JKKI: Jurnal Kedokteran dan Kesehatan Indonesia
Indonesian Journal of Medicine and Health
Journal homepage: https://journal.uii.ac.id/JKKI
P-ISSN 2085-4145 | E-ISSN 2527-2950

Non-communicable disease risk factors and Covid-19 antibody levels after vaccination

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Original Article

ARTICLE INFO
Keywords:
non-communicable diseases,
vaccine,
antibody,
Covid-19,
physical activities
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DOI: 10.20885/JKKI.Vol15.Iss1.art3
History:
Received: January 6, 2023
Accepted: Desember 27, 2023
Online: April 29, 2024

ABSTRACT

Background: Non-communicable diseases (NCDs) have been identified as predictors of the severity of Coronavirus Disease 2019 (Covid-19). Some factors like smoking, alcohol consumption, and physical inactivity, which are associated with NCDs, may potentially hinder the efficacy of vaccines, reducing their ability to prevent the severity and complications of infectious diseases such as the Covid-19.
Objective: This study investigated the NCD, risk factors associated with the levels of quantitative antibodies after the second Covid-19 vaccination.
Methods: A cross-sectional study was conducted at a Covid-19 vaccination centre in Jakarta. Ninety subjects, aged ≥18, completed demographic and NCDs risk factor questionnaires. Blood samples were collected and analysed by using the electro chemiluminescence immunoassay analyser (ECLIA) method to measure quantitative antibody levels 30 days after 2nd Covid-19 vaccination. The bivariate analysis was performed to explore associations among the variables. The logistic regression was subsequently performed to identify the factors that remained independent in influencing severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) antibody status.
Results: The mean value of antibody level in this study was 191 U/ml. The results indicated that 35.5% (n=32) of respondents had SARS-CoV-2 antibody levels below average. The regression results suggested that the odds of having higher antibody levels were reduced for individuals with hypertension (Adjusted Odd Ratio [AOR] = 0.74, p value = 0.022), diabetes (AOR = 0.82, p value = 0.038) comorbidities accompanied with smoking (AOR = 0.55, p value = 0.044), drinking alcohol (AOR = 0.92, p value = 0.030), and low physical activity levels (AOR = 0.67, p value = 0.043).
Conclusion: The study found that 35.5% of participants had SARS-CoV-2 antibody levels below the average. Factors such as hypertension, diabetes, comorbidities with smoking, alcohol consumption, and low physical activity were associated with reduced odds of higher antibody levels.

INTRODUCTION

Non-communicable diseases are a group of conditions not caused by acute infection that lead to health consequences and the need for long-term care. The etiology of NCDs is multifactorial and is caused by genetic, physiological, environmental, and behavioral factors.[1] According to the World Health Organization (WHO), 71% of all deaths worldwide were attributable to NCDs in 2018, with 77% occurring in low- and middle-income countries.[2] Referring to 2014 data from the Indonesian sample registration system, six of the ten most common diseases in Indonesia are NCDs, accounting for 21.1% of strokes, 12.9% of heart disease, 6.7% of diabetes mellitus, 5.3% of hypertension complications, 4.9% of chronic lung disease, and 2.7% of liver disease. The prevalence of NCDs in Indonesia, based on the 2018 National Basic Health Research (*Riset Kesehatan Dasar (Riskesdas)* 2018), continues to increase compared with the 2013 data. This increase is primarily due to harmful lifestyle changes, such as smoking, alcoholic beverages, lack of physical activity, and low consumption of fruits and vegetables.[3,4] Unhealthy dietary and lack of physical activities are consistent risk factors in individuals with hypertension, hyperglycemia, dyslipidemia, and obesity.[2]

During the first case of Covid-19 in Indonesia on 2nd March 2020, activities outside the home had been restricted, including working, schooling, and social activities, due to the government's implementation of a large-scale social restriction policy. This policy forced many people to restrict their activities at home and led to lifestyle changes that might trigger the NCDs. A cross-sectional study on 6,557 respondents, conducted in June 2020, stated that more than half of the respondents did not eat fruits and vegetables every day during the pandemic Covid-19.[5] The comprehensive study conducted in Brazil, which involved a diverse sample of 2,170 individuals aged 18 and above, shed light on the noteworthy impact of the Covid-19 pandemic on health-related behaviors. The research unveiled a significant upswing in the prevalence of alcohol consumption and smoking, with an approximate surge of 20% and 30%, respectively, among the study participants. Of particular concern was the discernible increase in these behaviors among individuals grappling with depressive symptoms, feelings of sadness, and self-reported stress. The pandemic's profound psychological toll appeared to be closely linked to a rise in both alcohol consumption and smoking rates. These findings showed the intricate interplay between mental health challenges and substance use during times of crisis. Further study analysis highlighted an intriguing correlation between diet quality and the likelihood of engaging in these detrimental behaviors. Individuals with a poorer diet quality were found to be 1.78 times more likely to consume alcohol and 1.58 times more likely to smoke. This association suggests that addressing and improving nutritional habits may have broader implications for mitigating the risk of engaging in harmful behaviors during challenging periods.[6]

The Covid-19 situation has made people harder to stay healthy and active. People around the world were facing challenges in performing enough physical activities because in some places they had decreased by 50%. This decline was partly due to the limited and unequal availability of safe outdoor community resources (such as parks, trails, exercise facilities, and sidewalks) that support physical activities.[7] The positive impact of physical activities on physical and mental well-being cannot be overstated. For children and adolescents, physical activities contribute to developing fundamental motor skills, coordination, and overall physical fitness. Regular exercise is pivotal in preventing and managing chronic health conditions in adults. Engaging in regular physical activities is also critical for the older population in maintaining mobility, balance, and overall independence. Regular physical activity has been shown to reduce the risk of falls and fractures among older people, contributing to a better quality of life in later years.[8,9] Several studies have demonstrated that regular physical activities can help prevent cardiovascular disease, diabetes, and obesity. Additionally, physical activities contribute to enhanced brain health, support mental well-being by reducing depression and anxiety, and even decrease the risk of falls and related injuries.[10,11] People who regularly perform moderate-intensity physical activities will have a better immune system than those who are not physically active. There is a theory that physical activities with moderate intensity activate the stress responses that generate signals to stimulate proliferation, cytokine production, differentiation, cell migration, antibody production, and inflammation.[12]

Furthermore, one way to prevent the Covid-19 severity is through vaccination. In Indonesia, the vaccines employed against Covid-19 encompass AstraZeneca, Sinovac, Moderna, Sinopharm, Novavax, Pfizer, and those produced by PT. Bio Farma (Persero).[13] These vaccines contain viral fragments such as mRNA and protein subunits of viruses, and some work with vectors from other viruses to trigger an immune response in our bodies to produce specific antibodies. Once antibodies are formed, they work with the rest of the immune system to destroy pathogens.[14]

Meanwhile, the risk factors that influence NCDs, such as consuming alcohol, smoking, physical inactivity, and obesity, can impair the vaccine responses by several mechanisms; for example, obese people may have lower antibody levels than non-obese people due to the chronic inflammation that developed from dysfunctional adipose tissue, can negatively affect antibody responses, harmful chemicals in tobacco burning can cause the downregulation of pre-B cells and pro-B cells in the murine marrow. This leads to an increase in mortality and morbidity from Covid-19. According to a meta-analysis, individuals who smoke may face a 1.5 times greater likelihood of experiencing severe complications from Covid-19 and an elevated risk of mortality. Moreover, alcohol consumption may compromise the body's capacity to defend against infections, including the Covid-19.[15]

Based on the discussion above, the authors aim to investigate the relationship between NCDs risk factors and Covid-19 quantitative antibody levels. Besides, the prevalence of NCDs is still high, and there is a lack of information about the relationship between NCDs risk factors and Covid-19 antibody levels in the population receiving the Covid-19 vaccines. Therefore, this study is suggested to raise increasing public awareness of NCD's risk factors to facilitate the implementation of preventive measures against NCDs.

MATERIAL AND METHODS

Study design

This cross-sectional study was conducted from April to June 2021, and its data collection was processed at a vaccination facility overseen by the School of Medicine and Health Sciences at Universitas Katolik Indonesia Atma Jaya, Jakarta, Indonesia.

Population and sample

The sample in this study was calculated by using the population proportion formula. The sample calculation resulted in an α of 5%, a prevalence of 50%, and a precision of 15% of 44 respondents. However, this study included all respondents at the vaccination center who met the inclusion criteria. The criteria were adults (≥ 18 years) who had been vaccinated twice with the same vaccine (Sinovac) and had provided written informed consent. Respondents with a history of diseases that could significantly compromise immunity, such as HIV/AIDS (human immunodeficiency virus/acquired immunodeficiency syndrome), multiple sclerosis, and lupus, were excluded, resulting in a total number of 90 respondents.

Variables and data collection

Data collection took place 30 days post the second vaccination, during which the participant's blood pressure and anthropometric measurements, including body weight and height for calculating body mass index (BMI), were recorded. The respondents' blood pressure measurements were assessed twice by using a spectrum aneroid sphygmomanometer. The results obtained from the two measurements were averaged and used as blood pressure data. The respondents' blood samples were then collected to check their post-vaccination antibodies by using the sandwich ECLIA method with Roche Cobas e411 instruments. The antibodies measured were IgG against the receptor binding domain (RBD), SARS-CoV-2 Spike protein (S), which assessed the adaptive humoral immune response against the SARS-CoV-2 Spike protein. After the measurement, the respondents received a link to complete the questionnaires through Google Forms. The WHO STEPwise approach to surveillance (STEPS) questionnaire included several questions to collect demographic data, NCDs risk factor status, and history of comorbid diseases.

The dependent variable in this study was post-vaccination antibody titer for Covid-19 and was categorized by above mean or below mean. The independent variables were smoking status, alcohol consumption status, nutritional status, physical activity intensity, and comorbidities. The smoking status was derived from the question "Do you currently smoke?" with response options of "yes" or "no" and the same manner for alcohol consumption. The nutritional status was determined from BMI measurements and categorized as obese (BMI ≥ 25 kg/m^2) or nonobese (BMI < 25 kg/m^2). The physical activity status was obtained from the question "Does your work involve activities that cause a large increase in respiration or heart rate (e.g., carrying or lifting heavy loads, and working in excavation or construction) for at least 10 minutes continuously?"; if the respondent answered "Yes," he or she would be placed in the moderate-intensity activity group, and if he or she replied "No," he or she would be placed in the low-intensity activity group. The participants were inquired about their medical history related to diabetes, hypertension, and dyslipidemia through straightforward questions such as "Have you ever been diagnosed with or experienced hypertension, diabetes mellitus, or dyslipidemia, as confirmed by a doctor?" Those who responded affirmatively were categorized into the comorbid groups for "Hypertension," "Diabetes Mellitus," and "Dyslipidemia."

Statistical analyses

The univariate analyses demonstrated the frequency of each variable. The bivariate analysis, employing the chi-square (χ^2) test, was conducted to explore the relationship between sociodemographic variables (age, sex, education levels, working and marital status) and NCD's risk factors (smoking, alcohol consumption, physical activity, BMI category, and comorbidities) with antibody level categories. For variables with a p-value≥ 0.25 in the bivariate analysis, binomial logistic regression was applied to identify factors that independently influenced the SARS-CoV-2 antibody status. The effect size was represented by the odds ratio (OR) in the bivariate analysis and adjusted OR (AOR) was utilized in presenting the results of multivariate analysis. All hypothesis tests were performed with a significance level of 5% and a confidence interval of 95%. All the data analysis were processed by using SPSS Statistics for Mac, version 26.0 (SPSS Inc., Chicago, Ill., USA).

Ethics

This research protocol was approved by the institutional ethics committee of the School of Medicine and Health Sciences, Universitas Katolik Indonesia Atma Jaya, No. 19/11/ KEP-FKIKUAJ/2022.

RESULTS

The demographic characteristics of the study participants are presented in Table 1. The respondents primarily comprised individuals aged 40 and older (75%), with a slight male gender bias (60%). Most of the participants, about 75 individuals (83.3%), held a diploma, bachelor's, or postgraduate degree, while 15 (16.7%) were high school graduates. This distribution indicates a predominantly well-educated sample. Most participants were married (75.6%), and 81 (90.0%) were employed.

In this study, the mean antibody level was determined to be 191 U/ml, prompting the classification of respondents into two categories: those with antibody levels equal to or above the mean and those below the mean. Notably, 35.5% (n=32) of the respondents fell into the latter

Table 1. Demographic characteristics of the respondents

Characteristics	Frequency (N)	%
Age (years)		
<40	31	34.4
≥40	59	65.6
Sex		
Male	54	60.0
Female	36	40.0
Educational Level		
Highschool Graduates	15	16.7
Diploma/Bachelor/Postgraduate	75	83.3
Marital Status		
Single/Divorced/Widowed	22	24.4
Married	68	75.6
Occupational Status		
Employed	81	90.0
Unemployed	9	10.0

category, indicating that a significant portion of the study population exhibited SARS-CoV-2 antibody levels below the average. The bivariate analysis in Table 2 explored the associations between demographic characteristics, various risk factors, and the categorized antibody levels. The results of this analysis revealed significant correlations, particularly concerning education level, smoking, and hypertension among the respondents (p<0.05). These findings indicated the potential factors influencing SARS-CoV-2 antibody levels within the study cohort.

To further understand the independent factors affecting SARS-CoV-2 antibody status, a regression analysis was conducted on variables that exhibited a p-value ≤ 0.25 in the bivariate results. The outcome of this regression analysis is presented in Table 3, providing insights into the variables that retained their significance in influencing the SARS-CoV-2 antibody status after accounting for potential confounding factors.

The regression results revealed that individuals

Table 2. The NCD risk factors by Covid-19 antibody level category

Variable	Antibody level category		p*	OR
	(<191 U/ml)	**(≥191 U/ml)**		
	(N=32)	**(N=58)**		
Age (years)				
<40	15 (39.5%)	23 (60. 5%)	0.507	1.343
≥40	17 (32.7%)	35 (67.3%)		Ref
Sex				
Male	16 (29.6%)	38 (70.4%)	0.150	0.526
Female	16 (44.4%)	20 (55.6%)		Ref
Education Level				
Highschool Graduates	9 (60.0%)	6 (40.0%)	0.030	3.391
Diploma/Bachelor/Postgraduate	23 (30.7%)	52 (69.3%)		Ref
Marital Status				
Single/Divorced/Widowed	10 (37.0%)	17 (63.0%)	0.848	1.096
Married	22 (34.9%)	41 (65.1%)		Ref
Working Status				
Employed	4 (36.4%)	7 (63.6%)	0.952	Ref
Unemployed	28 (35.4%)	51 (64.6%)		1.041
Smoking				
Yes	8 (61.5%)	5 (38.5%)	0.034	3.533
No	24 (31.2%)	53 (68.8%)		Ref
Drinking Alcohol				
Yes	7 (70.0%)	3 (30.0%)	0.061	5.133
No	25 (31.3%)	55 (68.7%)		Ref
Physical Activity				
Low intensity	26 (39.4%)	40 (60.6%)	0.207	1.950
Moderate intensity	6 (25.0%)	18 (75.0%)		Ref
BMI Category				
Non-obese	12 (33.3%)	24 (66.7%)	0.719	0.850
Obese	20 (37.0%)	34 (63.0%)		Ref
Hypertension				
Yes	12 (54.5%)	10 (45.5%)	0.032	2.880
No	20 (29.4%)	48 (70.6%)		Ref

Variable	Antibody level category (<191 U/ml) (N=32)	Antibody level category (≥191 U/ml) (N=58)	p*	OR
Diabetes				
Yes	6 (54.5%)	5 (45.5%)	0.160	2.446
No	26 (32.9%)	53 (67.1%)		Ref
Dyslipidaemia				
Yes	13 (44.8%)	16 (55.2%)	0.205	1.796
No	19 (31.1%)	42 (68.9%)		Ref

The data were expressed as n (%), NCD: Non-Communicable Disease, BMI: Body Mass Index, Covid-19: Coronavirus Disease 2019; *p <0.05 from Chi square analysis

with hypertension and diabetes were significantly associated with lower antibody levels. Moreover, respondents who reported smoking, alcohol consumption, and low levels of physical activity were also significantly associated with lower antibody levels. Delving into the odds ratios (OR) presented in Table 3, it is apparent that individuals with hypertension experienced a 26% reduction in the odds of having higher antibody levels (OR=0.74). Similarly, those with diabetes exhibited an 18% reduction in the odds of higher antibody levels (OR=0.82). Individuals who are smoking showed a substantial decrease in the odds of higher antibody levels (OR = 0.55). Similarly, individuals with a history of alcohol consumption demonstrated an 8% reduction in the odds (OR=0.92), while those with low physical activity levels experienced a 33% reduction in the odds (OR=0.67).

Table 3. Logistic regression analysis in factors affecting Covid-19 antibody levels

Variable	Coefficient (β)	p	Adjusted OR [AOR] (95% CI)
Sex			
Female	-0.131	0.803	2.78 (0.03-5.42)
Educational Level			
Low Education	0.553	0.988	1.71(0.47-2.79)
Comorbid			
Hypertension	-0.322	0.022*	0.74 (0.58-0.94)
Diabetes	-0.201	0.038*	0.82 (0.67-1.00)
NCD Risks			
Smoking	-0.625	0.044*	0.55 (0.42-0.71)
Drinking Alcohol	-0.107	0.030*	0.92 (0.75-1.12)
Low Physical Activity	-0.410	0.043*	0.67 (0.52-0.86)

*p<0.05, NCD: Non-Communicable Disease, Covid-19: Coronavirus Disease 2019

DISCUSSION

The findings of this study underly the importance of understanding the interplay between comorbid diseases, NCD risk factors, and post-vaccination Covid-19 antibody responses. As the world is still reporting Covid-19 cases, it is crucial to investigate the factors that may impact vaccine efficacy. This study reveals a significant association between comorbid diseases (specifically hypertension and diabetes) and also certain NCD risk factors (including alcohol consumption, smoking, and lack of physical activities) and post-vaccination Covid-19 antibody levels.

The observed association between hypertension and diabetes and post-vaccination antibody levels is consistent with previous research indicating that individuals with underlying health conditions may have a diminished response to vaccines. Comorbid diseases, such as hypertension and diabetes, can impair the immune system, affecting the body's ability to mount a robust immune response to vaccination.[16–19] This highlights the importance of identifying individuals with these comorbidities as potential candidates to be considered for their vaccine doses or alternative vaccination strategies to enhance their protection against Covid-19. However, it is suspected that risk factors for various comorbid diseases such as smoking, consuming alcohol, obesity, and lack of physical activities can affect antibody levels to be lower than people who do not have risk factors for developing comorbid diseases, as will be discussed next. This argument is supported by previous research by van Oort et al. stating that BMI, initiation of smoking, and alcohol dependence have significantly increased the odds ratios for essential hypertension; as a result, respondents with hypertension like those in this study have a tendency to have antibodies below average.[20]

The identified association between risk factors for NCDs, such as alcohol consumption, smoking, and physical inactivity, and the post-vaccination antibody levels underscores noteworthy public health considerations. It suggests that these risk factors are not inferior to the NCDs themselves to deteriorate the immune system. Alcohol consumption and smoking have known detrimental effects on the immune system, which can compromise the vaccine's effectiveness. Tobacco combustion produces harmful chemicals, including carbon monoxide, nicotine, nitrogen oxides, and cadmium. These substances have been found to negatively impact the immune system by causing the downregulation of pre-B and pro-B cells in the murine marrow. Essentially, exposure to these toxic components from tobacco smoke can disrupt the normal development and functioning of specific immune cells responsible for antibody production. This downregulation may compromise the body's ability to mount an effective immune response, contributing to the increased susceptibility to infections and other health issues associated with tobacco use.[21] A study by Mori et al. also stated that there was a significant negative correlation between anti-SARS-Cov-2 serum IgG protein S-RBD levels and smoking dependence (p=0.0001) after vaccination of BNT162b2.[22] In addition, alcohol abuse may reduce the number of B cells and alter the development and maturation of the bone marrow and spleen, where B cells develop. Excessive alcohol consumption inhibits the absorption of vitamin B and thus reduces the proliferation of the immune cells. Alcohol consumption also disrupts the production and function of crucial white blood cells, including neutrophils and macrophages, impairing the body's initial defense against infections. Alcohol interferes with antibody production, compromising the immune system's ability to recognize and neutralize harmful substances. Additionally, it disturbs the balance of cytokines, leading to an inappropriate immune response and chronic inflammation. The integrity of epithelial barriers, such as those in the gastrointestinal and respiratory systems, is compromised, making it easier for pathogens to enter the body. Chronic alcohol use can also result in liver damage, impacting the synthesis of essential immune proteins. Alterations in the gut microbiome due to alcohol consumption further disrupt immune function, contributing to an increased susceptibility to infections. The respiratory system is particularly affected, with chronic alcohol use associated with a heightened risk of respiratory infections, including pneumonia and acute respiratory distress syndrome. While moderate alcohol consumption may not have as pronounced adverse effects, maintaining a healthy lifestyle with moderation in alcohol intake is advisable to support overall immune function and well-being.[23,24] Research by Yamamoto et al. stated that there was a negative correlation between spiked IgG levels and weekly alcohol consumption.[25] The Covid-19 has affected human life in various aspects, both individually (various kinds of fears such as fear of illness and death) and socially (economic recession, limited education and work, and corona phobia). Given the scale of the consequences and the magnitude of the burden associated with stress, the Covid-19 pandemic can be considered a mass trauma, which can cause psychological problems such as changes in health behaviour and addiction problems, including alcohol consumption.[26,27] These findings emphasize the need for public health campaigns to raise awareness of the impact of these risk factors on vaccine responses and to encourage lifestyle modifications that promote better vaccine efficacy.

The link between physical inactivity and reduced post-vaccination antibody levels is consistent with the well-established relationship between regular physical activities and a robust immune response.[28,29] Engaging in physical exercises serves as a regulator of the immune system. During and after physical activity, pro- and anti-inflammatory cytokines are released, accompanied by an increase in lymphocyte circulation and cell recruitment. This practice has been linked to a lower incidence, reduced symptom intensity, and decreased mortality in individuals who regularly engage in physical activity, emphasizing the importance of proper execution to prevent harm. The initial response is primarily driven by type I interferons (IFN-I), facilitating the actions of macrophages and lymphocytes, with subsequent lymphocyte involvement. Covid-19 has been associated with suppressing the IFN-I response, and severe conditions are characterized by inflammatory cytokine storms, lymphopenia, circulatory alterations, and virus dissemination to other organs. Regular physical activity is recognized for strengthening the immune system, suggesting potential benefits in responding to viral infections. Therefore, consistently practicing intense physical activities is recommended as a complementary strategy to enhance and fortify the immune system in preparation for Covid-19 and making individuals more responsive to vaccines.[30] Encouraging physical activities and healthy lifestyles is not only important for general health but also for optimizing the effectiveness of Covid-19 vaccines.

While this research offers valuable insights, it is essential to acknowledge and address certain limitations. The study's cross-sectional design and dependence on self-reported data for NCD risk factors, such as smoking, alcohol consumption, and exercise habits, represent notable drawbacks. The authors collected information on these factors through straightforward questions. To enhance the robustness of future findings, researchers may consider adopting a longitudinal approach and incorporating objective measurements for these risk factors. Another limitation is the study's single-center focus, carried out exclusively at one vaccination center. It is advisable to conduct a multicentre study to capture a more accurate representation of demographic diversity and potential regional variations. This broader approach would facilitate a more comprehensive assessment of how comorbidities and NCD risk factors impact post-vaccination antibody levels. By involving multiple vaccination centers, researchers can better understand how these factors influence antibody responses across different populations, thereby improving the generalizability of the study's outcomes. This step is crucial for ensuring that the characteristics of a single location are balanced with the findings.

Moreover, in this study, participants were categorized based on their antibody levels to the mean, as no established reference values for Covid-19 antibody protective levels were available. This categorization method introduces potential bias and restricts the applicability of our findings to populations with distinct antibody levels or unique demographic profiles. To enhance the accuracy and generalizability of future assessments, subsequent research endeavors must establish standardized reference values for Covid-19 antibody protective levels. The reliance on mean-relative antibody levels poses a challenge in extrapolating our findings to populations with varying antibody responses or diverse demographic characteristics. Future studies should focus on defining universally accepted reference values for Covid-19 antibody protection. This standardization would facilitate more accurate and widely applicable evaluations of antibody levels across different populations.

Furthermore, additional factors that influence antibody response, such as the type of vaccine administered, hold the potential understandings. Examining the correlation between vaccine types and antibody levels can contribute significantly to a more thorough comprehension of the factors influencing vaccine efficacy. By exploring these dynamics, researchers can refine their understanding of how vaccines impact antibody responses, enabling nuanced and targeted approaches to vaccination strategies.

CONCLUSION

The study findings indicated that individuals with hypertension and diabetes were significantly associated with lower antibody levels. The respondents who smoke, drink alcohol, and are physically inactive were also associated with lower antibody levels. Identifying individuals with comorbid diseases, particularly hypertension and diabetes, should be a priority in vaccination strategies. Targeted interventions, such as additional booster doses, may be necessary to ensure their protection against Covid-19. Public health campaigns should also focus on reducing NCD risk factors, including alcohol consumption, smoking, and physical inactivity, to improve vaccine responses at the population levels. These campaigns can have a positive impact not only on Covid-19 vaccine efficacy but also on overall health and well-being.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ACKNOWLEDGMENT

The authors thank to the School of Medicine and Health Sciences, Universitas Katolik Indonesia Atma Jaya, for allowing to use its vaccination centre to conduct this study.

AUTHOR CONTRIBUTIONS

BYW collected the raw data and processed them by using data analysis applications. YA analysed and interpreted data. LH provided data acquisition facilities and infrastructure.

LIST OF ABBREVIATIONS

NCD: Non-communicable diseases, WHO: World Health Organization, *Riskesdas: Riset Kesehatan Dasar*, HIV: Human Immunodeficiency Virus, ECLIA: Electro Chemiluminescence Immunoassay Analyzer, AIDS: Acquired Immunodeficiency Syndrome, BMI: Body Mass Index, RBD: Receptor Binding Domain, Covid-19: Coronavirus Disease 2019

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