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# ANALYSIS OF THE PREVALENCE OF ANTI-SARS-CoV-2 ANTIBODIES IN GROUPS OF MEDICAL AND NON-MEDICAL PROFESSIONS

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**Abstract**
**Objectives:** The assessment of the prevalence of anti-SARS-CoV-2 antibodies in various professional groups is very important. Hence, the purpose of the following study was to analyze the seroprevalence of anti-SARS-CoV-2 antibodies among employees performing both medical and non-medical professions before the launch of SARS-CoV-2 vaccination. **Material and Methods:** The study was conducted among employers of 1 of the institutions: The Provincial Specialist Hospital of Władysław Biegański in Łódź, Poland, Radio Łódź and the Border Guards of Łódź Airport. Blood samples were collected in December 2020–February 2021. Patients were screened for the presence of SARS-CoV-2 antibodies. Simultaneously respondents were asked to complete a self-designed questionnaire including demographic data, detailed profession, history of SARS-CoV-2 infection and willingness to be vaccinated against COVID-19. **Results:** A total of 659 people were included in the study. The presence of anti-SARS-CoV-2 antibodies was found in 26.1% (N = 172) of the subjects. Seroprevalence was significantly higher in the group of rural residents ($p < 0.012$), participants who declared previous COVID-19 infection ($p < 0.001$) and healthcare workers (HCWs) ($p = 0.002$), especially nurses (35.5%, $p = 0.003$) and medics worked in areas dedicated to COVID-19 than in other specialties (38.7% vs. 26.8%, respectively, $p = 0.017$). There was no association between the presence of antibodies and the gender ($p = 0.118$), age ($p = 0.559$) or BMI ($p = 0.998$). **Conclusions:** Healthcare workers, in particular nurses, are at high risk of contracting COVID-19 in the workplace. Occupational infections can occur during occur not only during contact with the patient, but also with members of the medical team who do not show typical symptoms of the disease. Shortages in medical staff may also increase the number of infections among HCWs. Medical and hospital staff providing health services during the COVID-19 epidemic in Poland, may seek compensation in the event of consequences related to SARS-CoV-2 infection. The effectiveness of education and self-discipline in complying to safety rules among HCWs should also be constantly monitored. Int J Occup Med Environ Health. 2023;36(5):643–55

**Key words:**
**seroprevalence, exposure, occupational risk, COVID-19, healthcare workers, anti-SARS-CoV-2 antibodies**

## INTRODUCTION

According to the World Health Organization (WHO), by December 14, 2022, over 640 million cases of COVID-19 infection were diagnosed worldwide, of which nearly 6.6 million ended in death [1]. Research shows that in about 20–30% of patients COVID-19 infection is asymptomatic, and when the symptoms do occur, most cases are mild [2]. A severe course is observed in 15% of patients, while very severe, requiring mechanical ventilation with a ventilator, in about 5% [3]. Therefore, it can be suspected that a significant part of the population undergoes the disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) unknowingly [3].

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Serological tests are an effective tool for estimating the percentage of population previously infected with a specific pathogen, determining its prevalence in a given area and estimating mortality due to the infection it causes [4]. Testing for the presence of antibodies can be an important tool in the surveillance of the epidemic and in assessing the degree of possible herd immunity in particular areas or groups of people [5].

The structure of the new SARS-CoV-2 strain includes 4 structural proteins: spike protein (S), nucleocapsid protein (N), envelope protein (E) and membrane protein (M) [6]. Protein S and N have immunogenic properties [6].

The surface glycoprotein (S) forming the characteristic "spikes" on the surface of the virus envelope contains 2 subunits: S1 and S2 [8]. The first of them – S1– initiates infection through the association of the virion with the host cell membrane by binding to the receptor protein for angiotensin converting enzyme 2 (ACE2) [8]. The binding of S1 to the ACE2 receptor takes place in the region of the S1 spike called the receptor binding domain (RBD). This process is a key stage of infection with the SARS-CoV-2 virus [9].

Antibodies against S protein can target various epitopes, i.e., fragments of the antigen that directly bind to the free antibody, B cell receptor or T cell receptor [10]. Those that target the RBD domain have a neutralizing antibody (NAb), i.e., they are able to inactivate viruses, which results in developing immunity against infection [9]. Studies have reported that some antibodies targeted against the S1 subunit (but not against RBD) may also have this feature, but their potency and ability to inhibit viral association are believed to be low [11].

Antibodies against N protein have been shown to appear earlier than anti-S antibodies, therefore they can increase clinical sensitivity of the test in patients with mild COVID-19 disease who have a primary absence or weaker antibody response, but also when samples are collected at an early stage of the disease [12]. Consequently, in order to avoid false-negative results, it is recommended to detect the presence of antibodies against 2 different SARS-CoV-2 antigens in the blood serum [13].

Given the fact that the first vaccination against SARS-CoV-2 infection was introduced in Poland at the turn of December 2020 and January 2021, the results of studies evaluating the seroprevalence of anti-SARS-CoV-2 antibodies before this period may indicate with high accuracy the percentage of people that have acquired immunity through natural infection with this virus [5]. It is particularly important to assess the prevalence of anti-SARS-CoV-2 antibodies in various professional groups, especially in the environment of people working in healthcare, who are believed to be at high risk due to exposure to close contact with patients suffering from COVID-19 [14]. Hence, the purpose of the following study was to analyze the seroprevalence of anti-SARS-CoV-2 antibodies among employees performing both medical and non-medical professions before the launch of SARS-CoV-2 vaccination.

## MATERIAL AND METHODS

### Study design

The survey was conducted among people employed in 1 of the institutions: The Provincial Specialist Hospital of Dr. Władysław Biegański in Łódź, Radio Łódź, the Border Guards of the Airport in Łódź, Poland. The employees were invited to self-register for a test for the presence of anti-SARS-CoV-2 antibodies. Messages about the commencement of the above-mentioned screening program were sent through the heads of the organization departments of the above-mentioned institutions. The inclusion criteria were current employment in 1 of the 3 listed workplaces and the approval to sign relevant documents, including the Informed Consent Form for participation in the project. The exclusion criterion was failure to meet any of the above conditions. Control group was not created. The project was approved by the Bioethics Committee at the Medical University of Lodz (December 15, 2020).

Blood samples were collected in accordance with relevant guidelines and regulations in December 16, 2020–February 9, 2021. Simultaneously, respondents were asked to complete a self-designed questionnaire consisting of questions related to age (20–30, 31–40, 41–50, 51–60 years old), sex (female/male), height, weight, place of residence (rural/urban), profession (medical/non-medical) with detailed position of work (doctor, nurse, paramedic, laboratory diagnostician, other: what?), history of previous SARS-CoV-2 infections confirmed by real-time polymerase chain reaction (RT-PCR) or an antigen test (yes – when?/no) and willingness to be vaccinated against COVID-19 (yes/no/doesn't know).

**Laboratory tests**

Blood samples were tested at the Laboratory Diagnostics Department of the Provincial Specialist Hospital of Dr. Władysław Biegański in Łódź, Poland, using 1 of 2 immunological tests:

– Elecsys Anti-SARS-CoV-2, on the cobas 6000 analyzer (Roche, Indianapolis, USA), by the electrochemiluminescence immunoassay (ECLIA) method. This test uses a recombinant protein representing the N antigen and enables the qualitative detection of SARS-CoV-2 antibodies in human serum and plasma. Interpretation of the results is presented in Table 1.
– Elecsys Anti-SARS-CoV-2 S, on the cobas 6000 analyzer from Roche, by the ECLIA method. This test uses a recombinant protein representing the RBD of the S antigen of the virus and gives the possibility of quantitative detection of antibodies in the blood of the host with high affinity for SARS-CoV-2. Interpretation of the results is presented in Table 1.

**Statistical analysis**

The collected data were organized and graphically processed in Microsoft Excel. Statistical analysis was carried out in the Statistica 10.0 package by StatSoft. The analysis was designed to test the relationship between qualitative and nominal variables and serological status of the patient. For this purpose, the $\chi^2$ test was used. If the assumptions of the $\chi^2$ test were not met, Fisher's exact test with expansion for R×C tables (>2×2) was applied. The result of the statistical test was the so-called test probability (p), the low values of which testified to the statistical significance of the considered differences. In all analyzes the significance level of $p = 0.05$ was adopted. Accordingly, the results of $p < 0.05$ allow one to conclude that there are statistically significant relationships between the variables.

## RESULTS

A total of 659 people were included in the study. Men constituted 23.5% (N = 155) of the study population and women 76.5% (N = 504). The average age in the analyzed group was 45.6 years and the range was 20–73 years. Of all participants, 573 (86.9%) came from urban areas.

**Table 1.** Interpretation of the results of the test for antibodies against the SARS-CoV-2 nucleocapsid protein [15] and spike protein [16]

| Variable | Result | Interpretation |
|---|---|---|
| Nucleocapsid protein (cutoff index) | | |
| <1.0 | non-reactive | negative for anti-SARS-CoV-2 antibodies |
| ≥1.0 | reactive | positive for anti-SARS-CoV-2 antibodies |
| Spike protein | | |
| <0.80 u/ml | non-reactive | negative for anti-SARS-CoV-2 S antibodies |
| ≥0.80 u/ml | reactive | positive for anti-SARS-CoV-2 S antibodies |

The mean body mass index (BMI) was 26.0 kg/m$^2$ and in 45.7% of the respondents it remained within the normal range (BMI 18.5–24.9). Among all respondents, 61.2% (N = 403) represented medical professions, i.e., doctors (N = 82), nurses (N = 265) and other healthcare personnel (medical assistant, perfusionist, physiotherapist, pharmacist, medical analyst, electrocardiologist, N = 56). The remaining participants (38.8%, N = 256) had non-medical professions: journalists (N = 44), border guard officers (N = 50), administrative workers and secretaries (N = 118), economic workers (N = 18), technical workers (N = 26). Out of all HCWs 29.5% (N = 119) worked in departments dedicated to COVID-19 and the rest (N = 284, 70.5%) was employed on other hospital wards.

History of COVID-19 infection confirmed by RT-PCR or antigen test was reported by 90 subjects (73 in the group of medical workers and 17 in the group of non-medical workers). Most of the study population (67.8%, N = 447) declared willingness to be vaccinated against SARS-CoV-2; only 11.4% (N = 75) did not make a decision at the time of the study. About one fifth of the respondents (20.8%, N = 137) did not want to be vaccinated. The characteristics of the study group is presented in Table 2.

Seventy five patients were screened for the presence of anti-S antibodies and the rest had anti-N antibodies assessed. There were no subjects who had both tests performed. The presence of antibodies against the N or S protein of the virus was found in a total of 26.1% (N = 172) of the subjects. There was no association between the presence of antibodies and gender (27.6% among women vs. 21.3% among men, p = 0.118) nor age of the subjects tested (p = 0.559). Seroprevalence was not significantly different according to BMI and ranged 16.7–30% (p = 0.998). After dividing the study population into subgroups in relation to the place of residence, a positive titer of anti-SARS-CoV-2 antibodies was found in 24.4% of urban residents and in 37.2% of rural residents (p = 0.012). Seropositivity was reported in 87.8% of patients who declared previous COVID-19 disease and in 16.3% of patients who did not report having been infected (p < 0.001) (Table 3).

Medics accounted for 70.9% (N = 122) of all seropositive respondents (N = 172), and non-medics accounted for 29.1% (N = 50). Among people performing medical professions, anti-SARS-CoV-2 antibodies were detected in 30.3% (N = 122), while in the group of non-medical professions the percentage of positive antibodies was 19.5% (N = 50) (p = 0.002). A higher percentage of seropositive medics recruited in the study worked in areas dedicated to COVID-19 (infectious diseases), than in other departments (38.7% vs. 26.8%, respectively) and the difference was statistically significant (p = 0.017) (Table 4). The lowest seroprevalence was observed in the Intensive Care Unit (ICU). There were no people with positive results for the presence of antibodies among the medical staff of the laboratory and the hospital pharmacy. Moreover antibodies against SARS-CoV-2 were detected significantly more often in nurses (35.5%, p = 0.003) compared to doctor (15.9%) and other medical professions (26.8%) (Figure 1, Table 4). Among all medics who did not report previous SARS-CoV-2 infection (N = 330), 17.9% (N = 59) had positive titer of anti-SARS-CoV-2 antibodies, while in the case of people performing non-medical professions with negative history of COVID-19 infection (N = 239), this rate was 14.2% (N = 34) (p = 0.294).

## DISCUSSION

The results of this research carried out just before the rollout of vaccination against SARS-CoV-2 showed that 26.1% of respondents tested positive for anti-SARS-CoV-2 antibodies, of which 70.9% were medics and 29.1% were non-medics. Analyzing the above data more precisely, it can be concluded that seropositivity among medical professions was significantly higher compared to non-medical ones (30.3% vs. 19.5%, p = 0.002), analogous to the results reported by many other authors [17]. In December 2020 Rosińska et al. [5] conducted an analysis of anti-CARS-CoV-2

**Table 2.** Baseline characteristics of the study population of employers of The Provincial Specialist Hospital of Dr. Władysław Biegański in Łódź, Radio Łódź, and the Border Guards of the Airport in Łódź, Poland

| Variable | Paticipants (N = 659) |
|---|---|
| Sex [n (%)] | |
| female | 504 (76.5) |
| male | 155 (23.5) |
| Age [years] (M (range)) | 45.6 (20–73) |
| group [n (%)] | |
| 20–30 years | 73 (11.1) |
| 31–40 years | 136 (20.7) |
| 41–50 years | 213 (32.3) |
| 51–60 years | 182 (27.6) |
| >60 years | 55 (8.3) |
| BMI [kg/m$^2$] (M (range)) | 26.0 (17.0 – 48.2) |
| group [n (%)] | |
| underweight | 8 (1.2) |
| correct body weight | 301 (45.7) |
| overweight | 232 (35.2) |
| obesity | |
| first degree | 92 (13.9) |
| second degree | 20 (3.0) |
| third degree | 6 (1.0) |
| Place of residence [n (%)] | |
| urban | 573 (86.9) |
| rural | 86 (13.1) |
| Profession [n (%)] | |
| medical | 403 (61.2) |
| nurse | 265 (40.2) |
| doctor | 82 (12.4) |
| other | 56 (8.5) |
| non-medical | 256 (38.8) |
| journalist | 44 (6.7) |
| border guard officer | 50 (7.6) |
| administrative workers and secretaries | 118 (17.9) |
| economic workers | 18 (2.7) |
| technical worker | 26 (3.9) |
| Workplace [n (%)] | |
| Hospital of Dr. Władysław Biegański in Łódź | 514 (78.0) |
| COVID-19 departments | 119 (18.1) |
| other wards | 284 (43.1) |
| medical imaging | 7 (1.1) |
| cardiac surgery | 44 (6.7) |
| cardiology | 74 (11.2) |
| internal diseases | 75 (11.4) |
| anesthesiology and intensive care | 22 (3.3) |
| dermatology | 27 (4.1) |
| outpatient clinic | 18 (2.7) |
| hospital pharmacy | 12 (18.2) |
| laboratory | 5 (0.8) |
| economic department | 18 (2.7) |
| technical department | 26 (3.9) |
| administration | 67 (10.2) |
| Border Guards of the Airport in Łódź | 75 (11.4) |
| Radio Łódź | 70 (10.6) |
| History of diagnosed SARS-CoV-2 infection (positive RT-PCR test or antigen test) [n (%)] | |
| yes | 90 (13.7) |
| medical workers | 73 (18.1) |
| non-medical workers | 17 (6.6) |
| no | 569 (86.3) |
| medical workers | 330 (81.9) |
| non-medical workers | 239 (93.4) |
| Willingness to vaccinate against SARS-CoV-2 [n (%)] | |
| yes | 447 (67.8) |
| no | 137 (20.8) |
| doesn't know | 75 (11.4) |

RT-PCR – real-time polymerase chain reaction; SARS-CoV-2 – severe acute respiratory syndrome coronavirus.

antibodies prevalence in several Polish hospitals and in the general population. At that time 22% of tests proved to be positive. Seropositivity of medics was higher compared to the general population (25.0% vs. 16.5%). Similar

**Table 3.** Prevalence of anti-SARS-CoV-2 antibodies according to baseline characteristics of the study population of employers of The Provincial Specialist Hospital of Dr. Władysław Biegański in Łódź, Radio Łódź, and the Border Guards of the Airport in Łódź, Poland

| Variable | Participants (N = 659) [n (%)] | | p |
|---|---|---|---|
| | anti-SARS-CoV-2 antibodies positive (N = 172) | anti-SARS-CoV-2 antibodies negative (N = 487) | |
| Sex | | | 0.118 |
| female | 139 (27.6) | 365 (72.4) | |
| male | 33 (21.3) | 122 (78.7) | |
| Age | | | 0.559 |
| 20–30 years | 20 (27.4) | 53 (72.6) | |
| 31–40 years | 32 (23.5) | 104 (76.5) | |
| 41–50 years | 63 (29.6) | 150(70.4) | |
| 51–60 years | 46 (25.3) | 136 (74.7) | |
| >60 years | 11 (20.0) | 44 (80.0) | |
| BMI | | | 0.998 |
| underweight | 2 (25.0) | 6 (75.0) | |
| correct body weight | 77 (25.6) | 224 (74.4) | |
| overweight | 61 (26.3) | 171 (73.7) | |
| obesity | | | |
| first degree | 25 (27.2) | 67 (72.8) | |
| second degree | 6 (30.0) | 14 (70.0) | |
| third degree | 1 (16.7) | 5 (83.3) | |
| Place of residence | | | 0.012 |
| urban | 140 (24.4) | 433 (75.6) | |
| rural | 32 (37.2) | 54 (62.8) | |
| Profession | | | 0.002* |
| medical | 122 (30.3) | 281 (69.7) | |
| nurse | 94 (35.5) | 171 (64.5) | |
| doctor | 13 (15.9) | 69 (84.1) | |
| other | 15 (26.8) | 41 (73.2) | |
| non-medical | 50 (19.5) | 206 (80.5) | |
| journalist | 4 (9.1) | 40 (90.9) | |
| border guard officer | 13 (26.0) | 37 (74.0) | |
| administrative workers and secretaries | 23 (19.5) | 95 (80.5) | |
| economic worker | 5 (27.8) | 13 (72.2) | |
| technical worker | 5 (19.2) | 21 (80.8) | |

**Table 3.** Prevalence of anti-SARS-CoV-2 antibodies according to baseline characteristics of the study population of employers of The Provincial Specialist Hospital of Dr. Władysław Biegański in Łódź, Radio Łódź, and the Border Guards of the Airport in Łódź, Poland – cont.

| Variable | Participants (N = 659) [n (%)] | | p |
|---|---|---|---|
| | anti-SARS-CoV-2 antibodies positive (N = 172) | anti-SARS-CoV-2 antibodies negative (N = 487) | |
| History of diagnosed SARS-CoV-2 infection (positive RT-PCR test or antigen test) | | | <0.001 |
| yes | 79 (87.8) | 11 (12.2) | |
| no | 93 (16.3) | 476 (83.7) | |

RT-PCR – real-time polymerase chain reaction; SARS-CoV-2 – severe acute respiratory syndrome coronavirus.
* p calculated for the comparison between medical vs. non-medical professions.

**Table 4.** Prevalence of anti-SARS-CoV-2 antibodies according to baseline characteristics of the healthcare workers of The Provincial Specialist Hospital of Dr. Władysław Biegański in Łódź, Radio Łódź, and the Border Guards of the Airport in Łódź, Poland

| Variable | Participants (N = 403) [n (%)] | | p |
|---|---|---|---|
| | anti-SARS-CoV-2 antibodies positive (N = 122) | anti-SARS-CoV-2 antibodies negative (N = 281) | |
| Profession | | | 0.003 |
| nurse | 94 (35.5) | 171 (64.5) | |
| doctor | 13 (15.9) | 69 (84.1) | |
| other medical | 15 (26.8) | 41 (73.2) | |
| Workplace | | | 0.017* |
| COVID-19 departments | 46 (38.7) | 73 (61.3) | |
| other hospital wards | 76 (26.8) | 208 (73.2) | |
| medical imaging | 5 (71.4) | 2 (28.6) | |
| cardiac surgery | 14 (31.8) | 30 (68.2) | |
| cardiology | 22 (29.7) | 52 (70.3) | |
| internal diseases | 22 (29.3) | 53 (70.7) | |
| anaesthesiology and intensive care | 4 (18.2) | 18 (81.8) | |
| dermatology | 5 (18.5) | 22 (81.5) | |
| outpatient clinic | 4 (22.2) | 14 (77.8) | |
| hospital pharmacy | 0 (0.0) | 12 (100.0) | |
| laboratory | 0 (0.0) | 5 (100.0) | |

* p calculated for the comparison between personnel employed on COVID-19 vs. other hospital wards.

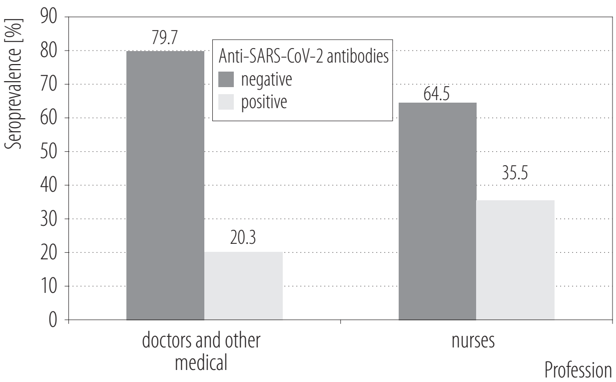


**Figure 1.** Seroprevalence of anti-SARS-CoV-2 antibodies in nurses versus doctors and other medical professions (p = 0.001) employed in The Provincial Specialist Hospital of Dr. Władysław Biegański in Łódź, Poland

results were obtained by Sandri et al. [18] in a study preformed in 7 medical institutions with different exposure to the COVID-19 epidemic in the areas of Lombardy, which was the first area in Europe to be most affected by the pandemic. The seroprevalence in medics reached approx. 11–13% (April–May 2020). The authors also described the higher prevalence of anti-SARS-CoV-2 antibodies in professionals from the Bergamo district (35–43%), compared to other facilities located in the study region (3–9%) and compared to the general population at that time (7.1% in Milan and 30.6% in Bergamo) [19,20]. Allen et al. reported that seroprevalence among HCWs in Ireland (October 2020) was 6 times higher than in the general population in this country [14]. According to Grant et al. [21] members of medical staff in the London NHS Trust were 2 times more likely to have anti-SARS-CoV-2 antibodies compared to the general population (31% vs. 17.5%, May–June 2020), while Mortgat et al. [22] in their multicenter study from 17 Belgian hospitals showed that the prevalence increased during the second wave of the epidemic from 7.7% in April 2020 to 19.7% in December 2020 and was higher than in the general population. Reports on the seropositivity of HCW from other countries at the end of 2020 were as follows: 4.1–15% Ireland (October 2020) [14], 18% Guatemala (November 2020) [23], 17% Kosovo (December 2020) [24].

Moreover, the authors reported that the seropositivity of nurses was the highest of all medical professions and reached 35.5%, which confirmed the hypothesis that this group is significantly more exposed to SARS-CoV-2 infection than doctors and other medical specialties, since a positive result of antibodies was diagnosed in only 15.9% of doctors and in 26.8% of other healthcare personnel. Similar observations concerning higher seroprevalence among nurses than among doctorswere reported by Allen et al. [14] (Ireland, 13% vs. 10%, October 2020), Brousseau et al. [25] (Canada, 11.9% vs. 7.2%, July–September 2020), Papasavas et al. [26] (USA, 8.2% vs. 3.8%, April–August 2020), Kahlert et al. [27] (Switzerland, 3.9% vs. 1.0%, June–August 2020). Only the minority of scientific papers report an increased chance of seropositivity among physicians than among nurses and other medical professions, e.g., Halili et al. [24] (Kosovo) and Mahto et al. [28] (India). These differences might be partly explained by the differences in length of time spent in direct contact with the patients between these 2 occupational groups. In their research Butler et al. [29] observed that nurses spend significantly more time in patients' rooms than doctors (32.9% during the day shift and 32.8% during the night shift for the nurses and 14.7% during day shift and 17.9% during night shift for the doctors). Moreover, it should be noted that the overall seroprevalence among HCWs in the above-mentioned studies is much lower than in the authors' analysis. Since in all of the origin countries the number of medical personnel per 10 000 residents in a given year 2020 was substantially higher than in Poland [30] (Poland: 67.6 nurses/midwives and 37.1 physicians; Ireland: 184.3 and 34.8; Canada: 110.8 and 24.3; USA: 124.7 and 35.5; Switzerland: 187.1 and 43.9), therefore, the reason for this discrepancy could be a lack of time to fully comply with the procedures for the use of personal protective equipment due to work overload.

A higher percentage of seropositive medics recruited in this study worked in departments dedicated to COVID-19

(38.7% vs. 26.8%), and the result was statistically significant (p = 0.017). Significant differences in the frequency of diagnosing anti-SARS-CoV-2 antibodies between healthcare professionals providing direct clinical care to a patient with COVID-19 and those working in a low-risk area were also described in several other studies [14,21,31], but the data are inconsistent, since several authors did not report this association, e.g., Lombardi et al. [32] (Italy) and Iruretagoyena et al. [33] (Chile). Moreover, Khan et al. [34] showed that employees caring for COVID-19 patients in 3 out of 82 hospitals in India had significantly lower seroprevalence than the others. Thus, there are opposing findings regarding direct assistance to COVID-19 patients at risk of SARS-CoV-2 infection in HCW, which may be related to the self-discipline of medics in relation to the compliance of applicable epidemiological procedures.

Interestingly, one of the lowest percentage of positive anti-SARS-CoV-2 antibodies was observed among ICU personnel (18.2%), similarly to the studies of Grant et al. [21] (25%), Shields et al. [35] (14.8%) and Martin et al. [31]. This may be due to the fact that most patients were intubated, i.e., ventilated in a closed circuit, or were admitted to the ward around the 10th day after infection, when the patient's infectiousness usually decreases [36,37]. Despite the lack of assessed parameters in terms of self-discipline of medical workers in the authors' study, the statement by Self et al. [38] should be quoted regarding significantly lower seroprevalence among staff who reported that they always wear the recommended face shield (recommended mask) when caring for patients (5.6%) compared to those who do not follow such recommendations (9.0%) (p = 0.012).

In the questionnaire prepared for the purpose of this study, people who declared infection with the SARS-CoV-2 virus, confirmed by the RT-PCR test, significantly more often received a positive diagnosis of the presence of anti-SARS-CoV-2 antibodies (87.8%) than patients who did not have history of COVID-19 infection. On the other hand 16.3% of patients who did not report any history of confirmed COVID-19 infection had positive anti-SARS-CoV-2 antibodies. This rate in HCWs was higher than in non-medics (17.9% vs. 14.2%, respectively), but the difference was not proven to be statistically significant. Other scientists also point to a high percentage of people who were detected with antibodies without prior confirmation of SARS-CoV-2 infection or the occurrence of typical symptoms, e.g., Self et al. [38] (from 13 centers treating COVID-19 patients in the USA, 69%), Iruretagoyena et al. [33] (Chile, 43%), Allen et al. [14] (Ireland, 39%), Grant et al. [21] (UK, 21.9%), Rosińska et al. [5] (Poland, 10.3%). Singh et al. [39] indicate the necessity for periodic examination of all HCW to prevent shortages of hospital staff due to the high risk of transmission by asymptomatic carriers.

Based on the original observations, a positive titer of antibodies was diagnosed significantly more often in rural residents (37.2%) than in urban residents (24.4%), while the compilations of cyclic studies by Murhekar et al. from India indicated a higher risk of SARS-CoV-2 infection in cities, especially in the vicinity of slums, than in the countryside [40–42]. The third study of the above-mentioned scientists conducted in August–December, 2020 had a similar pattern to the previous ones, however, a 2.5-fold increase in seroprevalence was observed in rural areas compared to urban areas (1.93-fold) and urban slums (1.07-fold) [42]. Namasivayam et al. also found significantly higher exposure to SARS-CoV-2 in urban areas in India [42]. Grant et al. in London found no significant relationship between antibody status and place of residence [21].

In this research work gender and age of the respondents turned out to be factors unrelated with higher occurrence of anti-SARS-CoV-2 antibodies, what is consistent with analyzes by Murhekar et al. (India) and Davila-Silezar et al. [23,41,42]. It can be noted, however, that based on the conclusions of Murhekar et al. drawn from the general population tests conducted at the turn of August and September 2020 in India, adults and the elderly had a relatively higher (although statistically insignificant) seroprevalence [42]. According to Namasivayam et al. [43] the population aged 5–17 was also less exposed to SARS CoV-2 infection compared to adults or the elderly. An analogy can be seen in the report by Rosińska et al. [5], where the prevalence of SARS-CoV-2 infections was the lowest in younger age groups (<35 years of age). The authors' analysis confirmed the information provided by Sandri et al. of no statistical significance between the BMI and the frequency of antibodies, however, it is worth noting that the highest number of positive results was recorded in the group of people with the 2nd degree obesity (30%) [18]. In the studies of Lombardi et al. a tendency can be demonstrated towards a positive test result in accordance with increasing BMI [32]. According to Mahamat et al. [44] it should be noted that obesity in the course of COVID-19 increases the absolute risk of death by 12%.

One limitation of this study is the evaluation of 2 different anti-CARS-CoV-2 antibodies. Due to the changing availability of tests for SARS-CoV-2 antibodies and rapidly emerging new technologies, especially in the first months of the pandemics, 75 patients were screened for the presence of anti-S antibodies, and the rest had anti-N antibodies assessed. There were no subjects who had both tests performed, so the analysis of potential double positivity of these tests is not possible. However, since in all of the cases the evaluation was performed before the launch of the vaccination programme, positive titer of any of the antibodies was considered to be a proof of the exposure to SARS-CoV-2 virus.

## CONCLUSIONS

In conclusion, healthcare workers, especially nurses, are at high risk of contracting COVID-19 in the workplace. The correctness and effectiveness of education and self-discipline in complying with safety rules during the epidemic of infectious diseases, primarily among nurses and doctors, as well as other medical professionals in Poland, should be particularly reconsidered. Nevertheless, occupational infections can occur not only during contact with the patient, but also with members of the medical team who do not show typical symptoms of the disease – people who are asymptomatic can be the source of infection for colleagues. The rationale behind this theory is the high percentage of people with positive anti-SARS-CoV-2 antibodies without prior evidence of COVID-19 infection. According to WHO estimates between 80 000 and 180 000 healthcare workers may have died of COVID-19 in January 2020–May 2021 [45]. For that reason, high occupational exposure to SARS-CoV-2 especially in nurses must be considered for compensation. Medical and hospital staff providing health services during the COVID-19 epidemic in Poland, may seek compensation in the event of SARS-CoV-2 infection, health damage or death as a result of infection. However, from the presented data it can be concluded that in the effective fight against the epidemic, not only personal protective equipment should be provided, but also the appropriate number of medical staff caring for sick patients, since staff shortages may increase the number of infections among HCWs.

### Author contributions

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**Interpretation of the results:** Paulina Biernacka, Anna Piekarska, Aleksandra Berkan-Kawińska
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