

KNOWLEDGE AND ATTITUDE ABOUT COVID-19 VACCINES AND THEIR BOOSTERS AMONG HEALTHCARE WORKERS (HCWS) AT SECONDARY AND TERTIARY CARE HOSPITALS IN KARACHI, PAKISTAN

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ABSTRACT

Background: Healthcare workers remained central to COVID-19 prevention and vaccination programmes, yet their confidence in vaccines was affected by changing recommendations, safety concerns, misinformation, and uncertainty regarding booster doses. Understanding their knowledge and attitudes was important because their vaccination decisions influenced personal protection, workplace safety, patient counselling, and wider public confidence. Evidence from Pakistani healthcare settings remained locally limited, particularly regarding booster-related knowledge and healthcare workers' willingness to receive or recommend additional vaccine doses to others.

Objective: To assess knowledge and attitudes regarding COVID-19 vaccines and booster doses among healthcare workers in secondary and tertiary care hospitals in Karachi.

Methods: This multicentre cross-sectional study included 379 healthcare workers recruited through convenience sampling from three hospitals. A structured, interviewer-administered questionnaire assessed participant characteristics, vaccination status, vaccine and booster knowledge, and booster attitudes. Scores were classified using modified Bloom's cut-offs. Descriptive analysis was performed using SPSS version 21.0.

Results: The mean age was 28.42 ± 7.50 years, and 62.0% were female. Overall, 90.5% were fully vaccinated, 84.2% had received a booster, and 47.2% reported previous COVID-19 infection. Knowledge of primary vaccines was high in 38.5%, moderate in 36.1%, and low in 25.3%; the mean score was 6.60 ± 1.87 . Booster knowledge was high in 18.5%, moderate in 40.1%, and low in 41.4%, with a mean score of 5.75 ± 1.91 . Positive, neutral, and negative booster attitudes were recorded in 50.9%, 19.3%, and 29.8%, respectively. Booster vaccination was recommended to patients by 85.5%, while 64.1% were willing to receive an additional dose.

Conclusion: Vaccination uptake was high, but booster-specific knowledge remained limited. Regular evidence-based education and clear institutional communication may strengthen informed confidence and healthcare workers' contribution to vaccine advocacy.

Keywords: Attitude of Health Personnel; COVID-19 Vaccines; Health Knowledge, Attitudes, Practice; Health Personnel; Immunization, Secondary; Pakistan; Vaccination Hesitancy.

INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic placed unprecedented pressure on healthcare systems and substantially altered the professional and personal lives of healthcare workers. Throughout successive waves of infection, healthcare workers remained at the forefront of diagnosis, treatment, infection control, vaccination and public health communication. Their frequent contact with infected individuals increased their risk of occupational exposure and created the possibility of transmitting infection to patients, colleagues and family members. The rapid development and deployment of COVID-19 vaccines therefore represented a major advancement in reducing severe disease, hospitalization and mortality, particularly among individuals at increased risk of exposure or adverse clinical outcomes (1). Healthcare workers were consequently prioritized during the initial phases of vaccination programmes, followed by recommendations for booster doses as immunity declined and new viral variants emerged. Despite early access to vaccination and greater familiarity with medical information, vaccine acceptance among healthcare workers has not been universal. A considerable proportion of healthcare professionals have reported uncertainty, delayed vaccination or reluctance to receive either the primary vaccine series or subsequent booster doses (2). This hesitancy is particularly important because healthcare workers occupy a dual position within vaccination programmes. In addition to protecting themselves through vaccination, they influence the attitudes and decisions of patients, families and communities. Patients often consider healthcare professionals to be trusted sources of health information, and the confidence expressed by healthcare workers can strengthen public acceptance of vaccination. Conversely, uncertainty or negative attitudes among healthcare professionals may reinforce misinformation and reduce vaccine uptake in the wider population.

Vaccine hesitancy is a complex and context-dependent phenomenon rather than a simple refusal of vaccination. It may arise from concerns about safety, effectiveness, adverse effects, duration of protection, the speed of vaccine development, distrust of institutions or uncertainty regarding changing recommendations. These concerns became more pronounced with the introduction of booster doses, as some healthcare workers questioned the need for additional vaccination after completing the primary series or recovering from COVID-19. Others were uncertain about the ability of existing vaccines to protect against newly emerging variants. The World Health Organization has identified vaccine hesitancy as an important global health challenge, while widespread vaccine coverage has been considered essential for limiting severe illness, reducing pressure on healthcare services and supporting the restoration of routine social and economic activity (3-6). Knowledge and attitude are closely related but distinct determinants of vaccination behaviour. Knowledge includes an understanding of vaccine indications, expected benefits, possible adverse effects, recommended schedules, eligibility criteria and the purpose of booster doses. Attitude reflects personal confidence, perceived necessity, trust in vaccine safety and effectiveness, willingness to recommend vaccination and readiness to receive future doses. Adequate knowledge may help healthcare workers evaluate vaccine-related information critically; however, knowledge alone does not always result in acceptance. Emotional concerns, personal experiences, workplace culture, social influences and exposure to misinformation may continue to shape attitudes even among medically trained individuals. Assessment of both knowledge and attitude is therefore necessary to obtain a meaningful understanding of booster-dose acceptance.

Evidence from different healthcare settings has demonstrated substantial variation in knowledge and attitudes towards COVID-19 booster vaccination. A qualitative study conducted in the United States found that healthcare workers were motivated to receive vaccination because they wished to protect themselves, their families, patients and communities. Most participants accepted and received booster doses, although some expressed concerns regarding reduced effectiveness. In Nepal, 68% of healthcare professionals were reported to have good knowledge and 78.6% demonstrated a favourable attitude towards COVID-19 booster vaccination (7). Similarly, a study among healthcare workers in the Czech Republic reported booster-dose acceptance of 71.3%, whereas 12.2% of participants were hesitant and 16.6% were opposed to the available booster vaccines (8). These findings indicate that professional training does not produce uniform perceptions and that acceptance may differ according to social, cultural, institutional and epidemiological circumstances. A favourable attitude towards booster vaccination has been associated with recognition of COVID-19 as a serious disease, confidence in the protective value of vaccines and the belief that vaccination can reduce the risk of infection or severe illness among family members and patients. Healthcare workers who obtain information from scientific journals, professional organizations and reliable clinical sources may be more likely to understand the rationale for booster doses. In contrast, commonly reported reasons for refusing or delaying boosters include fear of short- and long-term adverse effects, uncertainty about protection against emerging variants, inadequate knowledge of booster recommendations and doubts about the necessity of repeated doses (9). The continuing evolution of evidence and changes in vaccination policies may also create confusion, particularly where institutional communication is inconsistent or where healthcare workers rely on informal sources of information.

The situation is especially relevant in Pakistan, where healthcare institutions operate within diverse social, educational and resource settings. Karachi is the country's largest metropolitan city and contains a wide range of secondary and tertiary care hospitals serving a large and heterogeneous population. Healthcare workers in these institutions include physicians, nurses, pharmacists, allied health professionals, technicians and support staff, whose levels of training, access to scientific information and occupational exposure may differ considerably. These differences may influence their understanding of vaccination and their willingness to receive or recommend booster doses. However, locally generated evidence regarding the knowledge and attitudes of healthcare workers towards both COVID-19 vaccines and booster doses remains limited, particularly across secondary and tertiary care settings in Karachi. Identification of knowledge gaps and negative perceptions among healthcare workers can assist hospital administrations and public health authorities in

designing more responsive vaccination strategies. Educational interventions may be more effective when they address specific concerns rather than providing general messages. For example, uncertainty regarding adverse effects requires clear safety information, whereas doubts about effectiveness against variants require transparent explanation of the expected role and limitations of booster vaccination. Reliable institutional communication, opportunities for healthcare workers to discuss their concerns and access to updated scientific evidence may strengthen confidence and improve informed decision-making. Such measures may also enhance the ability of healthcare professionals to communicate accurately with patients and support broader vaccination programmes.

The central research question of the present study is: what are the levels of knowledge and attitudes regarding COVID-19 vaccines and their booster doses among healthcare workers employed in secondary and tertiary care hospitals in Karachi, Pakistan? It is anticipated that healthcare workers with better knowledge of vaccine safety, effectiveness and booster recommendations will demonstrate more favourable attitudes towards vaccination. Accordingly, the objective of this study is to assess the knowledge and attitudes of healthcare workers regarding COVID-19 vaccines and booster doses and to identify important areas of concern that may influence acceptance. The findings are expected to provide context-specific evidence for developing targeted educational initiatives, strengthening institutional vaccination communication and promoting informed acceptance of COVID-19 booster doses among healthcare professionals.

METHODOLOGY

A multicentre, hospital-based cross-sectional study was conducted at one tertiary care hospital and two secondary care hospitals in Karachi, Pakistan. The participating institutions included Aga Khan University Hospital, Stadium Road, and Aga Khan Hospital facilities located in Karimabad and Garden. The study population comprised healthcare workers employed at these hospitals, including medical doctors, nursing personnel and pharmacists. Healthcare workers who were employed at one of the selected institutions, belonged to one of the specified professional groups and agreed to participate were considered eligible. Individuals who declined or were unable to provide informed consent were excluded from the study. The required sample size was calculated using the single-population proportion formula at a 95% confidence level and an absolute precision of 5%. For the assessment of knowledge, an anticipated population proportion of 56% produced a minimum required sample size of 379 participants. For the assessment of attitudes, an anticipated proportion of 89% produced a smaller sample size requirement of 151 participants. The larger calculated sample size of 379 was therefore selected to ensure adequate precision for estimating both knowledge and attitude outcomes. Participants were identified and recruited through convenience sampling according to their availability within the participating hospitals.

Data were collected through face-to-face, interviewer-administered structured questionnaires. Potential participants were approached in designated areas of outpatient departments and inpatient wards, primarily during break periods, to minimize disruption to clinical responsibilities. Interviews were conducted in private or designated spaces within the hospitals to maintain confidentiality. Before data collection, the purpose and procedures of the study were explained to each participant in either Urdu or English, according to individual preference. Participants were informed that participation was voluntary, that they could decline to answer any question and that they could withdraw from the study at any stage without penalty or effect on their employment. No financial or non-financial incentives were offered. Written informed consent was obtained before administration of the questionnaire. The questionnaire required approximately 20 minutes to complete and consisted of three main components. The first component collected sociodemographic and professional information, including age, gender, ethnicity, educational level and occupation, together with information on previous COVID-19 infection and vaccination status. The second component assessed knowledge regarding COVID-19 vaccines and booster doses, while the third assessed attitudes towards COVID-19 booster vaccination. Knowledge regarding the primary COVID-19 vaccines was assessed through nine questions, and knowledge regarding booster vaccines was evaluated through ten questions. Attitudes towards COVID-19 booster vaccination were assessed using six items. The questionnaire was administered in a standardized manner to reduce variation between interviews, and completed forms were handled confidentially.

Data were entered and analysed using the Statistical Package for the Social Sciences, version 21.0. Data were reviewed for completeness and consistency before analysis. Categorical variables, including gender, ethnicity, educational level, occupation, history of COVID-19 infection and vaccination status, were summarized using frequencies and percentages. Continuous variables, including age and the calculated knowledge and attitude scores, were summarized using means and standard deviations. Where applicable, estimates were presented with 95% confidence intervals. Responses to Likert-scale attitude items were dichotomized for scoring. An “agree” response was assigned a score of 1, whereas “neutral” and “disagree” responses were assigned a score of 0. Similarly, binary questions were scored as 1 for a “yes” response and 0 for a “no” response when affirmation represented the intended correct or favourable response. Item scores were summed to obtain separate scores for knowledge of COVID-19 vaccines, knowledge of booster vaccines and attitudes towards booster vaccination. Each participant’s total score was subsequently converted into a percentage of the maximum possible score.

Knowledge levels were categorized according to the modified Bloom’s cut-off criteria. Participants who obtained less than 60% of the total possible score were classified as having a low level of knowledge, those who obtained 60%–79% were classified as having a moderate level of knowledge, and those who obtained 80%–100% were classified as having a high level of knowledge. Attitude scores were classified using the same cut-off approach: scores below 60% represented a negative attitude, scores between 60% and 79% represented a neutral attitude, and scores between 80% and 100% represented a positive attitude towards COVID-19 booster vaccination (10). The analysis was primarily descriptive, as no inferential statistical tests or multivariable analyses were specified. Ethical approval

was obtained from the Ethical Review Committee of Aga Khan University before the commencement of the study. The principles of voluntary participation, informed consent, privacy and confidentiality were observed throughout the research process. No personally identifying information was reported, and collected information was used only for the stated research purposes.

RESULTS

A total of 379 healthcare workers participated in the study. Their mean age was 28.42 ± 7.50 years, with a 95% confidence interval of 27.66–29.18 years. Of the participants, 235 (62.0%) were female and 144 (38.0%) were male. Urdu-speaking participants constituted the largest ethnic group (208, 54.9%), followed by Punjabi (54, 14.2%), Sindhi (51, 13.5%), other ethnic groups (40, 10.6%), Pashto-speaking participants (21, 5.5%), and Balochi-speaking participants (5, 1.3%). Nursing staff represented 127 (33.5%) participants, while 98 (25.9%) were classified under other occupations, 83 (21.9%) were doctors, 56 (14.8%) were laboratory employees, 11 (2.9%) were radiology employees, and 4 (1.1%) were physiotherapists. Pre-existing medical conditions were reported by 40 (10.6%) participants, whereas 339 (89.4%) reported none. A previous history of COVID-19 infection was reported by 179 (47.2%) healthcare workers. Most participants were fully vaccinated (343, 90.5%); 34 (9.0%) were partially vaccinated, and 2 (0.5%) were unvaccinated. A booster dose had been received by 319 (84.2%) participants, while 60 (15.8%) had not received one. Social media was the most frequently reported source of information about COVID-19 vaccines (246, 64.9%), followed by other sources (70, 18.5%), television (32, 8.4%), social circles (28, 7.4%), and newspapers (3, 0.8%). In addition, 334 (88.1%) participants stated that they would recommend COVID-19 vaccination to patients, while 11 (2.9%) would not and 34 (9.0%) were unsure.

The mean knowledge score for primary COVID-19 vaccination was 6.60 ± 1.87 out of 9. High knowledge was recorded among 146 (38.5%) participants, moderate knowledge among 137 (36.1%), and low knowledge among 96 (25.3%). Most participants recognized that COVID-19 could occur more than once (338, 89.2%) and that vaccinated individuals could still acquire the infection (346, 91.3%). Reduced mortality following vaccination was acknowledged by 303 (79.9%), reduced disease severity by 308 (81.3%), and community-level benefit by 317 (83.7%). Vaccination of individuals with comorbid conditions was supported by 238 (62.8%) participants. Vaccine safety during pregnancy was affirmed by 188 (49.6%), while 77 (20.3%) disagreed and 114 (30.1%) were uncertain. Immunity was believed to last six months by 203 (53.6%), two months by 70 (18.5%), and four or eight months by 53 (14.0%) each. Headache was the most commonly selected adverse effect (221, 58.3%), followed by body aches (89, 23.5%), fever (36, 9.5%), nausea or vomiting (21, 5.5%), influenza-like illness (9, 2.4%), and infertility (3, 0.8%). The mean knowledge score for COVID-19 booster vaccination was 5.75 ± 1.91 out of 10. Low booster-related knowledge was observed in 157 (41.4%) participants, moderate knowledge in 152 (40.1%), and high knowledge in 70 (18.5%). A booster dose was considered protective by 294 (77.6%) participants. Regarding timing after completion of the primary series, 204 (53.8%) selected six months, 130 (34.3%) selected three months, and 45 (11.9%) selected any time. Following recovery from COVID-19, 129 (34.0%) selected three or more months, 113 (29.8%) any time, 96 (25.3%) one month, and 41 (10.8%) two months. Reinfection after a booster dose was considered possible by 285 (75.2%). The same vaccine as the primary series was preferred by 146 (38.5%), a different vaccine by 124 (32.7%), and 109 (28.8%) were unsure. Uncertainty was also common regarding whether a different booster would produce better immunity (149, 39.3%) or more adverse effects (169, 44.6%).

The mean attitude score towards booster vaccination was 4.07 ± 1.77 out of 6. A positive attitude was identified in 193 (50.9%) participants, a neutral attitude in 73 (19.3%), and a negative attitude in 113 (29.8%). Booster administration for all fully vaccinated individuals was supported by 287 (75.7%), and mandatory booster vaccination was supported by 254 (67.0%). Perceived benefit to participants and their families was reported by 287 (75.7%) who agreed or strongly agreed. A total of 151 (39.8%) agreed or strongly agreed that they would not have received a booster if it had not been mandatory. Nevertheless, 324 (85.5%) stated that they would recommend booster vaccination to patients, and 243 (64.1%) were willing to receive an additional booster dose if required.

Table 1. Sociodemographic, professional, and vaccination characteristics of healthcare workers (n=379)

Characteristic	Category	n (%) / Mean $\pm$ SD
Age, years	Mean $\pm$ SD	28.42 $\pm$ 7.50
	95% CI	27.66–29.18
Gender	Male	144 (38.0)
	Female	235 (62.0)
Ethnicity	Urdu-speaking	208 (54.9)
	Punjabi	54 (14.2)
	Sindhi	51 (13.5)
	Pashto-speaking	21 (5.5)

	Balochi-speaking	5 (1.3)
	Other	40 (10.6)
Occupational group	Doctor	83 (21.9)
	Nursing staff	127 (33.5)
	Laboratory employee	56 (14.8)
	Physiotherapist	4 (1.1)
	Radiology employee	11 (2.9)
	Other healthcare worker	98 (25.9)
Pre-existing medical condition	Yes	40 (10.6)
	No	339 (89.4)
Previous COVID-19 infection	Yes	179 (47.2)
	No	200 (52.8)
COVID-19 vaccination status	Fully vaccinated	343 (90.5)
	Partially vaccinated	34 (9.0)
	Unvaccinated	2 (0.5)
Received a COVID-19 booster dose	Yes	319 (84.2)
	No	60 (15.8)
Main source of vaccine information	Social media	246 (64.9)
	Television	32 (8.4)
	Social circle	28 (7.4)
	Newspapers	3 (0.8)
	Other sources	70 (18.5)

SD: standard deviation; CI: confidence interval.

Table 2. Knowledge regarding COVID-19 vaccines and booster doses among healthcare workers (n=379)

Knowledge domain or item	Response/category	n (%) / Mean $\pm$ SD
Knowledge of primary COVID-19 vaccines	Mean score out of 9	6.60 $\pm$ 1.87
	High knowledge, 80%–100%	146 (38.5)
	Moderate knowledge, 60%–79%	137 (36.1)
	Low knowledge, <60%	96 (25.3)
COVID-19 infection can occur more than once	Yes	338 (89.2)
	No	20 (5.3)
	Not sure	21 (5.5)
Vaccinated individuals can still acquire COVID-19	Yes	346 (91.3)
	No	13 (3.4)
	Not sure	20 (5.3)
Vaccination reduces COVID-19-related mortality	Yes	303 (79.9)

	No	36 (9.5)
	Not sure	40 (10.6)
Vaccination reduces the severity of COVID-19	Yes	308 (81.3)
	No	36 (9.5)
	Not sure	35 (9.2)
COVID-19 vaccination is safe during pregnancy	Yes	188 (49.6)
	No	77 (20.3)
	Not sure	114 (30.1)
Individuals with comorbidities should receive vaccination	Yes	238 (62.8)
	No	55 (14.5)
	Not sure	86 (22.7)
Vaccination is beneficial for the community	Yes	317 (83.7)
	No	18 (4.8)
	Not sure	44 (11.6)
Perceived duration of post-vaccination immunity	Two months	70 (18.5)
	Four months	53 (14.0)
	Six months	203 (53.6)
	Eight months	53 (14.0)
Knowledge of COVID-19 booster doses	Mean score out of 10	5.75 ± 1.91
	High knowledge, 80%–100%	70 (18.5)
	Moderate knowledge, 60%–79%	152 (40.1)
	Low knowledge, <60%	157 (41.4)
A booster dose provides protection against COVID-19	Yes	294 (77.6)
	No	27 (7.1)
	Not sure	58 (15.3)
Perceived timing of booster after the primary series	Any time	45 (11.9)
	After three months	130 (34.3)
	After six months	204 (53.8)
Perceived timing of booster after recovery from COVID-19	Any time	113 (29.8)
	After one month	96 (25.3)
	After two months	41 (10.8)
	After three or more months	129 (34.0)
COVID-19 can occur after receiving a booster dose	Yes	285 (75.2)
	No	39 (10.3)
	Not sure	55 (14.5)
Preferred type of booster dose	Same as the primary vaccine	146 (38.5)

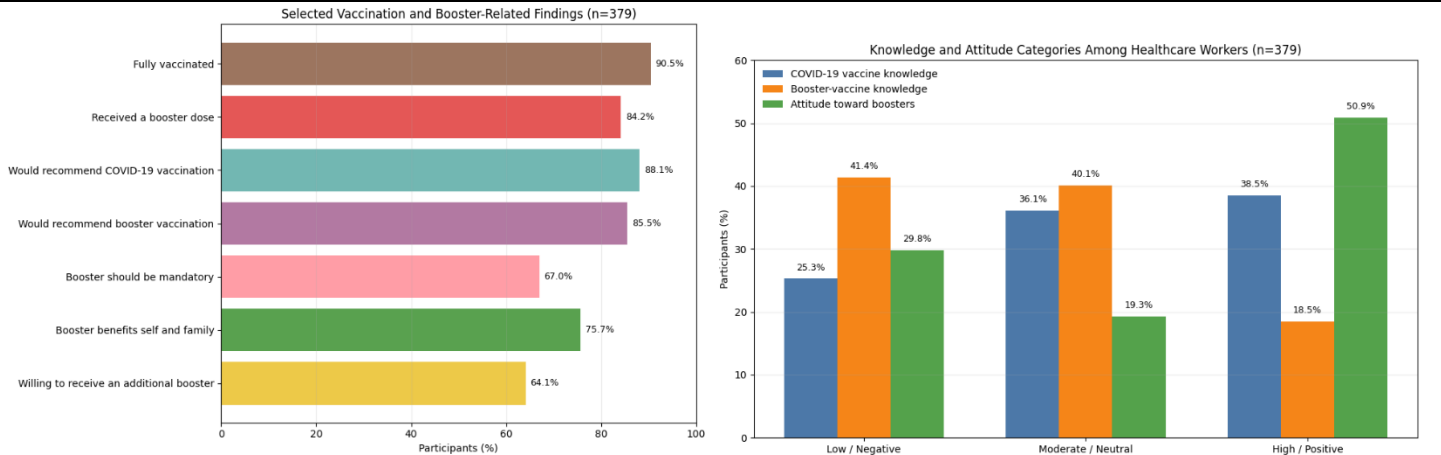
	Different from the primary vaccine	124 (32.7)
	Not sure	109 (28.8)
A different booster vaccine would provide better immunity	Yes	140 (36.9)
	No	90 (23.7)
	Not sure	149 (39.3)
A different booster vaccine would cause more adverse effects	Yes	81 (21.4)
	No	129 (34.0)
	Not sure	169 (44.6)

Knowledge levels were classified using the modified Bloom's cut-off criteria. Percentages may not total exactly 100% because of rounding.

Table 3. Attitudes towards COVID-19 vaccination and booster doses among healthcare workers (n=379)

Attitude domain or statement	Response/category	n (%) / Mean $\pm$ SD
Overall attitude towards COVID-19 booster vaccination	Mean score out of 6	4.07 $\pm$ 1.77
	Positive attitude, 80%–100%	193 (50.9)
	Neutral attitude, 60%–79%	73 (19.3)
	Negative attitude, <60%	113 (29.8)
Would not receive the primary COVID-19 vaccine if it were not mandatory	Yes	154 (40.6)
	No	186 (49.1)
	Not sure	39 (10.3)
Would recommend primary COVID-19 vaccination to patients	Yes	334 (88.1)
	No	11 (2.9)
	Not sure	34 (9.0)
Booster doses should be given to all fully vaccinated individuals	Yes	287 (75.7)
	No	41 (10.8)
	Not sure	51 (13.5)
Booster vaccination should be mandatory	Yes	254 (67.0)
	No	74 (19.5)
	Not sure	51 (13.5)
Receiving a booster would benefit the participant and family	Agree/strongly agree	287 (75.7)
	Neutral	64 (16.9)
	Disagree/strongly disagree	28 (7.4)
Would not receive a booster if it were not mandatory	Agree/strongly agree	151 (39.8)
	Neutral	80 (21.1)
	Disagree/strongly disagree	148 (39.1)
Would recommend booster vaccination to patients	Yes	324 (85.5)
	No	20 (5.3)
	Not sure	35 (9.2)

Willing to receive an additional booster dose if required	Yes	243 (64.1)
	No	63 (16.6)
	Not sure	73 (19.3)



DISCUSSION

The present study assessed knowledge and attitudes regarding COVID-19 vaccines and booster doses among healthcare workers employed at secondary and tertiary care hospitals in Karachi. The findings showed a high level of vaccine uptake, with 90.5% of participants having completed the primary vaccination series and 84.2% having received at least one booster dose. Nevertheless, knowledge was not uniformly high. Only 38.5% demonstrated high knowledge of primary COVID-19 vaccination, while 36.1% had moderate knowledge and 25.3% had low knowledge. The gap was more pronounced for booster vaccination, for which only 18.5% had high knowledge, whereas 40.1% and 41.4% had moderate and low knowledge, respectively. These findings indicated that high vaccination coverage did not necessarily reflect a consistently strong understanding of vaccine-related recommendations. The moderate and low levels of knowledge observed among a substantial proportion of participants may have reflected the rapidly changing nature of vaccine guidance during the pandemic. Recommendations concerning vaccine schedules, booster timing, eligibility, vaccine interchangeability and protection against emerging variants evolved as new evidence became available. At the same time, healthcare workers were exposed to large volumes of information through formal and informal channels. Social media was the principal source of vaccine-related information for almost two-thirds of the participants, which may have increased access to information but also created greater exposure to incomplete, outdated or misleading claims. A previous study conducted in Pakistan similarly reported average knowledge among approximately half of its participants regarding COVID-19 vaccines, adverse effects, allergic reactions and implications for autoimmune disorders (11). The similarity between these findings suggested that knowledge gaps persisted even among individuals working in healthcare settings and supported the need for structured institutional communication rather than reliance on unregulated information sources.

Despite these gaps, participants demonstrated adequate awareness of several important aspects of vaccination. Most recognized that vaccinated individuals could still acquire COVID-19, while approximately four-fifths acknowledged that vaccination reduced disease severity and mortality. A similarly large proportion considered vaccination beneficial for the community. These findings reflected a generally realistic understanding of vaccine effectiveness, particularly the distinction between complete prevention of infection and protection against severe outcomes. However, uncertainty remained in areas requiring more specific clinical knowledge. Only about half considered COVID-19 vaccination safe during pregnancy, and nearly one-third were unsure. Knowledge regarding vaccination among individuals with comorbidities was also less consistent. These areas were clinically important because uncertainty among healthcare workers could influence counselling provided to pregnant women and patients with chronic diseases, who might already have concerns about vaccine safety. Knowledge related to booster doses was weaker than knowledge related to the primary vaccination series. Although 77.6% believed that boosters provided protection and 75.2% recognized that infection could still occur after a booster dose, responses regarding the appropriate timing of booster administration, use of homologous or heterologous vaccines, comparative immunity and adverse effects were widely distributed. Considerable proportions remained uncertain about whether a different booster vaccine would provide stronger immunity or produce more adverse effects. Such variation may have resulted partly from changing national and international recommendations, differences between vaccine products and the absence of a single universally applicable booster schedule during different phases of the pandemic. These findings therefore should not have been interpreted solely as deficiencies among healthcare workers; they also reflected the complexity of communicating evolving scientific guidance in a clear and consistent manner.

The high vaccination and booster uptake observed in this study was comparable with findings from a study conducted in Western India, where healthcare workers also demonstrated high vaccine acceptance and knowledge (12). Such consistency supported the view that healthcare professionals generally recognized the occupational and public health importance of vaccination. In contrast, studies conducted in Qatar and Oman reported greater hesitancy, particularly because of concerns about safety, effectiveness and adverse events following immunization (13,14). Differences across settings may have been related to institutional vaccination requirements, the timing of data collection, vaccine availability, previous infection, public policy, professional role and confidence in health authorities. In the present study, vaccination had been mandatory within the participating healthcare system, which may have contributed substantially to the high uptake and limited the extent to which vaccination status represented voluntary acceptance. Attitudes towards booster vaccination were generally favourable, although they were not uniformly positive. Approximately half of the participants had a positive overall attitude, while nearly one-third had a negative attitude. Three-quarters believed that booster vaccination would benefit themselves and their families, 85.5% would recommend boosters to patients, and 64.1% were willing to receive an additional dose if required. These findings were consistent with studies reporting that healthcare workers who perceived vaccination as effective were more likely to endorse vaccines and recommend them to others (15-17). However, 39.8% agreed or strongly agreed that they would not have received a booster dose if it had not been mandatory. This apparent tension between high uptake, willingness to recommend vaccination and reluctance towards voluntary receipt suggested that institutional compliance and personal confidence were not always equivalent. Some participants may have accepted vaccination because of workplace requirements while retaining concerns about the strength of available evidence, effectiveness against infection or potential adverse effects.

The findings had practical implications for hospital administrators and public health authorities. Educational interventions should have addressed specific areas of uncertainty rather than repeating general messages about the benefits of vaccination. Regular evidence summaries, departmental briefings and question-and-answer sessions led by infectious disease specialists, pharmacists or occupational health teams could have improved understanding of vaccine safety, booster timing and changing recommendations. Because social media was the dominant information source, healthcare institutions could also have used verified digital platforms to distribute concise and updated guidance. Strengthening healthcare workers' confidence was particularly important because their recommendations could influence vaccine acceptance among patients and the wider community. A major strength of the study was its simultaneous assessment of knowledge about primary vaccines, knowledge about booster doses and attitudes towards boosters in a relatively large sample of healthcare workers. The inclusion of participants from secondary and tertiary care hospitals also provided information from more than one level of healthcare delivery. However, several limitations required consideration. Convenience sampling increased the likelihood of selection bias, and recruitment from hospitals belonging to one private healthcare system restricted generalizability to public hospitals, rural settings and other regions of Pakistan. Mandatory workplace vaccination may have inflated uptake and reduced the ability to distinguish genuine acceptance from compliance. The cross-sectional design prevented assessment of changes in knowledge and attitudes over time and did not permit causal conclusions. Self-reported vaccination history and attitudes were vulnerable to recall and social desirability bias. In addition, the absence of inferential analyses limited the identification of factors independently associated with knowledge, attitudes and booster acceptance.

Future studies should have included public and private institutions, probability-based sampling and healthcare workers from a broader range of professional groups and geographical settings. Longitudinal designs would have been useful for examining how attitudes changed with updated recommendations, emerging variants and additional booster campaigns. Multivariable analyses could also have explored the influence of occupation, age, previous infection, comorbidities, information sources and institutional policies. Qualitative interviews would have provided further insight into the reasons underlying the difference between high vaccine uptake and lower voluntary acceptance. Overall, the study demonstrated substantial vaccination coverage and broadly favourable attitudes but also identified important gaps in booster-related knowledge and continuing dependence on mandatory policies.

CONCLUSION

The study concluded that healthcare workers in secondary and tertiary care hospitals in Karachi generally demonstrated limited to moderate knowledge of COVID-19 booster vaccines, despite showing broadly favourable attitudes towards booster vaccination. Their willingness to receive and recommend booster doses appeared to be influenced by the perceived benefits of reducing severe disease, mortality, and transmission risks to patients and family members. These findings highlight the need for regular, evidence-based educational initiatives and clear institutional communication to address remaining knowledge gaps, strengthen informed vaccine confidence, and support the continued role of healthcare workers as trusted advocates for vaccination.

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AUTHOR CONTRIBUTION

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