Tropical Medicine and Health

RESEARCH

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COVID-19 vaccine booster uptake among healthcare workers in Bangladesh: predictors, challenges, and lessons from a low-income setting

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Abstract

Background Healthcare workers (HCWs) remain at an elevated risk of SARS-CoV-2 infection due to occupational exposure and waning vaccine-induced immunity. We conducted a longitudinal study to estimate cumulative uptake, incidence, and factors associated with COVID-19 booster dose uptake among Bangladeshi HCWs.

Methods Between March 2021 and December 2023, we followed 3099 HCWs recruited from 20 healthcare facilities across four divisions of Bangladesh. At enrollment, information was collected on sociodemographic and clinical characteristics, prior SARS-CoV-2 infection, and COVID-19 vaccination history. Booster uptake status was updated biweekly. Multivariable Cox proportional hazards regression models were used to estimate adjusted hazard ratios (aHRs) for predictors of booster uptake.

Results During follow-up, 1964 (63.4%) HCWs received at least one COVID-19 booster dose. However, uptake of the 2nd booster dose was low (6%). The incidence of booster uptake was 54.5 per 100 person-years (95% CI 50.0–59.5). The hazard of booster uptake was higher among HCWs with prior SARS-CoV-2 infection (aHR = 1.13; 95% CI 1.01–1.26) and among those working in both COVID-19 and general wards (aHR = 1.36; 95% CI 1.22–1.53). In contrast, prior adverse events following the primary series (aHR = 0.36; 95% CI 0.32–0.41) were associated with a lower hazard of booster uptake.

Conclusions Although more than half of HCWs received a booster, uptake declined with repeated dosing. Variations in the hazard of uptake by occupational exposure, prior infection, and adverse events reflect changing perceptions of risk and experiential factors in addition to access. Strengthening institutional vaccination policies and addressing behavioral barriers may thus support timely booster uptake among HCWs.

Keywords Booster uptake, COVID-19 vaccine, Healthcare workers, Bangladesh

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Introduction

The initial wave of the COVID-19 pandemic posed a substantial threat and caused significant mortality and morbidity among healthcare workers (HCWs). The nature of HCWs' occupation makes them particularly vulnerable to SARS-CoV-2 infection and, in turn, increases the risk of onward transmission to patients [1]. According to the World Health Organization (WHO), approximately 115,000 HCWs died globally due to COVID-19 [2]. Furthermore, studies have shown that HCWs experienced approximately tenfold higher COVID-19 morbidity than the general population during the early waves of the pandemic [3].

In addition to the protective measures, such as personal protective equipment (PPE), isolation, and physical distancing, establishing herd immunity through widespread vaccination has been central to managing the pandemic [4]. It was estimated that a COVID-19 vaccination program covering 40% of the United States population could reduce COVID-19 hospitalizations and deaths by approximately 65.6 and 69.3%, respectively [5]. However, the emergence of five variants of concern (VOC) of SARS-CoV-2 has been linked to increased transmissibility, reduced antibody neutralization, and diminished vaccine effectiveness [6, 7]. Breakthrough infections among fully vaccinated individuals further demonstrate waning immunity over time [8]. Reports suggest that by week 20 post-second dose, the efficacy of the ChAdOx1 nCoV-19 (Oxford-AstraZeneca) vaccine decreased by 48% [9], and the effectiveness of the BNT162b2 (Pfizer-BioNTech) vaccine dropped by 27% [10]. This waning immunity underscores the importance of booster vaccination strategies [11]. According to the World Health Organization (WHO) Strategic Advisory Group of Experts (SAGE) roadmap (2023), for high-priority groups such as HCWs with direct patient contact, an additional booster dose is recommended about 12 months after the last dose. However, a shorter interval (e.g., 6 months) may be considered for persons at the highest risk. These recommendations are context-specific and reflect the current epidemiological situation rather than a fixed annual schedule [12, 13].

In the early stages of the pandemic, HCWs in low- and middle-income countries (LMICs) faced higher infection risks due to limited PPE and inadequate infection prevention and control (IPC) measures [14]. Once vaccines became available, acceptance among HCWs was considerably higher than in the general population, with approximately 3.5 times higher acceptance in LMICs [15]. While most HCWs reported willingness to receive booster doses [16], evidence from multiple regions indicates that booster uptake continues to lag behind primary-series coverage [17, 18]. This is concerning, given their heightened risk of exposure to and potential transmission of SARS-CoV-2 within healthcare environments. Moreover, HCWs play a critical role in shaping public confidence in vaccination programs, particularly as boosters are essential to counter waning immunity and the emergence of new variants [19]. As such, this suboptimal booster uptake among HCWs highlights the need to identify and address the factors influencing their vaccination decisions across diverse contexts.

In 2021, approximately 9402 Bangladeshi HCWs were reported to be infected with the SARS-CoV-2 virus, including 186 physician deaths [20]. The case fatality rate among physicians in Bangladesh reached 4%, notably higher than the global average of 2.5% [21]. Bangladesh initiated COVID-19 vaccination with the Oxford-AstraZeneca vaccine (ChAdOx1-S) on January 27, 2021 and by October of the same year, eight additional vaccines had been approved for use [22]. The early response among HCWs was highly encouraging, with 91% completing their primary vaccination series. However, sustaining this momentum for continued protection proved challenging as the pandemic progressed and participation in subsequent vaccination rounds declined. Similar trends were observed across many LMICs, where booster coverage remained insufficient [23, 24]. This pattern was particularly concerning amidst the persistent threat of new variants and waning immunity, which heightened the vulnerability of HCWs and the broader population to subsequent waves of infection.

There remains a considerable gap in context-specific evidence from LMICs, such as Bangladesh, on the factors influencing COVID-19 booster-dose uptake among HCWs. Understanding these determinants remains essential for developing targeted interventions and vaccination policies that aim to improve booster coverage in this high-risk group. To address these critical evidence gaps, icddr,b, in collaboration with the Bangladesh Ministry of Health and Family Welfare (MoHFW), conducted a longitudinal study of a cohort of Bangladeshi HCWs to estimate the incidence of COVID-19 booster-dose uptake and elucidate the associated factors. The findings aim to guide the development of more context-appropriate vaccination strategies to protect HCWs, uphold healthcare system resilience, and enhance pandemic preparedness in Bangladesh and similar LMIC settings.

Methods

Study design and study site

We conducted a prospective cohort study among HCWs who were directly or indirectly involved in patient care. Participants were recruited from 20 health facilities across four administrative divisions (e.g., Dhaka, Chattogram, Khulna, and Rangpur) in Bangladesh. The facilities included five tertiary-level teaching hospitals, two

secondary-level district hospitals, and 13 primary-level upazilla health complexes encompassing both private and public facilities (Fig. 1).

Study population and baseline data collection

According to available administrative records, approximately 5000 HCWs were employed at the selected facilities at the start of the study period. All were invited to participate in February 2021, irrespective of prior COVID-19 infection or vaccination intentions. Recruitment employed an open cohort design, and a total of 3720 HCWs were enrolled. Of them, 3415 HCWs completed the primary COVID-19 vaccination series. For the present analysis, we restricted the sample to 3099 participants with a recorded date of receipt of the second dose.

Trained icddr,b study physicians and nurses recruited HCWs at the participating facilities. At baseline, data on sociodemographic characteristics (age, sex, socioeconomic status), pre-existing and current medical history, prior COVID-19 illness, and COVID-19 primary series vaccination status (date of vaccination, number of doses received, vaccine brand) were collected from HCWs in the study via face-to-face interviews. Data were collected on handheld tablets via an Android application, and COVID-19 primary series vaccination status was verified using participants' available vaccine cards.

Follow-up

We prospectively followed the HCWs from enrollment through December 2023. Participants were contacted at 14-day intervals by study physicians; if a scheduled

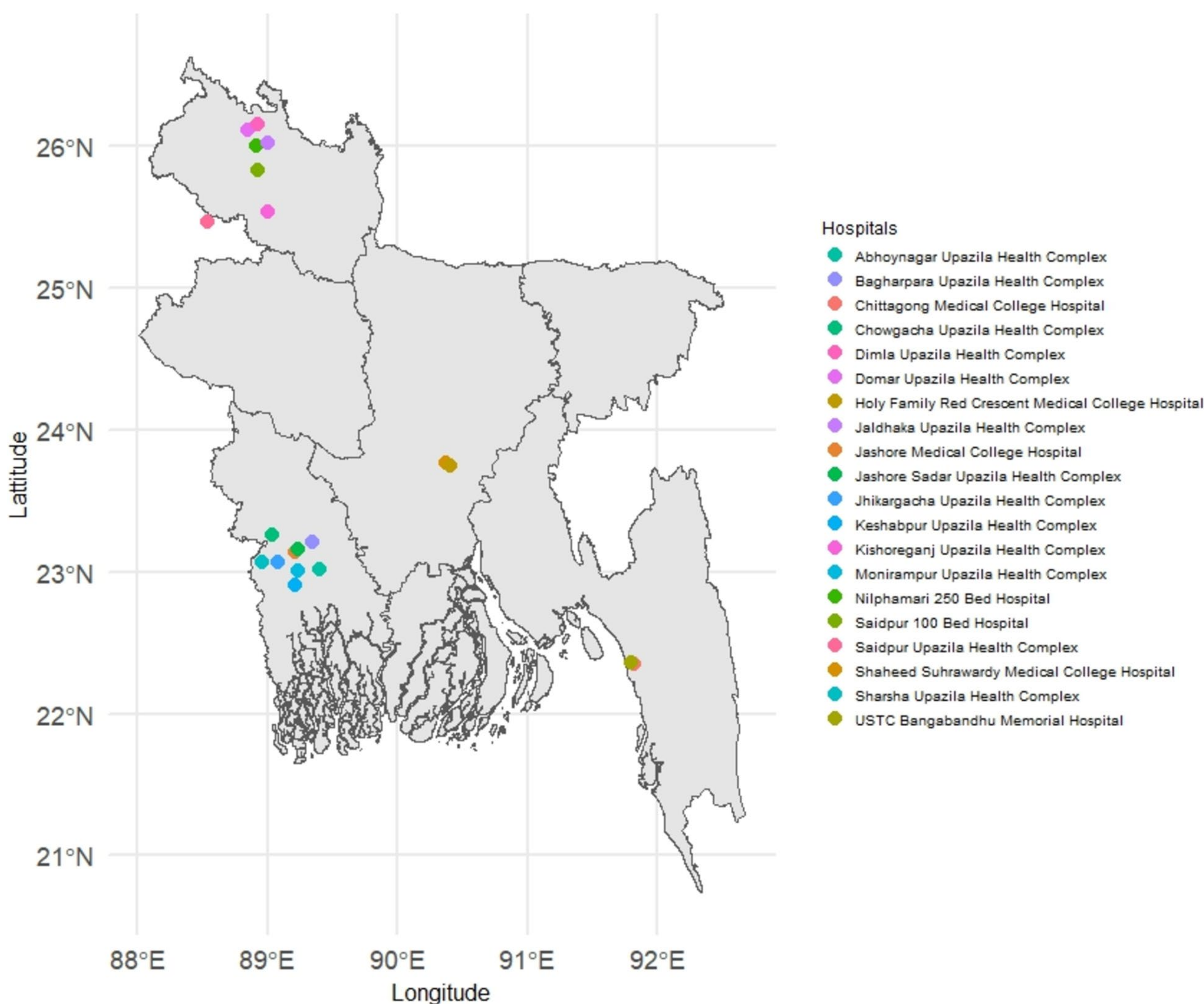


Fig. 1 Geographical location depicting 20 healthcare facilities from where HCWs were enrolled into the cohort between March 2021 and December 2023

follow-up was missed, contact was attempted over three consecutive days and, if unsuccessful, participants were re-contacted at the subsequent follow-up round. During each follow-up contact, participants were asked about changes in occupational exposure, including assigned working wards, contact with COVID-19-positive patients, performance of aerosol-generating procedures, and whether they had received an additional COVID-19 vaccine dose since the previous contact. Doses received at least four months after completion of the primary vaccination series were classified as booster doses [25]. The primary vaccination series in Bangladesh generally comprised two doses of COVID-19 vaccines, while booster doses were administered subsequently, with the 1st booster corresponding to the third dose and the 2nd booster to the fourth dose [26, 27].

Measurement of vaccine hesitancy

Vaccine hesitancy was assessed cross-sectionally before the COVID-19 booster vaccines became available at the study sites. This was done using a structured questionnaire informed by previously published frameworks on vaccine hesitancy and risk perception [28, 29]. The questionnaire items were contextually adapted for relevance to the local HCW setting in Bangladesh. The scale comprised nine statements assessing attitudes and perceptions toward COVID-19 booster vaccination, covering domains of confidence (perceived effectiveness, trust in vaccine information, and perceived benefits to self and community), perceived risk (concerns regarding side effects and comparative vaccine risk), and complacency (perceived necessity of booster vaccination). Responses were recorded on a five-point Likert scale ranging from 1 (“strongly disagree”) to 5 (“strongly agree”). Positively framed items indicating vaccine confidence were reverse-coded so that higher scores consistently reflected greater vaccine hesitancy.

Major explanatory variables

Based on the existing literature, we identified key explanatory variables that could impact the timing of uptake of additional COVID-19 vaccine doses among HCWs [18, 30–40]. These variables were grouped into socio-demographic, occupational, clinical and prior preventive behavior and attitude domains. Demographic factors included age, sex, educational level, and monthly family income. Occupational characteristics included healthcare provider type, healthcare facility type, and working ward during the pandemic. Clinical variables included the presence of comorbidities, prior SARS-CoV-2 infection history, and adverse events following the primary COVID-19 vaccine series. Prior preventive behavior and attitudes were assessed by influenza vaccine uptake in the previous season and vaccine hesitancy score.

Age was categorized as < 30 years, 30—44 years, and > 45 years. The highest level of education was classified as graduation and above (Postgraduate/MBBS/honors/diploma in medical technology/BSc/diploma in nursing) or as primary, secondary, or higher secondary completed or incomplete (class I-XII). Equivalently, monthly family income was categorized as less than Bangladeshi Taka (BDT) 25,000, BDT 25,000–50,000, BDT 50,000–75,000, and more than or equal to BDT 75,000. The co-morbidities included in this study were the presence of hypertension, diabetes, stroke, cancer, asthma, high blood cholesterol, chronic lung disease, and heart disease.

Statistical analysis

We used descriptive statistics to summarize participants’ characteristics. For continuous variables, we calculated the mean, the standard deviation (SD), the median, and the interquartile range (IQR) based on the distribution of each variable. We used counts and percentages to summarize the categorical variables. A composite vaccine hesitancy score was calculated for each participant as the mean of all nine items, with higher scores indicating greater hesitancy toward COVID-19 booster vaccination. Incidence rates of COVID-19 booster uptake, defined as the number of booster doses per 100 person-years at risk, were calculated using Poisson-based estimates with 95% confidence intervals (CIs).

Factors associated with receipt of a COVID-19 booster dose were analyzed using Cox proportional hazards regression. Participants entered the risk set four months after completion of their primary vaccination series and were followed until receipt of the 1st booster dose or censoring, whichever occurred first. Censoring was defined as the earliest of the end of the study period (31 December 2023) or the last recorded follow-up contact. Participants without a recorded booster and with a last successful follow-up substantially prior to the end of the study, despite repeated contact attempts across up to three follow-up cycles, were classified as lost to follow-up. Multivariable models were specified a priori and fitted hierarchically based on a conceptual framework representing hypothesized relationships among covariates and booster uptake (S1 Fig). Covariates were grouped into conceptually defined domains and entered sequentially from more distal background to more proximal behavioral and attitudinal variables. The first model included socio-demographic characteristics, followed by occupational factors, clinical and COVID-19-related experience, prior preventive behavior (influenza vaccination uptake), and attitudes (baseline vaccine hesitancy

score). All covariates were retained in subsequent models, regardless of statistical significance, to preserve the conceptual structure. Vaccine hesitancy was entered as a continuous variable to maintain information on attitudinal gradients. Adjusted hazard ratios (aHRs) with 95% confidence intervals were estimated from the fully adjusted model. Model fit across hierarchical specifications was compared using likelihood ratio tests for nested models and information criteria (Akaike and Bayesian). The proportional hazards assumption was evaluated using Schoenfeld residuals. We utilized a two-tailed alpha level of 0.05 as the threshold for statistical significance.

Kaplan–Meier survival plots were generated to illustrate the relationship between survival probability (i.e., the likelihood of receiving a booster or additional vaccination) and time since the last primary dose. These plots compared survival probabilities for the 1st and 2nd booster doses and examined differences in booster timing based on prior COVID-19 infection status. Additionally, a log-rank test was performed to assess whether the timing of booster doses differed significantly among groups categorized by prior COVID-19 infection status. All analyses were conducted using STATA 15.0 (Copyright 1985—2017 StataCorp LLC, StataCorp, 4905 Lakeway Drive, College Station, Texas 77,845 USA).

Ethical considerations

The Institutional Review Board (IRB) of icddr,b approved the study protocol. The Institutional Review Board at the US CDC relied on icddr.b's approval. All the HCWs included in the study provided written informed consent to participate.

Results

Demographic and clinical–epidemiological characteristics of the enrolled participants

Our cohort comprised 3099 HCWs who were followed between March 2021 and December 2023. Two-thirds of the participants (2051 persons) were female. The mean age of the participants was 37.7 years (SD 9.5). Approximately 47.5% (1472) of the enrolled participants were nurses, whereas 28.8% (893) were support staff, and 23.7% (734) were physicians. The majority of individuals in the study (60.4%) were employed at tertiary medical college hospitals, and only 28.1% (871) had a confirmed history of SARS-CoV-2 infection. However, only 1.9% (59) of the participants were employed in hospital wards designated solely for COVID-19 patients (Table 1).

Distribution of vaccine hesitancy constructs

Responses to the vaccine hesitancy items indicated moderate overall hesitancy toward COVID-19 booster vaccination (mean composite score: 2.32, SD 0.37). Items reflecting confidence in booster effectiveness, personal benefit, and information reliability had relatively low mean scores (range 1.99–2.20) (Fig. 2). In contrast, concerns related to perceived risk and necessity were more prominent: participants reported higher agreement with statements about worry regarding side effects (mean: 3.22, SD 0.97), perceived comparative risk of the booster (mean: 2.65, SD 0.83), and the belief that booster vaccination might not be necessary in the current situation (mean: 2.48, SD 0.73). The internal consistency of the nine-item scale was acceptable (Cronbach's $\alpha = 0.74$).

COVID-19 booster uptake in cohort members

In our study, the HCWs contributed 3438 person-years of observation following eligibility for booster vaccination. Of them, 1964 (63.4%) HCWs received at least one supplementary COVID-19 booster dose during the study period, whereas only 182 (6%) reported receiving the 2nd booster dose. The overall incidence of booster uptake in this cohort of HCWs was 54.5 per 100 years (95% CI 50.0—59.5). The median time to the 1st booster dose after the second was 285 days (IQR: 242–525), and to the 2nd booster after the 1st booster was 369 days (IQR: 320–459) among participants. The Kaplan–Meier survival plot showed that both boosters were rapidly taken by HCWs when offered, with a steep decline in the first months. After the early months, uptake plateaued for both boosters (S2 Fig). Furthermore, a history of prior COVID-19 infection also influenced the timing of booster uptake (S3 Fig), with a significant difference between HCWs who reported prior COVID-19 infection and those who were uninfected (log-rank test, $p = 0.009$).

For the 1st booster dose, participants contributed 3256 person-years of follow-up from eligibility until receipt of the 1st booster dose or censoring. The incidence rate of 1st booster uptake was 60.3 per 100 person-years. For the 2nd booster dose, the incidence rate was 7.8 per 100 person-years, based on 2345 person-years of follow-up.

The proportion of booster uptake for both doses was the lowest among physicians: 63% received a 1st booster dose, while only 3% received a 2nd booster dose (Fig. 3). Booster uptake was somewhat lower among young HCWs in our study group, with only 52% (333/640) of HCWs under the age of 30 receiving additional booster doses. HCWs from secondary healthcare institutions had the highest proportion of booster-dose acceptance, with 73.7% (415/563) adhering to the current vaccination protocol. In contrast, individuals from tertiary medical colleges had the lowest booster uptake rate at 57.7% (1079/1871) (Table 1). However, these proportions only represent cumulative uptake during follow-up.

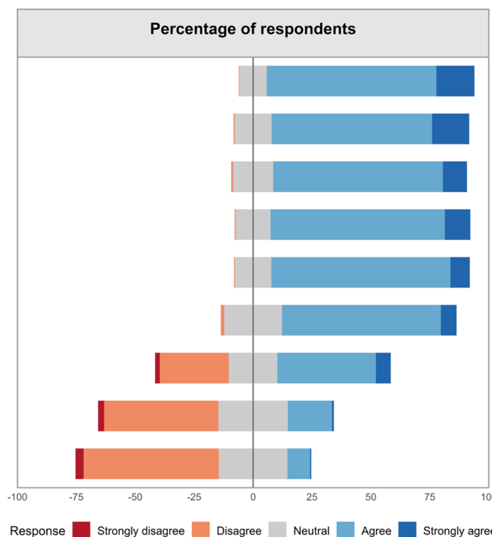
Table 1 Baseline information and demographic characteristics of the HCWs based on their booster uptake, *N*=3099

Characteristics	All sample	Received booster dose	
		No	Yes
	***n* (col.%)**	***n* (row%)**	***n* (row%)**
All sample	3099 (100)	1135 (36.6)	1964 (63.4)
Socio-demographic			
Age in years			
Mean ± SD	37.7 ± 9.5	36.4 ± 9.7	38.4 ± 9.4
< 30	640 (20.6)	307 (48)	333 (52)
30–44	1671 (54)	564 (33.8)	1107 (66.3)
≥ 45	788 (25.4)	264 (33.5)	524 (66.5)
Sex			
Female	2051 (66.2)	728 (35.5)	1323 (64.5)
Male	1048 (33.8)	407 (38.8)	641 (61.2)
Level of education			
Primary	284 (9.2)	117 (41.2)	167 (58.8)
Secondary	295 (9.5)	93 (31.53)	202 (68.5)
Graduation and above	2520 (81.3)	925 (36.71)	1595 (63.4)
Monthly family income (in BDT)			
Median (75th–25th) percentile	50,000 (70,000–30,000)	50,000 (80,000–30,000)	50,000 (70,000–29,000)
< 25,000	1289 (41.5)	526 (40.8)	763 (59.2)
25,000–50000	681 (22)	213 (31.3)	468 (68.7)
50,000–75000	619 (20)	206 (33.3)	413 (66.7)
≥ 75,000	510 (16.5)	190 (37.3)	320 (62.8)
Occupational			
Type of HCWs			
Physician	734 (23.7)	312 (42.5)	422 (57.5)
Nurse	1472 (47.5)	493 (33.5)	979 (66.5)
Support staff	893 (28.8)	330 (37)	563 (63.1)
Type of healthcare facilities			
Tertiary	1871 (60.4)	792 (42.3)	1079 (57.7)
Secondary	563 (18.2)	148 (26.3)	415 (73.7)
Primary	665 (21.5)	195 (29.3)	470 (70.7)
Working ward			
Non-COVID	1841 (59.4)	682 (37.1)	1159 (63)
COVID	59 (1.9)	20 (33.9)	39 (66.1)
Both	1199 (38.7)	433 (36.1)	766 (63.9)
Clinical			
Number of co-morbidities			
0	2129 (68.7)	807 (37.9)	1322 (62.1)
1	623 (20.1)	210 (33.7)	413 (66.3)
2+	347 (11.2)	118 (34)	229 (66)
Previously diagnosed with COVID-19 through a PCR test			
Undiagnosed	2228 (71.9)	847 (38)	1381 (62)
Diagnosed	871 (28.1)	288 (33.1)	583 (66.9)
Experienced an adverse event following the primary vaccine series			
No	774 (30.5)	278 (35.9)	496 (64.1)
Yes	1767 (69.5)	302 (17.1)	1465 (82.9)
Prior preventive behavior			
Influenza Vaccine Uptake in the last flu season			
No	2865 (92.5)	1036 (36.2)	1829 (63.8)
Yes	234 (7.5)	99 (42.3)	135 (57.7)

Table 1 (continued)

SD standard deviation, *BDT* Bangladeshi Taka, *HCWs* Healthcare Workers

Domain	Constructs	Mean (±SD)
Confidence	The COVID-19 booster vaccine is effective*	1.99 (±0.52)
	It is important to get the booster vaccine to strengthen my health*	2.05 (±0.56)
	It is important for community health that residents receive the booster*	2.10 (±0.54)
	The information I receive about the booster vaccine is reliable*	2.07 (±0.52)
	Booster vaccination protects my family and friends*	2.10 (±0.49)
	If recommended by government or health professionals, booster vaccination is beneficial*	2.20 (±0.58)
Perceived risk	Worried about possible side effects of the booster	3.22 (±0.97)
	Booster vaccination is riskier than ordinary vaccines	2.65 (±0.83)
Complacency	In the current situation, booster vaccination may not be necessary	2.48 (±0.73)



Responses were measured on a five-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree"). Positively worded items (*) were reverse-coded so that higher scores consistently indicate greater vaccine hesitancy across all constructs. Mean (±SD) values therefore range from 1 to 5, with higher values reflecting higher hesitancy.

Fig. 2 Mean scores and response distributions for COVID-19 booster vaccine hesitancy items among Bangladeshi HCWs (*N* = 3099)

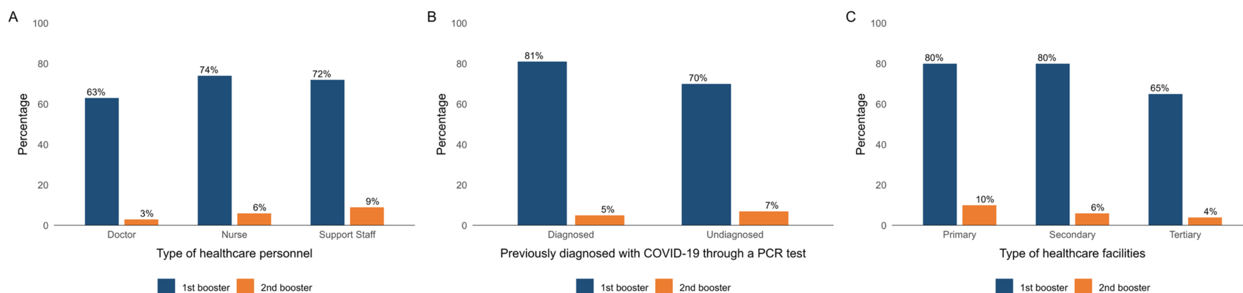
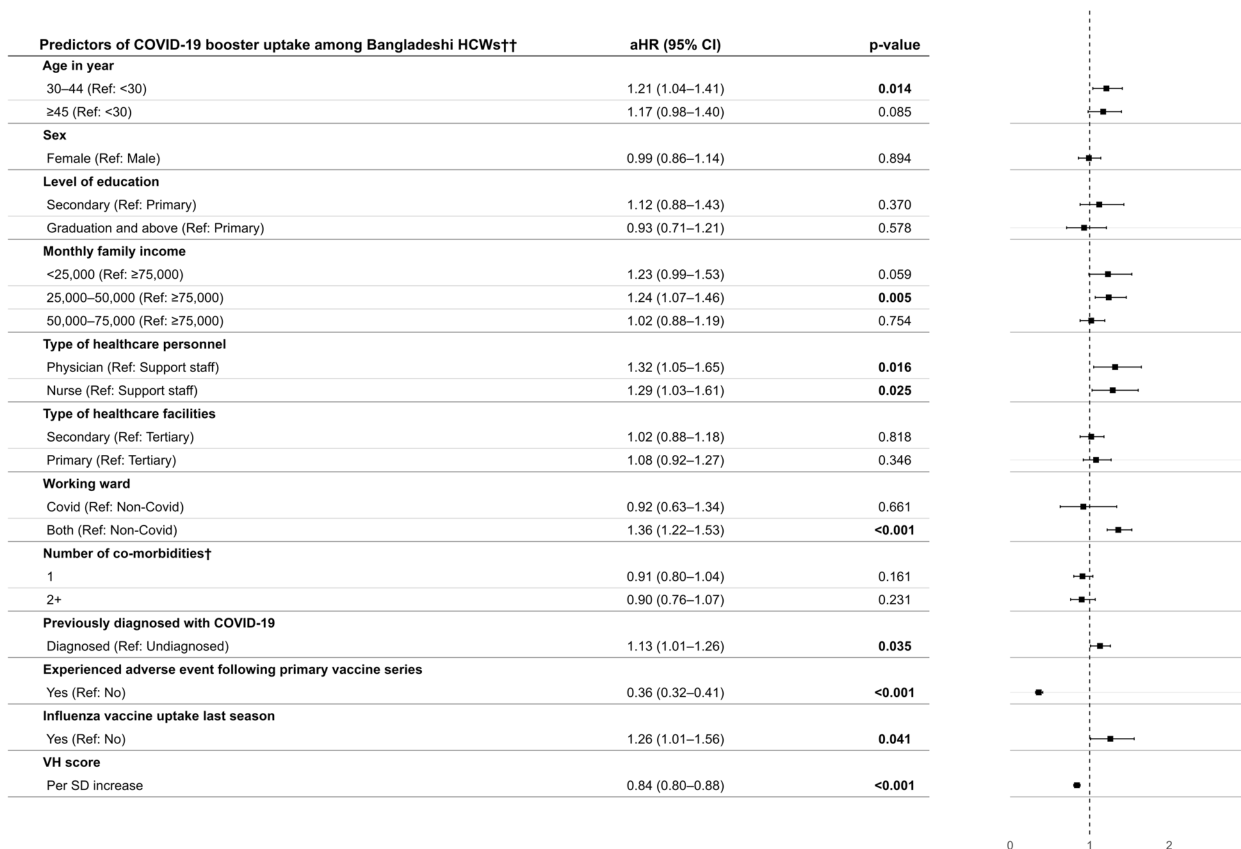


Fig. 3 Crude proportion of 1st and 2nd booster uptake among various demographic characteristics of the HCWs (*N* = 3099)

Factors associated with COVID-19 booster uptake among HCWs

In the adjusted model, several demographic, occupational, clinical, and behavioral factors were associated with the receipt of a COVID-19 booster dose (S1 Table). Sequential model building showed that inclusion of occupational and clinical variables modestly improved model fit, whereas the largest improvement was observed after adding prior vaccination behavior and vaccine hesitancy (S2 Table). All model extensions significantly improved fit compared with the previous model ($p < 0.001$).

Compared with HCWs aged < 30 years, those aged 30–44 years had a higher hazard for booster receipt (aHR = 1.21; 95% CI 1.04–1.41). Furthermore, physicians (aHR = 1.32, 95% CI 1.05–1.65) and nurses (aHR = 1.29, 95% CI 1.03–1.61) also had higher hazards of booster uptake than support staff. HCWs in our study who reported working in both COVID-19 and non-COVID-19 wards had a 36% higher hazard of booster uptake (aHR = 1.36, 95% CI 1.22–1.53) than those who worked only in non-COVID-19 wards (Fig. 4). Among clinical factors, prior SARS-CoV-2 infection was associated with a higher hazard of booster uptake (aHR = 1.13; 95% CI 1.01–1.26). On the other hand, HCWs who experienced adverse events following the primary vaccination series had a lower hazard of taking the booster dose (aHR = 0.36, 95% CI 0.32–0.41).



Predictors of COVID-19 booster uptake among Bangladeshi HCWs††	aHR (95% CI)	p-value
Age in year		
30–44 (Ref: <30)	1.21 (1.04–1.41)	**0.014**
≥45 (Ref: <30)	1.17 (0.98–1.40)	0.085
Sex		
Female (Ref: Male)	0.99 (0.86–1.14)	0.894
Level of education		
Secondary (Ref: Primary)	1.12 (0.88–1.43)	0.370
Graduation and above (Ref: Primary)	0.93 (0.71–1.21)	0.578
Monthly family income		
<25,000 (Ref: ≥75,000)	1.23 (0.99–1.53)	0.059
25,000–50,000 (Ref: ≥75,000)	1.24 (1.07–1.46)	**0.005**
50,000–75,000 (Ref: ≥75,000)	1.02 (0.88–1.19)	0.754
Type of healthcare personnel		
Physician (Ref: Support staff)	1.32 (1.05–1.65)	**0.016**
Nurse (Ref: Support staff)	1.29 (1.03–1.61)	**0.025**
Type of healthcare facilities		
Secondary (Ref: Tertiary)	1.02 (0.88–1.18)	0.818
Primary (Ref: Tertiary)	1.08 (0.92–1.27)	0.346
Working ward		
Covid (Ref: Non-Covid)	0.92 (0.63–1.34)	0.661
Both (Ref: Non-Covid)	1.36 (1.22–1.53)	**<0.001**
Number of co-morbidities†		
1	0.91 (0.80–1.04)	0.161
2+	0.90 (0.76–1.07)	0.231
Previously diagnosed with COVID-19		
Diagnosed (Ref: Undiagnosed)	1.13 (1.01–1.26)	**0.035**
Experienced adverse event following primary vaccine series		
Yes (Ref: No)	0.36 (0.32–0.41)	**<0.001**
Influenza vaccine uptake last season		
Yes (Ref: No)	1.26 (1.01–1.56)	**0.041**
VH score		
Per SD increase	0.84 (0.80–0.88)	**<0.001**

†† All variables shown in the table were included in the Cox proportional model.
† Co-morbidities include diabetes mellitus; cardiovascular diseases (including hypertension); asthma; chronic lung disease; chronic kidney disease; and chronic liver disease.

Fig. 4 Predictors of COVID-19 booster uptake among healthcare workers in Bangladesh, March 2021–December 2023

HCWs who had received influenza vaccination in the previous season had 1.26-fold higher hazard of booster uptake (aHR = 1.26; 95% CI 1.01–1.56). In contrast, greater baseline vaccine hesitancy was associated with slower uptake and for each SD increase in the hesitancy score, the hazard of receiving a booster decreased by approximately 16% (aHR = 0.84; 95% CI 0.80–0.88).

Discussion

Our study provides insights into COVID-19 vaccine booster uptake among HCWs in Bangladesh, a population integral to the functioning of the healthcare system during the current pandemic and potential future outbreaks. Our findings reveal that while a majority (63.4%) of HCWs received at least one booster dose, the uptake of the 2nd booster remains alarmingly low at only 6%. This gap is particularly concerning given the well-documented decline in vaccine-induced immunity over time, which necessitates booster doses to maintain adequate protection against emerging SARS-CoV-2 variants [41]. Furthermore, HCWs serve as the primary source of instilling vaccine confidence in the public. As such, limited vaccine uptake among HCWs is likely to translate into similar trends in the public.

The phased rollout of COVID-19 vaccination in Bangladesh initially prioritized HCWs during mass vaccination efforts that began in early 2021 (S4 Fig) [42], starting with the Oxford-AstraZeneca (Covishield) vaccine. Over time, the program expanded to incorporate multiple vaccine platforms, such as Pfizer-BioNTech, Sinopharm BIBP, and Moderna [43]. Booster doses were introduced gradually, with the 1st booster launched on a limited scale in December 2021 [44] and the second in December 2022 [45]. A nationwide implementation on 1 January 2023 followed this. However, by March 2023, the Government of Bangladesh shifted its focus to prioritizing vaccination for individuals who had not yet received their primary doses rather than continuing booster doses. Despite widespread national recommendations for booster vaccination, the vaccination campaign in Bangladesh evolved over time [46]. Shifts in eligibility criteria, vaccine availability, and public communication may have contributed to the observed variation in booster uptake among HCWs. The low completion rate of the 2nd booster

dose observed in this study may reflect a combination of changing guidelines, a lower perceived risk of severe illness, and concerns about vaccine efficacy. Addressing these challenges will require providing HCWs with clear, up—to-date information on the benefits of booster doses, particularly their role in preventing severe disease, hospitalization, and infection from emerging variants. Moreover, integrating booster vaccinations into routine healthcare practices and establishing dedicated delivery mechanisms for high-risk populations could significantly improve booster uptake [47].

The patterns in Bangladesh reflect challenges observed in other LMICs with similarly campaign-driven vaccination strategies. Studies from Africa and South Asia report low completion rates for COVID-19 booster doses among HCWs, despite strong uptake of the primary series. A multi-country analysis from Africa attributed poor booster coverage to reduced risk perception, limited communication, and inconsistent national guidance [48]. Evidence from Pakistan and India also shows declining booster uptake among HCWs following early vaccination campaigns, linked to shifting policies and reduced urgency as case numbers fell [18, 49]. These findings point to a broader challenge in many LMICs, where adult vaccination relies heavily on short-term campaigns rather than sustained, routine delivery platforms [50]. Global assessments further indicate that HCWs in LMICs face structural barriers to timely boosters, including supply interruptions, limited occupational vaccination programs, and weak institutional mechanisms to support repeated dosing [51]. Without more predictable booster policies, consistent supply, and integration of HCW boosters into routine occupational health services, frontline workers in LMICs will remain vulnerable to waning immunity and future variants.

HCWs who worked across both the COVID-19 and general patient care in our study were 1.36 times more likely (aHR = 1.36; 95% CI 1.22–1.53) to receive booster doses at any given point in time than those assigned exclusively to non-COVID wards. This uptake among rotating staff in our context likely reflects greater occupational exposure, which may have heightened their awareness of infection risk and accelerated their decision to receive a booster [52, 53]. Thus, it is crucial to prioritize booster promotion among HCWs in lower-exposure roles who may be more likely to delay booster uptake. At the same time, continued access should be maintained for HCWs working across multiple clinical areas so that they remain adequately protected against infection.

Approximately 67% of previously infected HCWs eventually received a booster dose in our study, and they had 13% higher hazard of booster uptake than those without prior infection (aHR = 1.13; 95% CI 1.01–1.26). This observation aligns with studies suggesting that prior infection can heighten perceived vulnerability and reinforce the perceived value of maintaining protection through booster vaccination [54, 55]. However, contrasting evidence also exists, with some studies reporting lower booster uptake among previously infected HCWs who believed their natural immunity provided sufficient protection [56, 57]. As such, tailored educational initiatives that emphasize the limited duration of natural immunity and the complementary benefits of booster vaccination may help sustain protection among HCWs.

In our analysis, receipt of seasonal influenza vaccination in the previous season was associated with a 1.26-fold-higher hazard of COVID-19 booster uptake among HCWs. This pattern is consistent with evidence from multiple studies showing that prior influenza vaccination behavior is associated with subsequent vaccine acceptance and timeliness, including for COVID-19 vaccination and booster doses [58, 59]. Previous influenza vaccination behavior thus likely reflects lower psychological and informational barriers and greater familiarity with vaccination processes. This, in turn, may translate into greater readiness to vaccinate and earlier uptake of boosters when they become available [60, 61]. In settings such as Bangladesh, where routine influenza vaccination is not yet established, introducing a seasonal program could provide a platform for routine adult vaccination and facilitate the timely uptake of future boosters among HCWs.

Greater baseline vaccine hesitancy and adverse events following the primary vaccination series were both associated with a lower hazard of COVID-19 booster dose uptake among HCWs in this study. However, they did not appear to reduce eventual booster coverage. Among HCWs, such delays are plausibly driven by heightened concerns about side effects, uncertainty about repeated dosing, or a reduced perception of urgency following earlier waves of infection. Moreover, the magnitude of association with prior adverse events was notable and should be interpreted as reflecting multiple overlapping processes. These include behavioral responses, heterogeneity in severity, and residual confounding, rather than as a single causal mechanism. Similar patterns of uptake among individuals who are hesitant and those with prior adverse reactions have been reported in other settings. Among both HCWs and the general population, concerns about vaccine safety and potential side effects are consistently cited as important barriers to timely vaccination [62–64]. This suggests that efforts to improve the timeliness of booster uptake should focus on addressing specific concerns around safety, side effects, and repeated dosing, through follow-up counseling and transparent communication after adverse events.

Our study has several potential limitations that should be considered when interpreting the findings. First, there is the possibility of selection bias. HCWs who chose to participate in the study may have different attitudes toward booster vaccination than those who did not, potentially skewing the results. Second, we relied on self-reported data on booster-dose vaccination status, which introduces the risk of recall bias and misclassification. Although the HCWs in our study received their booster vaccines at the study hospital, which may lend credibility to their reports, the lack of verification through vaccination cards means that inaccuracies cannot be entirely ruled out. Third, although we measured vaccine hesitancy using a composite scale, we did not assess other psychosocial constructs in depth, such as trust in health authorities, perceived institutional credibility, or social norms that may further explain variation in booster uptake. Finally, although our study included a large and diverse cohort of HCWs from various healthcare facilities, the findings may not be fully generalizable to all HCWs across Bangladesh. The study sample, though broad, may not capture the full range of experiences and behaviors of HCWs across different regions or healthcare settings, particularly in more rural or underserved areas. In addition, the second booster dose was introduced late (December 2022), and vaccination priorities shifted away from booster doses by early 2023. These temporal changes in availability and policy may have influenced the observed patterns of booster uptake.

Conclusion

Our study reveals that a substantial proportion of HCWs have received at least one COVID-19 booster dose, indicating a generally positive response to vaccination campaigns. However, the markedly lower uptake of the 2nd booster dose highlights challenges in sustaining repeated booster vaccination over time. Booster uptake in this cohort was shaped by prior infection, occupational exposure, vaccine hesitancy, and previous adverse events, which influenced the timing of booster receipt. These underscore that booster behavior among HCWs reflects a dynamic perception of risk and prior experience rather than access or eligibility. Thus, there is an urgent need for ongoing monitoring and targeted interventions to address specific barriers and concerns related to booster-dose uptake among the healthcare workforce. Integrating booster vaccinations into routine healthcare practices and streamlining the vaccination process may help reduce delays in uptake. Such measures are critical to strengthening the healthcare system's overall resilience against current and future public health threats as booster recommendations evolve and the perceived infection risk changes over time.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s41182-026-00960-4.

Supplementary Material 1.

Acknowledgements
The authors gratefully acknowledge the International Centre for Diarrhoeal Disease Research, Bangladesh (icddr,b) for its organizational and institutional assistance in facilitating this research. icddr,b extends its sincere appreciation to the Governments of Bangladesh and Canada for their continued and unrestricted support to the institute, which made this study possible. The authors also wish to express their heartfelt gratitude to Lindsey M. Duca, Susan Cornelia Kaydos-Daniels, Benjamin A. Dahl, and Nancy Ortiz of the U.S. Centers for Disease Control and Prevention (CDC) for their valuable contributions, insights, and guidance throughout the course of this work.

Author contributions
Md. Zakiul Hassan: Conceptualization, investigation, funding acquisition, writing —original draft, methodology, supervision, project administration; Ahamed Khairul Basher: Investigation, methodology, validation, visualization, writing—review and editing, supervision, project administration, data curation; Homayra Rahman Shoshi: Software, formal analysis, data curation, validation, visualization, writing—original draft; Md. Abdullah Al Jubayer Biswas: Methodology, validation, visualization, formal analysis, software, writing—review and editing; Ashrak Shad Pyash: Validation, visualization, formal analysis, software, writing—review and editing.; Saleh Haider: Writing—review and editing, data curation; Md. Azazul Haque: Writing—review and editing, data curation; Aninda Rahman: Methodology, writing—review and editing; Nazmul Islam: Methodology, writing—review and editing; Fahmida Chowdhury: Investigation, funding acquisition, writing—review and editing, supervision; Taufiqur Rahman Bhuiyan: Methodology, writing—review and editing; Mohammed Ziaur Rahman: Conceptualization, investigation, funding acquisition, writing—review and editing; Firdausi Qadri: Conceptualization, investigation, funding acquisition, writing—review and editing, methodology, validation, visualization, supervision.

Funding
The U.S. Centre for Disease Control and Prevention (CDC) (https://www.cdc.gov) provided funds for this study (Grant No GR-02312; Award ID: PO# 5263). The funder had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; or decision to submit the manuscript for publication. The authors and their contributions to the manuscript are independent of the funder.

Data availability
The authors assume responsibility for the data presented in this manuscript. Data cannot be made publicly available because this Human Subject Research dataset contains potentially sensitive information and hence is confidential from an ethical perspective. icddr,b recognises the public health, social, and intellectual value of providing access to its knowledge data. Data will be provided to interested researchers (Recipients) upon approval of a Data Licensing Application & Agreement (DLAA) by the icddr,b Data Centre Committee (DCC). Request for icddr.b research data should be addressed to Ms. Shiblee Sayeed, Senior Manager, Research Administration, at shiblee_s@icddrb.org.

Declarations

Ethics approval and consent to participate
The Institutional Review Board (IRB) of icddr,b approved the study protocol. The Institutional Review Board at the US CDC relied on icddr.b's approval. All the HCWs included in the study provided written informed consent to participate. All procedures performed in this study involving human participants were in accordance with the 1964 Declaration of Helsinki and its subsequent amendments. Written informed consent was obtained from all participants. The study team provided comprehensive oral and written explanations in the

local language (Bangla) regarding the research aims, objectives, potential risks and benefits, confidentiality, voluntary participation, the right to withdraw at any time, conflicts of interest, and compensation. Participants were reminded that their participation was entirely voluntary and that all information would remain confidential before they were asked to sign the consent form.

Consent for publication
Not applicable.

Permission to reproduce material from other sources
Not applicable.

Competing interests
The authors declare no competing interests.

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Received: 8 February 2026 Accepted: 21 April 2026
Published online: 29 April 2026

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