






Quantitation of antibodies against SARS-CoV-2 spike protein after two doses of CoronaVac in healthcare workers

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Funding information

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Abstract

Quantitation of antibodies to the spike protein of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was performed for the detection of adaptive immune response in healthcare workers (HCWs) vaccinated with CoronaVac. We prospectively recruited HCWs from a university hospital in Turkey. Serum samples from 1072 HCWs were obtained following 28 days of the first, and 21 days of the second dose. Detection and quantitation of SARS-CoV-2 antispikes were performed by the chemiluminescent microparticle immunoassay (SARS-CoV-2 IgG II Quant; Abbott). Results greater than or equal to the cutoff value 50.0 AU/ml were reported as positive. After the first dose, antispikes were detected in 834 of 1072 (77.8%) HCWs. Seropositivity was higher among females (84.6%) than males (70.6%) ($p < 0.001$) and was found to be highest in both women and men between the ages of 18–34. After the second dose, antibodies were detected in 1008 of 1012 (99.6%) HCWs. Antibody titers were significantly higher in those who had coronavirus disease-2019 before vaccination than those who did not ($p < 0.001$). Antibody positivity and median antibody titers were significantly less in HCWs with chronic diseases compared to those without ($p < 0.05$ and $p < 0.001$, respectively). In conclusion, our findings indicated that a relatively high frequency (99.6%) of humoral immunity was produced in HCWs aged 18–59 after two doses of CoronaVac. Quantitation of antibodies may help facilitate longitudinal monitoring of the antibody response, which will be especially useful in deciding the dose of the vaccine in vulnerable groups such as those over 60 years of age and those with chronic diseases.

KEYWORDS

anti-spike IgG, chemiluminescent microparticle immunoassay, CoronaVac, healthcare workers, SARS-CoV-2

1 | INTRODUCTION

Healthcare workers (HCWs) continue to be on the front line of the fight against the coronavirus disease-2019 (COVID-19) pandemic. For their honor, 2021 has been designated by the World Health Organization as the International Year of Health and Care Workers

in appreciation and gratitude for their dedication to this fight. Though HCWs have a high potential for direct or indirect exposure to patients or infectious materials with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the Centers for Disease Control and Prevention recommended healthcare personnel be among those offered the first doses of COVID-19 vaccines.

Therefore, prioritizing HCWs for vaccination has been at the forefront of SARS-CoV-2 vaccination programs internationally.

Within the scope of combating the COVID-19 pandemic, Turkey had given emergency use approval (EUA) for the use of CoronaVac and vaccination started with HCWs on January 14, 2021 in Turkey. CoronaVac is a chemically inactivated whole virus vaccine for COVID-19 developed by Chinese biopharmaceutical company Sinovac Life Sciences and is created from African green monkey kidney cells (Vero cells) that have been inoculated with SARS-CoV-2 CN02 strain. It has shown good immunogenicity in mice, rats, and nonhuman primates with vaccine-induced neutralizing antibodies, which could neutralize ten representative strains of SARS-CoV-2.¹

Antibodies serve as biomarkers of immunity; detection of specific antibodies can provide information on adaptive immunity against SARS-CoV-2. Neutralization tests seen as the gold standard for assessing specific immunity and a benchmark for other antibody assays requires individual tests with incubation times of 5–7 days. This complexity and the need for increased biosafety level 3 precautions make it difficult for routine testing on a large scale.^{2,3}

Quantitative assays detecting anti-SARS-CoV-2 antibodies may help determine specific antibody response to vaccines, individual antibody titer, and longitudinal monitoring of the antibody response.⁴ They also may assess whether a person's antibody levels are a result of the adaptive immune response induced by infection, versus a vaccine-induced response.⁵

Most serologic assays are qualitative and use either full-length or truncated versions of the nucleocapsid (N) or spike (S) SARS-CoV-2 protein as the target for antibody detection. SARS-CoV-2 spike protein is highly conserved among all human coronaviruses and is involved in receptor recognition, viral attachment, and entry into host cells. Due to its indispensable functions, it represents one of the most important targets for the COVID-19 vaccine and therapeutic research.⁶

Abbott recently developed a quantitative immunoassay that measures antibodies against the receptor-binding domain (RBD) of the S1-subunit of the SARS-CoV-2 S protein, the target of vaccines in development and in use.⁷ To determine the immunogenicity of CoronaVac against SARS-CoV-2, this study aimed to quantify the humoral immune response induced in HCWs after the first and second doses of vaccination. Furthermore, we planned to evaluate the longitudinal dynamics of the antibody response to SARS-CoV-2 after 4 and 6 months following the initial dose. Here, we report the preliminary results of the study.

2 | MATERIALS AND METHODS

2.1 | Study design

HCWs of both genders, 18 years of age or older, who agreed to participate in this prospective study and those who underwent two-dose (28-day interval) SARS-CoV-2 vaccination with

CoronaVac between January 14, 2021 and February 21, 2021 were included. HCWs who had COVID-19 in less than 90 days, and who were pregnant were not vaccinated and were not included in the study.

This study, approved by the Ministry of Health Scientific Research Platform, was run at the microbiology laboratory of Sanko Hospital, which is a tertiary-care teaching university hospital (600 beds), located in Gaziantep, the southeastern part of Turkey. Ethics approval was obtained from Institutional Clinical Research Ethics Committee (approval number: 2021/02/01). All participants signed the voluntary Informed Consent Form ensuring they undergo screening evaluation and completed a questionnaire consisting of 17 questions designed to obtain information about demographic and clinical data, including former exposure to COVID-19. HCWs who refused vaccination or were not able to finish sample collection were excluded.

2.2 | Vaccination protocol

All participants had received two doses of the inactive CoronaVac vaccine. The vaccine used in this study was manufactured by Sinovac Life Sciences. It is produced from a novel coronavirus (strain CN02) grown in the kidney cell cultures (Vero Cell) of the African green monkey and contains inactivated SARS-CoV-2 virus, aluminum hydroxide, disodium hydrogen phosphate, sodium dihydrogen phosphate, and sodium chloride. A dose of 0.5 ml contains 600 SU of SARS-CoV-2 virus antigen. Vaccination of HCWs was performed in the hospital with the recommended dosing interval of 28 days between the first and second doses administered im to deltoid.

2.3 | Sample collection

Sequential blood samples were collected from HCWs to determine the levels of antispikes immunoglobulin G (IgG) antibodies; first 28 days after the initial dose (between February 11 and 17, 2021) and second after 21 days following the second dose of vaccination (between March 4 and 10, 2021). Participants underwent blood sampling with standard venipuncture at the hospital. Transfer of the samples and serum separation were done at the laboratory within 2 h of collection.

2.4 | Analysis of samples

The SARS-CoV-2 IgG II Quant assay (Abbott) is designed to detect IgG antibodies to the RBD of the S1 subunit of the spike protein of SARS-CoV-2 in serum and plasma from individuals who are suspected to have been infected by SARS-CoV-2. The assay is also to be used as an aid in evaluating the immune status of individuals with quantitative measurement of IgG antibodies induced by vaccination.

This assay is an automated, two-step immunoassay for the qualitative and quantitative determination of IgG antibodies to SARS-CoV-2 in human serum and plasma using chemiluminescent microparticle immunoassay technology. Sample, SARS-CoV-2 antigen-coated paramagnetic microparticles, and assay diluent are combined and incubated according to the manufacturer's instructions. The IgG antibodies to SARS-CoV-2 present in the sample bind to the SARS-CoV-2 antigen-coated microparticles. The mixture is washed. Anti-human IgG acridinium-labeled conjugate is added to create a reaction mixture and incubated. Following a wash cycle, Pre-Trigger and Trigger Solutions are added.

2.5 | Interpretation of results

The resulting chemiluminescent reaction is measured as a relative light unit (RLU). There is a direct relationship between the amount of IgG antibodies to SARS-CoV-2 in the sample and the RLU detected by the system optics. Detection was carried on with Architect *i*2000SR instrument (Abbott). Test results greater than or equal to the cutoff value stated in the assay's package insert, that is, 50 arbitrary units per milliliter (50 AU/ml) were reported as reactive and interpreted as positive for SARS-CoV-2 antispikes IgG antibodies. Results below the cutoff value are reported as nonreactive and interpreted as negative. This assay has an analytical measuring interval of 21–40 000 AU/ml (up to 80 000 AU/ml with on-board 1:2 dilution). The assay presented a positive predictive agreement of 99.4% (95% confidence interval [95% CI]: 96.50%–99.97%) and a negative predictive agreement of 99.6% (95% CI: 99.15%–99.37%), and was in agreement with a neutralization method (positive agreement, 100.0%; 95% CI: 95.72%–100.00%).⁸

2.6 | Statistical analysis

As descriptive statistics, median and minimum–maximum values for continuous variables, and frequency and percentage values for qualitative variables were given. In group comparisons, one-way analysis of variance or independent samples *t* test was used for continuous variables and χ^2 test was used for qualitative variables. In all evaluations, $p < 0.05$ was considered statistically significant.

3 | RESULTS

A total of 1072 voluntary HCWs gave written informed consent and completed the questionnaire at the beginning of the study. The median age of the participants was 33.2 years (95% CI—0.67: 32.6–33.9 years). The cohort had a slightly greater representation from female individuals, with 51.5% female and 48.5% male. The age distribution of this cohort was as follows: 18–34 years old, 642 (59.9%); 35–59 years old, 406 (37.9%); 60 years and older, 24 (2.2%) (Table 1).

After 28 days of the first dose of CoronaVac, antispikes IgG antibodies were detectable in 834 of 1072 (77.8%; 95% CI—0.025: 75.44%–80.4%) HCWs. Seropositivity was higher among females (467/552; 84.6%) than males (367/520; 70.6%) ($p < 0.001$) and was found to be highest in both women and men between the ages of 18–34 (88.9% and 79.5%, respectively). Among HCWs between 35 and 59 years, antispikes IgG antibodies in females and males were 75.3% and 64.2%, respectively, and among those more than 60 years 37.5% in both genders. There was no statistically significant difference between age groups of both genders in terms of antibody positivity ($p < 0.05$).

While answering the questionnaire, 277 of 1072 (25.8%) HCWs informed that they had COVID-19 before vaccination and been previously tested PCR-positive for SARS-CoV-2 on a combined nasal and oropharyngeal swab. Out of 277 HCWs, 82 had COVID-19 in the last 3 months, 148 had 4–6 months before, and 47 had more than 6 months before the first dose of vaccine. A total of 49 (4.6%) of HCWs reported that they were not sure whether they had COVID-19 before vaccination, though none had a prior PCR-confirmed diagnosis of COVID-19. After the first dose of the vaccine antispikes, antibodies were detected in 273/277 (98.6%) of HCWs who had COVID-19, and in 527/746 (70.6%) of HCWs who did not have COVID-19. The difference of antibody positivity between HCWs with and without COVID-19 was statistically significant ($p < 0.001$).

After the first vaccine, antibody titers were found 3–4 times higher in those who had COVID-19 than those who did not, and the difference was statistically significant ($p < 0.001$). Though antibody titers were not significantly different between the age groups in workers with a history of COVID-19, there were statistically significant differences in antibody titers between age groups both in men and women who have not had COVID-19 ($p < 0.001$ for both). The highest antibody titers were found between ages 18 and 34.

HCWs No. (%)				
Age (years)	Female	Male	Total	(95% CI)
18–34	399 (72)	244 (47)	643 (60)	0.276 (25.3–25.8)
35–59	145 (26)	260 (50)	405 (37.8)	0.581 (42.5–43.7)
≥60	8 (2)	16 (3)	24 (2.2)	1.783 (63.1–66.7)
Total	552 (51.5)	520 (48.5)	1072 (100)	

TABLE 1 Demographic characteristics of HCWs

Abbreviations: CI, confidence interval; HCW, healthcare worker.

TABLE 2a Quantitative assessment of SARS-CoV-2 antispikes IgG positivity in HCWs on Day 28 after 1st dose of vaccination with CoronoVac

Characteristics of HCWs (n = 835)			Antispikes IgG			
			Positive	Median	Minimum	Maximum
Age by group	Gender	COVID-19 History	No. (%)	AU/ml	AU/ml	AU/ml
18–34 years (n = 642)	Male	PCR-confirmed	50 (100)	857.55	65.20	15008.00
		Unknown	10 (76.9)	528.20	23.10	1340.90
		Not infected	134 (74)	95.30	5.20	6115.30
		Male total	194 (79.5)	143.25	5.20	15008.00
	Female	PCR-confirmed	106 (99.1)	883.20	33.70	11435.60
		Unknown	12 (92.3)	224.60	49.00	2163.40
		Not infected	236 (84.9)	151.00	0.10	3585.40
		Female total	354 (88.9)	268.50	0.10	11435.60
		Total	548 (85.4)	232.15	0.10	15008.00
35–59 years (n = 406)	Male	PCR-confirmed	71 (97.2)	1083.00	13.20	104990.00
		Unknown	4 (30.8)	40.20	1.60	1915.30
		Not infected	92 (52.9)	56.85	0.70	11365.00
		Male total	167 (64.2)	105.90	0.70	104990.00
	Female	PCR-confirmed	39 (97.5)	923.65	24.10	6957.70
		Unknown	9 (90)	120.70	18.50	1664.30
		Not infected	62 (64.6)	83.40	0.02	8219.00
		Female total	110 (75.3)	154.10	0.02	8219.00
		Total	277 (68.2)	127.40	0.02	104990.00
≥60 years (n = 24)	Male	PCR-confirmed	5 (100)	436.40	69.30	7968.90
		Unknown	0 (0)	–	–	–
		Not infected	1 (9.1)	17.30	1.10	111.10
		Male total	6 (37.5)	31.45	1.10	7968.90
	Female	PCR-confirmed	2 (100)	1455.90	1273.60	1638.20
		Unknown	0 (0)	–	–	–
		Not infected	1 (16.7)	38.20	4.00	318.60
		Female total	3 (37.5)	45.50	4.00	1638.20
		Total	9 (37.5)	38.20	1.10	7968.90
			834 (77.8)	200.50	0.020	104990.00

Abbreviations: COVID-19, coronavirus disease-2019; HCW, healthcare worker; IgG, immunoglobulin G; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

An extensively wide concentration range of positive samples was observed, ranging from 50 to 104 990 AU/ml; the highest concentration belonged to an administrative staff within the age group 35–59 years who had received two times convalescent plasma during his COVID-19 6 months ago. The proportion of HCWs infected with SARS-CoV-2 by age group and gender, and their quantitative antispikes IgG results according to their COVID-19 history are given in Table 2a.

Although all HCWs completed their allocated two-dose vaccination schedule, serum samples were obtained from 1012 participants after 21 days following the second dose, 521 (51.5%) were female and 491 (48.5%) were male. Sixty HCWs refused or were unable to give a blood sample after the second dose of the vaccine. After the second dose of CoronaVac, antispikes IgG antibodies were detected in 1008 of 1012 (99.6%) HCWs; there were only 4 out of 1012 (0.4%) who remained seronegative after the second dose of

vaccine. Two of the four patients with no antibody response were females (36 years with no risk factor and 67 years with hypertension) and two were males (47 years with diabetes mellitus and 48 years with no risk factor); none had a COVID-19 history before. After the second dose antibodies were detected in all 259 (100%) HCWs who had COVID-19, and in 703 of 706 (99.6%) who did not have COVID-19. Quantitative assessment of SARS-CoV-2 antispikes IgG positivity in HCWs after the second dose and according to their COVID-19 history is shown in Table 2b.

In this study, HCWs consisted of academicians who were not actively dealing with patients (4.7%), medical doctors in clinical practice (7%), 4th, 5th, and 6th-grade medical faculty students doing an internship in several wards at the hospital (14.1%), other healthcare assistants, such as nurses, dieticians, physiotherapists, pharmacists, emergency medical technicians, radiology technicians, anesthesia technicians, laboratory technicians (29.8%), and assistant staff, such as caregivers, patient counselors, security, transportation, cleaning staff (33.1%), and administrative staff (11.3%) working at Sanko University hospital. Out of 1072, 213 (19.9%) HCWs were working in departments serving only COVID-19 patients. Both after the first and second doses of vaccine, there were no significant differences in antibody titers according to the occupation of HCWs. The median antibody titer was not significantly different among workers occupied at the departments serving COVID-19 patients than among those working in other departments ($p > 0.05$). The highest median antibody titer in those who had COVID-19 was detected in the HCWs working in the computed tomography unit of the radiology department, and the highest median antibody titer in those who did not have COVID-19 in ICU. Occupational roles and COVID-19 history of HCWs, including those working in units serving COVID-19 patients in the last 12 months, are provided in Table 3.

Of 1072 HCWs, 225 (21%) informed that they had at least one chronic disease; hypertension (59.6%) was the most commonly reported clinical complaint. Antibody positivity rate was lower in HCWs who did not have COVID-19 and had at least one chronic disease (59.6%) compared to those without the chronic disease (73.3%); the difference was statistically significant ($p = 0.004$). Median antibody titers were found to be significantly higher in HCWs who did not have a chronic disease ($p < 0.001$). Only a minority of the participants (2.1%) reported receiving immunosuppressive therapy in the last 12 months. No significant difference in terms of antispikes IgG positivity between HCWs who received immunosuppressive treatment and those who did not was observed ($p = 0.650$). Clinical information of HCWs and their antispikes IgG results are given in Table 4.

4 | DISCUSSION

This study aimed to determine and quantitate the level of antibodies directed against the spike protein of SARS-CoV-2 following vaccination of HCWs with two consecutive doses of CoronaVac. For most clinically approved vaccines, binding antibody titers serve as a

surrogate of protection. Bartsch et al.⁹ describe a relationship between antibody titers and functional antibody activity to SARS-CoV-2 over time. For many pathogens and vaccines, specific antibody levels or functions represent the critical protective threshold of immunity. The need for multiple rounds of immunization suggests that more antigen or boosting may be required to push the immune system to generate functional immunity required for protection.¹⁰

In this prospective longitudinal study, we aimed to assess the antispikes IgG positivity and to quantitate the level of antibodies directed against the spike protein of SARS-CoV-2 following vaccination of HCWs with two consecutive doses of an inactivated virus vaccine, CoronaVac. Here, we report the preliminary results; this study will continue with monitoring antibody titers of HCWs 4 and 6 months after the first vaccine. Serum samples obtained from HCWs after the first and second doses of vaccination with CoronaVac showed 77.8% and 99.6% seropositivity, respectively. If we extract HCWs who have had a PCR-confirmed COVID-19 ($n = 277$), or who were not sure to be infected or not with SARS-CoV-2 ($n = 49$) before participating in the study, seropositivity after the first dose remains 70.5% (526/746). The antibody positivity rate was 71.4% (35/49) in HCWs who were not sure whether they had COVID-19 or not. The antibody status of these participants might reflect community-acquired immunity, resulting from unwitting exposure in daily medical practice.

After the first vaccine, the rate of antibody positivity and the amount of antibody titers were found higher in those who had COVID-19 than those who did not, and the differences were statistically significant ($p < 0.001$, $p < 0.001$, respectively). This result showed that people who had COVID-19 can generate high antibody levels even with a single dose of vaccination, thus they could undergo a different vaccination schedule.

People older than 60 years have an increased risk of severe illness and death from COVID-19, especially those with underlying chronic conditions. The response to vaccines is usually reduced in older adults due to immune senescence. Zhiwei et al.¹¹ reported in their clinical trial that CoronaVac was well tolerated and immunogenic in healthy adults aged 60 years and older and neutralizing antibody responses to live SARS-CoV-2 were not reduced in that population. Our findings showed that the antispikes antibody response in HCWs ≥ 60 years old ($n = 24$) after the first dose was relatively low (37.5%); however, immunogenicity reached a level close to that in the 18–59 age group after the second dose (95.7%). A CoronaVac study from Chile reported the seroconversion rate for the ≥ 60 years old group 18.1% after 14 days of the first dose, and 100% after 28 days of the second dose.¹² As mentioned by Grupper et al.¹³ age is an important factor in the humoral response induced after vaccination regardless of chronic medical conditions. We conclude that two doses of vaccination with CoronaVac were capable of inducing a humoral response in people over 60 years of age.

Patients with comorbidities tend to have a reduced immune response to infection or vaccination, and consequently, there is often a need for higher vaccine dosage or scheduling changes in these patients.¹³ Geisen et al.¹⁴ reported that patients with chronic

TABLE 2b Quantitative assessment of SARS-CoV-2 antispikes IgG positivity in HCWs on Day 21 after 2nd dose of vaccination with CoronaVac

Characteristics of HCWs (n = 1008)			Antispikes IgG			
			Positive No. (%)	Median AU/ml	Minimum AU/ml	Maximum AU/ml
18–34 years (n = 599)	Male	PCR-confirmed	46 (100)	1012.20	459.80	13192.60
		Unknown	12 (100)	757.85	259.60	3441.50
		Not infected	172 (100)	952.80	130.50	6267.30
		Male total	230 (100)	964.60	130.50	13192.60
	Female	PCR-confirmed	97 (100)	1193.30	219.60	40780.00
		Unknown	12 (100)	1681.75	1009.30	2469.90
		Not infected	260 (100)	1181.70	54.40	16086.00
		Female total	369 (100)	1193.30	54.40	40780.00
		Total	599 (100)	1119.60	54.40	40780.00
		35–59 years (n = 390)	Male	PCR-confirmed	69 (100)	1212.90
Unknown	12 (92.3)			497.00	17.00	1828.90
Not infected	163 (99.4)			776.95	34.90	18755.50
Male total	244 (99.2)			835.35	17.00	6923.70
Female	PCR-confirmed		40 (100)	1183.85	270.00	6038.40
	Unknown		10 (100)	1434.30	503.20	1838.30
	Not infected		93 (98.9)	1106.30	28.30	11666.90
	Female total		143 (99.3)	1155.50	28.30	11666.90
	Total		387 (99.2)	923.60	17.00	66923.70
	≥60 years (n = 23)		Male	PCR-confirmed	5 (100)	771.90
Unknown		0 (0)		–	–	–
Not infected		10 (100)		656.80	158.50	1224.90
Male total		15 (100)		705.10	114.40	7308.20
Female		PCR-confirmed	2 (100)	1588.80	1403.90	1773.70
		Unknown	0 (0)	–	–	–
		Not infected	5 (83.3)	831.15	10.10	1224.90
		Female total	7 (87.5)	1076.75	10.10	1773.70
		Total	22 (95.7)	733.50	10.10	7308.20
		Total	1008 (99.6)	1022.40	10.10	66923.70

Abbreviations: COVID-19, coronavirus disease-2019; HCW, healthcare worker; IgG, immunoglobulin G; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

inflammatory diseases exhibited significantly lower levels of specific immunoglobulins against the SARS-CoV-2 spike protein following two-dose vaccination. In our study, we found that antibody positivity rate and median antibody titers were significantly lower in HCWs who had chronic diseases than those who did not ($p < 0.05$ and $p < 0.001$, respectively). The possibility remains that patients with chronic diseases will need a booster if their antibody titers diminish more rapidly than healthy individuals. Continued monitoring of vulnerable patient groups will be critical in the successful long-term vaccination against SARS-CoV-2.

This study had several limitations. First, this was a single-center study; therefore, selection bias might have affected our findings. Second, we did not check the seroprevalence of SARS-CoV-2 antispikes antibodies in HCWs before vaccination; therefore, we could not give data for seroconversion.

Detection and quantitation of anti-spike IgG antibodies to SARS-CoV-2 are essential for the estimation of the humoral response induced by vaccination. Our study findings indicated that a relatively high frequency (99.6%) of HCWs produced humoral immunity after two consecutive doses of CoronaVac. As mentioned previously,

Occupation of HCWs	HCWs No. (%)	PCR-confirmed COVID-19 cases No. (%)	Antispikes IgG Positive No. (%)
Academic member	50 (4.7)	6 (12)	30 (60)
Doctor of medicine	74 (7)	23 (31)	47 (63.5)
Medicine student	152 (14.1)	15 (9.8)	118 (77.6)
Healthcare assistant	319 (29.8)	95 (29.7)	279 (87.5)
Assistant staff	355 (33.1)	100 (28.1)	266 (74.9)
Administrative staff	122 (11.3)	38 (31.1)	94 (77)
Total	1072 (100)	277 (25.8)	834 (77.8)

HCWs in units serving COVID-19 patients	HCWs No. (%)	PCR-confirmed COVID-19 cases No. (%)	Antispikes IgG Positive No. (%)
Emergency	139 (65.2)	34 (24.4)	107 (77)
COVID-19 service	37 (17.4)	15 (40.5)	32 (86.5)
Intensive care unit	24 (11.3)	10 (41.6)	22 (91.7)
Radiology-CT unit	10 (4.7)	4 (40)	9 (90)
COVID-19 laboratory	3 (1.4)	0 (0)	3 (100)
Total	213 (100)	63 (29.6)	173 (81.2)

TABLE 3 Occupational roles and COVID-19 history of HCWs including those working in units serving COVID-19 patients

Abbreviations: COVID-19, coronavirus disease-2019; CT, computed tomography; HCW, healthcare worker; IgG, immunoglobulin G; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

TABLE 4 Clinical characteristics of HCWs

Antispikes IgG					
HCWs w/wo chronic diseases	COVID-19 History No. (%)	Positive No. (%)	Median (AU/ml)	Minimum (AU/ml)	Maximum (AU/ml)
No chronic disease (<i>n</i> = 847) (79%)	PCR-confirmed 210 (24.8)	208 (99)	8926.0	24.1	104 990
	Not infected 595 (70.2)	436 (73.3)	111.1	0.02	11 365
Chronic disease (<i>n</i> = 225) (21%)	PCR-confirmed 67 (29.8)	65 (97)	1024.2	13.2	16152.5
	Not infected 151 (67.1)	90 (59.6)	71.4	0.3	8219

Antispikes IgG					
HCWs w/wo immunosuppressive treatment	COVID-19 History No. (%)	Positive No. (%)	Median (AU/ml)	Minimum (AU/ml)	Maximum (AU/ml)
Not immunosupp. (<i>n</i> = 1049) (97.9%)	PCR-confirmed 269 (25.6)	265 (98.5)	909.1	13.2	104 990
	Not infected 732 (69.8)	518 (70.8)	101.8	0.02	11 365
Immunosupp. tx (<i>n</i> = 23) (2.1%)	PCR-confirmed 8 (35.8)	8 (100)	2399.8	716.7	7614
	Not infected 14 (60.9)	8 (57.1)	53.8	5	668.7

Abbreviations: COVID-19, coronavirus disease-2019; CT, computed tomography; HCW, healthcare worker; IgG, immunoglobulin G; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

quantitative determination of anti-SARS-CoV-2 antibodies may help facilitate longitudinal monitoring of the antibody response in individual patients and specifically monitor antibody response to vaccines.¹⁵ Although the induction of the humoral response after two consecutive doses of CoronaVac was considered positive for most HCWs aged 18–59 years, lower rates of antibody production and

lower median antibody titers were detected in participants aged more than 60 years and those with comorbidities. Although our findings are preliminary, additional data obtained in antibody titers at the end of the 4th and 6th months following the first dose will prompt consideration for changing the dose/schedule of vaccinations in vulnerable patient groups.

ACKNOWLEDGMENTS

This work was funded by the Scientific Research Projects Unit of Sanko University. The funder of the study had no role in study design, data collection, data analysis, or data interpretation, or writing of the report. The authors would like to thank the laboratory staff at Sanko Hospital for completing the antibody testing.

CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

AUTHOR CONTRIBUTIONS

Ayşen Bayram and Hadiye Demirbakan were responsible for the project administration, methodology, and writing of the study. İpek Koçer and Merve Erdoğan were responsible for the acquisition, analysis, and interpretation of the results. Pınar Günel Karadeniz was responsible for statistical analysis.

PEER REVIEW

The peer review history for this article is available at <https://publons.com/publon/10.1002/jmv.27098>

DATA AVAILABILITY STATEMENT

Data are available on request due to privacy/ethical restrictions. The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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How to cite this article: Bayram A, Demirbakan H, Günel Karadeniz P, Erdoğan M, Koçer İ. Quantitation of antibodies against SARS-CoV-2 spike protein after two doses of CoronaVac in healthcare workers. *J Med Virol*. 2021;93: 5560-5567. <https://doi.org/10.1002/jmv.27098>