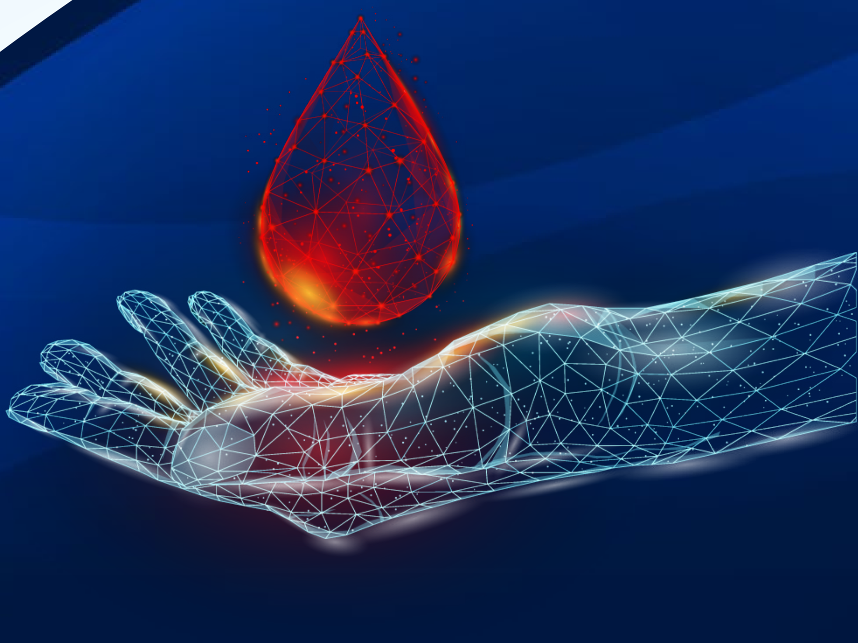
Alliance for Public Health

#sos_project 2.0

ASSESSMENT OF THE PREVALENCE OF SARS-COV-2 ANTIBODIES
among blood donors in Ukraine

UKRAINE, KYIV
2022



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1. List of abbreviations

SARS-CoV-2	Coronavirus causing an acute respiratory disease
Ab	antibodies
anti-SARS-CoV-2	SARS-CoV-2 antibodies
BD	
RBC	Regional Blood Centers
ELISA	enzyme-linked immunosorbent assay

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3. Introduction

3.1. Prerequisites and justifications

On February 25, 2020, the World Health Organization (WHO) announced the highest risk of COVID-19 epidemic, and on March 11, 2020 the COVID-19 pandemic was declared. Back then, COVID-19 cases were registered in 114 countries, with their number exceeding 118 thousand cases, including over 4 thousand deaths. Etiologically, the COVID-19 pandemic is related to the SARS-CoV-2 coronavirus, new for the humanity, which got its name as, like SARS, it causes a severe acute respiratory syndrome, but with much lower mortality.

In Ukraine, the first confirmed case of SARS-CoV-2 infection was registered on March 3, 2020 in a man from Chernivtsi region. According to the Ukrainian Ministry of Health, as of December 1, 2020 (when we started planning our research study), there were 745,123 people with COVID-19 registered in the country, with 12,548 deaths and 355,172 people recovered. Despite the restrictive measures, Ukraine has so far failed to overcome the uncontrolled spread of the disease, which negatively affects the public health as well as the national economy. That is why there is a need to carry out research studies, which would help to adjust anti-epidemic and preventive measures and improve the COVID-19 testing techniques.

One of the key prerequisites for information support of anti-epidemic and preventive measures is data on the detection of specific SARS-CoV-2 markers in different populations. In this regard, seroepidemiological studies, in particular population studies, are an important source of information on the spread of COVID-19, the dynamics of SARS-CoV-2 transmission, the number of people who had the disease, the interventions to mitigate the consequences of COVID-19 pandemic, vaccine prevention strategies, etc. [1, 2]. Seroprevalence data within the surveillance system allow to identify people who were previously infected (including those who had a mild or subclinical form of the disease and have not been officially reported); assess the potential for the accumulation of people with SARS-CoV-2 antibodies; identify the most susceptible age groups and other populations, risk factors, etc. [3]. Analyzing the frequency of detection of SARS-CoV-2 antibodies helps to compare the prevalence of COVID-19 in different countries, different parts of a country or among different populations. Seroepidemiological studies will definitely play a crucial role in public health interventions in response to the pandemic. Thus, seroepidemiological studies have shown that the number of COVID-19 cases and the burden of the disease are significantly underestimated, as only part of the cases is diagnosed and registered. SARS-CoV-2 seropositivity studies carried out in the United States and European countries have shown that, when adjusted for potential false-positive/false-negative testing results, the prevalence of COVID-19 is approximately 10 or more times higher than the reported numbers [4, 5].

It should be noted that interpretation of the results is complicated by significant heterogeneity in the accuracy of serological tests, leading to an issue of selecting the most informative diagnostic tests to monitor the serostatus after COVID-19 disease or vaccination. From this point of view, it might be interesting to study the effectiveness of detecting antibodies using different tests [6]. Anonymous samples from donors aged 17–69 years were tested using three diagnostic kits: Euroimmun IgG, Abbott IgG and a test developed by Public Health England. Over time, seroprevalence determined with the Abbott test increased from 3.0% to 12.3%; with the Euroimmun test — from 9.9% to 13.0%; with the Public Health England test — from 3.5% to

14.1%. Combining Abbott and Euroimmun test results allowed to increase the effectiveness of SARS-CoV-2 antibodies detection by 1.6% and 0.6%, respectively, as compared with the use of Euroimmun alone, which indicates that it is reasonable to use multiple tests produced by different manufacturers.

The number of detected individuals with SARS-CoV-2 antibodies serves as an evidence base for assessing the scope of COVID-19 transmission. One of the adult sub-populations is blood donors (BDs), who were tested for SARS-CoV-2 antibodies in different countries around the world at the start of the pandemic, mostly to determine the prevalence of COVID-19:

- ***France****, March-April 2020: study results showed the prevalence of SARS-CoV-2 antibodies among BDs at the level of 2.7–3.0%. This study did not find any differences in the COVID-19 prevalence among different age and gender groups [7, 8];*
- ***Brazil,*** *April 14–27, 2020: testing results for 2,837 BDs were analyzed, with the share of positive results reaching 4.0%. Despite the short period of data collection, researchers indicate an increase in the share of positive results over time, with differences observed depending on the age of BDs: younger people were more likely to have a marker of infection compared to older participants [9];*
- ***Kenya****, April-June: a survey covering 3,098 BDs was conducted, with 5.6% seroprevalence. Significant differences were seen in the geographic spread of COVID-19 [10];*
- ***China****, August 2020: insignificant rates of SARS-CoV-2 antibodies were observed, only at 0,9% [11];*
- ***Germany****, March-June 2020: the study covered regular blood donors in three federal states, with an average detection rate of SARS-CoV-2 antibodies being 0.95% and ranging from 0.66% to 1.22% in different areas [12];*
- ***Saudi Arabia****, May 2020: SARS-CoV-2 seroprevalence rate was estimated at the level of 1.4% [12]. However, a similar study carried out in August-September 2020 among healthcare workers (a risk group) showed a significantly higher seroprevalence level — 24.2% [13].*

Apart from the studies on the presence of antibodies, there is a question of susceptibility of people with different blood types to COVID-19. For instance, French researchers report that SARS-CoV-2 seroprevalence in donors with blood type O (I) was lower as compared to donors with other blood types [14]. Another study also demonstrated that people with blood type O (I) have a lower risk of getting infected with SARS-CoV-2 [15]. However, the number of studies on this aspect of susceptibility to COVID-19 is still limited so this issue needs further exploration.

3.2. Expected application of research results

In Ukraine, studying the presence of SARS-CoV-2 antibodies among BDs is one of the most feasible options given the accessibility of this group for testing, allowing to assess the prevalence of SARS-CoV-2 in relatively healthy people of working age. Besides, the terms for the engagement of blood donors are the same for all regions of Ukraine, which allows to compare the prevalence of SARS-CoV-2 antibodies in different areas. As per the Resolution of the Ukrainian Cabinet of Ministers No. 1099 dated November 11, 2020, funding was allocated to procure test systems to test BDs for SARS-CoV-2 antibodies, and from January 2021 such testing was conducted in all regions of Ukraine. It was planned that the testing would be conducted throughout 2021. However, as there was no centralized procurement of diagnostic kits, different blood centers purchased different test systems. Though there is quite a big number of publications on testing of BDs, our research team was not able to find any that contained information not only on demographic or geographic factors, but also on the linkage between the serological status of BDs in terms of SARS-CoV-2 and epidemiological or medical aspects of COVID-19. However, this data could be obtained if the studies conducted in addition to testing would also include a survey of the participants.

The main goal of our study was to assess the prevalence of COVID-19 and determine its territorial characteristics based on the frequency of detection of SARS-CoV-2 antibodies in BDs as an indicator group of the adult population. The survey of BDs aimed at answering a number of crucial questions, namely at identifying the ratio between asymptomatic and clinical forms of COVID-19, the specifics of patients seeking health care (for instance, patient-initiated examination), the laboratory tests to confirm clinical diagnosis, etc. Besides, the plan was to investigate the linkage between the reported incidence of COVID-19 and the detection of SARS-CoV-2 antibodies as well as to assess the infection rates by comparing the levels of SARS-CoV-2 antibodies detected at different times.

The study was carried out by Ukrainian Public Organization "Association of Blood Service of Ukraine", L.V. Gromashevsky Institute of Epidemiology and Infectious Diseases, International ChariTable Foundation "Alliance for Public Health", and municipal non-profit enterprises "Regional Blood Centers" in the target cities of study implementation.

4. Study design

4.1. Study goal and objectives

Study goal: assess the spread of COVID-19 among BDs from different regions of Ukraine and extrapolate the results to the adult population by testing and surveying the target group.

The following objectives were set forth based on the study goal:

1. ***Identify*** *the share of people with SARS-CoV-2 antibodies among BDs by regions of Ukraine and establish any age or gender related differences;*
2. ***Estimate*** *the proportion of clinical and asymptomatic forms of COVID-19 in BDs;*
3. ***Establish*** *the frequency of people with suspected COVID-19 seeking health care;*
4. ***Estimate*** *the duration of persistence of SARS-CoV-2 antibodies after the disease and depending on its severity;*
5. ***Determine*** *if there is a linkage between the official incidence of COVID-19 and the detection of SARS-CoV-2 antibodies in different regions of Ukraine.*

4.2. Research methods

The study to determine COVID-19 prevalence among BDs had a cross-sectional design with two components — a biological study and a survey on the experience of BDs. Biological data were collected by testing BDs for the presence of SARS-CoV-2 antibodies using ELISA tests and the survey was conducted in the format of individual face-to-face interviews. To achieve the study objectives, official statistics on the incidence of COVID-19 in Ukraine and in the target regions was also analyzed.

4.3. Target group

The target group of the study included BDs (whose blood samples were taken on the day of their visit to blood centers), who met the following eligibility criteria (Table 1).

Table 1. Criteria for BD enrolment

Eligibility criteria	**Verification method**
Age 18 to 60 years old	Passport data
Residing in a specific region of Ukraine at the time of blood donation	Passport data
Written consent to participate in both components of the study: ELISA testing for SARS-CoV-2 antibodies; survey regarding behavioral practices	Informed consent to participate in the study
Exclusion criteria	
Getting one or two doses of SARS-CoV-2 vaccine	Self-declaration
Refusal to participate in one or more components of the study	Lack of informed consent to participate in the study

4.4. Study geography and respondent sampling

When the project was planned, it was expected that the study would cover at least 10 thousand BDs in six cities of Ukraine (Dnipro, Zhytomyr, Poltava, Mykolaiv, Ternopil and Uzhhorod), which would be sufficient to fully reflect different regions of the country. The target cities were chosen based on their geographical location and preliminary assessment of the ability of Regional Blood Centers to conduct the study. It was expected that the sample size in the target cities would be proportional to the population of the region aged 18–60 years and the monthly number of blood donations. From the total sample, only 10–15% of donors who donated blood or blood products repeatedly during the project implementation were to be evaluated.

Unfortunately, the expected sample was not implemented in full scope as at the final stage of project planning it turned out that in some cities (Dnipro and Mykolayiv) the heads of Regional Blood Centers refused to conduct a research study not agreed with or regulated by the Ministry of Health of Ukraine and implemented on a voluntary basis. Thus, it was necessary to urgently amend the list of cities participating in the project. Besides, in the spring of 2021, some blood centers ran out of the tests to detect SARS-CoV-2 antibodies. The data on the actual number of BDs who were tested and interviewed within the project are presented below.

Table 2. Study regions and number of blood donors tested

Target cities	Number of BDs tested and surveyed by months							
	April	May	June	July	August	September	October	**Total**
Zhytomyr	244	329	-	-	-	736	191	**1,500**
Vinnytsia	-	-	96	-	-	-	-	**96**
Poltava	483	1,099	804	-	-	-	-	**2,390**
Ternopil	127	-	-	-	-	-	-	**127**
Uzhhorod	398	281	461	-	-	-	-	**1,140**
Total	**1,253**	**1,709**	**1,360**	**-**	**-**	**736**	**191**	**5,253**

4.5. Research questions and hypotheses

The study had to answer the following questions:

- *What is the seroprevalence of COVID-19 based on the frequency of detection of SARS-CoV-2 antibodies in blood donors?*
- *Are there any geographical differences in the seroprevalence of COVID-19?*
- *Does the risk of SARS-CoV-2 infection depend on age and gender?*
- *What is the share of people who had an acute respiratory disease in 2020–2021 and had antibodies to SARS-CoV-2?*
- *What is the share of people who did not have an acute respiratory disease or COVID-19 but had antibodies to SARS-CoV-2?*
- *What is the share of people with laboratory-confirmed COVID-19 who had antibodies to SARS-CoV-2 at different times after the disease?*
- *Is there a linkage between the blood type and the frequency SARS-CoV-2 infection?*

The study was to test the following hypotheses:

- *The official COVID-19 incidence rates* correlate with the rate of detection of SARS-CoV-2 antibodies in the adult population, extrapolated based on the COVID-19 seroprevalence in blood donors.*
- *COVID-19 incidence registration dynamics correlates with the dynamics of detecting SARS-CoV-2 antibodies in BDs.*
- *There is a linkage between the blood type and the frequency of SARS-CoV-2 antibodies detection.*
- *Relatively healthy individuals with asymptomatic/mild progression or with suspected COVID-19 are less likely to seek medical care.*
- *Serological markers (antibodies to SARS-CoV-2) in individuals with asymptomatic/mild disease are reduced to undetecTable levels within three months.*
- *The persistence of SARS-CoV-2 antibodies depends on the severity of the disease (based on the survey questions regarding inpatient treatment).*

5. Research procedures

5.1. Data collection

The following key data sources were used: survey among BDs; laboratory testing results; official statistics on COVID-19 cases in the target regions.

Participation in the study was voluntary, which was confirmed by informed consent forms signed by the participants.

All participants who signed informed consent forms took part in a survey followed by testing of their blood samples for the presence of SARS-CoV-2 antibodies in the relevant blood center laboratories. A structured survey with a questionnaire developed by the research team was conducted by health workers of the Regional Blood Centers.

The questionnaire included the following key sections:

- *general section (donor code and number, age, gender, etc.);*
- *medical section (results of the survey on the possibility of SARS-CoV-2 infection, COVID-19 disease, laboratory confirmation of clinical diagnosis, etc.);*
- *data of the laboratory testing of donor serum/plasma sample for SARS-CoV-2 antibodies using the ELISA method recording optical density of the sample and limit value of the test used (indicating the name and the series of the test).*

5.2. Data processing and analysis

Data analysis included a descriptive analysis of the survey results, laboratory tests, official statistics on the incidence of COVID-19 and assessment of the differences between the results obtained for different time periods.

6. Study results

6.1. Sociodemographic and professional characteristics of blood donors

6.1.1. Age

In line with the study protocol, according to which the target group included people aged 18–60, the majority of the donor sample (99.4%) were people aged 18–59, with 0.6% being people 60 years of age or older.

In all the target cities with sufficient samples (Zhytomyr, Poltava, Uzhhorod), there were statistically significantly fewer older people in the donor sample than in the general adult population and statistically more younger people (data was compared for the 18–64 age group with the chi-square criterion applied). The data is presented in Tables 3–5.

Table 3-5. Comparison of the age distribution among blood donors in Zhytomyr, Poltava and Uzhhorod spring-summer sample, with the general city population aged 18–64 (with statistically significant difference in distributions at the .000 level, chi-square criterion)

	Zhytomyr		Poltava		Uzhhorod	
	Donor sample	City population	Donor sample	City population	Donor sample	City population
18-19 years old	3,8%	2,8%	3,3%	2,5%	3,8%	3,4%
20-24 years old	15,2%	7,3%	8,6%	7,3%	14,7%	8,9%
25-29 years old	17,5%	10,1%	12,8%	9,3%	16,8%	10,6%
30-34 years old	21,5%	12,0%	17,0%	12,3%	18,4%	12,7%
35-39 years old	17,1%	15,6%	16,7%	16,3%	15,9%	14,6%
40-44 years old	11,2%	11,7%	13,5%	12,3%	10,0%	11,9%
45-49 years old	6,8%	10,5%	13,0%	11,1%	9,7%	10,5%
50-54 years old	4,0%	9,6%	9,5%	9,7%	6,1%	9,1%
55-59 years old	2,3%	10,3%	4,8%	9,7%	4,3%	8,9%
60-64 years old	0,5%	10,1%	0,8%	9,4%	0,4%	9,4%

Thus, in the target cities with sufficient samples (Zhytomyr, Poltava, Uzhhorod), there was a significant difference between the age structure of BDs and the city population.

6.1.2. Gender

Most of the blood donors, who took part in the study in 5 cities (Zhytomyr, Poltava, Uzhhorod, Vinnytsia, Ternopil) were male — 68.1%, while the share of women was 31.9%. This proportion differs greatly from the gender structure of the Ukrainian population in general: according to the State Statistics Service, in 2021 the share of men among people permanently residing in Ukraine was 45.2%, while the share of women was 54.8%. Table 6 presents data for the target cities with sufficient samples.

Table 6. Comparison of the BD sample with the city population in terms of gender distribution

City	Gender distribution among BDs (%)		Gender distribution in the population according to the State Statistics Service (%)	
	male	female	male	female
Zhytomyr (spring-summer)	63.7	36.3	44.7	55.3
Poltava (spring-summer)	71.1	28.9	45	55
Uzhhorod (spring-summer)	70.9	29.1	45.3	54.7
Zhytomyr, autumn	56.4	43.6	44.7	55.3

The same pattern is observed in each of the target cities with sufficient samples for independent analysis: the share of men among the BDs participating in the study is statistically significantly higher than the share of men in the general adult population of the city. Thus, the share of women is statistically significantly lower (.000).

The same is true if we analyze not the entire population of the city, but only people aged 18–64 (comparable to the donor sample). The data is presented in Table 7.

Table 7. Comparison of the BD sample with the city population aged 18–64 in terms of gender distribution

City	Gender distribution among BDs (%)		Gender distribution in the population according to the State Statistics Service (%)	
	male	female	male	female
Zhytomyr (spring-summer)	63.7	36.3	47.3	52.7
Poltava (spring-summer)	71.1	28.9	48.2	51.8
Uzhhorod (spring-summer)	70.9	29.1	47.5	52.5
Zhytomyr (autumn)	56.4	43.6	47.3	52.7

The share of men among the blood donors participating in the study is statistically significantly higher than the share of men aged 18–64 in the general adult population of the city (.000). Thus, the share of women is statistically significantly lower (.000).

6.1.3. Share of healthcare workers

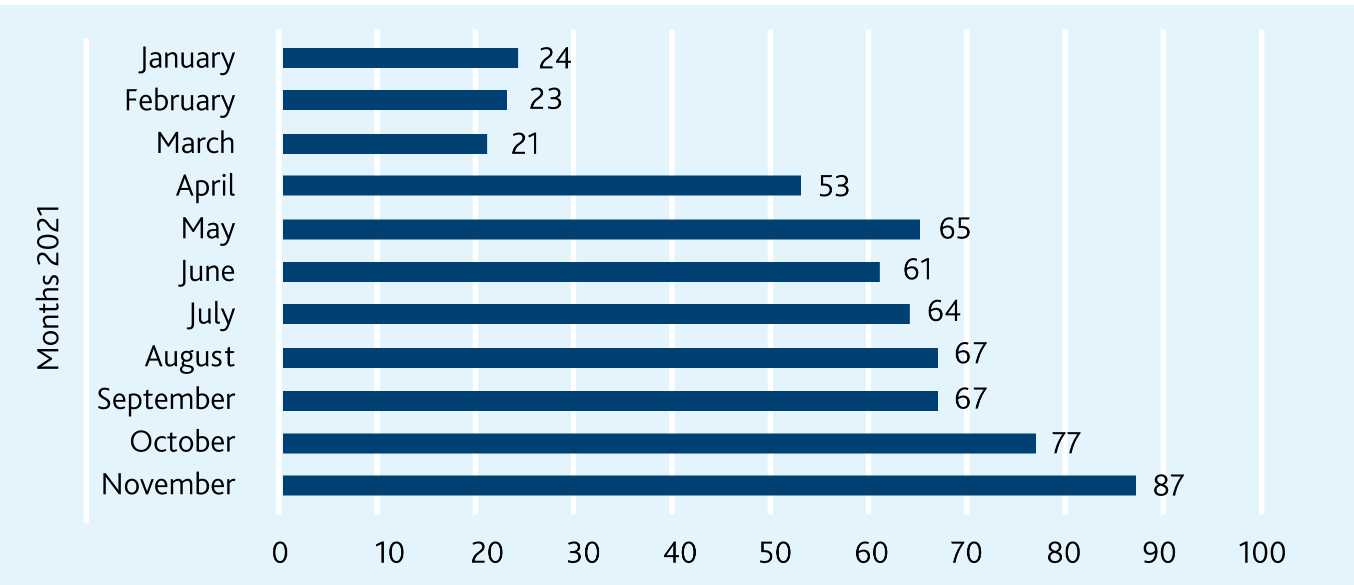
The share of healthcare workers among the BDs participating in the study was higher than among the general adult population of Ukraine: 5.8% in the sample of 5 cities (Zhytomyr, Poltava, Uzhhorod, Vinnytsia, Ternopil), which is significantly higher than in Ukraine in general (about 1.3%). The share of healthcare workers among BDs in Poltava, Zhytomyr and Uzhhorod was 6%, while among the adult population of Poltava, Zhytomyr and Zakarpattia regions — only 1.5%.

6.2.Results of donors testing for SARS-CoV-2 antibodies

6.2.1. Results of donors testing for SARS-CoV-2 antibodies by study cities

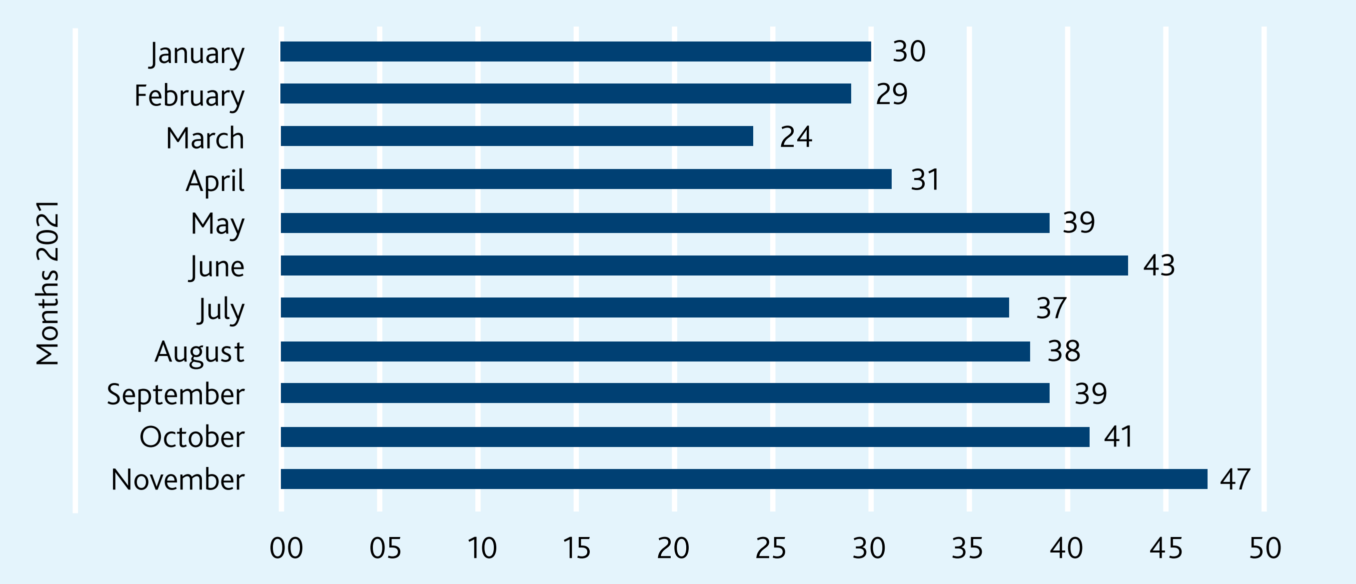
The highest SARS-CoV-2 antibodies seroprevalence among BDs (based on gender and age weighted data for each city) in spring and summer was recorded in Zhytomyr (63.1%), which is statistically significantly higher than in Poltava (43.5%) and Uzhhorod (25.8%). We assumed that high seroprevalence in Zhytomyr could be related to the use of different tests than in Poltava and Uzhhorod. However, when analyzing the data of routine examination of all BDs at Zhytomyr site, the research team saw that in the first quarter of 2021 detection of SARS-CoV-2 antibodies was in the range of 21–24%, with the same test system used as in the further study. In April 2021, this indicator sharply increased to 53% and then continued to steadily grow (Figure 1). This, in our opinion, demonstrates a real deterioration of the COVID-19 epidemic situation in Zhytomyr.

Picture 1. Dynamics of detecting SARS-CoV-2 antibodies among BDs in Zhytomyr (2021)



For comparison, we can refer to similar data for Poltava (Picture 2), where we can see a gradual increase in the detection of SARS-CoV-2 antibodies among BDs, but without any spikes after the first quarter.

Picture 2. Dynamics of detecting SARS-CoV-2 antibodies among BDs in Poltava (2021)



When we compared seroprevalence levels between Zhytomyr-Poltava, Zhytomyr-Uzhhorod and Poltava-Uzhhorod, we found out that they differed significantly (Table 8).

Table 8. Comparison of SARS-CoV-2 seroprevalence rates among BDs in Zhytomyr, Poltava and Uzhhorod (spring-summer sample)

	Seroprevalence indicators in cities	**Statistical significance of the difference (binomial criterion)**
Zhytomyr	63,1% (58,2 – 66,3%)	.000, (statistically significant difference)
Poltava	43,5% (40,5 – 44,5%)	.000, (statistically significant difference)
Uzhhorod	25,8% (22,1 – 27,2%)	.000, (statistically significant difference)

6.2.2 Impact of weighting by age and gender on the assessment of SARS-CoV-2 antibodies seroprevalence among blood donors

Weighing was done separately for each city by gender and age, using the official statistics on the gender and age structure of the population in the cities participating in the study (Table 9).

Table 9. Comparison of SARS-CoV-2 antibodies seroprevalence rates among blood donors in Zhytomyr, Poltava and Uzhhorod using weighted and unweighted data

Cities (time frame)	**Unweighted data (%)**	**Weighted data (%)**	**Deviation**
Zhytomyr (spring-summer)	62.7	63.1	+0.4 percentage points
Zhytomyr (autumn)	72.8	75.9	+3.1 percentage points
Poltava (spring-summer)	42.3	43.5	+1.2 percentage points
Uzhhorod (spring-summer)	24.5	25.8	+1.3 percentage points

The data received in the course of the study showed that there was a need to use age and gender weighted data when comparing seroprevalence rates in different regions, which we did when comparing indicators for the target cities.

6.2.3. Impact of sensitivity and specificity of test systems on the detection of SARS-CoV-2 antibodies among blood donors

Two test systems were used in the study: EQUI SARS-CoV-2 IgG swift (in Zhytomyr) and DIA-SARS-CoV-2-NP-IgG (in all other cities). The EQUI SARS-CoV-2 IgG swift test system is intended for simultaneous detection of IgG antibodies to S and N proteins of the pathogen, and the DIA-SARS-CoV-2-NP-IgG test system is intended only for the N protein.

According to the instruction, sensitivity of the EQUI SARS-CoV-2 IgG swift test is 100%, while its specificity is 96.1%.

Sensitivity of DIA-SARS-CoV-2-NP-IgG test system, based on the instruction, is 85.71% (on days 12–16 from symptoms onset) and 100% (on days 18–20), while its specificity lies within the range from 95.35 to 99.81%. The following characteristics were taken for calculations: sensitivity — 100%, specificity — 95.35%.

Rogan-Gladen's estimator was used to assess the influence of test sensitivity and specificity on the seroprevalence results[1]. Such estimator is used in cases when tests have sensitivity or specificity lower than 100%. It allows measuring the true prevalence of serological markers of a pathogen using the formula:

$$\text{True Prevalence} = \frac{\text{Apparent Prevalence} + (\text{Specificity} - 1)}{\text{Specificity} + (\text{Sensitivity} - 1)}$$

where **true prevalence** is the proportion of all those who are tested who are actually positive; **apparent prevalence** is the proportion of all those who are tested who, rightly or wrongly, test positive.

Table 10 presents the data weighted by age and gender as compared with the weighted data taking into account sensitivity and specificity of the tests used.

1 https://influentialpoints.com/Training/estimating_true_prevalence.htm

Table 10. Comparison of SARS-CoV-2 antibodies seroprevalence in BDs, adjusted for sensitivity and specificity of the tests used

Cities (time frame)	**Weighted data (%)**	**Weighted data considering sensitivity and specificity of the tests (%)**	**Deviation**
Zhytomyr (spring-summer)	63.1	61.6	-1.5 percentage points
Zhytomyr (autumn)	75.9	74.8	-1.1 percentage points
Poltava (spring-summer)	43.5	40.7	-2.8 percentage points
Uzhhorod (spring)	25.8	22.2	-3.6 percentage points

According to the data obtained, there was no significant impact of using different test systems on assessing if the difference in the seroprevalence of SARS-CoV-2 antibodies among BDs in different cities was significant. However, it should be noted that only the data provided by manufacturers were taken into account when assessing the impact of test sensitivity and specificity. No comparative studies were conducted to assess sensitivity and specificity of various test systems, so there is still a possibility that different tests can have different diagnostic strength while used routinely, especially given the fact that they detect antibodies to different antigens.

6.2.4. Comparison of the results of BD testing for SARS-CoV-2 antibodies with the official statistics

Comparing the results of BD testing with the official COVID-19 incidence statistics is complicated by a number of factors. Firstly, donor sampling was limited to the age group of 18–60 years. Secondly, there is no data on what share of BDs reside in the city and in the region. That is why we present several options to compare the results of our study and the official statistics. It should be noted that the official statistics (taken from the COVID-19 dashboard of the National Health Service of Ukraine)[2] was taken as of April 1, 2021. Besides, the official statistics only allows to separate the age group over 20 years old, while the blood donor tested were aged 18 and over. Based on our study, seroprevalence of SARS-CoV-2 antibodies among BDs significantly exceeds the official incidence of COVID-19 in the same age group in all cities. The study results showed significant differences in seroprevalence of SARS-CoV-2 antibodies among BDs in different cities. At the same time, according to the official statistics the incidence levels in the three cities (Poltava, Uzhhorod, Zhytomyr) do not differ significantly (Table 11).

2 https://edata.e-health.gov.ua/e-data/dashboard/covid19

Table 11. Comparison of SARS-CoV-2 antibodies seroprevalence among BDs in Zhytomyr, Poltava and Uzhhorod with the official statistics on the incidence of COVID-19

City	Seroprevalence among BDs (%)	Cumulative incidence among city residents aged 20-59 (absolute number)	Number of people aged 20-59 in the city	Cumulative number of people who had COVID-19 before April 1, 2021, per 100,000 population	Cumulative incidence among city residents aged 20-59 (%)
Poltava	43,5	16215	168754	9609	9,9
Uzhhorod	25,8	7357	68936	10672	11,1
Zhytomyr (spring and autumn waves)	63,1 (spring)	12694	156609	8106	8,4
		15004			9,9

Considering that there is not statistically significant difference in the level of seroprevalence among different age groups of BDs (as we will show below) and given that BDs can include both residents of the regional center and the region, we present a comparison of the seroprevalence of SARS-CoV-2 antibodies in BDs and COVID-19 incidence rates in relevant regions (for all age groups). Thus, we see that the highest seroprevalence level in Zhytomyr corresponds to the highest incidence rate in Zhytomyr region (Table 12). However, based on the study results we see that the seroprevalence level among BDs in Poltava is statistically significantly higher than among BDs in Uzhhorod, though there is no significant difference in COVID-19 incidence rates in the respective regions.

Table 12. Comparison of SARS-CoV-2 antibodies seroprevalence among BDs in Zhytomyr, Poltava and Uzhhorod with the data on COVID-19 incidence in the target regions

City/region	Seroprevalence among BDs (%)	Cumulative incidence in the region as of April 1, 2021 (absolute number)	Population of the region (average number in January-September 2021)	Percentage of the region's population who had COVID-19 according to official statistics
Poltava/ Poltava region	43,5	58383	1365333	4,3
Uzhhorod/ Zakarpattia region	25,8	55999	1248419	4,5
Zhytomyr (spring, autumn)/ Zhytomyr region	63,1 (spring)	73059	1190054	6,1
	75.9 (autumn)			7,6

We found a discrepancy between the SARS-CoV-2 antibodies seroprevalence among BDs and the reported COVID-19 incidence rates in the target cities. If we look at the incidence rates at the regional level, seroprevalence among BDs in Zhytomyr corresponds to the highest COVID-19 incidence level in Zhytomyr region (as compared to Zakarpattia and Poltava regions). However, higher SARS-CoV-2 antibodies seroprevalence among BDs in Poltava does not correspond to the lowest incidence rate registered in Poltava region.

In our opinion, the incidence levels may be influenced by a number of local factors: people seeking health care, accessibility of medical services and testing (PCR and antigen tests), approaches to case registration, procedures for supply and storage of testing materials, quality of laboratory testing, etc. Considering higher prevalence of asymptomatic and mild forms of the disease, data on seroprevalence of antibodies to the virus are a more sensitive indicator to compare the prevalence of COVID-19 in different regions. It should be noted that an important prerequisite to obtain comparable results in such studies is applying unified approaches to the sampling of respondents and using the same diagnostic tools.

6.2.5. Comparison of the results of SARS-CoV-2 antibody testing among BDs with the data of the national study conducted in Ukraine

With certain limitations, the results of our study can be compared with the results of the national seroprevalence study[3] conducted in Ukraine in the summer of 2021. The limitation of such comparison is that the national study data are presented for regions, not cities. Both studies — among BDs and the national study — demonstrate a significantly higher SARS-CoV-2 antibodies seroprevalence levels than the reported incidence rates. In the national study, IgG SARS-CoV-2 antibodies detection rate was 40.5% (95% CI: 39.3–41.7%), while in our study among BDs in the target regions this rate ranged from 63.1% (58.2–66.3%) in Zhytomyr to 43.5% (40.5–44.5%) in Poltava and 25.8% (22.1–27.2%) in Uzhhorod. However, if we look at the cities (or cities and regions, to be more precise), results of the two studies do not correlate very well. For instance, the study among BDs in Uzhhorod showed the lowest SARS-CoV-2 antibodies seroprevalence among the three cities, while according to the national survey it is the highest (Table 13). Besides, seroprevalence rates among BDs in Zhytomyr are much higher than those obtained in the national survey. It should be noted that the data we obtained in Zhytomyr align with a fairly high incidence of COVID-19.

Table 13. Comparison of SARS-CoV-2 antibodies seroprevalence among BDs in Zhytomyr, Poltava, Uzhhorod and seroprevalence among adults in the respective regions according to the national study results

Cities and regions	Result of BD testing	Result of the national study
Poltava **(Poltava region for the national study)**	43,5%	31,3%
Uzhhorod **(Zakarpattia region for the national study)**	25,8%	48,1%
Zhytomyr (spring wave) **(Zhytomyr region for the national study)**	63,1%	39,1%

3 More detailed information about the study can be found at https://phc.org.ua/news/v-ukraini-vpershe-provedut-vseukrainske-doslidzhennya-schodo-poshirenosti-covid-19

6.2.6. Comparison with the BD testing results in other countries

For the purpose of comparison, we selected the studies provided that their time frames allowed comparing their results with the results of BD testing in the cities of Ukraine. As you can see below, SARS-CoV-2 antibodies seroprevalence rates among the Ukrainian blood donors are higher than those in Sweden, Italy or the United States (the entire country), and may be comparable to those in the regions of Pakistan and South Africa (Table 14).

Table 14. Comparison of SARS-CoV-2 antibodies seroprevalence among BDs in Ukraine with the results of studies in other countries

Countries	Indicators
Pakistan (Karachi province, December 2020 – February 2021) [16]	53.4%
Sweden (Stockholm, February 2021) [17]	19.2%
Italy (South-East, Foggia, February-March 2021) [18]	19%
United States (all states, May 2021) [19]	20.2%
South Africa (January-May 2021) [20]	47.4%
Ukraine (April-October 2021)	45.5%

6.2.7. SARS-CoV-2 antibodies seroprevalence among BDs depending on age and gender

The study among BDs shows that the presence of SARS-CoV-2 antibodies in BDs does not depend on the age of respondents (Table 15). Based on the chi-square test, seroprevalence is not statistically significantly related to age (significance level 0.405).

Table 15. SARS-CoV-2 antibodies seroprevalence in BDs from different age groups

Age groups (years)	Negative test result	Positive test result
18-19	54,7%	45,3%
20-24	55,7%	44,3%
25-29	53,7%	46,3%
30-34	57,4%	42,6%
35-39	52,5%	47,5%
40-44	54,7%	45,3%
45-49	52,0%	48,0%
50-54	55,7%	44,3%
55-59	52,6%	47,4%
60-64	41,4%	58,6%

However, our data show that the presence of SARS-CoV-2 antibodies in BDs depends on the gender. Based on the chi-square test and Fisher's exact test, SARS-CoV-2 antibodies seroprevalence among BDs is statistically significantly related to gender (significance level 0.000): seroprevalence level among women is higher (Table 16).

Table 16. SARS-CoV-2 antibodies seroprevalence among men and women

Gender	Negative test result	Positive test result
Male	57.2%	42.8%
Female	48.7%	51.3%

6.2.8. Difference in seroprevalence of SARS-CoV-2 antibodies among healthcare and non-healthcare workers

Based on the chi-square test and Fisher's exact test, seroprevalence of SARS-CoV-2 antibodies among BDs is not statistically significantly related to the fact if a person works in health care (significance level 0.992 for the chi-square test and 0.953 for the Fisher's test).

Table 17. SARS-CoV-2 antibodies seroprevalence among healthcare workers and non-healthcare workers

Professional status	Negative test result	Positive test result
Non-healthcare workers	54.5%	45.5%
Healthcare workers	54.8%	45.2%

6.3. Presence of SARS-CoV-2 antibodies among BDs depending on blood type

Distribution of donors by blood type corresponds to data on the Ukrainian population in general. Among donors with blood type O (I), there are relatively fewer positive results of testing for SARS-CoV-2 antibodies, with the highest results reported among donors with blood type AB (IV) (Table 18).

Based on the chi-square criterion, SARS-CoV-2 antibodies seroprevalence is statistically significantly related to the blood type (significance level 0.006).

Table 18. SARS-CoV-2 antibodies seroprevalence depending on blood type

Blood types	Share among tested BDs	Negative test result	Positive test result
O (I)	33	57,3%	42,7%
A (II)	38	53,8%	46,2%
B (III)	19	54,0%	46,0%
AB (IV)	9	48,2%	51,8%

At the same time, the survey showed that there was almost the same level of BDs with different blood types reporting the experience of acute respiratory infections and/or COVID-19 in 2020–2021, with no statistically significant difference based on the chi-square test (Tables 19, 20).

Table 19. Experience of COVID-19 in 2020–2021 (based on the survey among BDs)

Blood types	Have you had COVID-19?		Laboratory-confirmed COVID-19 diagnosis
	No	Yes	
O (I)	88,0%	12,0%	9,8%
A (II)	87,2%	12,8%	10,4%
AB (IV)	87,1%	12,9%	11,7%
B (III)	87,8%	12,2%	10,2%
Всього	87,5%	12,5%	10,3%

Table 20. Experience of an acute respiratory disease in 2020–2021 (based on the survey among BDs)

Blood types	Have you had an acute respiratory disease?	
	No	Yes
O (I)	84,6%	15,4%
A (II)	87,0%	13,0%
AB (IV)	83,9%	16,1%
B (III)	84,2%	15,8%
Всього	85,4%	14,6%

Summary analysis of the data in tables 19–20 suggests that BDs with blood type AB (IV) were more likely to have asymptomatic COVID-19.

It should be noted that in publications there is no single point of view on the linkage between COVID-19 progression and blood type. Thus, a study [21] showed that among patients with COVID-19 most people had blood type A (II) (57%), followed by blood type O (I) (24.8%). Authors of the study [22] state that most researchers believe that blood type O (I) is associated with a lower risk of developing COVID-19. Another study demonstrated a significant correlation between the increase in COVID-19 morbidity and mortality and the share of the population with blood type A (II) [23].

6.4. Experience of an acute respiratory disease and/or COVID-19 among BDs based on the survey results

Based on the study protocol, blood donors answered the following questions within the survey:

- *Have you had an acute respiratory disease in 2020–2021? If yes, please approximately indicate month and year.*
- *Have you had a laboratory test for COVID-19? If yes, please approximately indicate month and year; test type (PCR or test for antibodies); result (positive or negative).*
- *Have you had COVID-19? If yes, please approximately indicate month and year.*
- *(if you had COVID-19) Did you seek medical care?*
- *(if you sought medical care) Did you receive inpatient or outpatient treatment?*
- *(if you sought medical care) Did your doctor refer you for COVID-19 laboratory testing?*
- *(if you were referred for laboratory testing) Was your COVID-19 diagnosis confirmed by laboratory testing?*
- *(if the diagnosis was confirmed with laboratory testing) What was the method used to confirm the diagnosis: PCR, rapid test for antigen, test for antibodies?*

The responses were used in particular to measure the share of donors with persistent antibodies after confirmed COVID-19 depending on the time elapsed after the disease; the share of donors who had asymptomatic COVID-19; and to identify if antibody persistence was related to the severity of the disease.

In this section, indicators were calculated without age or gender weighting. The numbers are presented for the whole period of study for all five cities. Chi-square test and Fisher's exact test were used to determine the statistical significance of differences in SARS-CoV-2 antibodies seroprevalence among BDs with different acute respiratory disease and/or COVID-19 experience.

6.4.1. Experience of an acute respiratory disease in BDs

14.6% of BDs reported having an acute respiratory disease in 2020–2021. 2.1% of BDs (or 14.6% of those who had an acute respiratory disease) were sick during 3 months, 6.7% (46.0%) — during 4–6 months, and 5.8% (39.5%) — during 6 months before the study.

Based on the chi-square test and Fisher's exact test, SARS-CoV-2 antibodies seroprevalence was statistically significantly associated with having an acute respiratory disease (significance level 0.000 for both tests): seroprevalence was higher among those who had an acute respiratory disease. SARS-CoV-2 antibodies were detected in 58.1% of those who had an acute respiratory disease in 2020–2021 and in 43.4% of those who denied having any acute respiratory diseases (Table 21). With certain assumptions, this number can be considered an estimate of the asymptomatic COVID-19 cases.

Table 21. Detection of SARS-CoV-2 antibodies depending on the experience of an acute respiratory disease

Groups	Positive test result	Negative test result
Had an acute respiratory disease in 2020-2021	58.1%	41.9%
Did not have an acute respiratory disease in 2020-2021	43.4%	56.6%

6.4.2. Experience of COVID-19 in BDs

12.5% of BDs reported having COVID-19 in 2020–2021. This number does not take into account if the diagnosis was confirmed with laboratory testing.

Overall, 21.5% of BDs reported having an acute respiratory disease, COVID-19 or both in 2020–2021. 9.1% of blood donors said that they had only an acute respiratory disease, 6.9% — only COVID-19, and 5.5% said that they had both (Table 22). 37.6% of those who had an acute respiratory disease thought they had COVID-19 and 62.4% thought they did not.

Table 22. The share of those who had an experience of an acute respiratory disease or COVID-19

Groups of blood donors	Had COVID-19 in 2020-2021	Did not have COVID-19 in 2020-2021	Total
Had an acute respiratory disease in 2020-2021	5.5%	9.1%	14.6%
Did not have an acute respiratory disease in 2020-2021	6.9%	78.4%	85.4%
Total	12.5%	87.5%	100.0%

Based on the chi-square test and Fisher's exact test, SARS-CoV-2 antibodies seroprevalence is statistically significantly associated with having COVID-19 (significance level 0.000 for both tests): SARS-CoV-2 antibodies seroprevalence among those who thought they had COVID-19 was higher. SARS-CoV-2 antibodies were detected in 70.6% of those who reported having COVID-19 in 2020–2021 based on to the results of testing during blood donation. Meanwhile, SARS-CoV-2 antibodies were detected in 41.9% of those who denied having COVID-19 (Table 23).

Table 23. Detection of SARS-CoV-2 antibodies depending on the experience of COVID-19

Groups of blood donors	Positive test result	Negative test result
Had COVID-19 in 2020-2021	70.6%	29.4%
Did not have COVID-19 in 2020-2021	41.9%	58.1%
Total	45.5%	54.3%

6.4.3. Laboratory confirmed COVID-19 cases in BDs based on the survey results

23.8% of BDs reported being tested for COVID-19 before participating in the study. In particular, 10.4% reported that they were referred for testing by their doctor.

12.4% of BDs reported testing positive for COVID-19 with PCR, rapid SARS-CoV-2 antigen or antibody tests. Excluding those who tested positive for antibodies, 10.3% had laboratory confirmed COVID-19.

2.1% of BDs (or 20.7% of those who reported having COVID-19) had laboratory confirmed COVID-19 diagnosis with PCR or SARS-CoV-2 antigen test during 3 months, 3.9% (37.6%) — 4–6 months, 4.3% (41.7%) — over 6 months before the study. It is not possible to determine the approximate time of the disease for those who previously tested positive for SARS-CoV-2 antibodies, as only the date of their testing is known.

Based on the chi-square test and Fisher's exact test, SARS-CoV-2 antibodies seroprevalence is statistically significantly associated with laboratory confirmed COVID-19 (significance level 0.000 for both tests): SARS-CoV-2 antibodies were detected in 70.4% of those who reported having COVID-19 in 2020–2021 based on to the results of testing during blood donation (Table 24). However, 29.6% tested negatively for antibodies during blood donation, which shows a decrease in the level of antibodies in some people over time. Meanwhile, SARS-CoV-2 antibodies were detected in 42.7% of those who denied having COVID-19.

Table 24. Detection of SARS-CoV-2 antibodies depending on the laboratory confirmed COVID-19 diagnosis in the past

Groups of blood donors	Positive test result	Negative test result
Had laboratory confirmed COVID-19 in 2020-2021	70.4%	29.6%
Did not have laboratory confirmed COVID-19 in 2020-2021	42.7%	57.3%

SARS-CoV-2 antibodies were detected in 81.3% of BDs who reported laboratory-confirmed COVID-19 with a PCR or an antigen test during 3 months before the study (Table 25). Thus, almost one in five donors who reported laboratory-confirmed COVID-19 no more than 3 months before testing had no antibodies to SARS-CoV-2.

Table 25. Detection of SARS-CoV-2 antibodies depending on the time elapsed after laboratory-confirmed COVID-19

Groups of blood donors	SARS-CoV-2 antibodies detected	
	Absolute number	**%**
Laboratory confirmed COVID-19 **0-3 months** before donation	112	81.3
Laboratory confirmed COVID-19 **4-6 months** before donation	203	65.5
Laboratory confirmed COVID-19 **7-9 months** before donation	174	67,2
Laboratory confirmed COVID-19 **10-12 months** before donation	42	78,6
Laboratory confirmed COVID-19 **over 13 months** before donation	9	77,8
Total	**540**	**70,6**

After 3 months since the laboratory confirmation, the probability to detect SARS-CoV-2 antibodies slightly decreased. Only 65.5% of those who had laboratory-confirmed COVID-19 4–6 months before the study had antibodies detected during blood donation, while the share of people with antibodies detected increased slightly in people who had COVID-19 7–9 and 10–12 months before the study. It could be interpreted as the so-called "natural booster immunization" through contacts with people with COVID-19 or virus carriers, however due to the small sample of people, who had COVID-19 10–12 months or more before the study, such conclusions may be premature. If we only look at two intervals — 0–3 months and more than 3 months — the chi-square criterion and Fisher's exact criterion are statistically significant.

6.4.4. Seeking medical care with COVID-19 and disease progression

One of the study objectives was to establish the frequency of people with suspected COVID-19 seeking medical care. Among the BDs who reported having COVID-19, 83.3% visited a doctor. Thus, one in six (16.7%) respondents among those who considered they were sick did not seek any medical care. Among those with laboratory confirmation of COVID-19 with a PCR or an antigen test, 89.6% sought medical care and 10.4% did not. Thus, when people received a laboratory confirmation it prompted them to seek medical care.

82.3% of those who had laboratory-confirmed COVID-19 with a PCR or an antigen test received outpatient care and 17.7% — inpatient care. Based on the chi-square test and Fisher's exact test, seroprevalence of SARS-CoV-2 antibodies was statistically significantly related to whether the respondent received inpatient or outpatient care for COVID-19 (significance level 0.034 for chi-square test and 0.037 for Fisher's exact test): seroprevalence among those who received outpatient treatment for COVID-19 was higher than among those who were treated in hospitals — 72.5% and 61.5%, respectively (Table 26). At first sight, it may seem that people with more severe disease progression were slightly less likely to retain antibodies by the time of testing.

Table 26. Correlation between the detection of SARS-CoV-2 antibodies and the experience of COVID-19 treatment

Treatment type	SARS-CoV-2 antibodies detected	SARS-CoV-2 antibodies not detected
Outpatient treatment	72.4%	27.6%
Inpatient treatment	61.5%	38.5%

However, there might be another possible explanation: a person who experienced a more severe form of COVID-19 (received inpatient treatment) will donate blood later than a person who experienced a milder progression of COVID-19 and received outpatient treatment. So, we calculated the average time interval from the disease to the blood donation for BDs who received inpatient and outpatient treatment (Table 27).

Table 27. Average time from COVID-19 to BD testing for SARS-CoV-2 antibodies

Groups of blood donors	Interval from disease to donation (months)
Outpatient treatment	5.9
Inpatient treatment	6.4

Respondents who received inpatient treatment donated blood on average 2 weeks later than those who received outpatient treatment. However, the difference was not statistically significant (significance level 0.086), which may be related to the relatively small number of blood donors who received inpatient treatment — 63 people. The conclusion about a higher seroprevalence rate among people who received outpatient treatment requires further exploration.

Another study objective was to estimate the proportion of clinical and asymptomatic forms of COVID-19 in BDs. To achieve this objective, we performed the following calculations. During the study period, SARS-CoV-2 antibodies were detected in 2,391 BDs; 424 of them received treatment for COVID-19 (and had a laboratory-confirmed diagnosis): 63 received inpatient treatment and 361 — outpatient treatment. Among the BDs who tested positive for SARS-CoV-2 antibodies, 1,967 people experienced asymptomatic or mild forms of COVID-19, which did not require medical care (82.3%), while 361 BDs who received outpatient treatment (15.1%) had moderate or mild form of the disease requiring medical care; and severe forms of COVID-19 requiring inpatient treatment were reported in 2.6% of cases. Thus, the ratio of asymptomatic and clinical forms of COVID-19 in the target group of BDs is 4.6, so for every one clinical form of the disease there are about 5 asymptomatic cases.

6.4.5. Data from other studies

According to the national study[4], the overall seroprevalence in the adult population of Ukraine is 40.4% — this number can be viewed as the lower limit of the number of people infected with SARS-CoV-2 since the start of the pandemic. In Poltava region, this indicator was 31.3%, in Zhytomyr region — 39.1%, in Ternopil region — 44.0%, in Zakarpattia region — 48.1%, and in Vinnytsia region — 50.2%.

As for the testing coverage, 30.6% of the respondents reported having a PCR test, 8.6% — testing for antibodies (with the responses not being mutually exclusive). Only 27.4% of those with SARS-CoV-2 antibodies had previously received a laboratory confirmation of COVID-19. Overall, 15.1% of the adult population of Ukraine had ever received a laboratory confirmation of COVID-19, with 73.5% retaining antibodies at the time of the study: both indicators are close to those received in our study among BDs.

According to the national study, 21.8% of the adult population of Ukraine believe that they had COVID-19 (had a positive PCR test result or were diagnosed in an unspecified manner). Besides, from March 1, 2020 to June-July 2021 (when the survey and the blood sampling took place), 8.4% had pneumonia, 6.1% — influenza, and 33.7% — an acute respiratory disease. These numbers are much higher than those received in the study of blood donors.

On April 13–15, 2021, Kyiv International Institute of Sociology (KIIS) conducted a national public opinion poll using the CATI methodology[5]. The sample was representative of the adult population of Ukraine (except for the territories temporarily not controlled by the Ukrainian government). Based on the survey, 29.1% of Ukrainians consider that they had COVID-19: 16.9% were tested, 12.0% had typical symptoms (another 0.2% did not specify how they established their diagnosis).

In March 2021, Rating Sociological Group conducted a CATI survey representative of the adult population of Ukraine (except for the territories temporarily not controlled by the Ukrainian government)[6]. According to the survey results, 24% of the respondents considered they had COVID-19. Among those who thought they had the disease, half tested positive for COVID-19, almost as many had symptoms but did not test. Among those who had COVID-19, 42% had a mild disease, 45% — moderate and 13% — severe.

The lower share of those who believe they had COVID-19 among blood donors as compared to the general adult population of Ukraine can potentially indicate a more frequent asymptomatic progression of the disease among relatively healthy people aged 18 to 60 years.

4 More detailed information about the study can be found at https://phc.org.ua/news/v-ukraini-vpershe-provedut-vseukrainske-doslidzhennya-schodo-poshirenosti-covid-19

5 https://www.kiis.com.ua/?lang=ukr&cat=reports&id=1032&page=8

6 https://ratinggroup.ua/research/ukraine/vakcinaciya_v_ukraine_barery_i_vozmozhnosti_18-19_marta_2021.html

Conclusions

1. The share of blood donors who had SARS-CoV-2 antibodies significantly differed in various regions of Ukraine and ranged from 63.1% (58.2–66.3%) in Zhytomyr to 43.5% (40.5–44.5%) in Poltava and 25.8% (22.1–27.2%) in Uzhhorod.

2. No age-related differences were established in the detection of SARS-CoV-2 antibodies among BDs.

3. Seroprevalence of SARS-CoV-2 antibodies among BDs is statistically significantly related to gender: seroprevalence among women was 51.3%, among men — 42.8%.

4. In most regions, there was no linkage between the official COVID-19 incidence rates and SARS-CoV-2 antibody detection rates among BDs.

5. SARS-CoV-2 seroprevalence in BDs was not related to the share of healthcare workers, as the study found that there was no difference in the detection of antibodies among healthcare and non-healthcare workers (46% and 45%, respectively).

6. Among those BDs who reported having COVID-19, 83.3% visited a doctor. Thus, one in six (16.7%) respondents among those who considered they were sick did not seek any medical care. Among those with laboratory-confirmed COVID-19, 89.6% sought medical care and 10.4% did not.

7. The estimated ratio of clinical and asymptomatic forms of COVID-19 among BDs with SARS-CoV-2 antibodies was 5:1. Among the BDs who tested positive for SARS-CoV-2 antibodies, 82.3% experienced asymptomatic or mild forms of COVID-19, which did not require medical care; 15.1% had moderate or mild forms of the disease requiring medical care; and severe forms of COVID-19 requiring inpatient treatment were reported in 2.6% of cases.

8. After 3 months since the laboratory confirmation, the probability to detect SARS-CoV-2 antibodies decreased. Among those who had laboratory-confirmed COVID-19 three months prior to testing during blood donation, SARS-CoV-2 antibodies were detected in 81.3% of cases; 4–6 months — 65.5%; 7–9 months — 67.2%; 10–12 months — 78.6%. Meanwhile, only two intervals — under 3 months and over 3 months — were statistically significant based on the chi-square test and Fisher's exact test.

9. Seroprevalence of SARS-CoV-2 antibodies was statistically significantly associated with having an acute respiratory disease. SARS-CoV-2 antibodies were detected in 51.3% of those who had an acute respiratory disease in 2020–2021 and in 42.8% of those who did not. The latter number can be roughly viewed as the rate of asymptomatic COVID-19 cases.

10. There is a linkage between the blood type and the detection of SARS-CoV-2 antibodies. Seroprevalence in BDs with blood type AB (IV) was the highest (51.8%), and with blood type O (I) was the lowest (42.7%), with a statistically significant difference. However, the incidence of acute respiratory infections and/or COVID-19 in 2020–2021 did not differ significantly among people with different blood types, which may indicate the prevalence of asymptomatic forms of COVID-19 in people with blood type AB (IV).

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