vaccinations have been long accepted in LMICs. According to the Wellcome Global Monitor study in 2018, 95% and 92% of participants in South Asia and East Africa perceived vaccination (in general term) as safe, respectively, compared to 59% in western Europe [6]. Therefore, in the south Asian context, preserving a high confidence in the safety and desirability of COVID-19 vaccines may be the most critical elements while ongoing supply and infrastructural issues are addressed [26].

The main source of information among people in rural Bangladesh were television and relatives, and only 11% were social media users. This is likely due to poor internet coverage and digital literacy among people residing in rural areas [18]. Ironically, this may have been the very reason which prevented people from misinformation [28], thus explaining a slightly

higher acceptance rate among social media non-users compared to users, and to the overall higher acceptance rate (Table 2). Indeed, studies in sub-Saharan African countries [26] and developed countries [29] suggest COVID-19 vaccine resistant individuals were more likely to obtain information from non-traditional and non-authoritative sources, such as social media or unofficial websites. On the other hand, a lack of access to internet may have contributed to a slower start to the vaccination uptake in Bangladesh during the initial roll-out period [10]. This is mainly due to the requirement for online registration for the vaccines [8], which would have been difficult for those living in rural areas. The government has temporarily removed this requirement until 26 February 2022 to accelerate vaccine uptake in the country [30]. Such removal of barriers to getting vaccinated should be continued and would only be possible provided vaccine supply and distribution improves [8].

Trust in the health department, as well as practical knowledge (such as COVID-19 vaccine dosage, how to register for the vaccine, and where to get vaccinated) were correlates of acceptance and/or uptake. The importance of knowledge in COVID-19 vaccine acceptance has been observed previously from studies in the general Bangladeshi population [31] and is echoed globally [27]. While previous data suggest substantial hesitancy due to knowledge of side effects from the COVID-19 vaccines [4], most participants who were hesitant or have not had their vaccines yet cited practical reasons (e.g., not within the eligible age category or want to see others take it first). A previous study demonstrated that people in rural Bangladesh have significantly lower levels of knowledge about COVID-19 and pandemic-appropriate behaviour [32]. Interestingly, in France, hesitancy was highest for vaccines manufactured in China and lowest for a vaccine manufactured in Europe [33]. On the contrary, Chinese-made vaccines

were rather well accepted among our participants (24%) compared to UK- or US-made vaccines (1.2% and 8.4% respectively). These findings highlight that population dynamics regarding vaccinations may vary country-to-country depending on societal norms, political climate as well as traditional culture. Ongoing and effective public health campaigns remain critical to increase vaccine literacy and ensure continued support for national vaccination efforts – thus turning the high levels of acceptance into coverage.

We have identified key messages which should be considered by local and national plans. Firstly, our study and others [5, 13-15] have shown that majority of Bangladeshis, including those in rural areas, recognise the need to be protected from COVID-19. Therefore, health authorities should continue to advocate the importance of getting vaccinated and provide evidence-based information using both offline and online platforms and delivered using layman's terms. Secondly, while there was a low likelihood of social media-driven misinformation , people in rural areas are also more likely to resort to non-traditional treatments or mythical beliefs [34], and these factors should always be considered by policymakers. The final issue would be to improve vaccine supply. While Bangladesh could continue obtaining vaccines from other countries, there may be merit in expanding the funding and resource allocations for alternative avenues to address shortages [35], such as by having locally produced vaccines. This would reduce the reliance on and defuse political issues with supplier countries (such as India, China and Russia) in relation to vaccine supply [36]. Globally, there remains a need to promote LMICs to be on top of priority list for vaccine distribution, and a wider acknowledgement and implementation of mitigation strategies to combat "vaccine hoarding" by developed countries [37].

This study is limited to its cross-sectional design, wherein incidence cannot be measured, and causal inference cannot be made. Nonetheless, the findings of this study may help inform the development of diagnostic tools to assess vaccine acceptance in rural areas. Our results are also pertinent to inform policy in other low income and low resource countries.

Conclusions

In conclusion, COVID-19 vaccine acceptance is very high in rural Bangladesh, and COVID-19 vaccine literacy is associated with both its acceptance and uptake. Measures undertaken at the national, provincial, district and local levels in Bangladesh should be directed to increase vaccine literacy and improve supply and infrastructure, particularly for those living in rural areas. Global policies should address the "band-aid" approach of only vaccinating developed countries and resolve global vaccine inequity, which will propel us a step closer to ending the COVID-19 pandemic for good.

Author contributions

FS, BB, BS, AS and OB designed the survey. MC, MI, LA and HC collected and managed the data. SA, FS and AA analysed the data under BB's supervision. FS drafted the manuscript. BB, BS, AS, OB, MC, MI, HC, AA, LA and SA revised the manuscript and provided intellectual input.

Conflicts of interest

None to declare.

Funding

This study received no funding.

Data sharing statement

No additional data available.

Acknowledgement

FS is supported by an Alfred Deakin Postdoctoral Research Fellowship.

Ethics approval

This study has been approved by Monash University Human Research Ethics Committee (Project ID 29358), and respective local authorities in Bangladesh.

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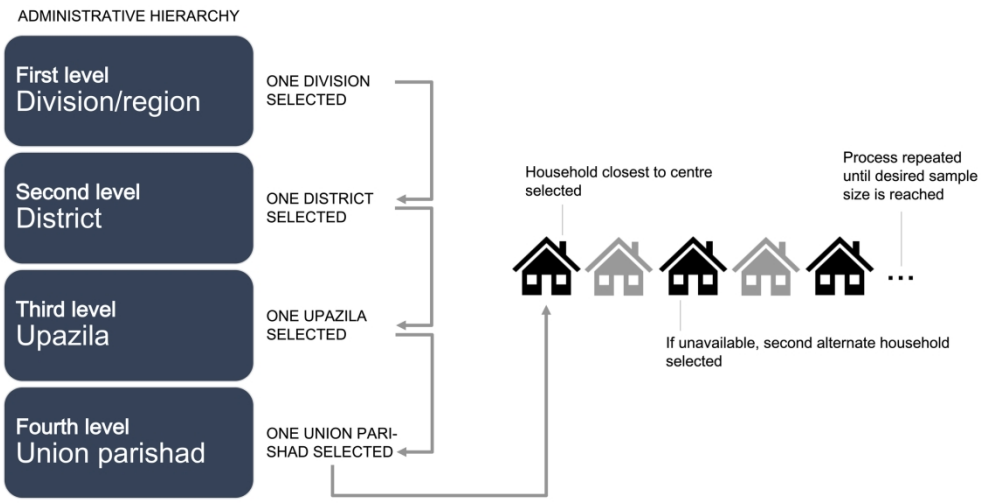
Figure legends

Figure 1. Sampling method.

For data sampling, one of eight divisions/regions in Bangladesh (the first level of administrative hierarchy) was randomly selected. Subsequently, one district (the second level of administrative hierarchy) was randomly selected, followed by random selection of an upazila (third level of administrative hierarchy) from the selected district. Finally, a union parishad (the fourth and final level of administrative hierarchy) was selected from this upazila. A household closest to the centre point of the union parishad was identified as the first household for enrolment. Then, a household member was selected according to the 'Kish Grid' method. If the selected household member was unavailable, the next eligible household was approached. The second eligible household was selected by skipping the next household, and choosing the subsequent household (i.e., every alternate household).



Sampling method.

211x106mm (300 x 300 DPI)

Supplementary Appendix

Supplementary Appendix 1. Sample size calculation

For the survey, the following formula was used to calculate the sample size:

$$n = Z^2 \times p\,(1 - p) \div d^2$$

wherein,

n = the required sample size (respondents/households).

p = the proportion of vaccine hesitancy in rural Bangladesh, which is approximately 35% according to a recent study (1).

d = degree of accuracy desired, which is set at 3%.

$Z\frac{1-\alpha}{2}$ = the standard normal deviation value, which is usually set at 1.96 to maintain a 95% confidence level for the estimated prevalence of vaccine hesitancy.

The above calculation indicated the sample size required was 971. Considering the nationwide generalisability and socio-demographic heterogeneity of the population, the sample size was multiplied by the design effect of 1.5 (2) to adjust sampling variance related to the multi-stage study design (3). This resulted in a sample size of 1,457. Additionally, a 5% non-sampling error was applied, and the final sample size was determined to be 1,533 participants/households to approach for participation.

Supplementary Appendix 2. Training for data collectors and pilot study

Two support persons and five interviewers were appointed for data collection. The support persons originated from the local area of data collection site. Their roles were to help the team navigate the area and build rapport with the local residents. The interviewers had a minimum of graduate level degree and have had previous data collection experience. One of the interviewers was a registered medical nurse. The primary investigator organised a one-week online workshop via Zoom for the interviewers to be familiarised with the aim of the study and content of the questionnaires. The medical nurse was trained to conduct anthropometric and blood pressure measurements and for COVID-19 risk management.

Mock interviews were conducted to ensure full comprehension of relevant data collection techniques and proper conduct in difficult situations. Corrections were made following the mock interviews as appropriate. Thereafter, the interviewers were assigned a designated area to proceed with data collection. Data collectors were also trained to carry out study procedures under COVID-safe protocols. This included mask-wearing, collecting data from participants in a well-ventilated area, physical distancing of 1.5 meters, and using hand sanitizers before and after every procedure.

A pilot study was initially conducted on 24 participants from the selected sampling area to check the acceptability and feasibility of the questionnaire and the average time required for completion. No major amendments were made to the questionnaire.

Supplementary Appendix 3. Quality control of data collection

To ensure that the quality of the study is maintained, data collection and management processes were regularly monitored by the two local study investigators. The investigators also carried out a random consistency check for at least 5% of the interviewed questionnaires to ensure all the details in the questionnaires have been correctly undertaken.

Supplementary Appendix 4. Data access and storage

During the study period, the data was collected, managed and securely stored in REDCap. The data was also exported to Google spreadsheets and saved in a secure university-allocated network storage (Monash University (S:) shared drive) as a backup. Only the research team (chief

investigator and co-investigators) had access to these password-protected electronic databases. The data will be stored in both REDCap and Monash (S:) drive for 5 years as per Monash University data retention policy, after which it will be permanently deleted.

Supplementary Appendix 5. Operational definitions

BMI was calculated and classified as follows: <18.50 kg/m^2 for underweight, 18.50 to 22.99 kg/m^2 for normal (used as reference variable), 23.00 to 27.49 kg/m^2 for overweight and ≥27.50 kg/m^2 for obese (4, 5). A high waist-to-hip ratio was defined as >0.90 for men and >0.85 for women (4, 6). Hypertension was defined as either a documented diagnosis of hypertension, taking of antihypertensive medications or a further two high blood pressure readings in 3-day intervals during the study period (i.e., if systolic blood pressure measurement was ≥140 mmHg and/or diastolic blood pressure measurement was ≥90 mmHg) (7). The presence of anxiety and depression was defined as a score of five or more using the GAD-7 scale (8) and PHQ-9 (9) respectively.

Supplementary Appendix 5. Additional analysis output

Table S1. Univariable logistic regression of demographic, lifestyle and clinical correlates and COVID-19 vaccine acceptance and uptake in rural Bangladesh

Variable	Vaccine acceptance		Received COVID-19 vaccine	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Demographics				
Gender (ref: Male)				
Female	**2.3 (1.4 - 3.7)**	**0.001**	1.0 (0.8 - 1.2)	0.822
Age groups (ref: <30 years)				
30 - 50 years	**4.7 (2.8 - 7.9)**	**<0.001**	**3.3 (2.5 - 4.3)**	**<0.001**
>50 years	**3.4 (1.9 - 6.1)**	**<0.001**	**4.9 (3.6 - 6.7)**	**<0.001**
Marital status (ref: Not married)				
Married	**4.9 (2.8 - 8.9)**	**<0.001**	**4.8 (2.8 - 8.1)**	**<0.001**
Others	**5.5 (1.8 - 17.0)**	**0.003**	**6.1 (3.2 - 11.8)**	**<0.001**
Education level (ref: Illiterate)				
Primary	0.9 (0.5 - 1.8)	0.833	1.0 (0.8 - 1.3)	0.943
Secondary	0.6 (0.3 - 1.0)	0.061	**0.8 (0.6 - 1.0)**	**0.046**
Undergraduate and above	0.8 (0.3 - 2.3)	0.622	**0.6 (0.4 - 0.9)**	**0.022**
Employment status (ref: Unemployed)				
Employed	1.1 (0.5 - 2.6)	0.742	**0.5 (0.3 - 0.8)**	**0.002**
Housewife	2.3 (1.0 - 5.6)	0.063	**0.5 (0.3 - 0.7)**	**0.001**
Others	**0.3 (0.1 - 0.8)**	**0.016**	**0.1 (0.0 - 0.2)**	**<0.001**
Anthropometric and lifestyle behaviour				

BMI (kg/m²) (ref: Normal)				
Underweight	2.3 (0.9 - 5.8)	0.088	1.0 (0.7 - 1.5)	0.941
Overweight	**2.3 (1.4 - 3.9)**	**0.002**	**1.5 (1.2 - 1.8)**	**0.002**
Obese	**2.8 (1.4 - 5.5)**	**0.005**	**1.5 (1.2 - 2.0)**	**0.003**
Smoking history (ref: Non smoker)				
Former smoker	0.5 (0.2 - 1.1)	0.100	**1.6 (1.0 - 2.4)**	**0.045**
Current smoker	**0.4 (0.3 - 0.7)**	**0.001**	0.9 (0.7 - 1.2)	0.432
Use of chewing tobacco (ref: Non user)				
Former user	0.5 (0.1 - 1.6)	0.216	1.3 (0.6 - 2.7)	0.463
Current user	0.8 (0.5 - 1.3)	0.330	**1.3 (1.1 - 1.7)**	**0.018**
Clinical conditions				
Have chronic disease (ref: No)				
Yes	**1.9 (1.1 - 3.2)**	**0.030**	**1.5 (1.2 - 1.8)**	**<0.001**
Have anxiety or depression (ref: No)				
Yes	0.8 (0.5-1.2)	0.232	1.0 (0.8-1.3)	0.869
Attitude towards vaccination (in general terms) prior to COVID-19 pandemic				
Aware of benefits of vaccines (ref: No)				
Yes	**2.1 (1.1 - 3.8)**	**0.017**	1.1 (0.8 - 1.6)	0.550
Have been vaccinated previously e.g., for influenza (ref: No)				
Yes	1.5 (0.9 - 2.4)	0.070	**0.7 (0.6 - 0.8)**	**0.001**
Knowledge of COVID-19 vaccination				
Understood dosage (ref: No)				
Yes	**6.4 (3.5 - 11.5)**	**<0.001**	**19.9 (7.2 - 54.8)**	**<0.001**
Familiar with the brands (ref: No)				
Yes	1.2 (0.5 - 2.9)	0.745	**2.3 (1.5 - 3.4)**	**<0.001**

Source of information for COVID-19 vaccination				
Source of information (ref: Others)				
Television	21.4 (1.3 - 347.9)	0.031	-	-
Social media	10.1 (0.6 - 169.3)	0.110	**0.5 (0.3 - 0.7)**	**<0.001**
Relatives or friends	20.4 (1.2 - 335.1)	0.040	1.0 (0.8 - 1.2)	0.600
Availability and potential barriers of getting COVID-19 vaccine				
Understood how to register for COVID-19 vaccine (ref: No)				
Yes	**3.6 (2.1 - 5.9)**	**<0.001**	**3.6 (2.5 - 5.2)**	**<0.001**
Understood where to get the COVID-19 vaccine (ref: No)				
Yes	17.6 (6.2 - 49.9)	<0.001	-	-
Distance from vaccination centre (in km)				
Distance (km)	0.9 (0.9 - 1.0)	0.450	1.0 (1.0 - 1.1)	0.136
Would you take the vaccine if it is no longer free? (ref: No)				
Yes	**3.1 (1.9 - 4.8)**	**<0.001**	1.1 (0.9 - 1.3)	0.493
Influence of previous COVID-19 status				
Have been diagnosed with COVID-19 (ref: No)				
Yes	-	-	0.5 (0.1 - 2.7)	0.423
A close relative or friends have been previously diagnosed with COVID-19 (ref: No)				
Yes	-	-	**5.4 (2.1 - 14.0)**	**0.001**
Influence of personal beliefs				
Do you trust the government regarding information related to COVID-19 vaccine? (ref: No)				
Yes	**6.8 (3.6 - 13.6)**	**<0.001**	**2.9 (1.5 - 5.3)**	**0.001**
Do you trust the health department regarding information related to COVID-19 vaccine? (ref: No)				
Yes	**11.7 (5.7 - 24.1)**	**<0.001**	**2.8 (1.3 - 5.7)**	**0.007**
Do you think pharmaceutical companies developed the vaccine to help society? (ref: No)				
Yes	1.5 (0.9 - 2.4)	0.104	1.0 (0.8 - 1.2)	0.838
Does your religion have any restrictions on getting vaccinated? (ref: No)				

Yes	-	-	0.5 (0.0 - 5.5)	0.572

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-10
Bias	9	Describe any efforts to address potential sources of bias	*6-7*
Study size	10	Explain how the study size was arrived at	Suppl Appendix 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-10
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	6-7
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	NA
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	Fig 1, pg 17
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers of outcome events or summary measures	10-17
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-17
		(*b*) Report category boundaries when continuous variables were categorized	Table 1
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18-20
Generalisability	21	Discuss the generalisability (external validity) of the study results	20-21
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	21

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Evaluation of COVID-19 vaccine acceptance and uptake in rural Bangladesh: a cross-sectional study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2022-064468.R1
Article Type:	Original research
Date Submitted by the Author:	12-Sep-2022
Complete List of Authors:	Savira, Feby; Deakin University Institute for Health Transformation, Deakin Health Economics & Global Centre for Preventive Health and Nutrition; Monash University School of Public Health and Preventive Medicine Alif, Sheikh M.; Monash University School of Public Health and Preventive Medicine Afroz, Afsana; Monash University School of Public Health and Preventive Medicine, Department of Epidemiology and Preventive Medicine; The University of Melbourne School of Population and Global Health, Centre of Epidemiology and Biostatistics Siddiquea, Bodrun Naher; Monash University, School of Public Health and Preventive Medicine Shetty, Aishwarya; Monash University School of Public Health and Preventive Medicine Chowdhury, Hasina; Monash University School of Public Health and Preventive Medicine Bhattacharya, Oashe; Monash University School of Public Health and Preventive Medicine Chowdhury, Mohammad ; First Capital University of Bangladesh, Department of Public Health Islam, Md. Shariful; First Capital University of Bangladesh, Department of Public Health Ali, Liaquat; Bangladesh University of Health Sciences Billah, Baki; Monash University School of Public Health and Preventive Medicine
Primary Subject Heading:	Public health
Secondary Subject Heading:	Health policy, Epidemiology
Keywords:	COVID-19, EPIDEMIOLOGY, Health policy < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Public health < INFECTIOUS DISEASES

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Evaluation of COVID-19 vaccine acceptance and uptake in rural Bangladesh: a cross-sectional study

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Abstract

Objective: The objective of this study was to evaluate the acceptance and uptake of coronavirus disease 2019 (COVID-19) vaccines in rural Bangladesh.

Design: This was a cross-sectional study conducted between June and November 2021.

Setting: This study was conducted in rural Bangladesh.

Participants: People older than 18 years of age, not pregnant, no history of surgery for the last three months were eligible to participate.

Primary and secondary outcomes: The primary outcomes were proportions of COVID-19 vaccine acceptance and roll-out participation among the rural population. The secondary outcome was identification of correlates which contributed to COVID-19 vaccine acceptance and roll-out participation. Chi-square tests and multivariable logistic regression analyses were performed to identify relevant correlates such as sociodemographic factors, clinical conditions, and COVID-19 related factors.

Results: A total of 1,603 participants was enrolled. The overall COVID-19 vaccine acceptance was very high (1,521/1,601, 95%), and half of the participants received at least one dose of the COVID-19 vaccine. Majority of participants wanted to keep others safe (89%) and agreed to the benefits of COVID-19 vaccines (88%). To fulfil the requirement of online registration for

the vaccine at the time, 62% of participants had to visit an internet café and only 31% downloaded the app. Over half (54%) of participants were unaware of countries they knew and trust to produce the COVID-19 vaccine. Increased age, being housewives, underweight and undergraduate education level were associated with vaccine acceptance, while being female, increased age and being overweight/obese were associated with vaccine uptake. Trust in the health department and practical knowledge regarding COVID-19 vaccines were positively associated with both vaccine acceptance and uptake.

Conclusion: This study found a very high COVID-19 vaccine acceptance in rural Bangladesh. Policymakers should support interventions aimed at increasing vaccine and general health literacy and ensure ongoing vaccine supply and improvement of infrastructure in rural areas.

Keywords: COVID-19 vaccine, acceptance, uptake, rural Bangladesh

Word count: 4,348

Article summary (strengths and limitations of this study)

- Despite numerous publications measuring vaccine acceptance in Bangladesh, there remains significant underrepresentation of rural communities in the COVID-19 vaccine literature. This study addresses this important research gap. We found a very high COVID-19 vaccine acceptance in rural Bangladesh, despite evident barriers such as low health literacy and poor access to digital resources.
- The strengths of this study include the large sample of community-level data and use of offline data collection methods suitable for the assessment of rural population.
- The limitations include inability to make inference and calculate incidence due to the cross-sectional nature of the study. We also did not collect income-related data.

Introduction

Mass vaccinations have been demonstrated to effectively curb the spread of the coronavirus disease 2019 (COVID-19) pandemic in many countries, allowing livelihoods to return to a new normal [1]. However, vaccine hesitancy has resulted in delay of acceptance or complete refusal of safe and efficacious COVID-19 vaccines across the globe [2, 3]. In early 2021, a study of low-to-middle income countries (LMICs) across Asia, Africa and South America reported an overall COVID-19 vaccine acceptance rate of 80.3% [4]. Acceptance rates in Bangladesh, India, Pakistan, and Nepal were lower at the time, at 65%, 66%, 72% and 74% respectively [5]. In many countries, including LMICs, the risk of potential vaccine hesitancy remains significant due to complex political, geographical, social, and other determinants [6].

As at 29 August 2022, 71% of the entire Bangladeshi population have received two doses of the COVID-19 vaccines and 6% have received the boosters [7]. Prior to reaching the World Health Organization (WHO) global double-dose vaccination target of 70% [8], Bangladesh was among the slowest in Asia and globally to reach this target. The reason was due to vaccine inequity and a lack of supply, as also seen in other LMICs [9, 10]. In contrast, most high income countries have vaccinated majority of their population by late 2020 or early 2021, including significant population vaccinated with boosters as at August 2022 [11]. While currently available COVID-19 vaccines do not necessarily prevent COVID-19 infection, it is highly effective at preventing hospital systems from being overwhelmed by COVID-19 patients (due to reduced hospitalisation) [12]. The WHO further emphasised the need to ensure high level of vaccine coverage in all countries due to ongoing threat posed by COVID-19 pandemic, such as emergence of new variants [13].

To date, there are no vaccine acceptance studies that have been conducted off-line solely in the rural population in Bangladesh. Majority of previous studies, except for one study [14], also utilised online data collection methods [5, 15-18]. These studies included mostly young to middle aged people living in urban areas. Crucially, most Bangladeshis living in rural/remote areas do not have access to online resources and would be excluded from internet-based studies [19]. Therefore, despite numerous publications measuring vaccine acceptance in Bangladesh, there remains significant underrepresentation of rural communities in the COVID-19 vaccine literature. Rural Bangladesh population also represents 62.2% of the entire population [20], are more likely to have lower socioeconomic status and have poorer access to healthcare facilities [21]. It is imperative that their perspectives are not left behind in policy decisions. Additionally, the data collection period of these prior studies was before or during the initial phase of the vaccine roll-out program [5, 9, 15-17]. It is of interest whether vaccine acceptance has changed over time with changing circumstances, such as improved understanding of the COVID-19 vaccine. The effects of other potentially critical determinants on COVID-19 vaccine acceptance in the rural population, such as the effect of misinformation of vaccine safety and efficacy, social media and previous COVID-19 diagnosis, and barriers to receiving vaccines, are also unknown. Therefore, using offline data collection methods, this cross-sectional study aimed to evaluate COVID-19 vaccine acceptance and participation rates in rural Bangladesh, between June and November 2021.

Methods

Study design and population

We conducted a cross-sectional study in rural Bangladesh from June to November 2021. For sampling, a multi-stage cluster random approach was used. Households were selected from 17 villages in rural Bangladesh and data was collected from an eligible member in the selected household using the 'Kish Grid' method [22]. Sample size calculation is provided in Supplementary Appendix 1.

Patient and public involvement

Patients or the public were not involved in the design, reporting, or dissemination plans of our research.

Sampling method

A multi-stage cluster random sampling method was used. Randomness was maintained in all selection processes. Geographically, Bangladesh is divided into eight divisions/regions, the first level of administrative hierarchy (Figure 1). One division was randomly selected from these eight divisions, followed by a further random selection of one district from all districts (the second level of administrative hierarchy) of the selected division. Thereafter, an upazila (third level of administrative hierarchy) was selected from the selected district. Finally, a union parishad (the fourth and final level of administrative hierarchy) was selected from this upazila.

The interviewers firstly identified a household closest to the centre point of the union parishad as the first household for enrolment. Then, using a predefined inclusion criteria, a household member was interviewed [23]. The selection criteria included adults aged ≥18 years who

provided consent, not pregnant, without history of surgery in the last three months, and reside in the recruited household within the targeted villages. People residing in urban Bangladesh were excluded.

The 'Kish Grid' method was used to collect data from an eligible member in the selected household [22]. This method required interviewing only a single eligible member of the selected household. If the selected household member was unavailable (e.g., household shutdown or decline to participate), the next eligible household was approached (Figure 1). The second eligible household was selected by skipping the next household, and choosing the subsequent household (i.e., every alternate household). This process was repeated until the required sample size of at least 1,553 participants was reached (see Supplementary Appendix 1 for sample size calculations). A total of 17 villages were covered in this survey.

Throughout the data collection period, sex and age group proportion were maintained. Training was provided for data collectors, including COVID-safe practice (see Supplementary Appendix 2 for more information).

Participants' consent

Prior to commencement of the interview, the data collector informed the participants regarding the details of the study, including freedom to participate and how the information will be used. If the participant agreed to participate, an explanatory statement was provided and any queries from participants were addressed. The participants were asked to sign a consent form after which they were interviewed.

Data collection

A structured questionnaire was developed for this study based on published literature and validated questionnaires. The questions were written in plain and simple English, which was translated into Bengali, the local language. To ensure consistency, the Bengali version was again converted to English. The questionnaire took approximately 40 minutes to complete per participant. Research Electronic Data Capture (REDCap), a secure web-based application, was used to create the survey, pool and manage data. REDCap ensures validated data entry, helps track data manipulation, and enables easy and automated data export into common statistical software packages. Supplementary Appendix 3 and 4 provide details on quality control of data collection, and data access and storage, respectively.

We collected participants' socio-demographic information (age, sex, marital status, education level, and employment status), lifestyle factors (smoking status and consumption of chewing tobacco alone or with betel leaf), anthropometric measures (height, weight, waist and hip size), and clinical conditions (hypertension, coronary artery disease, kidney disease, cancer, asthma, stroke, anxiety and depressive symptom). Vaccine acceptance was determined using a close-ended question inquiring participants' willingness to get vaccinated as the main outcome variable. It has two categorical responses: yes (indicating acceptance) and maybe/no (hesitance). Vaccine hesitancy was defined as a delay in acceptance or downright refusal of vaccines albeit readiness of vaccine services, as per World Health Organisation's definition [24]. Vaccine roll-out participation was determined using a close-ended question inquiring whether participants have received at least the first dose of COVID-19 vaccine. The question

had two categorical responses (yes and no). Non-demographic correlates which may have contributed to vaccine acceptance and roll-out participation were determined. This included questions surrounding participants' general knowledge regarding vaccinations prior to the pandemic, knowledge and/or experience regarding the COVID-19 vaccine (including availability, accessibility, perceptions of risk and benefits, scheduling and compliance) and factors which may contribute to hesitancy such as political and religious factors, previous COVID-19 status, trust (or a lack thereof) in health systems or pharmaceutical industries, and potential source of vaccine misinformation such as use of social media. We also explored willingness-to-pay perceptions if the COVID-19 vaccine was no longer available for free in Bangladesh.

Measures of anthropometric and clinical variables

Participants' heights and weights were collected. Blood pressure measurement was undertaken three times in 5-minute intervals. History of chronic disease including coronary artery disease (CAD), kidney disease, diabetes, asthma, cancer, arthritis and stroke were validated through a documented diagnosis or medication history (verified by a medical doctor) or any past clinical procedures. Anxiety and depressive symptom were assessed using the Generalized Anxiety Disorder-7 (GAD-7) scale [25] and Patient Health Questionnaire (PHQ-9) [26] respectively, both of which have been validated for use in the Bangladeshi context [27, 28]. Operational definitions are provided in Supplementary Appendix 5.

Outcome measures

The main outcomes of interest were prevalence of vaccine acceptance and uptake of the COVID-19 vaccine. Vaccine acceptance was defined as the individual decision to accept or refuse vaccines when presented with the opportunity to vaccinate [29]. Vaccine uptake was defined as having received at least one dose of the COVID-19 vaccine.

Statistical analysis

Descriptive statistics of demographic, lifestyle and clinical variables of vaccine acceptance and roll-out participation were presented as frequencies and percentages for categorical variables and means and standard deviations for continuous variables. Chi-square test was performed to assess the association between vaccine acceptance and roll-out participation with all potential correlates. Multivariable logistic regression analyses along with stepwise variable selection were performed for two main outcome variables: COVID-19 vaccine acceptance (yes/no) and if one has received at least one dose of COVID-19 vaccine (yes/no). Adjusted odds ratio (OR) and 95% confidence intervals (CIs) were presented from stepwise multivariable logistic regression analysis. A two-tailed p-value of 0.05 was considered statistically significant. All the statistical analyses were performed in the statistical software Stata version 17.0.

Results

Characteristics of study participants

Table 1 details the characteristics of the study participants. The total number of participants in this study were 1,603, wherein 51% were male. The mean age of participants was 42.3±14.2 years. Majority of participants were married (87.8%) and attended secondary school as their

highest level of education (42.2%). The proportion of participants who were married or employed was identical (44.5%). Of all participants, nearly a fifth (19.8%) were active smokers and 24.0% were regular users of chewing tobacco. The mean BMI of participants was 24.2±6.2 kg/m^2. Almost a third (30.7%) of study participants presented with a chronic disease.

Table 1. Distribution of COVID-19 vaccine acceptance and roll-out in rural Bangladesh, according to sociodemographic, lifestyle and clinical factors (n=1,603)

Variables	Vaccine acceptance			Received COVID-19 vaccine		
	Yes, n (%)	No, n (%)	p-value	Yes, n (%)	No, n (%)	p-value
All participants	1521 (95.0%)	82 (5.0%)		801 (50.0%)	802 (50.0%)	
SOCIODEMOGRAPHIC FACTORS						
Sex						
Male	761 (93.1)	57 (6.9)	**0.001**	411 (50.2)	407 (49.8)	0.822
Female	760 (96.8)	25 (3.2)		390 (49.7)	395 (50.3)	
Age groups						
<30 years	333 (88.3)	44 (11.7)	**<0.001**	99 (26.3)	278 (73.7)	**<0.001**
30 - 50 years	777 (97.3)	22 (2.8)		430 (53.8)	369 (46.2)	
>50 years	411 (96.3)	16 (3.8)		272 (63.7)	155 (36.3)	
Marital status						
Married	1347 (95.6)	61 (4.3)	**<0.001**	725 (51.5)	683 (48.5)	**<0.001**
Not married	76 (81.7)	17 (18.3)		17 (18.3)	76 (81.7)	
Others	98 (96.1)	4 (3.9)		59 (57.8)	43 (42.2)	
Education level						

Illiterate/never went to school	422 (96.1)	17 (3.9)		234 (53.3)	205 (46.7)	
Primary school	392 (95.8)	17 (4.2)	0.181	217 (53.1)	192 (46.9)	**0.026**
Secondary	632 (93.5)	44 (6.5)		319 (47.2)	357 (52.8)	
Undergraduate & above	75 (94.9)	4 (5.1)		31 (39.2)	48 (60.8)	
Employment status						
Unemployed	100 (93.5)	7 (7.5)		72 (67.3)	35 (32.7)	
Employed/self-employed	673 (94.3)	41 (5.7)	**<0.001**	367 (51.4)	347 (48.6)	**<0.001**
Housewife	692 (97.1)	21 (2.9)		352 (49.4)	361 (50.6)	
Students or retirees	56 (81.2)	13 (18.8)		10 (14.5)	59 (85.5)	
LIFESTYLE-RELATED FACTORS						
Body mass index (kg/m^2)						
Normal (18.5 - 22.9 kg/m^2)	511 (91.9)	45 (8.1)		247 (44.4)	309 (55.6)	
Underweight (<18.5 kg/m^2)	129 (96.2)	5 (3.7)	**0.001**	60 (44.8)	74 (55.2)	**0.002**
Overweight (23.0 - 27.5 kg/m^2)	569 (96.2)	22 (3.7)		317 (53.6)	274 (46.4)	
Obese (>27.5 kg/m^2)	312 (96.8)	10 (3.1)		177 (54.9)	145 (45.1)	
Smoking history						
Current smoker	288 (91.1)	28 (8.9)		150 (47.5)	166 (52.5)	
Ex-smoker	85 (92.4)	7 (7.6)	**0.001**	56 (60.9)	36 (39.2)	0.076
Non smoker	1140 (96.0)	47 (3.9)		593 (49.9)	594 (50.1)	
Chewing tobacco or betel leaf users						
Current user	362 (94.0)	23 (6.0)		212 (55.1)	173 (44.9)	
Former user	28 (90.3)	3 (9.7)	0.318	17 (54.8)	14 (45.2)	0.053
Non user	1130 (95.3)	56 (4.7)		571 (48.2)	615 (51.8)	
Use of social media						
Yes	267 (89.6)	31 (10.4)	**<0.001**	108 (36.2)	190 (63.8)	**<0.001**

No	1254 (96.1)	51 (3.91)		693 (53.1)	612 (46.9)	
CLINICAL FACTORS						
Chronic disease						
No conditions	965 (93.8)	64 (6.2)		483 (46.9)	546 (53.1)	
Hypertension	134 (95.1)	7 (4.9)		77 (54.6)	64 (45.4)	
Diabetes	204 (97.1)	6 (2.9)		123 (58.6)	87 (41.4)	
Heart disease	51 (98.1)	1 (1.9)	0.124	25 (48.1)	27 (51.9)	**0.022**
Asthma	72 (97.3)	2 (2.7)		38 (51.4)	36 (48.6)	
Others*	95 (97.9)	2 (2.1)		55 (56.7)	42 (43.3)	
Anxiety						
Have anxiety	239 (92.3)	20 (7.7)	**0.038**	677 (50.4)	667 (49.6)	0.462
Do not have anxiety	1282 (95.4)	62 (4.6)		124 (47.8)	135 (52.1)	
Depressive symptom						
Have depressive symptom	285 (95.6)	13 (4.4)		650 (49.8)	655 (50.2)	
Do not have depressive symptom	1236 (94.7)	69 (5.3)	0.513	151 (50.6)	147 (49.3)	0.788

*Stroke, arthritis, cancer, kidney disease and others.

Table 2 provides a summary finding of key practical and behavioural questions. Among our study participants, only 21.1% had a smartphone and 18.6% were social media users. Television and relatives/friends were the main source of information. Participants had a good understanding of vaccine benefits and side effects in general, but only 49.9% have been previously vaccinated with other vaccines prior to COVID (e.g., influenza vaccine). Only 31.2% of participants who had registered for the vaccine used the registration app; most

participants have not tried it (68.4%). Nearly all participants responded positively to questions related to trust in the government and health department. Regarding trust in pharmaceutical companies, the responses were divided. Over half (54.1%) of participants did not know which country they were aware of and trusted to produce the COVID-19 vaccine.

Table 2. Key practical and behavioural questions regarding COVID-19 vaccination in rural Bangladesh

Questions	Response		
	Yes, n (%)	No, n (%)	Unsure/others, n (%)
Attitude towards vaccination (in general terms) prior to COVID-19 pandemic			
Are you aware of the benefits of vaccines?	1451 (90.6)	151 (9.4)	N/A
Are you aware of potential side effects of vaccines?	1178 (73.5)	424 (26.5)	N/A
Have you been vaccinated previously e.g., for influenza?	794 (49.9)	796 (50.1)	N/A
Previous experience with vaccination prior to COVID-19 pandemic			
Was the place you had your vaccination in clean?	773 (97.7)	18 (2.3)	N/A
Did you consider the delivery of the vaccine safe?	655 (82.9)	135 (17.1)	N/A
Did you experience any side effects after getting vaccinated?	125 (15.9)	659 (84.1)	N/A
Knowledge of COVID-19 vaccination			
Have you heard about the COVID-19 vaccine?	1597 (99.7)	5 (0.3)	N/A
Do you understand the dosage?	1525 (95.2)	77 (4.8)	N/A
Are you familiar with the brands?	1484 (92.9)	113 (7.1)	N/A
Are you aware of the potential side-effects?	1341 (83.7)	261 (16.3)	1 (0.1)
Source of information for COVID-19 vaccination			
What is your main source of COVID-19 information?	-	-	-

Television	895 (55.8)	N/A	N/A
Social media	166 (10.4)	N/A	N/A
Relatives or friends	534 (33.3)	N/A	N/A
Others	8 (0.5)	N/A	N/A
Do you trust your main source of information?	1253 (78.2)	6 (0.4)	343 (21.4)
Do you use social media?	298 (18.6)	1305 (81.4)	N/A
If yes, which platform do you use?	-	-	-
Facebook messenger	288 (96.6)	N/A	N/A
Instagram or others	10 (3.4)	N/A	N/A
If yes, do you always believe everything you find there?	22 (7.4)	12 (4.0)	264 (88.6)
If yes, do you think all the information is from a trusted source?	21 (7.1)	18 (6.0)	259 (86.9)
Availability and potential barriers of getting the COVID-19 vaccine			
Do you have smartphones?	338 (21.1)	1265 (78.9)	N/A
Do you understand how to register for the COVID-19 vaccine?	1439 (89.8)	164 (10.2)	N/A
Have you registered for the COVID-19 vaccine?	1242 (77.9)	353 (22.1)	N/A
If yes, did you find the overall registration process easy?	1016 (87.2)	149 (12.8)	N/A
If yes, was the app easy to download and use?	73 (31.2)	1 (0.4)	160 (68.4)*
Any out-of-pocket costs associated with the registration?	1019 (71.4)	241 (16.9)	167 (11.7)
Do you know where to get the COVID-19 vaccine?	1587 (99.1)	15 (0.9)	N/A
Is it easy to travel there?	1518 (95.7)	37 (2.3)	31 (2.0)
Influence of previous COVID-19 status			
Have you been tested for COVID-19 before?	25 (1.6)	1578 (98.4)	N/A
Have you been diagnosed with COVID-19 before?	6 (0.4)	1597 (99.6)	N/A
Has a close relative or friend been previously diagnosed with COVID-19?	31 (1.9)	1571 (98.1)	N/A
Influence of personal beliefs			

Do you trust the government information related to COVID-19 vaccine?	1550 (96.8)	11 (0.7)	41 (2.6)
Should the government make the COVID-19 vaccine compulsory?	1541 (96.1)	32 (2.0)	30 (1.9)
Is the government doing a good job with the roll-out?	1452 (90.6)	77 (4.8)	73 (4.6)
Do you trust the health department related to COVID-19 vaccine?	1566 (97.8)	15 (0.9)	20 (1.3)
Is the health department is doing a good job with the roll-out?	1479 (92.6)	56 (3.5)	63 (3.9)
Do you think pharmaceutical companies developed the vaccine to help society?	626 (39.1)	827 (51.8)[$]	146 (9.1)
Does your religion have any restrictions on getting vaccinated?	3 (0.2)	1513 (94.4)	87 (5.4)
Which country were you aware of and trust to produce the COVID-19 vaccine?	-	-	-
India	45 (2.8)	N/A	N/A
China	461 (28.8)	N/A	N/A
Russia	15 (0.9)	N/A	N/A
UK	19 (1.2)	N/A	N/A
USA	135 (8.4)	N/A	N/A
Non-vaccine producing countries	59 (3.6)	N/A	N/A
I do not know	865 (54.1)	N/A	N/A
If you had to pay for the vaccine (i.e., no longer free), would you pay for it?	911 (56.9)	514 (32.1)	176 (11.0)

*Neither easy nor difficult or have not tried yet; [$]To help society and for profit, or only for profit; N/A: not applicable

Vaccine acceptance in rural Bangladesh

Overall vaccine acceptance among study participants was very high (1,521/1,601, 95.0%) (Table 1). Acceptance was higher in female compared to male (96.8% vs. 93.1% respectively, p = 0.001), but lowest in the youngest age group (<30 years, 88.3%) compared to older age groups (30-50 years and >50 years, 97.3% and 96.3% respectively) (p < 0.001). Vaccine

acceptance appeared to be lowest in those who were not married (81.7%, p < 0.001). The prevalence of acceptance was similar across different education levels. In terms of employment status, acceptance was lowest in students or retirees (81.2%) compared to unemployed (93.5%) and employed/self-employed (94.3%) participants, and highest among housewives (97.1%). Higher BMI was positively associated with higher proportion of COVID-19 vaccine acceptance (normal: 91.9% vs. obese: 96.8%, p = 0.001). Non-smokers had the highest proportion of acceptance compared to former or current smokers (96.0%, 92.4% and 91.1% respectively, p = 0.001), while the prevalence was not significantly different among chewing tobacco users and non-users. In terms of clinical conditions, acceptance was lower among those with anxiety compared to those without (92.3% vs. 95.4%, p = 0.038), and similar trends was observed across different types of chronic diseases or presence of depressive symptom.

The reasons for acceptance among participants were primarily due to wanting to keep others safe (88.6%), followed by feeling socially pressured to get vaccinated (7.7%). The reasons for not wanting to get vaccinated among those who are hesitant included falling into an ineligible age category (27.5%), confident that their bodies could fight the virus naturally (23.8%) and wanting to see others take the vaccine first (20%). In terms of personal beliefs/attitude, 88.3% believed that there are benefits associated with being vaccinated from COVID-19. These included being protected from catching COVID-19 (82%), reaching herd immunity for the community to be safe (9.7%), and ability to travel domestically (5.2%).

The results from the stepwise multivariable logistic regression analysis (Table 3) revealed that increased age (OR 4.4, 95 % CI 2.4 - 8.2, p < 0.001 to 5.2, 95% CI 2.5 - 10.7, p < 0.001), being

a housewife (OR 2.9, 95% CI 1.6 - 5.2, p = 0.001) or underweight (OR: 3.2, 95% CI 1.0 - 9.7, p = 0.043) were associated with higher COVID-19 vaccine acceptance. Participants with at least undergraduate qualifications were more likely to accept the vaccine (OR: 3.6, 95% CI 1.0 - 12.7, p = 0.045), while being a student or retiree reduced the likelihood by 60% (95% CI 0.1 – 0.9, p = 0.029). Presence of anxiety or depressive symptom was associated with 50% reduced likelihood of vaccine acceptance. In terms of COVID-19 related factors, knowledge of the dosage (OR 3.2, 95% CI 1.5 – 6.9, p = 0.003), where to register for the vaccine (OR 3.4, 95% CI 1.7 – 6.7, p = 0.001) and where to get the vaccine (OR 5.0, 95% CI 1.2 – 20.5, p = 0.026), as well as willingness to pay if the vaccine was no longer free (OR 3.1, 95% CI 1.8 – 5.4, p < 0.001) were strongly related to vaccine acceptance. For personal belief, trust in the health department was crucial (OR 4.9, 95% CI 2.0 – 12.0, p = 0.001). The results of simple logistic regression of vaccine acceptance are presented in Supplementary Appendix 5, Table S1.

Table 3. Stepwise multivariable logistic regression of demographic, lifestyle, clinical and COVID-19 related correlates and COVID-19 vaccine acceptance and uptake in rural Bangladesh

Variable	Vaccine acceptance		Received COVID-19 vaccine	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Demographics				
Sex (ref: Male)				
Female	-	-	**1.3 (1.1 - 1.7)**	**0.027**
Age groups (ref: <30 years)				
30 - 50 years	**4.4 (2.4 - 8.2)**	**<0.001**	**2.7 (2.1 - 3.8)**	**<0.001**

>50 years	5.2 (2.5 - 10.7)	<0.001	4.7 (3.3 - 6.7)	<0.001
Education level (ref: Illiterate)				
Primary	-	-	-	-
Secondary	-	-	-	-
Undergraduate and above	3.6 (1.0 - 12.7)	0.045	-	-
Employment status (ref: Unemployed)				
Employed	-	-	-	-
Housewife	2.9 (1.6 - 5.2)	0.001	-	-
Students or retirees	0.4 (0.1 - 0.9)	0.029	0.5 (0.2 - 0.9)	0.040
Anthropometric and lifestyle behaviour				
BMI (kg/m²) (ref: Normal)				
Underweight	3.2 (1.0 - 9.7)	0.043	-	-
Overweight	-	-	1.3 (1.0 - 1.7)	0.021
Obese	-	-	1.4 (1.1 - 1.8)	0.037
Clinical conditions				
Have anxiety or depressive symptom (ref: No)				
Yes	0.5 (0.3 - 0.9)	0.003	-	-
Attitude towards vaccination (in general terms) prior to COVID-19 pandemic				
Have been vaccinated previously e.g., for influenza (ref: No)				
Yes	-	-	0.7 (0.5 - 0.9)	0.007
Knowledge of COVID-19 vaccination				
Understood COVID-19 dosage (ref: No)				
Yes	3.2 (1.5 - 6.9)	0.003	17.0 (6.1 - 47.9)	<0.001
Availability and potential barriers of getting COVID-19 vaccine				
Understood how to register for COVID-19 vaccine (ref: No)				

Yes	3.4 (1.7 - 6.7)	0.001	3.7 (2.4 - 5.6)	<0.001
Understood where to get the vaccine (ref: No)				
Yes	5.0 (1.2 - 20.5)	0.026	-	-
Would you take the vaccine if it is no longer free? (ref: No)				
Yes	3.1 (1.8 - 5.4)	<0.001	-	-
Influence of personal beliefs				
Do you trust the health department regarding information related to COVID-19 vaccine? (ref: No)				
Yes	4.9 (2.0 - 12.0)	0.001	-	-

The following covariates were introduced into the model but were not statistically significant for both vaccine acceptance and uptake: *marital status, smoking history, use of chewing tobacco, chronic disease, aware of benefits of vaccines, familiar with COVID-19 vaccine brands, trust in government.*

Vaccine roll-out participation in rural Bangladesh

Half of the study participants have had at least one dose of the COVID-19 vaccine (Table 1). The roll-out participation rate (i.e., proportion of those who have received the vaccine) was similar across sex, but there was a clear upward trend in roll-out participation when stratified by age groups (26.3% to 63.7%, $p < 0.001$). Just over half (51.5%) of those who were married had received the vaccine, while 76.1% of unmarried participants had received it. Participation rate appeared to have decreased as education level increases (illiterate: 53.3% vs. undergraduate and above: 39.2%, $p = 0.026$). The proportion of those who have received the vaccine was similar according to smoking status, including among users/non-users of chewing tobacco or betel leaf. The prevalence of those who have been vaccinated was generally higher

in those with comorbid conditions (48.1%-58.6%) than without (46.9%, p = 0.022), but not significantly different when stratified by mental health conditions.

Out of 803 participants who have taken the first dose, 79.2% reported no side effects. Among these first-dose takers, 99.8% were planning to or already took their second vaccination dose. Of those who have taken the second dose (n=263), 99.6% were compliant (i.e., were vaccinated according to the scheduled time), and 88.1% reported having no side effects. Most participants received the vaccines in district hospitals (76.3%) or government registered clinics (22.5%).

Most common reasons of those who have not received the vaccine were a lack of interest (25.1%) and not within the eligible age category (18.9%). For those who have registered (or were intending to register) for the vaccine, participants either visited (or will be visiting) an internet café (61.6%), used their own or someone else's smartphone (15.8%) or directly visited a government hospital (12.8%).

According to the stepwise multivariable logistic regression analysis (Table 3), sociodemographic correlates of roll-out participation were female (OR 1.3, 95% CI 1.1 – 1.7, p = 0.027), increased age (OR 2.7, 95% CI 2.1 – 3.8, p<0.001 to 4.7, 95% CI 3.3 – 6.7, p<0.001), and being overweight or obese (OR 1.3, 95% CI 1.0 – 1.7 and 1.4, 95% CI 1.0-1.8, respectively). Students and retirees were 50% less likely to have been vaccinated than unemployed participants (95% CI 0.2 – 0.9, p = 0.040). Interestingly, previous vaccination (prior to COVID) were associated with reduced likelihood of having received the vaccine (OR 0.7, 95% CI 0.5-0.9, p = 0.007), while knowledge of the dosage (OR 17.0, 95% CI 6.1-47.9, p

< 0.001) and how to register for the vaccine (OR 3.7, 95% CI 2.4-5.6, p < 0.001) were related to vaccine uptake. The results of simple logistic regression of vaccine uptake are presented in Supplementary Appendix 5, Table S1.

Discussion

This study assessed vaccine acceptance among people living in rural Bangladesh. Offline data collection methods were employed to counter a low digital literacy and/or access among the rural population. We found a high COVID-19 acceptance rate of 95% in this population eleven months since start of the roll-out program in January 2021. This acceptance rate is substantially higher than findings from the general Bangladeshi population (51%-68%) at the initial phase of the roll-out [5, 15-18] and in a study conducted prior to the roll-out, which included 52% rural participants and reported 75% willingness rate [14]. Our observed acceptance rate is further supported by a higher rate of COVID-19 vaccine uptake for at least one dose in rural Bangladesh compared to national data at the end of the data collection period (50% vs. 36% in November 2021). Therefore, our findings suggest an improvement in acceptance over time.

Our finding of an exceptionally high COVID-19 vaccine acceptance in rural Bangladesh contrasts a previous sub-analysis of the general Bangladeshi population [14] and countries with similar demographic profile such as India [30], wherein rural residents were more likely to mistrust vaccines. However, vaccine decisions are highly multifactorial and can change over time [31, 32]. A recent publication found that over 90% of the general Bangladeshi population had a positive change in attitude towards COVID-19 vaccines after receive their vaccination [33]. Importantly, Bangladesh recently met the 70% double-dose target supported by the World

Health Organization-led COVAX program [34]. Health campaigns conducted by the Bangladeshi government, non-profit organisations as well as local community champions have strongly contributed to improving vaccine literacy and diminishing the social stigma surrounding vaccination [35]. Indeed, eleven months into the roll-out program, our data suggest that 89% of rural participants wanted to keep others safe and 88% agreed to the benefits of COVID-19 vaccines.

The main source of information among people in rural Bangladesh were television and relatives, and only 11% were social media users. This is likely due to poor internet coverage and digital literacy among people residing in rural areas [19]. Ironically, this may have been the very reason which prevented people from misinformation [36], thus explaining a slightly higher acceptance rate among social media non-users compared to users, and to the overall higher acceptance rate (Table 2). Indeed, studies in sub-Saharan African countries [31] and developed countries [37] suggest COVID-19 vaccine resistant individuals were more likely to obtain information from non-traditional and non-authoritative sources, such as social media or unofficial websites. On the other hand, a lack of access to internet may have contributed to a slower start to the vaccination uptake in Bangladesh during the initial roll-out period [7]. This is mainly due to the requirement for online registration for the vaccines [9], which would have been difficult for those living in rural areas.

Trust in the health department, as well as practical knowledge (such as COVID-19 vaccine dosage, how to register for the vaccine, and where to get vaccinated) were correlates of acceptance and/or uptake. The importance of knowledge in COVID-19 vaccine acceptance has

been observed previously from studies in the general Bangladeshi population [38, 39] and is echoed globally [32]. While previous data suggest substantial hesitancy due to knowledge of side effects from the COVID-19 vaccines [4], most participants who were hesitant or have not had their vaccines yet cited practical reasons (e.g., not within the eligible age category or want to see others take it first).

A previous study demonstrated that people in rural Bangladesh have significantly lower levels of knowledge about COVID-19 and pandemic-appropriate behaviour [40]. This is further reflected by significant proportion (54%) of rural residents who responded 'I do not know' when asked which country they were aware of and trust to produce the vaccine (Table 2). In comparison, 70% of the general Bangladeshi population were aware of their vaccine source and manufacturer [39]. Interestingly, in France, hesitancy was highest for vaccines manufactured in China and lowest for a vaccine manufactured in Europe [41]. On the contrary, Chinese-made vaccines were rather well accepted among our participants (24%) compared to UK- or US-made vaccines (1.2% and 8.4% respectively). These findings highlight that population dynamics regarding vaccinations may vary depending on the levels of health literacy, societal norms, political climate as well as traditional culture.

Strenghts and limitations

The strength of this study is the use of well-validated sampling methodologies and large sample size, as well as the use of offline data collection methods. While online data collection methods are more efficient [42], people in rural areas lack access to online resources. Therefore, we

strongly recommend future studies assessing the rural population to conduct data collection methods in-person.

There are limitations to this study. A cross-sectional design means incidence cannot be measured, and causal inference cannot be made. We did not collect participant income data, thus were unable to assess its association with vaccine acceptance. Nonetheless, the methods and findings of this study are relevant in informing the development of diagnostic tools to assess vaccine acceptance or similar outcomes in rural areas. The results are also pertinent to inform policy in other low income and low resource countries.

Policy recommendations

We have identified key messages which should be considered by policymakers. Firstly, to further increase the vaccination rates (including boosters), policy makers need to identify hard-to-reach population. Approximately 60% of older people have yet to be vaccinated in Bangladesh, mostly citing a lack of awareness of where to obtain the vaccine [35]. Mobilising special teams to reach hard-to-reach communities directly may be needed to vaccinate them [35]. Secondly, our study shows that rural Bangladeshis, despite faced with lower resource and access to healthcare information and infrastructure, recognise the need to be protected from COVID-19. Therefore, to ensure vaccine acceptance remains high in rural Bangladesh, health authorities should continue to support interventions aimed at increasing vaccine and general health literacy in rural areas. Thirdly, Bangladesh must ensure ongoing vaccine supply. This is currently well supported by the COVAX program [34]. However, there may be merit in expanding the funding and resource allocations for alternative avenues to guarantee

procurement [43], such as by having locally produced vaccines. This would reduce the reliance on and defuse political issues with supplier countries (such as India, China and Russia) in relation to vaccine supply [44], and empower local pharmaceutical companies to invest in vaccine development. Finally, to prepare for future health emergencies, there remains a need to promote LMICs to be on top of priority list for vaccine and other healthcare supply distribution, and a wider acknowledgement and implementation of mitigation strategies to combat "resource hoarding" by developed countries, as observed with the COVID-19 vaccines [45].

Conclusions

In conclusion, COVID-19 vaccine acceptance is very high in rural Bangladesh, and COVID-19 vaccine literacy is associated with both its acceptance and uptake. Measures undertaken at the national, divisional, district and local levels in Bangladesh should be directed to increase vaccine literacy and ensure ongoing vaccine supply and improvement in healthcare infrastructure, particularly for those living in rural areas.

Author contributions

FS, BB, BS, AS and OB designed the survey. MC, MI, LA and HC collected and managed the data. SA, FS and AA analysed the data under BB's supervision. FS drafted the manuscript. BB, BS, AS, OB, MC, MI, HC, AA, LA and SA revised the manuscript and provided intellectual input.

Conflicts of interest

None to declare.

Funding

This study received no funding.

Data sharing statement

No additional data available.

Acknowledgement

FS is supported by an Alfred Deakin Postdoctoral Research Fellowship (Deakin University).

Ethics approval

This study has been approved by Monash University Human Research Ethics Committee (Project ID 29358), and respective local authorities in Bangladesh.

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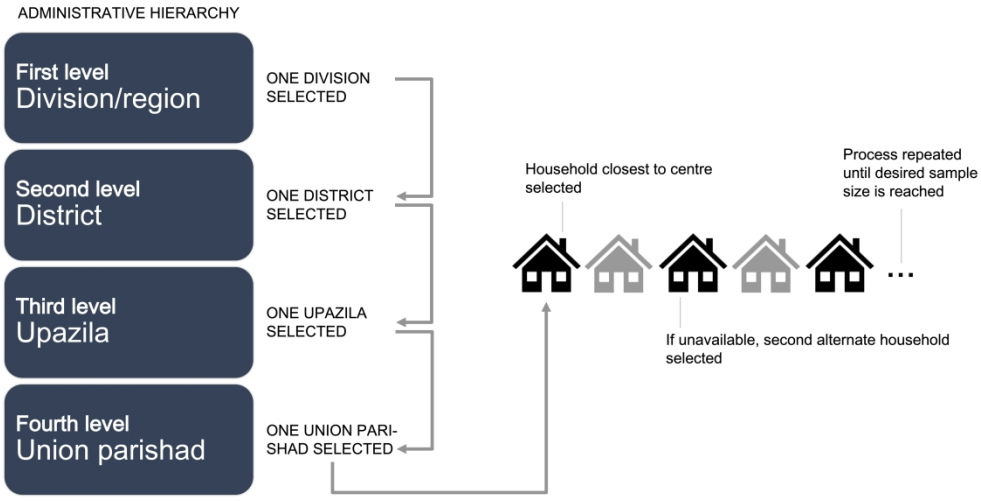
Figure legends

Figure 1. Sampling method.

For data sampling, one of eight divisions/regions in Bangladesh (the first level of administrative hierarchy) was randomly selected. Subsequently, one district (the second level of administrative hierarchy) was randomly selected, followed by random selection of an upazila (third level of administrative hierarchy) from the selected district. Finally, a union parishad (the fourth and final level of administrative hierarchy) was selected from this upazila. A household closest to the centre point of the union parishad was identified as the first household for enrolment. Then, a household member was selected according to the 'Kish Grid' method. If the selected household member was unavailable, the next eligible household was approached. The second eligible household was selected by skipping the next household, and choosing the subsequent household (i.e., every alternate household).



Sampling method.

211x106mm (600 x 600 DPI)

Supplementary Appendix

Supplementary Appendix 1. Sample size calculation

For the survey, the following formula was used to calculate the sample size:

$$n = Z^2 \times p\,(1 - p) \div d^2$$

wherein,

n = the required sample size (respondents/households).

p = the proportion of vaccine hesitancy in rural Bangladesh, which is approximately 35% according to a recent study (1).

d = degree of accuracy desired, which is set at 3%.

$Z\frac{1-\alpha}{2}$ = the standard normal deviation value, which is usually set at 1.96 to maintain a 95% confidence level for the estimated prevalence of vaccine hesitancy.

The above calculation indicated the sample size required was 971. Considering the nationwide generalisability and socio-demographic heterogeneity of the population, the sample size was multiplied by the design effect of 1.5 (2) to adjust sampling variance related to the multi-stage study design (3). This resulted in a sample size of 1,457. Additionally, a 5% non-sampling error was applied, and the final sample size was determined to be 1,533 participants/households to approach for participation.

Supplementary Appendix 2. Training for data collectors and pilot study

Two support persons and five interviewers were appointed for data collection. The support persons originated from the local area of data collection site. Their roles were to help the team navigate the area and build rapport with the local residents. The interviewers had a minimum of graduate level degree and have had previous data collection experience. One of the interviewers was a registered medical nurse. The primary investigator organised a one-week online workshop via Zoom for the interviewers to be familiarised with the aim of the study and content of the questionnaires. The medical nurse was trained to conduct anthropometric and blood pressure measurements and for COVID-19 risk management.

Mock interviews were conducted to ensure full comprehension of relevant data collection techniques and proper conduct in difficult situations. Corrections were made following the mock interviews as appropriate. Thereafter, the interviewers were assigned a designated area to proceed with data collection. Data collectors were also trained to carry out study procedures under COVID-safe protocols. This included mask-wearing, collecting data from participants in a well-ventilated area, physical distancing of 1.5 meters, and using hand sanitizers before and after every procedure.

A pilot study was initially conducted on 24 participants from the selected sampling area to check the acceptability and feasibility of the questionnaire and the average time required for completion. No major amendments were made to the questionnaire.

Supplementary Appendix 3. Quality control of data collection

To ensure that the quality of the study is maintained, data collection and management processes were regularly monitored by the two local study investigators. The investigators also carried out a random consistency check for at least 5% of the interviewed questionnaires to ensure all the details in the questionnaires have been correctly undertaken.

Supplementary Appendix 4. Data access and storage

During the study period, the data was collected, managed and securely stored in REDCap. The data was also exported to Google spreadsheets and saved in a secure university-allocated network storage (Monash University (S:) shared drive) as a backup. Only the research team (chief

investigator and co-investigators) had access to these password-protected electronic databases. The data will be stored in both REDCap and Monash (S:) drive for 5 years as per Monash University data retention policy, after which it will be permanently deleted.

Supplementary Appendix 5. Operational definitions

BMI was calculated and classified as follows: <18.50 kg/m^2 for underweight, 18.50 to 22.99 kg/m^2 for normal (used as reference variable), 23.00 to 27.49 kg/m^2 for overweight and ≥27.50 kg/m^2 for obese (4, 5). A high waist-to-hip ratio was defined as >0.90 for men and >0.85 for women (4, 6). Hypertension was defined as either a documented diagnosis of hypertension, taking of antihypertensive medications or a further two high blood pressure readings in 3-day intervals during the study period (i.e., if systolic blood pressure measurement was ≥140 mmHg and/or diastolic blood pressure measurement was ≥90 mmHg) (7). The presence of anxiety and depression was defined as a score of five or more using the GAD-7 scale (8) and PHQ-9 (9) respectively.

Supplementary Appendix 5. Additional analysis output

Table S1. Univariable logistic regression of demographic, lifestyle and clinical correlates and COVID-19 vaccine acceptance and uptake in rural Bangladesh

Variable	Vaccine acceptance		Received COVID-19 vaccine	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Demographics				
Gender (ref: Male)				
Female	**2.3 (1.4 - 3.7)**	**0.001**	1.0 (0.8 - 1.2)	0.822
Age groups (ref: <30 years)				
30 - 50 years	**4.7 (2.8 - 7.9)**	**<0.001**	**3.3 (2.5 - 4.3)**	**<0.001**
>50 years	**3.4 (1.9 - 6.1)**	**<0.001**	**4.9 (3.6 - 6.7)**	**<0.001**
Marital status (ref: Not married)				
Married	**4.9 (2.8 - 8.9)**	**<0.001**	**4.8 (2.8 - 8.1)**	**<0.001**
Others	**5.5 (1.8 - 17.0)**	**0.003**	**6.1 (3.2 - 11.8)**	**<0.001**
Education level (ref: Illiterate)				
Primary	0.9 (0.5 - 1.8)	0.833	1.0 (0.8 - 1.3)	0.943
Secondary	0.6 (0.3 - 1.0)	0.061	**0.8 (0.6 - 1.0)**	**0.046**
Undergraduate and above	0.8 (0.3 - 2.3)	0.622	**0.6 (0.4 - 0.9)**	**0.022**
Employment status (ref: Unemployed)				
Employed	1.1 (0.5 - 2.6)	0.742	**0.5 (0.3 - 0.8)**	**0.002**
Housewife	2.3 (1.0 - 5.6)	0.063	**0.5 (0.3 - 0.7)**	**0.001**
Others	**0.3 (0.1 - 0.8)**	**0.016**	**0.1 (0.0 - 0.2)**	**<0.001**
Anthropometric and lifestyle behaviour				

BMI (kg/m²) (ref: Normal)				
Underweight	2.3 (0.9 - 5.8)	0.088	1.0 (0.7 - 1.5)	0.941
Overweight	**2.3 (1.4 - 3.9)**	**0.002**	**1.5 (1.2 - 1.8)**	**0.002**
Obese	**2.8 (1.4 - 5.5)**	**0.005**	**1.5 (1.2 - 2.0)**	**0.003**
Smoking history (ref: Non smoker)				
Former smoker	0.5 (0.2 - 1.1)	0.100	**1.6 (1.0 - 2.4)**	**0.045**
Current smoker	**0.4 (0.3 - 0.7)**	**0.001**	0.9 (0.7 - 1.2)	0.432
Use of chewing tobacco (ref: Non user)				
Former user	0.5 (0.1 - 1.6)	0.216	1.3 (0.6 - 2.7)	0.463
Current user	0.8 (0.5 - 1.3)	0.330	**1.3 (1.1 - 1.7)**	**0.018**
Clinical conditions				
Have chronic disease (ref: No)				
Yes	**1.9 (1.1 - 3.2)**	**0.030**	**1.5 (1.2 - 1.8)**	**<0.001**
Have anxiety or depression (ref: No)				
Yes	0.8 (0.5-1.2)	0.232	1.0 (0.8-1.3)	0.869
Attitude towards vaccination (in general terms) prior to COVID-19 pandemic				
Aware of benefits of vaccines (ref: No)				
Yes	**2.1 (1.1 - 3.8)**	**0.017**	1.1 (0.8 - 1.6)	0.550
Have been vaccinated previously e.g., for influenza (ref: No)				
Yes	1.5 (0.9 - 2.4)	0.070	**0.7 (0.6 - 0.8)**	**0.001**
Knowledge of COVID-19 vaccination				
Understood dosage (ref: No)				
Yes	**6.4 (3.5 - 11.5)**	**<0.001**	**19.9 (7.2 - 54.8)**	**<0.001**
Familiar with the brands (ref: No)				
Yes	1.2 (0.5 - 2.9)	0.745	**2.3 (1.5 - 3.4)**	**<0.001**

Source of information for COVID-19 vaccination				
Source of information (ref: Others)				
Television	21.4 (1.3 - 347.9)	0.031	-	-
Social media	10.1 (0.6 - 169.3)	0.110	**0.5 (0.3 - 0.7)**	**<0.001**
Relatives or friends	20.4 (1.2 - 335.1)	0.040	1.0 (0.8 - 1.2)	0.600
Availability and potential barriers of getting COVID-19 vaccine				
Understood how to register for COVID-19 vaccine (ref: No)				
Yes	**3.6 (2.1 - 5.9)**	**<0.001**	**3.6 (2.5 - 5.2)**	**<0.001**
Understood where to get the COVID-19 vaccine (ref: No)				
Yes	17.6 (6.2 - 49.9)	<0.001	-	-
Distance from vaccination centre (in km)				
Distance (km)	0.9 (0.9 - 1.0)	0.450	1.0 (1.0 - 1.1)	0.136
Would you take the vaccine if it is no longer free? (ref: No)				
Yes	**3.1 (1.9 - 4.8)**	**<0.001**	1.1 (0.9 - 1.3)	0.493
Influence of previous COVID-19 status				
Have been diagnosed with COVID-19 (ref: No)				
Yes	-	-	0.5 (0.1 - 2.7)	0.423
A close relative or friends have been previously diagnosed with COVID-19 (ref: No)				
Yes	-	-	**5.4 (2.1 - 14.0)**	**0.001**
Influence of personal beliefs				
Do you trust the government regarding information related to COVID-19 vaccine? (ref: No)				
Yes	**6.8 (3.6 - 13.6)**	**<0.001**	**2.9 (1.5 - 5.3)**	**0.001**
Do you trust the health department regarding information related to COVID-19 vaccine? (ref: No)				
Yes	**11.7 (5.7 - 24.1)**	**<0.001**	**2.8 (1.3 - 5.7)**	**0.007**
Do you think pharmaceutical companies developed the vaccine to help society? (ref: No)				
Yes	1.5 (0.9 - 2.4)	0.104	1.0 (0.8 - 1.2)	0.838
Does your religion have any restrictions on getting vaccinated? (ref: No)				

Yes	-	-	0.5 (0.0 - 5.5)	0.572

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7-10
Bias	9	Describe any efforts to address potential sources of bias	*6-7*
Study size	10	Explain how the study size was arrived at	Suppl Appendix 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-10
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	6-7
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	NA
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	Fig 1, pg 17
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers of outcome events or summary measures	10-17
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-17
		(*b*) Report category boundaries when continuous variables were categorized	Table 1
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	18
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	18-20
Generalisability	21	Discuss the generalisability (external validity) of the study results	20-21
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	21

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.