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Risk Factors of COVID-19 Infection Among Health Workers Post-Vaccination in Jakarta

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Abstract

One of the best approaches to stop the COVID-19 pandemic is vaccination. In Indonesia, the first round of vaccinations was prioritized for health workers on January 14, 2021 (first dose) and March 1, 2021 (second dose). However, some health workers who have been vaccinated were found to be reinfected after receiving the second dose. This cross-sectional study examined the risk factors for COVID-19 infection among health workers after vaccination using secondary and primary data. The data analysis was carried out in univariate (examining the frequency distribution and proportion of independent variables), bivariate (Chi-square test to explore the relationship between independent and dependent variables), and multivariate (Logistic Regression to assess the strength of the relationship between independent and dependent variables). The results showed that the variables associated with post-vaccination infection included COVID-19 infection history (PR: 2.16, p-value <0.05), age (PR: 0.64, p-value <0.05), hypertension (PR: 1.52, p-value <0.05), direct contact with patients (PR: 2.02, p-value <0.05). It is recommended that health workers aged >37 years with a history of diabetes mellitus, hypertension, or previous COVID-19 infection, working directly with patients, and using Personal Protective Equipment level 1 daily should be prioritized for booster vaccinations.

Keywords: COVID-19, health workers, infection disease, pandemic, vaccination

Introduction

Coronaviruses belong to a large family that includes the Middle East Respiratory Syndrome (MERS) and severe acute respiratory syndrome (SARS). Coronavirus disease 2019 (COVID-19) is a novel disease that has not been previously identified in humans and is zoonotic, indicating it can be transmitted between animal and human.[1] COVID-19 is primarily transmitted between individuals through droplets generated by coughing or sneezing rather than airborne particles. Consequently, those in close contact with COVID-19 patients are at the highest risk of infection. To mitigate the spread of the virus, standard preventive measures include hand washing with soap and clean water, practicing proper cough and sneeze etiquette, and implementing infection prevention and control (IPC) measures in health facilities, particularly in emergency units are essential.[2] In Wuhan City, China, a case of pneumonia with an unknown cause was identified as a new type of coronavirus on January 7, 2020. World Health Organization (WHO) declared it a Public Health Emergency of International Concern (PHEIC) on January 30, 2020. During that period, the number of COVID-19 cases increased rapidly, spreading from China to other countries.[3]

One of the biggest hopes for stopping the COVID-19 pandemic is the use of vaccines.[4] According to a previous study of 5,455 health workers at the University of California, San Diego (UCSD) and 9,535 health workers at the University of California, Los Angeles (UCLA) who received the second dose of the COVID-19 vaccine, 1.19% at UCSD and 0.97% at UCLA were infected with COVID-19.[5] Similarly, another study showed that out of 4,081 health workers who received the Pfizer-BioNTech COVID-19 vaccine, 22 (0.54%) were infected with COVID-19 within 1 to 10 days after vaccination.[6] Since then, efforts to develop a vaccine against the SARS-CoV-2 etiological virus have so far been a remarkable success, with various vaccine modalities produced in a very short time.[7] The primary objectives of COVID-19 vaccination are to

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reduce the transmission of the virus, decrease morbidity (disease severity) and mortality (death rate) from COVID-19, and achieve herd immunity in the community, which can only be accomplished by ensuring high vaccination coverage, maintaining an even distribution of vaccination throughout the region.[7,8]

Given the lack of publications addressing the significant risk of COVID-19 reinfection among health workers, both globally and in Indonesia, the authors are motivated to investigate the risk factors associated with COVID-19 infection in post-vaccination health workers. The primary aim was to expedite the administration of booster vaccines to health workers, particularly those at higher risk. Unlike previous studies,[5-6] this study specifically examined the rate of COVID-19 reinfection among health workers.

Although the COVID-19 pandemic has diminished in severity, new variants continue to emerge. This study reviewed the evolution of these variants, the efficacy of vaccines developed for earlier strains, and their impact on infections caused by newer variants. Understanding long-term vaccine protection is crucial, as the effectiveness of vaccines and post-vaccination risk factors will inform the need for revaccination, booster doses, or tailored vaccination strategies for health workers.

As frontline defenders against infectious diseases, health workers play a vital role in preventing future pandemics, making this study essential for ensuring their protection not only during the COVID-19 pandemic but also in preparation for future outbreaks. The findings may inform policies that safeguard health workers in the long term. In a broader context, building resilience against infectious diseases remains a priority, and this study could enhance understanding of effective risk mitigation strategies, particularly within the healthcare sector.

Method

This cross-sectional study involved collecting data on both exposure and outcomes at a single point in time. Data processing was conducted using STATA version 14.2 with licensed and serial number 10699393. This study compared two groups of health workers who were reinfected by COVID-19 and those who were not, aiming to identify risk factors associated with a higher likelihood of COVID-19 infection after receiving the second dose of vaccination. The dependent variable was COVID-19 infection following the second dose, while independent variables included age, sex, history of COVID-19 infection, diabetes mellitus (DM), hypertension, coronary heart disease (CHD), chronic obstructive pulmonary disease (COPD), direct patient contact, use of public transportation, close contact with COVID-19 cases at work and home, use of personal protective equipment (PPE), and working hours.

This study was conducted from March to July 2021, utilizing case data from March 20 to May 30, 2021. The population included all health workers in the Special Capital Region of Jakarta Province who had received the complete second dose of the COVID-19 vaccine. The sample comprised active health workers, regardless of age, sex, or medical history, including those with or without close patient contact. Inclusion criteria required participants to have received both vaccine doses and active WhatsApp contacts listed in the COVID-19 Handling and National Economic Recovery Committee (CHNERC) data. Exclusion criteria included health workers unwilling to complete the questionnaire via Google Forms by May 30, 2021, as well as those with inactive WhatsApp numbers despite being registered in the CHNERC data.

The sample size used was determined based on the hypothesis test formula for the difference between two proportions, as outlined by Lemeshow S (2008).[9]

$$n = \frac{\left(z_{1-\alpha/2}\sqrt{2\overline{P}(1-\overline{P})} + z_{1-\beta}\sqrt{P_1(1-P_1)+P_2(1-P_2)}\right)^2}{(P_1-P_2)^2}$$

After being adopted from Stanley Lemeshow's formula, the results of the minimum sample size for each independent variable are presented in Table 1.

Table 1. Sample Size Calculation Table

Variable	P1	P2	n - Group	2n
Age	0.402	0.224	105	210
Sex	0.447	0.27	114	228
History of COVID-19 infection	0.0008	0.08	96	192
Diabetes mellitus	0.78	0.36	20	40
Hypertension	0.53	0.36	133	266
Coronary heart disease	0.25	0.37	232	464
Chronic obstructive pulmonary disease	0.2	0.39	89	178
Use of transportation	0.38	0.62	66	133
Close contact with COVID-19 patients	0.073	0.227	83	166

Based on the calculation of the sample size for independent variables, the largest number of samples was 240 per group of health workers infected with COVID-19 after vaccination and 328 groups of health workers who were not infected with COVID-19 after vaccination, with a total of 568 samples. Primary data was collected through Google Forms questionnaires and distributed to health workers who received a complete second dose between March 2020 and May 2021 through WhatsApp contacts listed in CHNERC data. Secondary data consists of the Special Capital Region of Jakarta Provincial Health Office report regarding health workers who were fully vaccinated in the same period. To assess post-vaccination COVID-19 infection, the authors asked two key questions: "After receiving the complete second dose of the COVID-19 vaccine, were you reinfected with COVID-19?" and "Before receiving the complete second dose of the COVID-19 vaccine, had you ever been infected with COVID-19?"

These questions aimed to clarify whether respondents were infected before or after their second vaccination. Data analysis was conducted in three stages: univariate (examined the frequency distribution and proportion of independent variables in both reinfected and non-infected groups), bivariate (employed the Chi-square test to explore relationships between independent and dependent variables, with a p-value threshold of 0.05 indicating statistical significance), and multivariate (assessed the strength of associations between independent variables and the dependent variable using Logistic Regression) analysis.

The use of PPE was categorized into three levels, as defined by the Directorate General of Pharmaceuticals and Medical Devices, Ministry of Health of the Republic of Indonesia.[10] These levels are based on the risk associated with health workers' activities and their potential exposure to aerosols. Level 1 is for health workers with low-risk activities that do not generate aerosols. The required PPE includes surgical masks, gowns, and gloves. Level 2 is for health workers in patient care areas or handling non-respiratory samples. The required PPE includes head coverings, eye protection, surgical masks, gowns, and disposable gloves. Level 3 is for health workers in direct contact with suspected or confirmed COVID-19 patients or performing aerosol-generating procedures. The required PPE includes head covering, face protection, eye protection, N95 mask, cover-all, surgical gloves, and waterproof boots.[10]

Results

Most health workers were not reinfected with COVID-19 (57.75%). They were generally aged ≤37 years (63.38%), female (78.35%), and had no history of previous COVID-19 infection (70.25%). Most health workers also did not have comorbid conditions such as DM (88.73%), hypertension (82.92%), CHD (99.12%), or COPD (98.59%). Most health workers worked directly with patients (70.07%) and did not use public transportation (72.71%). They had close contact with COVID-19 patients at work (77.29%) but had never been in close contact with COVID-19 patients at home (70.77%). Regarding PPE usage, more health workers used level 2 PPE (38.91%) and level 1 PPE (38.38%). Additionally, many health workers worked more than 8 hours daily (52.82%) (Table 2).

Table 2. Description of Respondent Characteristics

Variable	n	%
Post-vaccination infection		
Yes	240	42.25
No	328	57.75
Age		
>37 years	208	36.62
≤37 years	360	63.38
Sex		
Male	123	21.65
Female	445	78.35

History of COVID-19 infection		
No	399	70.25
Yes	169	29.75
Diabetes mellitus		
Yes	64	11.27
No	504	88.73
Hypertension		
Yes	97	17.08
No	471	82.92
Coronary heart disease		
Yes	5	0.88
No	563	99.12
Chronic obstructive pulmonary disease		
Yes	8	1.41
No	560	98.59
Face-to-face or directly with patients		
Yes	398	70.07
No	170	29.93
Use of public transportation		
Yes	155	27.29
No	413	72.71
Close contact with COVID-19 in the work environment		
Yes	439	77.29
No	129	22.71
Close contact with COVID-19 in the home environment		
Yes	166	29.23
No	402	70.77
Use of Personal Protective Equipment		
Level 1	218	38.38
Level 2	221	38.91
Level 3	129	22.71
Business hours		
>8 hours	300	52.82
<8 hours	268	47.18

Table 3. Post-Vaccination Risk Factor Analysis

Risk Factor	Post-Vaccination COVID-19 Infection				PR (95% CI)	p-value
	Infectious		Non-Infectious			
	n	%	n	%		
Age						
>37 years	77	37.02	131	62.98	0.81 (0.66-1.01)	0.054
<37 years	163	45.28	197	54.72		
Sex						
Male	52	42.28	71	57.72	1.00 (0.79-1.26)	0.995
Female	188	45.25	257	57.75		
History of COVID-19 infection						
Yes	39	23.08	257	57.75	2.18 (1.63-2.92)	<0.000*
No	201	50.38	198	49.62		
Diabetes mellitus						
Yes	40	62.5	24	37.5	1.57 (1.27-1.99)	0.000*
No	200	39.68	304	57.75		
Hypertension						
Yes	56	57.73	41	42.27	1.47 (1.20-1.81)	0.000*
No	184	39.07	287	60.93		
Coronary heart disease						
Yes	1	20.0	4	80.0	0.47 (0.08-2.73)	0.312
No	200	39.68	304	57.75		
Chronic obstructive pulmonary disease						
Yes	3	37.5	5	62.5	0.88 (0.36-2.170)	0.784
No	200	39.68	304	57.75		
Directly with patients						
Yes	189	47.49	209	52.51	1.58 (1.23-2.04)	0.000*
No	200	39.68	304	57.75		
Use of public transportation						
Yes	64	41.29	91	58.71	0.96 (0.78-1.21)	0.776
No	200	39.68	304	57.75		
Close contact with COVID-19 in the work environment						
Yes	190	43.28	249	56.72	1.12 (0.79-1.56)	0.361
No	200	39.68	304	57.75		
Close contact with COVID-19 in the home environment						

Yes	72	43.37	94	56.63	1.04 (0.84-1.28)	0.726
No	200	39.68	304	57.75		
Use of Personal Protective Equipment						
Level 1	103	47.25	115	57.25	1.46 (0.94-2.28)	0.093
Level 2	88	39.82	133	60.18	1.08 (0.69-1.69)	0.743
Level 3	49	37.98	80	62.02	Reff	Reff
Working hours						
>8 hours	127	42.33	173	57.67	1.00 (0.83-1.22)	0.967
≤8 hours	200	39.68	304	57.75		

Note: *p-value <0.05

Table 3 explains that the proportion of health workers aged >37 years who were reinfected with COVID-19 (37.02%) was lower than those aged ≤37 years (45.28%). The prevalence ratio (PR) was 0.81 (95% CI 0.66-1.01), indicating that health workers aged >37 years were 0.81 times less likely to be reinfected compared to younger workers. There was no significant difference in the reinfection rates between male (42.28%) and female (42.25%) health workers, with a PR value of 1.00, suggesting equal risk for both sexes.

Health workers without a previous COVID-19 infection had a higher infection rate (50.38%) after vaccination than those with a history of infection (23.08%). The PR value of 2.18 indicated that those without prior infection were 2.18 times more likely to be infected. Health workers with a history of DM had a reinfection rate of 62.5%, compared to 39.68% for those without, with a PR of 1.57. The reinfection rate for those with hypertension was 57.73%, higher than 39.07% for those without, yielding a PR of 1.47.

Workers with a history of coronary heart disease had a lower reinfection rate (20%) than those without (42.45%), with a PR of 0.47. The reinfection rate for health workers with COPD was 37.5%, lower than 42.32% for those without, resulting in a PR of 0.88. Health workers who had direct contact with patients had a higher reinfection rate (47.49%) than those who did not (30%), with a PR of 1.58, indicating a significantly increased risk for those in direct contact.

The reinfection rate among health workers using public transportation (41.29%) was similar to those who did not (42.62%), with a PR of 0.95, suggesting comparable risks. The reinfection rate for workers in close contact with COVID-19 patients at work was 43.28%, higher than 38.76% for those not in close contact, with a PR of 1.12. The reinfection rate for those in close contact with COVID-19 patients at home was 43.28%, nearly the same as 41.79% for those not in contact, with a PR of 1.04.

The reinfection rate was higher among health workers using level 1 (47.25%) compared to those using level 2 (39.82%) and level 3 PPE (37.98%). The PR for level 1 PPE was 1.46, indicating a higher risk than level 3 PPE, while the risk for level 2 PPE was similar to that of level 3. There was no difference in the reinfection rates for health workers working more than 8 hours (42.33%) compared to those working 8 hours or less (42.16%), with a PR of 1.00, indicating equal risk regardless of work hours.

Table 4. Early Complete Model

Variable	p-value	PR	95% CI
Age	0.006	0.64	0.47-0.88
Sex	0.855	1.03	0.75–1.41
History of COVID-19 infection	<0.000	2.16	2.53–3.05
Diabetes mellitus	0.002	1.85	1.26–2.70
Hypertension	0.009	1.54	1.11–2.12
Coronary heart disease	0.495	0.50	0.06–3.62
Chronic obstructive pulmonary disease	0.953	1.03	0.32–3.27
Directly with patients	<0.000	2.00	1.42–2.80
Use of public transportation	0.780	0.96	0.71–1.28
Close Contact with COVID-19 in the work environment	0.717	1.06	0.76–1.46
Close Contact with COVID-19 in the home environment	0.962	1.01	0.76–1.33
Use of Personal Protective Equipment Level 1	0.033	1.48	1.03–2.13
Use of Personal Protective Equipment Level 2	0.619	1,09	0.76-1.56
Working Hours	0.991	1.00	0.77-1.29

The analysis aimed to identify the best model for predicting post-vaccination COVID-19 outcomes using a backward elimination method. Independent variables with weak relationships to the infection, indicated by p-values >0.05, were systematically removed, starting with the variable that had the largest Wald X^2. This process continued until a suitable model was formed, where all remaining variables had significant Wald X^2 values (p-value <0.05). The findings from this model analysis are presented in Table 5.

Table 5. Analysis Fit Model Table

Type	Information
Model 1	
Put out variables Working hours	There are still some variables with insignificant Wald X^2 values. The COVID-19 close contact variable in the home environment has the largest Wald X^2 value.
Model 2	
Put out variables COVID-19 close contact in the home environment	There are still some variables with insignificant Wald X^2 values. The COPD variable has the largest Wald X^2 value.
Model 3	
Put out variables Chronic obstructive pulmonary disease	There are still some variables with insignificant Wald X^2 values. The sex variable has the largest Wald X^2 value.
Model 4	
Put out variables Sex	There are still some variables with insignificant Wald X^2 values. The public transportation user variable has the largest Wald X^2 value.
Model 5	
Put out variables Use of public transportation	There are still some variables with insignificant Wald X^2 values. The COVID-19 close contact variable in the work environment has the largest Wald X^2 value.
Model 6	
Put out variables COVID-19 close contact in the work environment	There are still some variables with insignificant Wald X^2 values. The coronary heart disease variable has the largest Wald X^2 value.
Model 7	
Put out variables Coronary heart disease	All remaining variables in the model have significant Wald X^2 values, including age, diabetes mellitus, hypertension, history of infection, PPE use, and direct patient contact.

From the table above, the best-fit model to predict the occurrence of COVID-19 infection in post-vaccination health workers is obtained, namely a model that includes six variables: age, diabetes mellitus, hypertension, history of infection, use of PPE, and face-to-face. The following is the fit model in this study:

Table 6. Fit Model Table

Variable	p-value	PR	95% CI
Age	0.004	0.634	0.46–0.86
Diabetes Mellitus	0.002	1.823	1.24–2.66
Hypertension	0.001	1.529	1.11–2.10
Infection history and PPE use	<0.000	2.160	1.53–3.05
Level 1	0.027	1.494	1.04–2.13
Level 2	0.619	1.1	0.77–1.55
Face-to-face or direct contact with patients	<0.000	2.02	1.45–2.82

From Table 6, the best-fit model to predict the occurrence of COVID-19 infection in post-vaccination health workers includes six variables: age, DM, hypertension, history of infection, use of PPE, and direct contact with the patients. The analysis identified that among six independent variables, the most significant factor in predicting outcomes was a history of COVID-19 infection. This variable exhibited the highest beta coefficient (0.770) and the largest PR of 2.16, indicating that health workers with a prior COVID-19 infection had a 2.16 times higher risk of reinfection than those without such a history after adjusting for other variables.

Discussion

Age was a protective factor, as indicated by a PR value <1 (0.63) with a 95% CI of 0.46–0.86. Statistically, health workers aged >37 years showed a reduced risk of contracting COVID-19 after vaccination by 37% (1–0.63 = 0.37 or 37% relative protection). Angiotensin-converting enzyme 2 (ACE2) activity or expression can increase, especially in older adults or males, who are more likely to have higher ACE2 expression. Higher levels of ACE2 can increase cell susceptibility to SARS-CoV-2 because the virus enters and replicates by binding to ACE2.[11]

This study did not align with the literature stating that age is a protective factor against COVID-19 infection.[11] This study determined that the proportion of health workers aged ≤37 years was higher (63.38%) than those aged >37 years, so it can be postulated that these older health workers were aware that they were at higher risk of exposure to COVID-19, and this caused them to follow the health protocols more strictly. The finding aligned with the Health Belief Model (HBM) theory of behavior change, where it has been suggested that a person will act more obediently to treat or prevent if they feel susceptible to the disease.[12] Following this perspective, older individuals with family responsibilities are expected to be more motivated to comply with health measures due to greater responsibility.[13]

Diabetes mellitus was a risk factor for health workers reinfected with COVID-19, with a PR value of 1.82 (CI 95%: 1.24-2.66). Statistically, health workers who had a history of the disease were at 1.82 times greater risk of being reinfected with COVID-19 than those without. This result was in line with a previous study stating that DM is a risk factor for COVID-19 infection.[14] Another previous study stated that DM increases susceptibility to infections due to chronic hyperglycemia, marked by elevated HbA1c levels.[15] This condition hampers the function of mononuclear and polymorphonuclear phagocyte cells (PPC), particularly affecting the respiratory burst needed to eliminate microorganisms within monocytes and neutrophils. Prolonged high blood sugar leads to the formation of Advanced Glycosylation End Products (AGEs), which further impair PPC function (neutrophils). Consequently, individuals with diabetes have a reduced ability to phagocytize microorganisms compared to those without the disease, as the intracellular killing process is disrupted.[15]

The mobilization and chemotaxis of polymorphonuclear (PMN) cells in DM patients are diminished, affecting their movement toward infection sites.[16] Mononuclear cells, such as monocytes, also show abnormalities; specifically, the quantity of monocytes is lower in diabetic patients, and their ability to detect microorganisms is impaired due to decreased sensitivity of their membrane receptors.[16] In addition, patients with the diseases have higher ACE2 receptors, especially in the lungs, liver, and pancreas.[17] Since ACE2 is a SARS-Cov-2 receptor in the human body, this higher expression contributes to increased infectivity of SARS-CoV-2 in DM patients compared to non-diabetic patients.[17]

Hypertension was a risk factor predicting the probability of health workers reinfected with COVID-19, with a PR value of 1.52 (CI 95%: 1.11-2.10). Statistically, health workers with a history of hypertension had a 1.52 times greater risk of being reinfection COVID-19 than those without. Previous studies in China support this result, stating that hypertension is a risk factor for COVID-19 infection.[14,18,19]

Hypertension is linked to COVID-19 infections, as uncontrolled blood pressure can further disrupt the immune system.[11] Hypertension can also alter the number of circulating lymphocytes. Although antihypertensive medications, such as ACE inhibitors (ACEI) and angiotensin receptor blockers (ARB), are used to treat hypertension, they can increase the risk of SARS-CoV-2 infection. This is because these medications boost ACE2 expression, increasing the availability of receptors for SARS-CoV-2 to bind to, thereby making it easier for the virus to attach to target cells and increasing patient susceptibility to infection.[20]

Personal Protective Equipment was a risk factor that can predict the probability of health workers reinfected with COVID-19, with a PR value of 1.49 (CI 95%: 1.04-2.13). Statistically, health workers using level 1 and 2 PPE had a 1.49- and 1.10-times greater risk of being reinfected to COVID-19 than those who use level 3 PPE after controlling other variables. A previous study stated that PPE is a risk factor for COVID-19 infection, with an OR value of 0.20 (95% CI: 0.11-0.37).[21] In this study, it was explained that using surgical or N95 masks by health workers can reduce the risk of respiratory virus infection by up to 80% compared to not using a mask.[21]

According to the WHO, COVID-19 transmission can also occur through direct contact with an infected person or indirectly through contaminated objects (e.g., stethoscopes, thermometers), as droplets can settle on surfaces where the virus can survive.[3] To reduce this risk, WHO recommends using PPE to protect against splashes, aerosols, and direct contact. The ideal PPE should be lightweight, comfortable, flexible, safe, durable, standard-compliant, easy to maintain, and not restrict movement.

History of COVID-19 infection was the most significant determinant or risk factor for predicting COVID-19 infection in health workers after vaccination, with a PR value of 2.16 (CI 95%: 1.53-3.05). Statistically, health workers without previous COVID-19 infection were 2.16 times more likely to be infected by COVID-19 after vaccination than those with a history of previous infection after controlling other variables. A previous study at the Howard Hughes Medical Institute's Molecular Laboratory of Immunology indicates that immunity to SARS-CoV-2 in COVID-19 survivors can last for six months or more after recovery.[22] Six months post-infection, antibodies become stronger and more effective against mutated virus strains. While antibodies remain in blood plasma for several weeks or months, their levels significantly decline over time. The immune system employs memory B cells, which recognize pathogens and can rapidly produce new antibodies upon re-exposure rather than continuously generating antibodies.[22] This suggests that individuals previously infected may have a more robust immune response if re-exposed to the virus, as their immune system can quickly generate effective antibodies through memory B cells.

Direct contact with patients was a risk factor for predicting COVID-19 infection in health workers after vaccination, with the largest PR value of 2.02 (CI 95%: 1.45-2.82). Statistically, health workers who deal directly with patients were at 2.82 times greater risk of being reinfection COVID-19 compared to those who do not deal directly with patients after

controlling other variables. A bivariate analysis of health workers' workplaces and post-vaccination infection rates revealed a correlation between direct patient contact and infection. The data showed that a higher proportion of infected workers had direct patient contact in hospitals (67.5%), primary health cares (PHCs) (25.4%), and health offices (7.1%) compared to those without direct patient interaction.

For hospitals, the most infected workers were found in the emergency room (ER) (20.99%), followed by the intensive care unit (ICU) (17.28%), treatment room (16.67%), and polyclinic room (15.43%). For PHCs were found in the ER (34.43%), followed by the polyclinic room (27.87%). For health offices, were found in the Disease Prevention and Control Unit (35.29%). These findings suggested that direct patient contact increased the risk of post-vaccination infection among health workers. In addition, dealing directly with patients increases the risk of exposure to COVID-19 because there are still many patients who come to the hospital/public health department even though screening at the beginning of treatment has not been maximized. This condition increases the possibility that COVID-19 patients are still treated like ordinary patients.[14] Previous studies mentioned that direct contact with patients is a risk factor for COVID-19 infection.[14,23]

This study raised concerns about information bias, as the diagnosis of infected versus uninfected health workers was based solely on questionnaire responses without additional verification. Variability in educational backgrounds might lead to differing perceptions of questions, impacting the consistency of responses. Data collection via Google Forms further complicated standardizing perceptions. To mitigate biases, the authors applied uniform inclusion and exclusion criteria for health workers receiving the second dose of vaccine. However, there was misclassification regarding PPE use, as health workers might have varied understandings of PPE levels based on knowledge and environment.

This study's internal validity was strong, with no selection bias and only non-differential information bias, allowing for generalization to similar populations. Future research should be able to collect age data in ratio form rather than categorically to allow for median or mean cutoffs and validate the definition of post-vaccination infection using PCR data.

Recommendations for the Special Capital Region of Jakarta Provincial Health Office include preventive policies for health workers with diabetes or hypertension, restricting their direct patient contact to reduce post-vaccination infection rates, mandating level 3 PPE for health workers in direct patient care, especially in high-risk areas like the ER and ICU, and prioritizing booster vaccinations for health workers aged >37 years or with significant comorbidities. The suggestions for hospitals are enhancing infection prevention training for workers in high-risk areas, raising awareness about universal precautions through promotional efforts, conducting annual health check-ups for workers with comorbid conditions, and considering shift schedules for those aged >37 years. For the health workers, the authors advise regular health check-ups, particularly for those with comorbidities, and strict adherence to health protocols, including wearing at least Level 2 PPE, maintaining hydration, and avoiding communal eating and conversation while unmasked.

Conclusion

Of the 13 variables, 6 are related to the incidence of post-vaccination COVID-19 infection in the Special Capital Region of Jakarta Province's health workers. These include age, diabetes mellitus, hypertension, history of COVID-19 infection, PPE use (at level 1), and direct contact with the patient. In this study, the most significant determinant or predictor factor of post-vaccination COVID-19 infection is the history of COVID-19 infection. Additionally, health workers aged >37 years, have a history of diabetes mellitus, hypertension, and COVID-19 infection, deal directly with patients, and use level 1 PPE in daily work should be prioritized to get booster vaccinations.

Abbreviations

SARS: severe acute respiratory syndrome; COVID-19: coronavirus disease 2019; PPE: personal protective equipment; WHO: World Health Organization; UCSD: University of California, San Diego; UCLA: University of California, Los Angeles; DM: diabetes mellitus; CHD: coronary heart disease; COPD: chronic obstructive pulmonary disease; PPE: personal protective equipment; CHNERC: COVID-19 Handling and National Economic Recovery Committee; PR: prevalence ratio; ACE2: angiotensin-converting enzyme; PPC: polymorphonuclear phagocyte cells; ER: emergency room, ICU: intensive care unit; PHC: primary health care.

Ethics Approval and Consent to Participate

The authors guarantee the confidentiality of the Special Capital Region of Jakarta Provincial Health Office's data solely for research purposes and the confidentiality of respondents' identities. This research has passed the ethical consideration of the Faculty of Public Health, Universitas Indonesia, with ethics letter number 432/UN2. F10. D11/PPM.00.02/2021.

Competing Interest

The author declares that no significant competing financial, professional, or personal interests might have affected the performance or presentation.

Availability of Data and Materials

Data are not available due to the ethical restrictions of the research. Participants of this study did not agree that their data should be shared publicly.

Authors' Contribution

NAP: Guides researchers on appropriate research methods, helps determine variables, and assists in selecting suitable data analysis techniques. MKS: Aids researchers in correcting inaccurate or inconsistent results and ensures compliance with research methods. YD: Supports researchers in data collection, questionnaire distribution, data sorting, analysis, and overall research process assistance. NWDA: Helps researchers locate research sources, such as relevant national and international journals, distributes questionnaires, and interprets research findings. RM: Assists researchers with precise data analysis and interpretation of results, as well as journal registration.

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