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ORIGINAL PAPER

HEALTHCARE WORKERS HIGHLY AFFECTED DURING THE COVID-19 EPIDEMIC WAVE IN POLAND PRIOR TO VACCINATION AVAILABILITY: SEROPREVALENCE STUDY

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Abstract

Background: The aim of the study was to assess seroprevalence of anti-SARS-CoV-2 antibodies among healthcare workers (HCW) before introduction of vaccination, in selected areas in Poland as well as to identify potential risk factors and estimate the cumulative incidence of COVID-19 infections in this population. **Material and Methods:** The authors conducted a sero-epidemiological, cross-sectional study among HCW of 5 non-COVID-19 hospitals in Poland. The recruitment took place in December 1–23, 2020, all HCW at selected hospitals could volunteer into the study. All persons were screened with rapid SARS-CoV-2 IgM/IgG tests in capillary blood. In case of positive result, 5 ml of venous blood was drawn for confirmatory testing with ELISA assay. The authors estimated prevalence of laboratory confirmed anti-SARS-CoV-2 antibody presence and examined factors associated with positive result. Cumulative incidence was estimated applying 2-source capture-recapture method to serology results and self-report of past infection. **Results:** Out of 1040 HCW included in the analysis, one-fourth (25.2%) received a positive result for anti-SARS-CoV-2 antibodies by ELISA test, the prevalence among women was 25.3% (95% CI: 22.5–28.4) and 24.6% (95% CI: 19–31.2) among men. The prevalence of anti-SARS-CoV-2 antibodies was the highest among respondents who declared home contact with a confirmed COVID-19 case, 43.9% (95% CI: 32.4–56.1). It was also elevated among those who indicated contact with patients with COVID-19, 32.5% (95% CI: 26.7–38.8) and business contacts, including at the workplace, 28.9% (95% CI: 22.5–36.3). The estimated cumulative incidence of COVID-19 infections in the population, using the capture-recapture method was 41.2% (95% CI: 38.1–44.2). **Conclusions:** Healthcare workers remained at increased risk of infection largely due to work-related contacts with infected patients, although home exposure was also common. Estimated cumulative incidence is higher than the antibody prevalence, which indicates the need to monitor HCW for possible immunity waning, also post-immunization immunity. Med Pr. 2022;73(2):109–23

Key words: Poland, risk factors, COVID-19, SARS-CoV-2, healthcare workers, seroprevalence

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INTRODUCTION

Healthcare workers (HCW) remain at increased risk for certain infectious diseases, in particular to those spread by direct contact or air and droplet borne [1]. Despite infection control policies, outbreaks of air or droplet borne pathogens occur in hospitals and in health settings in general, including influenza, seasonal coronaviruses and rhinoviruses [2]. This also included the outbreaks of SARS during 2002–2003 epidemic, when the virus was spreading mainly in the healthcare settings and affecting healthcare workers [1,3].

Similarly, the COVID-19 outbreak hit especially hard in hospital and long-term healthcare settings. A study performed in USA and UK during the first wave documented a 3.4 higher risk of infection among the healthcare workers than in the general population [4]. Initially, the lack of protective equipment or inadequate use of the protective equipment and direct contact with COVID-19 patients substantially increased the risk of infection for HCW [4,5]. Healthcare workers working with COVID-19 patients were at greater risk than front-line HCW and the front-line HCW in turn had higher risk than HCW working at other settings [6,7].

In studies published at a later date, comprising data from the second wave in 2020, being a front-line HCW is inconsistently reported as a risk factor, with exposures at community or within households playing a more dominant role [8], although some studies still showed elevated occupational risk for HCW [9]. Pooled seroprevalence after the first wave in Europe and North America, based on published literature, was estimated at 8.5% and 12.7%, respectively [5], although some hospitals noted levels as high as 30% [10]. Longitudinal assessments point to correlation of seroconversion among HCW and the incidence rate in the communities that they serve [11]. In addition, prevalence among HCW tends to be higher in areas, where prevalence in the general population is also higher [9,12].

Seroprevalence studies are a well-recognised tool to measure the cumulative incidence of infection for which durable antibody response develops. The antibodies against SARS-CoV-2 have been shown to last at least 6–8 months [13], although the detection rate may differ according to specific tests used [14].

Therefore, many countries use seroprevalence studies as a means to study the true burden of COVID-19, to monitor the level of incidence as well as to establish risk factors for infection in specific populations or to evaluate interventions [15,16]. It can also be used as the basis to estimate infection fatality rates for COVID-19 [17].

In Poland, the first wave of infections in spring 2020 was very limited [18]. Healthcare workers experienced shortages of personal protective equipment during the first months of the epidemic, but with time the situation improved. Many hospitals introduced routine screening for SARS-CoV-2 infection both among the medical personnel and among patients admitted to the hospital. As early as March 2020, most hospitals placed tight restrictions on visitors, and in paediatric wards, parents that stayed with their children were not allowed to leave while the child was hospitalized.

It is therefore expected that the infections among HCW in the second wave (fall 2020) were commonly due to non-occupational exposures, although no data exists so far to support such a claim. Consequently, the study aimed at measuring the cumulative incidence among HCW of the selected hospitals as well as establishing associated factors for infections, both at the occupational and non-occupational level. Furthermore, the level of undiagnosed infections in this group was considered.

MATERIAL AND METHODS

The authors performed a sero-epidemiological, cross-sectional study among HCW of 5 hospitals in Poland. The recruitment took place in December 1–23, 2020, right after the fall 2020 epidemic wave, which peaked in early November. The hospitals were purposefully selected in 3 administrative regions (Pomorskie voivodeship: Gdańsk, Wejherowo; Mazowieckie voivodeship: Warsaw, Grójec; Wielkopolskie voivodeship: Krotoszyn) to represent areas both with higher and with lower registered incidence than the average incidence in Poland, as already described elsewhere [18]. The target sample size was calculated with assumption of 20% seroprevalence and ±3–4% admissible error, which yields desired sample size of 818–1440. The authors aimed at a sample size of 1000 participants and each hospital was asked to invite 150–350 personnel depending on the number of employees. All HCW employed in the hospital at the time of the study, were eligible for the study, including medical doctors, nurses, midwives, rehabilitators, technicians, and receptionists – all could volunteer for

participation. Other hospital staff with no or occasional contact with patients were also invited to participate in the study. The volunteering HCW were registered to the study on the first-come-first-served basis.

According to employment data as of December 31, 2020, the participation rate for each hospital was as follows: hospital in Gdańsk – 11.8%, Wejherowo – 8.7%, Warsaw – 10.2%, Grójec – 19.9% and Krotoszyn – 47.8%. All participants were informed about the study procedures and asked to provide written informed consent.

The study included rapid and laboratory testing combined with a questionnaire. The questionnaire contained demographic information and 12 questions about potential exposures and prior COVID-19 diagnosis. It was self-administered, online or paper-based.

Rapid tests and laboratory methods

Initially, all persons were screened with rapid tests 2019-nCoV IgG/IgM Detection Kit (Colloidal Gold-Based) by Vazyme (Nanjing, China), for detection of IgM and IgG antibodies against SARS-CoV-2 in capillary blood. In case of a positive result in either IgM or IgG rapid test, 5 ml of venous blood was drawn for laboratory confirmation testing with ELISA assay, also in both IgM and IgG, using a commercial assay (NovaLisa by NovaTec, Dietzenbach, Germany). This assay detects antibodies against N viral protein.

Prior to use, the rapid tests were internally evaluated on 69 pre-pandemic samples and 22 samples collected from persons with positive SARS-CoV-2 PCR test, 11 collected at the time of PCR test and 11 collected 7 days after the positive PCR test. The specificity for IgG and IgM assays were 97.1% (95% CI: 89.9–99.6) and 100% (95% CI: 94.8–100), respectively. The sensitivity for the samples collected at the time of administering the PCR test was 18% (95% CI: 2.3–51.2) for IgG and 0% (95% CI: 0–28.5) for IgM. The value increased in samples collected after 7 days, respectively to 81.8% (95% CI: 48.2–97.7) and 27.3% (95% CI: 6.0–61.0). Given these results individuals were classified as positive or negative based on combined results for IgG and IgM.

Definition of a positive result

For the purpose of seroprevalence estimation a positive case was defined as a person who tested positive for an IgM or IgG rapid test and had positive results in IgM ELISA or IgG ELISA. A negative result was interpreted as a person who either tested non-reactive in both rapid tests or had a positive rapid test but both ELISA assays tested negative. People who did not meet the above criteria, i.e., with indeterminate results, were excluded from further analysis. The authors expect this procedure to provide specific results, with a negligible number of false positive results.

Statistical methods

Seroprevalence was defined as the proportion of positive cases among the study group. Categorical predictors were analysed with χ^2 tests and continuous predictors (age) with t-test. In addition the authors performed a multivariable analysis of factors associated with the positive result using logistic regression model, which included sex, age group, region and medical profession in addition to statistically significant factors.

Due to decreased sensitivity of the rapid test, some cases could be missed and thus seroprevalence could no longer represent the cumulative incidence in the target group. As a sensitivity analysis a total number of cases was estimated using Lincoln-Petersen estimate for capture-recapture analysis [19] considering as one data source the self-reported prior positive result (antigen or PCR test) and the positive serology test as the second. This method is an application of an approach proposed in Simondon and Khodja [20] to estimate the number of cases from multiple measurements with different sensitivities. Assuming the 2 sources are independent, it is possible to estimate the number of cases that were missed by routine PCR and/or antigen screening and for whom the serology algorithm yielded a negative result due to suboptimal sensitivity and obtain an overall number of study participants who were infected between the beginning of the epidemic (the first case in Poland was diagnosed on March 4, 2020) and the time of the study (December 2020). The observation time was approx. 9 months. The cumulative incidence per 9 months was defined as the estimated overall number of the participants who were infected during the 9 months of epidemic duration over the total number of participants included in the study.

All calculations were performed in STATA 14.2 (StataCorp LLC, College Station, Texas, USA).

Ethics

The study complies with ethical standards in epidemiological research and the Helsinki Declaration as revised in 2013. The protocol was reviewed by the Ethical Committee of the National Institute of Public Health – National Institute of Hygiene in Warsaw (opinion No. 2/2020).

RESULTS

Overall, 1119 participants were recruited to the study, of which valid case classification was established for 1094 participants and 25 (2.2%) were excluded due to inconsistent/indeterminate test results. Additionally, 54 (4.9%) were excluded due to missing or incomplete questionnaires. Finally, 1040 were included in the analysis, 191 (18.4%) men and 849 (81.6%) women. The mean and median age was 46.9 and 49 years, respectively. By profession 19.9% were medical doctors, 42.7% nurses, midwives or medical caregivers, 5.8% were paramedics, 18.5% worked in other professions that included contact with patients, and 13.1% worked at the hospital in other capacities, such as administration. Most participants reported working in hospital wards (73.8%), only 8.1% and 7.8% reported working in emergency rooms or outpatient clinics respectively, however it must be noted that these options were not mutually exclusive. Most of the hospital staff declared working at a single workplace (67.2%), however 28.4% declared employment at multiple workplaces and 4.4% declared consulting multiple clinics within a single hospital. Detailed study population characteristics divided by region are presented in Table 1.

Among the surveyed employees in all voivodeships, approx. 50% of respondents declared that they had no direct contact (without appropriate personal protection equipment) with a person diagnosed with COVID-19 during the period of infectivity. In the period from February 2020 to the time of this study, 88.7% of respondents had at least one COVID-19 test, but only 12.5% had >5 prior tests. Testing frequency differed significantly between sites. The most common reason for such a test was the detection of the virus among other persons in the workplace (Table 1).

Among the study population of 1040 participants, one-fourth (25.2%, 95% CI: 22.6–27.9) received a positive result for anti-SARS-CoV-2 antibodies by ELISA test. The prevalence among women was 25.3% (95% CI: 22.5–28.4) and 24.6% (95% CI: 19–31.2) among men. Among most age groups, except the youngest age group <25, the prevalence oscillated between 22–28%. Similarly, all types of professions had comparable prevalence ranging 20.3–29.2%. The seroprevalence was significantly higher among HCW working in hospital wards and significantly differed by region in univariable analysis. Table 2 presents the seroprevalence among HCW according to their demographics.

Table 2 also shows the prevalence of anti-SARS-CoV-2 antibodies depending on the reported exposures. The prevalence of anti-SARS-CoV-2 antibodies was the highest among those that declared household contact with a confirmed COVID-19 case and amounted to 43.9% (95% CI: 32.4–56.1). It was also high among those who indicated contact with infected patients 32.5% (95% CI: 26.7–38.8), business contacts with a confirmed COVID-19 case, including at the workplace 28.9% (95% CI: 22.5–36.3). Among the respondents who indicated no direct contact with the confirmed case, 17.8% (95% CI: 14.8–21.4) obtained a positive result for anti-SARS-CoV-2 antibodies.

Among the surveyed employees, who participated in special events such as weddings, communions, baptisms, or funerals in the period from February 2020, the prevalence of anti-SARS-CoV-2 antibodies was 20.9% (95% CI: 16.7–25.7) while among people who did not participate in such events, the prevalence was higher and amounted to 26.8% (95% CI: 23.7–30.2). Similarly, a positive result for anti-SARS-CoV-2 antibodies was obtained by more respondents – 25.8% (95% CI: 23.1–28.6) – among those that had not participated in organized trips or summer camp in the period since the restrictions were lifted. In comparison, among those that took part in such trips, the prevalence of antibodies was 14.1% (95% CI: 7.4–25). Frequenting different shopping venues or restaurants and using public transportation were not associated with increased seroprevalence (Table 2).

The results of the multivariable analysis show that neither region, workplace nor medical profession were significantly associated with positive result (Table 3). The positive result was significantly predicted by reporting a household contact (adjusted odds ratio [AOR] 3.66, 95% CI: 2.10–6.38) and contact in workplace, including a contact with a positive patient (AOR 2.09, 95% CI: 1.44–3.03).

Among HCW who did not notice any symptoms of the disease in the period from the beginning of February 2020 to the time of the study, about 9% had a positive ELISA test. Almost 55% of people reporting a loss of smell or taste in the survey tested positive. The most common symptom indicated by the surveyed HCW was fatigue, and among these people, the test confirmed the presence of anti-SARS-CoV-2 antibodies in almost 40% (Figure 1a).

Conversely, in those who tested positive for antibodies, the most common symptoms were fatigue (62%), muscle pain (55%), and headache (52%) (Figure 1b).

Table 4 presents data on self-declared previous positive COVID-19 test result, positive serology of ELISA

Table 1. Study population characteristics, prior testing and known exposures by voivodeship – Poland, December 2020

Variable	Participants (N = 1040)								p
	Mazowieckie voivodeship		Pomorskie voivodeship		Wielkopolskie voivodeship		all voivodeships		
	n	%	n	%	n	%	n	%	
Demographic factors									
age	295	100.0	448	100.0	297	100.0	1040	100.0	0.000
0–24 years	13	4.4	8	1.8	2	0.7	23	2.2	
25–34 years	43	14.6	96	21.4	32	10.8	171	16.4	
35–44 years	49	16.6	86	19.2	53	17.8	188	18.1	
45–54 years	91	30.8	155	34.6	108	36.4	354	34.0	
55–64 years	80	27.1	91	20.3	88	29.6	259	24.9	
65–74 years	19	6.4	12	2.7	14	4.7	45	4.3	
sex	295	100.0	448	100.0	297	100.0	1040	100.0	0.049
female	254	86.1	354	79.0	241	81.1	849	81.6	
male	41	13.9	94	21.0	56	18.9	191	18.4	
Employment factor									
profession	276	100.0	442	100.0	293	100.0	1011	100.0	0.000
medical doctor	30	10.9	143	32.4	28	9.6	201	19.9	
nurse/midwife/medical caregiver	89	32.2	194	43.9	149	50.9	432	42.7	
paramedic	10	3.6	20	4.5	29	9.9	59	5.8	
other, working in contact with patients	88	31.9	69	15.6	30	10.2	187	18.5	
other, including aministration	59	21.4	16	3.6	57	19.5	132	13.1	
work type (not exclusive)									
hospital ward	128	45.4	373	87.4	233	81.5	734	73.8	0.000
emergency room	19	6.7	32	7.5	30	10.5	81	8.1	0.215
outpatient clinic	44	15.6	25	5.9	9	3.1	78	7.8	0.000
workplace	288	100.0	424	100.0	288	100.0	1000	100.0	0.002
single workplace	211	73.3	269	63.4	192	66.7	672	67.2	
consulting multiple clinics within single hospital	10	3.5	29	6.8	5	1.7	44	4.4	
multiple workplaces	67	23.3	126	29.7	91	31.6	284	28.4	
Testing and exposures									
direct contact	285	100.0	420	100.0	286	100.0	991	100.0	0.069
no	162	56.8	212	50.5	142	49.7	516	52.1	
yes, business-related, including workplace contact	55	19.3	62	14.8	49	17.1	166	16.8	
yes, social contact	3	1.1	8	1.9	4	1.4	15	1.5	
yes, household contact	20	7.0	30	7.1	16	5.6	66	6.7	
yes, contact with patient	45	15.8	108	25.7	75	26.2	228	23.0	
quarantine	294	100.0	445	100.0	297	100.0	1036	100.0	0.000
yes	120	40.8	146	32.8	164	55.2	430	41.5	
no	174	59.2	299	67.2	133	44.8	606	58.5	

Table 1. Study population characteristics, prior testing and known exposures by voivodeship – Poland, December 2020 – cont.

Variable	Participants (N = 1040)								p
	Mazowieckie voivodeship		Pomorskie voivodeship		Wielkopolskie voivodeship		all voivodeships		
	n	%	n	%	n	%	n	%	
Testing and exposures – cont.									
prior COVID test	295	100.0	445	100.0	296	100.0	1036	100.0	0.000
not tested	22	7.5	41	9.2	54	18.2	117	11.3	
1 test	66	22.4	119	26.7	69	23.3	254	24.5	
2–5 tests	142	48.1	237	53.3	157	53.0	536	51.7	
>5 tests	65	22.0	48	10.8	16	5.4	129	12.5	
reason for prior COVID test (not exclusive)									
contact with confirmed case	83	30.7	179	44.0	103	42.7	365	39.8	0.001
COVID detected at workplace	133	49.8	236	58.0	158	65.6	527	57.6	0.002
intensified symptoms	19	7.0	58	14.3	7	2.9	84	9.2	0.000
screening tests among employees	144	53.9	143	35.1	63	26.0	350	38.2	0.000
quarantine	40	14.8	49	12.0	63	26.0	152	16.5	0.000
return from travel abroad	4	1.5	4	1.0	1	0.4	9	1.0	0.474
contact with person returning from abroad	1	0.4	3	0.7	1	0.4	5	0.5	0.777
own request	22	8.1	26	6.4	9	3.7	57	6.2	0.111
prior test positive	277	100.0	404	100.0	241	100.0	922	100.0	0.911
yes	66	23.8	93	23.0	59	24.5	218	23.6	
no	211	76.2	311	77.0	182	75.5	704	76.4	

Table 2. Prevalence of anti-SARS-CoV-2 antibodies by demographic, employment characteristics, and reported exposure or potential exposures outside of work – Poland, December 2020

Variable	Participants (N = 1040)		Prevalence [%]	95% CI	p
	n	anti-SARS-CoV-2 antibodies positive [n]			
Demographic factor					
sex					0.837
female	849	215	25.3	22.5–28.4	
male	191	47	24.6	19–31.2	
age					0.365
0–24 years	23	2	8.7	2.1–29.6	
25–34 years	171	40	23.4	17.6–30.3	
35–44 years	188	45	23.9	18.4–30.6	
45–54 years	354	99	28	23.5–32.9	
55–64 years	259	66	25.5	20.5–31.2	
65–74 years	45	10	22.2	12.3–36.8	

Table 2. Prevalence of anti-SARS-CoV-2 antibodies by demographic, employment characteristics, and reported exposure or potential exposures outside of work – Poland, December 2020 – cont.

Variable	Participants (N = 1040)		Prevalence [%]	95% CI	p
	n	anti-SARS-CoV-2 antibodies positive [n]			
Employment factor					
profession					0.118
medical doctor	201	51	25.4	19.8–31.9	
nurse, midwife or medical caregiver	432	126	29.2	25.1–33.6	
paramedic	59	13	22	13.2–34.5	
other, working in contact with patients	187	38	20.3	15.1–26.7	
other, including administration	132	28	21.2	15–29.1	
work type (not exclusive)					
hospital ward	734	202	27.5	24.4–30.9	0.005
emergency room	81	9	11.1	5.9–20.1	0.002
outpatient clinic	78	12	15.4	8.9–25.3	0.037
workplace					0.772
single workplace	672	170	25.3	22.1–28.7	
consulting multiple clinics within single hospital	44	9	20.5	10.9–35.1	
multiple workplaces	284	71	25	20.3–30.4	
voivodeship					0.031
Mazowieckie	295	59	20	15.8–25	
Pomorskie	448	128	28.6	24.6–32.9	
Wielkopolskie	297	75	25.3	20.6–30.5	
Exposure factor					
direct contact with confirmed case					0.000
no	516	92	17.8	14.8–21.4	
yes, business-related, including workplace contact	166	48	28.9	22.5–36.3	
yes, social contact	15	4	26.7	10–54.3	
yes, household contact	66	29	43.9	32.4–56.1	
yes, conctact with patient	228	74	32.5	26.7–38.8	
public transportation					0.602
never/does not use	685	169	24.7	21.6–28	
less than once a month	100	27	27	19.2–36.6	
1–2 times/month	61	20	32.8	22.1–45.6	
1–3 times/week	65	16	24.6	15.6–36.6	
daily or almost daily	126	28	22.2	15.8–30.4	
restaurants					0.471
never/does not visit	620	163	26.3	23–29.9	
less than once a month	257	61	23.7	18.9–29.3	
1–2 times/month	132	27	20.5	14.4–28.2	
1–3 times/week	25	8	32	16.6–52.6	
daily or almost daily	2	0	0	0–0	

Table 2. Prevalence of anti-SARS-CoV-2 antibodies by demographic, employment characteristics, and reported exposure or potential exposures outside of work – Poland, December 2020 – cont.

Variable	Participants (N = 1040)		Prevalence [%]	95% CI	p
	n	anti-SARS-CoV-2 antibodies positive [n]			
Exposure factor – cont.					
occasional event					0.043
0	720	193	26.8	23.7–30.2	
1	316	66	20.9	16.7–25.7	
travel abroad					0.92
0	885	224	25.3	22.5–28.3	
1	133	33	24.8	18.2–32.9	
organized trip					0.036
0	974	251	25.8	23.1–28.6	
1	64	9	14.1	7.4–25	
shopping					
online					0.776
never/does not use	258	59	22.9	18.1–28.4	
less than once a month	167	46	27.5	21.3–34.8	
1–2 times/month	255	68	26.7	21.6–32.4	
1–3 times/week	272	65	23.9	19.2–29.3	
daily or almost daily	62	15	24.2	15.1–36.5	
at malls					0.827
never/does not use	144	39	27.1	20.4–35	
less than once a month	84	19	22.6	14.9–32.8	
1–2 times/month	182	49	26.9	21–33.9	
1–3 times/week	440	108	24.5	20.7–28.8	
daily or almost daily	168	38	22.6	16.9–29.6	
at local shops					0.989
never/does not use	269	69	25.7	20.8–31.2	
less than once a month	82	21	25.6	17.3–36.2	
1–2 times/month	99	24	24.2	16.8–33.7	
1–3 times/week	368	88	23.9	19.8–28.6	
daily or almost daily	184	46	25	19.3–31.8	
at baazar					0.965
never/does not use	617	150	24.3	21.1–27.9	
less than once a month	136	36	26.5	19.7–34.6	
1–2 times/month	104	25	24	16.8–33.2	
1–3 times/week	89	20	22.5	14.9–32.4	
daily or almost daily	30	8	26.7	13.8–45.3	

Table 3. Factors associated with anti-SARS-CoV-2 antibodies in multivariable analysis – Poland, December 2020

Variable	AOR	95% CI	p > z
Sex			
female	1.00		
male	0.99	0.61–1.60	0.962
Age			
18–34 years	1.00		
35–49 years	1.18	0.75–1.85	0.469
≥50 years	1.13	0.72–1.76	0.600
Voivodeship			
Mazowieckie	1.00		
Pomorskie	1.42	0.94–2.14	0.098
Wielkopolskie	1.17	0.76–1.82	0.470
Profession			
medical doctor	1.00		
nurse, midwife or medical caregiver	1.14	0.71–1.83	0.595
paramedic	0.86	0.40–1.86	0.707
other, working in contact with patients	1.01	0.57–1.79	0.977
other, including administration	1.17	0.62–2.20	0.624
Working at hospital ward			
no	1.00		
yes	1.34	0.87–2.05	0.185
Direct contact with confirmed case			
no	1.00		
yes, business-related, including workplace contact	1.91	1.26–2.89	0.002
yes, social contact	1.60	0.49–5.21	0.438
yes, household contact	3.66	2.10–6.38	0.000
yes, conctact with patient	2.09	1.44–3.03	0.000

AOR – adjusted odds ratio.
Cases with missing values in one more covariates were excluded from the analysis (N = 80).

test performed during this study and the capture-recapture estimation based on self-reported prior diagnosis and serology results. The estimated cumulative incidence was 41.2% (95% CI: 38.1–44.2). The proportion of diagnosed infections amounted to 50.8% (95% CI: 44.5–57.2), but was significantly lower among paramedics, 16.7% (95% CI: 3.9–49.6) and higher among medical doctors, 68.1% (95% CI: 53.4–79.9).

Twenty-nine surveyed HCW declared a positive result in previous tests carried out in the second quarter of 2020, before the COVID-19 seroprevalence study. Among 27.6% of these people, ELISA tests showed the presence of anti-SARS-CoV-2 antibodies. Only 6 respondents indicated a positive test result in previous tests from the third quarter, while the presence of antibodies in this group was 33.3%. Finally, 156 employees declared a positive result of previous tests for the SARS-CoV-2 virus performed in the fourth quarter of 2020, serological testing confirmed antibodies in 62.8% of people from this group (Figure 2).

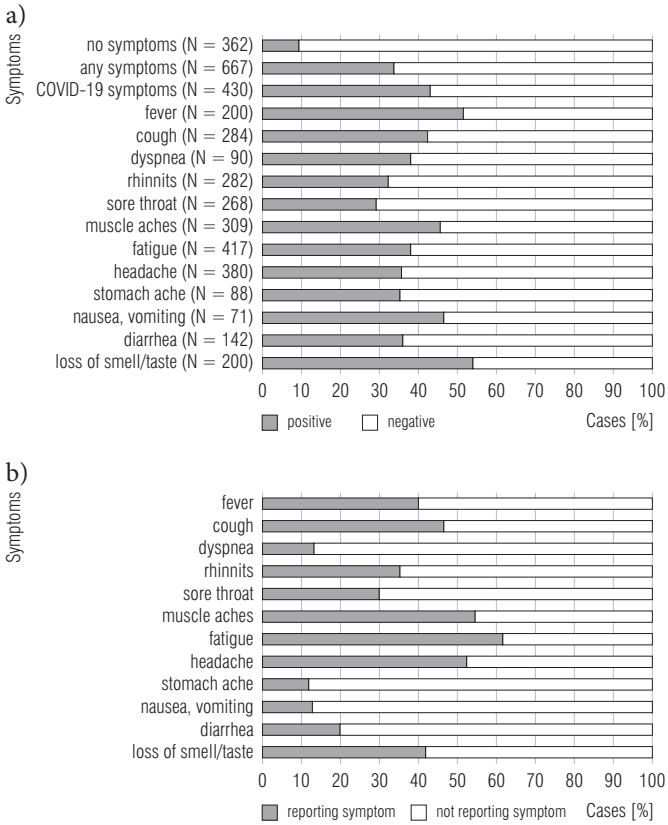
DISCUSSION

A very high estimate of seroprevalence was found among HCW working in hospitals, of whom one in four had a positive result (25.2%, 95% CI: 22.6–27.9). When adjusting for test sensitivity, the cumulative incidence exceeded 40% (41.2%, 95% CI: 38.1–44.2). This estimate corresponds to the period before immunisation became available and only when one significant

Table 4. Proportion of previously diagnosed and results of capture-recapture estimation based on self-reported prior diagnosis and serology results – Poland, December 2020

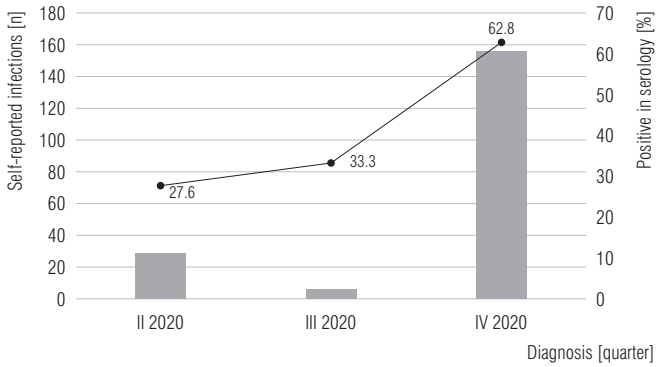
Variable	Participants with either prior diagnosis of SARS-CoV-2 infection or positive serology (N = 335)					p	Capture–recapture estimated		
	prior diagnoses (N = 218) [n]	positive serology (N = 238) [n]	prior diagnosis and positive serology (N = 121) [n]	diagnosed (total 50.8) [%]	95% CI (total 44.5–57.2)		total positive (N = 428) [n]	prevalence (total 41.2) [%]	95% CI (total 38.1–44.2)
Age						0.309			
0–24 years	4	2	1	50	1.9–98.1		8	34.8	16.4–57.3
25–34 years	43	37	25	67.6	50.8–80.8		63	36.8	29.6–44.5
35–44 years	39	40	21	52.5	37–67.5		74	39.4	32.3–46.7
45–54 years	84	88	43	48.9	38.5–59.3		171	48.3	43–53.6
55–64 years	41	61	26	42.6	30.8–55.4		96	37.1	31.2–43.3
65–74 years	7	10	5	50	21.2–78.8		14	31.1	18.2–46.6
Sex						0.29			
female	181	195	96	49.2	42.2–56.3		367	43.2	39.9–46.6
male	37	43	25	58.1	42.9–72		63	33	26.4–40.1
Profession						0.012			
other, including administration	20	26	10	38.5	21.8–58.4		52	39.4	31–48.3
other, working in contact with patients	31	34	17	50	33.5–66.5		62	33.2	26.5–40.4
medical doctor	51	47	32	68.1	53.4–79.9		74	36.8	30.1–43.9
nurse/midwife/medical caregiver	112	116	59	50.9	41.8–59.9		220	50.9	46.1–55.7
paramedic	3	12	2	16.7	3.9–49.6		18	30.5	19.2–43.9
Voivodeship						0.161			
Mazowieckie	66	55	30	54.5	41.2–67.3		121	41	35.3–46.9
Pomorskie	93	119	65	54.6	45.5–63.4		170	37.9	33.4–42.6
Wielkopolskie	59	64	26	40.6	29.2–53.1		145	48.8	43–54.7

Cases with positive serology, for whom the prior positive status was missing were excluded from the analysis (N = 24).



Cases with missing information about symptoms were excluded from the analysis (N = 11, including 4 cases with positive result).

Figure 1. a) Positive results among participants reporting symptoms (N = 1029) and b) cases reporting symptoms among cases with positive result (N = 258) – Poland, December 2020



Cases reporting prior positive result, but with date of diagnosis missing were excluded from the analysis (N = 25).

Figure 2. Self-reported infections by quarter and corresponding positive serology results (N = 193) – Poland, December 2020

epidemic wave had been observed. The estimate did not differ by the type of work done and was only associated with known contact with a confirmed case. The proportion diagnosed was 50.8% (95% CI: 44.5–57.2) overall but was significantly lower among paramedics (16.7%) and administration and support staff (38.5%) and higher among medical doctors (68.1%).

The seroprevalence in comparison to other countries is high but similar to the levels achieved in some countries in various time periods before the introduction of vaccination campaigns [6,10,21]. Although the pooled seroprevalence in systematic reviews was significantly lower than in this study, the results were very heterogeneous across studies and countries [5]. A large national level cross-sectional serosurvey among HCW in the UK revealed regional variation of seroprevalence: from 23.9% in London to 8.8% in the South West UK (overall 16.3%) [22]. Therefore, the results of this study, although they indicate high prevalence in all 3 studied regions, are not necessarily generalizable for all HCW in Poland.

Contrary to other studies the authors found no major differences in seroprevalence among different categories of HCW working in contact with patients in comparison to other staff, with no contact with patients. The prevalence was higher among HCW working in the inpatient hospital wards than working in the emergency room or clinic, which can be explained by outbreaks occurring in hospital wards, and/or mixed exposure to infection, both in the workplace and in the community. This is supported by the results of multivariable analysis, in which the fact of working at the hospital ward, after adjusting for the reported contact with confirmed case, was no longer significantly associated with increased prevalence.

In each of the 3 regions covered by the current study, outbreaks of COVID-19 were reported in hospital wards, affecting patients and staff despite strict control measures including routine HCWs screening and pre-admission screening of patients. The first outbreaks of infections in Polish non-COVID-19 hospitals were reported as early as April 2020, including in the Wielkopolskie voivodeship, however, scientific publications describing hospital outbreaks are scarce [23]. Almost two-thirds of respondents with positive results were able to indicate prior contact with an infected case. The majority of the contacts were work-related (121/153; 79% of all contacts) and included contact with an infected patient (60%) or with an infected member of the staff during work or breaks (40%). Among staff with no contact with patients who had positive results, 30% indicated contact with an infected case in the workplace. This may point to spread of infections among hospital staff. Similar conclusions were drawn in a study from Boston [24], that found that seropositivity correlates with behaviour practices observed during breaks and in the break room

rather than with work activities. The majority of infections being acquired either from private contacts or semi-private contacts at work was also reported in a German study [25].

The authors note that half of infections were diagnosed, which is high in comparison to the proportion estimated for the total population [26]. At the same time, HCW were the priority group for testing, even if implementation of routine screening of asymptomatic HCW was not mandated and left to local hospital decision. Conversely, the tests should be performed among HCW in case of symptoms, even if the symptoms were mild. In this study approx. 40% of participants reported having had one of the typical COVID-19 symptoms (fever, cough, shortness of breath, loss of smell/taste), but only 9.1% of all those tested before this study were tested because of symptoms and most of the tests were performed either as screening or in the event of outbreaks at the workplace or, specifically, after contact with a confirmed case. Such a large disproportion between the percentage of HCW with symptoms typical of COVID-19 and the percentage of those screened due to symptoms may result from the initially accepted indications for testing only in the case of dyspnea, temperature >38°C or cough and no indications for testing in case of mild symptoms of infection. This gap should be filled with regularly repeated workplace tests, but in most hospitals, tests were performed infrequently as 25% of HCW included in the study had been tested only once, and 11% not at all.

It should be noted that even if the rate of diagnosis was not as low as in general in Poland, as many as 20% of HCW (half of the estimated 40% cumulative incidence) could have at some point attended work while infectious. Thus, the potential for healthcare associated outbreaks originating from infected HCW was high. This only underlines the importance of prioritizing immunization of HCW, also for the benefit of the patients, and the need for strict adherence of HCW to personal protection measures, especially masks.

The antibodies last at least 6 months so it is expected that the seroprevalence results reflect the incidence among HCW during the fall 2020 wave of the epidemic in Poland, which is further supported by the finding of this study indicating low seroprevalence among respondents who were infected in spring 2020. The number of cases in Poland prior to September 2020 was low. In addition, seroprevalence among HCW in one hospital in Poland before the fall of 2020 was very low, not exceeding 1% [27], and in 2 others was 1.2% and 10% [28]. However, due to local outbreaks in hospitals occurring earlier that year [18], some hospitals could have been more affected than others before the fall 2020 wave. This explains the substantial difference in the results of this study between the seroprevalence (25.2%) and estimated cumulative incidence (41.2%).

Detection levels of cases who reported prior infections >3 months before this study were low. This draws attention to the potentially poor performance of rapid antibody tests in a real-world situation with lowered antibody levels. Antibody levels were shown to moderately decrease >6–8 months after infection, with faster decay of anti-nucleocapsid IgG, especially in younger adults and those without symptoms [29]. Although many studies show high diagnostic accuracy of the rapid immunochromatographic tests compared to ELISA or ECLIA tests, comparison tests are usually performed during the phase of high IgG antibody titers, i.e., in the 3–4 weeks after infection. Few publications describe the sensitivity of rapid tests months after infection, and thus it is possible that test sensitivity is significantly reduced the more time elapses after infection [30].

Limitations

The study had several limitations. Firstly, the authors relied on a convenience sample of healthcare workers, including only hospital-based workers, in selected hospitals. The conclusions can therefore only relate to HCW working in hospitals and should be interpreted with caution, as the selected hospitals may systematically differ from other hospitals in Poland. The authors purposefully selected hospitals and even though all HCW workers in the hospital were invited only a fraction were in fact tested. However, hospitals in 3 different regions of Poland were chosen and the differences among the regions were insignificant in multivariate analysis. Also, no differences were noted by the type of work done, so even if some professions were less likely to participate it should not affect the overall estimate.

Moreover, the study's population at risk is effectively defined by current employment in one of the hospitals included in the study. To estimate cumulative incidence it was assumed that the current employment corresponds to employment over the whole pandemic period. In truth there were some changes in employment, but rather modest, ranging 5–22% depending on the hospital.

Furthermore, the authors used a testing algorithm using a rapid screening test as the first step of the study.

This could have misclassified the true cases. To account for this, the authors provided in addition an adjusted estimate, which incorporates information on the past positive tests. However, the authors acknowledge that the capture-recapture method, which was used to estimate the number of individuals who had been previously infected with SARS-CoV-2, tends to overestimate the true number in case the data sources are not independent. Whether or not the sensitivity of the seroprevalence assay and prior diagnosis are fully independent, cannot be inferred from the data and remains an assumption. In addition, this method does not allow to account for reinfections, which in turn would cause the estimate of cumulative incidence to be biased downwards. The authors note, though that as the major epidemic wave in Poland occurred only in the fall 2020 and the reinfections usually occur after several months from initial infection, it is not expected that many would have occurred by December 2020, when the study was performed.

CONCLUSIONS

In the period before the vaccinations against COVID-19 HCW in non-COVID hospitals were particularly exposed to infection. The prevalence of anti-SARS-CoV-2 antibodies did not differ significantly among different categories of HCWs and was only associated with work in the inpatient hospital wards and known contact with a confirmed case. The authors also observed that the seroprevalence was lower among HCW who recovered from COVID after several months of infection. This may indicate immunity wanning that can leave the HCW unprotected. Protection of the HCWs is necessary not only for their own health but also to avoid hospital outbreaks and ensure continuity of the health services. It is also crucial to monitor HCW for possible immunity waning both after infection and after vaccination in order to implement early enough the necessary measures, such as a booster vaccine dose.

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