BMJ Open

Risk of SARS-CoV-2 infection among front-line healthcare workers in Northeast Brazil: a respondent-driven sampling approach

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To cite: Albuquerque MdFPM, Souza WV, Montarroyos UR, *et al*. Risk of SARS-CoV-2 infection among front-line healthcare workers in Northeast Brazil: a respondent-driven sampling approach. *BMJ Open* 2022;**12**:e058369. doi:10.1136/bmjopen-2021-058369

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2021-058369).

Received 14 October 2021
Accepted 13 May 2022

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ABSTRACT

Objectives We assessed the prevalence of SARS-CoV-2 infection, personal protective equipment (PPE) shortages and occurrence of biological accidents among front-line healthcare workers (HCW).

Design, setting and participants Using respondent-driven sampling, the study recruited distinct categories of HCW attending suspected or confirmed patients with COVID-19 from May 2020 to February 2021, in the Recife metropolitan area, Northeast Brazil.

Outcome measures The criterion to assess SARS-CoV-2 infection among HCW was a positive self-reported PCR test.

Results We analysed 1525 HCW: 527 physicians, 471 registered nurses, 263 nursing assistants and 264 physical therapists. Women predominated in all categories (81.1%; 95% CI: 77.8% to 84.1%). Nurses were older with more comorbidities (hypertension and overweight/obesity) than the other staff. The overall prevalence of SARS-CoV-2 infection was 61.8% (95% CI: 55.7% to 67.5%) after adjustment for the cluster random effect, weighted by network, and the reference population size. Risk factors for a positive RT-PCR test were being a nursing assistant (OR adjusted: 2.56; 95% CI: 1.42 to 4.61), not always using all recommended PPE while assisting patients with COVID-19 (OR adj: 2.15; 95% CI: 1.02 to 4.53) and reporting a splash of biological fluid/respiratory secretion in the eyes (OR adj: 3.37; 95% CI: 1.10 to 10.34).

Conclusions This study shows the high frequency of SARS-CoV2 infection among HCW presumably due to workplace exposures. In our setting, nursing assistant comprised the most vulnerable category. Our findings highlight the need for improving healthcare facility environments, specific training and supervision to cope with public health emergencies.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Respondent-driven sampling (RDS) technique applied in this study allowed the enrolment of the healthcare workers (HCW), a hard-to-reach population regarding their work conditions, during the pandemic.
⇒ The study has a large sample size including the major categories of healthcare professionals who attended patients with COVID-19 in the public, private or newly implemented campaign hospitals.
⇒ Data were collected using a web-based platform, allowing the use of an online questionnaire, also facilitating timely data analysis and less transcript data errors.
⇒ The RDS chains could potentially induce the recruitment of participants with similar characteristics, which was prone to selection bias.
⇒ The source of SARS-CoV-2 infection among HCW could not be ascertained and this is another limitation of the study.

INTRODUCTION

The unprecedented rapid spread of SARS-CoV-2 and its potentially severe outcomes have greatly impacted the healthcare system, the global economy and security.[1 2] According to the WHO, the global cumulative number

of confirmed COVID-19 cases had reached approximately 364.2 million infections and 5.6 million deaths by 28 January 2022.[3] In Brazil, approximately 24.5 million COVID-19 cases and 624 413 related deaths were reported within the same period. These figures represent almost 7% and 11% of the global COVID-19 cases and registered deaths, respectively, yet the Brazilian population represents approximately 2.5% of the global population. In Brazil, COVID-19 epidemiological data showed a high burden on the hospital system with 678 235 patients admitted with a positive RT-PCR for SARS-CoV-2 between February 2020 and April 2021. Hospital mortality increased from 34.8% in the first wave (25 February 2020 to 5 November 2020) to 39.3% in the second wave (6 November 2020 to 30 April 2021). The highest in-hospital mortality rates are concentrated in the northeast and north states of the country, which are also the regions with lower Human Development Indexes.[4] Since the beginning of the pandemic, the federal government has opposed the recommendations for social distancing and individual protection measures while endorsing ineffective pharmaceutical interventions, hampering the epidemic control efforts of the public health authorities at the state and municipal levels.[5]

Healthcare workers (HCW) are considered a high-risk group due to the nature of their work. An Anglo-American prospective cohort that included approximately 100 000 HCW showed a 3.4-fold higher risk of self-reporting a positive test for COVID-19 among front-line workers compared with the general community using a smartphone application.[6] A systematic review and meta-analysis covering the period from the inception of the pandemic to August 2021, showed a significant burden of COVID-19 among HCW in several countries, with a pooled prevalence of 11% (95% CI: 7% to 16%) in studies using PCR testing.[7] Another systematic review and meta-analysis suggested that exposure in settings with familiar contact increases SARS-CoV-2 transmission. However, exploring the transmission pattern in health facilities, workplace and social settings has been challenging due to limited data thus far.[8] These previous reviews did not include studies from Brazil.

In the Americas, 569 304 COVID-19 cases, including 2506 deaths, had been reported among HCW by August 2020.[9] According to public health surveillance, approximately 32% of Mexico City HCW (n=11 226) had been infected with SARS-CoV-2 by July 2020.[10] Additionally, cross-sectional studies conducted in Brazil, Colombia and Ecuador revealed lack of personal protective equipment (PPE) among 70% of front-line workers in the early pandemic response.[11] In line with the previous studies, a survey among HCW reported PPE shortages during the first COVID-19 wave in Brazil 2020,[12] and the inadequate working conditions were also reported by the media.[13] In Brazil, the prevalence of SARS-CoV-2 infection using RT-PCR in teaching hospitals varied from 15% to 42.4% among symptomatic HCW in the south and southeast regions, respectively.[14–16] However, information on the prevalence of SARS-CoV-2 infection among front-line HCW and risk factors for most regions of Brazil is limited.

This study assessed the prevalence of SARS-CoV-2 infection and evaluated PPE shortages, the use of individual protective measures, and biological accidents among HCW in Recife metropolitan area of Northeast Brazil.

METHODS

Study design

This prospective study assessed the frequency of infected HCW and their risk factors, using the respondent-driven sampling (RDS) methodology,[17] and collecting data with a smartphone-based application. RDS was chosen as a sampling approach for two main reasons: restrictions in conducting face-to-face interviews due to lockdown and the lack of a frame list of front-line HCW attending emergency rooms, hospitals and new field hospitals. RDS approach is based on direct participant involvement.

The baseline findings are described following the Strengthening the Reporting of Observational Studies in Epidemiology guidelines for RDS.[18]

Setting

The study was conducted in the Recife metropolitan region, Pernambuco state, Northeast Brazil, where the first COVID-19 case was reported on 12 March 2020. The peak of the first pandemic wave was during the 21st epidemiologic week in 2020.[19 20] This densely populated region comprises 15 municipalities with approximately 4 million inhabitants, corresponding to 42% of the state population.[21] The Brazilian unified health system (Sistema Unico de Saude) has provided universal coverage since 1990, with heterogeneity among the regions.[22]

Formative research

Formative research (FR) was conducted with the four HCW categories included in the study (physicians, nurses, nurse assistants and physical therapists). The FR applied in-depth interviews to explore workplace changes, use and access to PPE, routine attendance and possible acceptability of the study.

Participants and public involvement

Participants and/or the public were not involved in the design. However, the FR was valuable to adequate the research questions considering participants' priorities, experience and preferences. Also, the chosen methodology RDS requires direct involvement of the study participants in the recruitment and in indicating other members of the network. Therefore, the participants had an active role in the enrolment of other participants and in the development of the field work. This project was planned in collaboration with the official healthcare department and professional associations. The coordinators issued periodic reports with preliminary results to the institutions, local newspapers and social media. The final results will be disseminated by institutional platforms.

Participants

We recruited HCW attending suspected or confirmed patients with COVID-19 from 21 May 2020 to 10 February 2021. Recruitment started with five 'seeds' for each category, non-randomly selected from the target population. We asked each participant to identify five other members of the same professional network category, providing their names and mobile phone numbers to the fieldworkers. The process continued until a suitable sample size was reached. This study did not offer any incentive.

We calculated a sample size of 1100 HCW, considering a 95% CI to estimate a 40% prevalence of infection with a 5% error and a design effect of three.

The network size of each HCW was measured by the final answer to the following questions: (1) 'How many colleagues do you know, who also know you by name, work in the Recife metropolitan region and are assisting patients with COVID-19?', (2) 'How many of those colleagues have been in professional contact with you in the last 2 weeks?' and (3) 'How many of them are close to you and you would invite to participate in this study?'

Variables

We applied the WHO questionnaire developed as an operational tool to determine the risk of COVID-19 virus infection among HCW exposed to a patient with COVID-19 in a healthcare facility. This questionnaire was developed as an interim guidance for risk assessment by the WHO personnel/experts in response to COVID-19 pandemic in the early months (March 2020).[23] The variables were:

1. Age, sex and professional category.
2. Self-reported comorbidities (diabetes mellitus, hypertension, overweight or obesity, cardiopathy, nephropathy and others).
3. Healthcare attending—public or private sector, outpatient, emergency rooms and intensive care units (ICU); number of healthcare facilities.
4. Adherence to infection prevention and control (IPC). We checked for gloves, medical masks, face shields, goggles or protective glasses and waterproof aprons. These variables were grouped as: (a) always as recommended (more than 95% of the time); (b) most of the time (ranging from 50% to 95%); (c) occasionally (1%–49%); (d) never; and (e) unavailable.
5. Adherence to IPC when performing aerosol-generating procedures (AGPs) using the above-mentioned grading criteria. In this section, we added the N95 respirator. The variables related to adherence to IPC (items 4 and 5) were grouped as always versus not always.
6. Accidents with biological material—(a) during the period of healthcare interaction and (b) if there was an accident with biological fluid or respiratory secretions, which type it was (splash in the mucous membrane of eyes, mouth, or nose; non-intact skin; and puncture-sharp accident).

Outcome measure

The primary outcome was the frequency of positive self-reported PCR tests. In the study, HCW were considered as a priority population for COVID-19 tests as part of the COVID-19 public health response at state level. Laboratory confirmation was performed at the Pernambuco Public Health Laboratory (LACEN), which is the reference laboratory for the diagnosis of SARS-CoV-2 regionally. Also, PCR-based swab was the most available test for HCW, and the technique used has been previously published.[24]

Data collection

Data were collected using a web-based software platform by FITec (Recife, Pernambuco, Brazil). The HCW answered the questionnaire by accessing a link that could be opened on a smartphone or a computer browser.

Data analysis

Participants were weighted by the size of each category, provided by each professional board and by the inverse of the size of their professional network, based on the following question: 'How many of these colleagues are close to you and would you invite to participate in this study?' To avoid the influence of extreme network sizes on the weight of each professional, we limited the network size to 3–150 for outlier correction.[25] For missing data—representing around 8% of the total—we used available information from the other two questions related to network size, and when necessary, we applied the overall mean of the stratum. The seeds (primary) were used to define the cluster of the study.

Categorical variables are presented as percentages and 95% CIs by HCW category and overall frequencies adjusted for the design. The χ^2 test was used for comparison between groups. We calculated the means, medians and 95% CIs for continuous variables. Bivariate analysis was performed to assess the association between potential risk factors and RT-PCR positivity. Variables associated with the outcome at $p<0.20$ were included in the multivariate model. In the final model, we considered variables at the $p<0.10$ level statistically significant. All statistical analyses were performed using Stata, V.15.0 (StataCorp LLC, College Station, Texas, USA).

RESULTS

Participants

We recruited 2474 HCWs and 1525 of them were included in the analysis, in the following categories: 527 physicians, 471 registered nurses, 263 nursing assistants and 264 physical therapists. The exclusions were: 638 HCW who did not sign the informed consent, 238 that refused to participate and 28 did not complete the questionnaires. Figure 1 illustrates the recruitment chain for each category.

Descriptive data

Overall, women represented 81.1% (95% CI: 77.8% to 84.1%) of the sample after adjustment to the reference

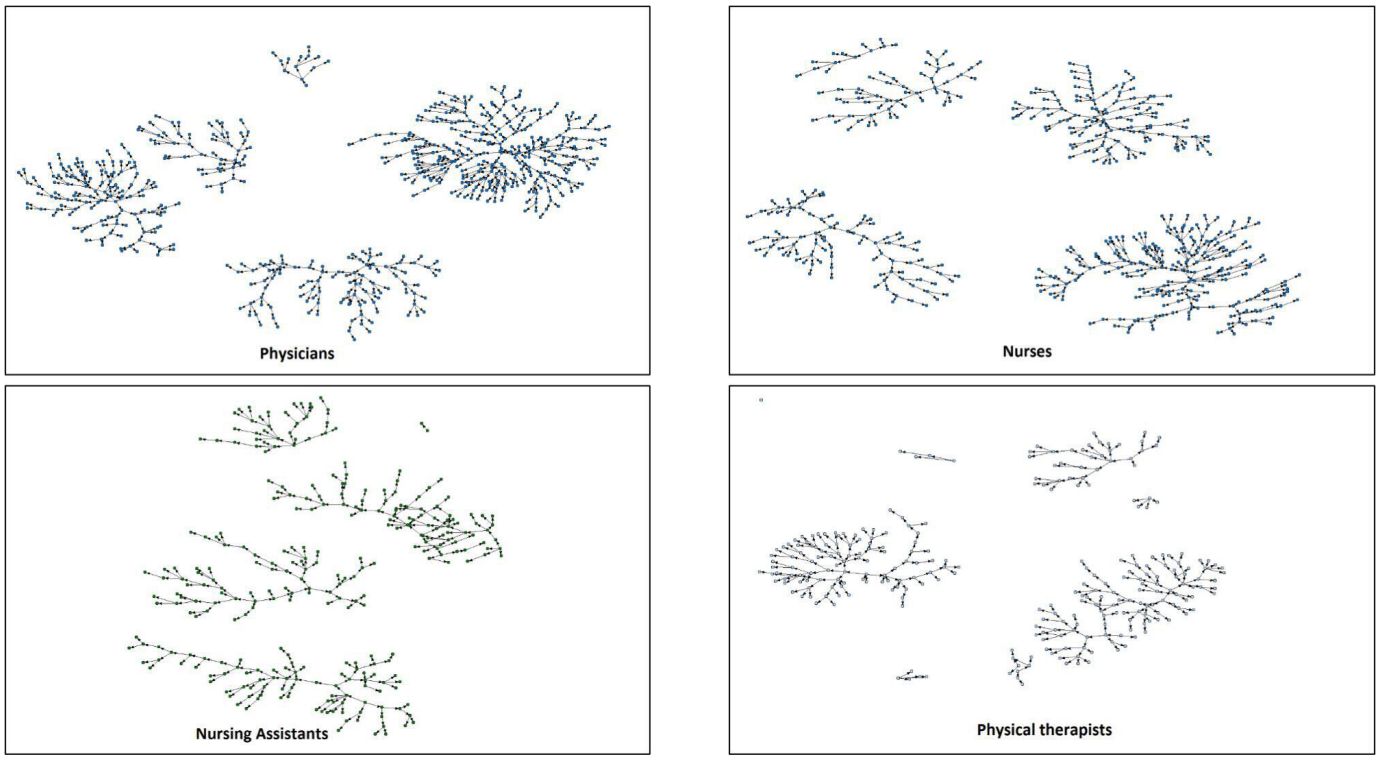

Figure 1 Respondent-driven sampling recruitment chains.

population and for the study design (table 1). Women also predominated in all professional categories, with the lowest percentage among physicians (63.4%; 95% CI: 58.6% to 67.9%) and the highest among nurses (86.7%; 95% CI: 82.7% to 89.9%) and nursing assistants (85.5%; 95% CI: 79.8% to 89.7%). The age distribution was as follows: 32.7% (95% CI: 28.8% to 36.9%) and 35.6% (95% CI: 31.5% to 40.0%) were <30 and 30–39 years old, respectively. Only 0.1% of the participants were aged≥60 years. Physicians and physical therapists were the youngest groups, comprising 56.6% (95% CI: 51.7% to 61.4%) and 45.1% (95% CI: 38.3% to 52.1%), respectively, of those 20–29 years old. Comorbidities affected 30.1% (95% CI: 26.1% to 34.3%) of the studied population. Overweight/obesity (12.6%; 95% CI: 9.9% to 15.9%) and hypertension (11.9%; 95% CI: 9.2% to 15.1%) were the most prevalent comorbidities among nursing assistants and nurses than among the other categories. In total, 71.4% (95% CI: 67.6% to 74.9%) of HCW attended COVID-19 cases exclusively in the public sector, including hospitals, emergency units, ambulance services and primary care units. Most HCW (73.5%; 95% CI: 69.2% to 77.3%) worked either in emergency rooms or ICU. Notably, 55.8% (95% CI: 51.0% to 60.6%) of the physicians and 37.8% (95% CI: 31.3% to 44.8%) of the physical therapists indicated working in three or more institutions during the pandemic (table 1).

Overall, 78.0% (95% CI: 74.2% to 81.3%) of the participants received training on the use of PPE. Physical therapists (87.0%; 95% CI: 81.6% to 91.0%) and nursing assistants (81.1%; 95% CI: 74.8% to 86.1%) received a higher and similar frequency of training compared with the other categories. Almost half of the HCW (47.7%) reported a shortage of PPE items during the COVID-19 pandemic. Regarding wearing PPE in routine activities, the overall frequencies varied widely for each item: 90.1% (95% CI: 87.7% to 92.0%) for single-use gloves to 29.9% (95% CI: 25.9% to 34.2%) for face shields. Most HCW (82.2%; 95% CI: 78.4% to 85.5%) reported performing AGPs on patients with COVID-19. Almost all participants reported having always used single-use gloves (98.4%; 95% CI: 96.4% to 99.3%) and N95 respirators (86.4%; 95% CI: 82.5% to 89.5%) during AGPs. The N95/PPF2 respirator was reused for more than 7 days by approximately 28.3% (95% CI: 24.7% to 32.1%) of the participants, with highest and lowest frequencies reported by physicians (49.3%; 95% CI: 44.4% to 54.2%) and nursing assistants (20.6%; 95% CI: 15.4% to 27.0%), respectively. Overall, 63.7% (95% CI: 57.8% to 69.2%) of the HCW reported always wearing all PPE items as recommended by the WHO. The self-perception of SARS-CoV-2 risk of infection in the previous 15 days varied: 33.4% for 'performing a procedure on a patient with COVID-19'; 17.7% for 'sharing the break room with their colleagues'; 16% for the 'reuse of N95 respirators'; 10.6% for the 'use of poor quality PPE'; 10.2% during 'doffing'; 9.6% for 'working with colleagues with COVID-19 symptoms'; 1.9% for 'lack of PPE in the service'; and 0.5% for 'donning PPE'. HCW reported 186 episodes of exposure to biological fluids/respiratory secretions during healthcare interaction with patients with COVID-19. Accidents were more frequent among physicians (13.9%; 95% CI: 11.0% to 17.4%) and less frequent among physical therapists (7.6%; 95% CI: 4.9% to 11.7%) (table 2).

Table 1 Demographic, clinical and working baseline characteristics of healthcare workers in the metropolitan region of Recife, Northeast Brazil, 2020—2021

	Physicians (n=527)		Nurses (n=471)		Nursing assistants (n=263)		Physical therapists (n=264)		Total	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Sex										
Female	63.4	58.6 to 67.9	86.7	82.7 to 89.9	85.5	79.8 to 89.7	70.3	63.6 to 76.3	81.1	77.8 to 84.1
Male	36.6	32.1 to 41.4	13.2	10.1 to 17.3	14.5	10.2 to 20.2	29.7	23.7 to 36.4	18.9	15.9 to 22.2
Age, years										
<30	56.6	51.7 to 61.4	25.8	21.6 to 30.6	26.9	20.8 to 33.9	45.1	38.3 to 52.1	32.7	28.8 to 36.9
30–39	34.1	29.6 to 38.9	37.3	32.5 to 42.4	34.5	28.0 to 41.6	45.3	38.5 to 52.4	35.6	31.5 to 40.0
≥40	9.3	6.8 to 12.6	36.9	32.1 to 41.9	38.6	32.0 to 45.7	9.6	6.2 to 14.4	31.7	27.6 to 36.0
Any comorbidity										
Any	23.3	19.5 to 27.6	33.9	29.2 to 38.8	32.0	25.8 to 38.9	19.0	14.1 to 25.1	30.1	26.1 to 34.3
None	76.7	72.4 to 80.5	66.1	61.2 to 70.8	68.0	61 to 74.2	81.0	74.9 to 85.9	69.9	65.7 to 73.8
Diabetes	1.0	0.4 to 2.6	2.1	1.1 to 4.1	2.0	0.8 to 5.1	0.4	0.1 to 3.1	1.8	0.9 to 3.4
Hypertension	4.0	2.5 to 6.4	13.2	10.0 to 17.1	14.4	10.1 to 19.9	4.8	2.5 to 8.9	11.9	9.2 to 15.1
Overweight/obesity	7.3	5.3 to 10.0	11.1	8.2 to 14.6	14.9	10.6 to 20.4	8.9	5.6 to 13.7	12.6	9.9 to 15.9
Heart disease	0.4	0.1 to 1.3	1.2	0.5 to 3.0	0.9	0.2 to 3.5	0.0	–	0.1	0.3 to 2.1
Kidney disease	0.0	–	0.2	0.03 to 1.5	0.1	0.02 to 1.1	0.8	0.2 to 3.1	0.2	0.1 to 0.6
Others comorbidities	13.1	10.1 to 16.7	14.8	11.6 to 18.8	9.4	5.9 to 14.7	6.9	4.2 to 11.4	10.8	8.4 to 13.8
Number of workplaces										
<3	44.2	39.4 to 49.0	91.8	88.4 to 94.2	95.2	92.0 to 97.2	62.2	55.2 to 68.7	84.2	82.1 to 86.1
≥3	55.8	51.0 to 60.6	8.2	5.8 to 11.6	4.8	2.8 to 8.0	37.8	31.3 to 44.8	15.8	13.9 to 17.9
Missing	2		0		1		0		3	
Institution provider										
Private	5.2	3.5 to 7.8	7.2	4.8 to 10.5	7.0	4.1 to 11.5	14.8	10.4 to 20.5	7.2	5.3 to 9.8
Public	44.5	39.7 to 49.3	81.2	76.8 to 85.0	79.8	73.5 to 85.0	35.2	28.9 to 42.2	71.4	67.6 to 74.9
Both	50.3	45.5 to 55.2	11.6	8.7 to 15.4	13.2	9.1 to 18.9	50.0	43 to 56.9	21.4	18.4 to 24.7
Work setting										
Outpatient/inpatient clinics	12.0	9.1 to 15.6	41.6	36.6 to 46.8	27.7	21.6 to 34.7	11.5	7.6 to 17.0	26.5	22.7 to 30.8
ICU/emergency	88.0	84.4 to 90.9	58.4	53.2 to 63.4	72.3	65.3 to 78.4	88.5	83.0 to 92.4	73.5	69.2 to 77.3

Frequency for each professional category: adjusted for cluster random effect and weighted by network size. Total frequency: adjusted for cluster random effect and weighted by network and population size.
ICU, intensive care unit.

Table 2 Adherence to infection prevention and control during healthcare interactions with patients with COVID-19 and accidents with biological materials

	Physicians (n=527)		Nurses (n=471)		Nursing assistants (n=263)		Physical therapists (n=264)		Total	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Training on PPE use										
Yes	68.9	64.2 to 73.2	72.3	67.4 to 76.7	81.1	74.8 to 86.1	87.0	81.6 to 91.0	78.0	74.2 to 81.3
No	31.1	26.8 to 35.8	27.7	23.3 to 32.6	18.9	13.9 to 25.2	13.0	9.0 to 18.4	22.0	18.7 to 25.8
Missing	3		0		0		0		3	
While providing routine assistance to patients with COVID-19, have you used these PPE:										
Single gloves										
Always	74.1	69.6 to 78.1	84.4	80.3 to 87.8	95.4	90.9 to 97.7	96.1	92.1 to 98.1	90.1	87.7 to 92.0
Not always	25.9	21.9 to 30.4	15.6	12.2 to 19.7	4.6	2.3 to 9.1	3.9	1.9 to 7.9	9.9	8.0 to 12.3
Missing	2		2		0		1		5	
Surgical mask										
Always	45.3	40.6 to 50.2	58.6	53.5 to 63.6	51.0	43.8 to 58.1	36.9	30.3 to 44.0	50.5	46.0 to 54.9
Not always	54.7	49.8 to 59.4	41.4	36.4 to 46.5	49.0	41.9 to 56.1	63.1	56.0 to 69.6	49.5	45.1 to 53.9
Missing	2		2		0		1		5	
N95 respirator										
Always	64.4	59.6 to 68.9	57.4	52.3 to 62.4	66.3	59.1 to 72.9	87.3	81.6 to 91.4	65.9	61.4 to 70.0
Not always	35.6	31.1 to 40.3	42.6	37.6 to 47.7	33.7	27.1 to 40.9	12.7	8.6 to 18.4	34.1	30.0 to 38.6
Missing	2		2		0		1		5	
Face shield										
Always	19.6	16.0 to 23.9	28.8	24.4 to 33.7	31.6	25.3 to 38.6	42.4	35.7 to 49.3	29.9	25.9 to 34.2
Not always	80.4	76.1 to 84.0	71.2	66.3 to 75.6	68.4	61.4 to 74.7	57.6	50.7 to 64.3	70.1	65.8 to 74.1
Missing	2		2		0		1		5	
Goggles/protective glasses										
Always	18.7	15.3 to 22.7	24.6	20.4 to 29.3	38.3	31.6 to 45.4	45.6	38.7 to 52.6	33.2	29.1 to 37.6
Not always	81.3	77.2 to 84.7	75.4	70.7 to 79.5	61.7	54.6 to 68.4	54.4	47.4 to 61.3	66.8	62.3 to 70.9
Missing	2		2		0		1		5	
Disposable gown										
Always	48.0	43.3 to 52.9	50.8	45.6 to 55.9	63.8	56.6 to 70.4	67.2	60.3 to 73.3	59.2	54.8 to 63.5
Not always	52.0	47.1 to 56.7	49.2	44.1 to 54.4	36.2	29.5 to 43.4	32.8	26.7 to 39.7	40.8	36.5 to 45.2
Missing	2		2		0		1		5	
Waterproof apron										
Always	30.5	26.2 to 35.2	38.6	33.7 to 43.7	48.9	41.6 to 56.3	62.6	55.3 to 69.4	44.9	40.5 to 49.5

Continued

Table 2 Continued

	Physicians (n=527)		Nurses (n=471)		Nursing assistants (n=263)		Physical therapists (n=264)		Total	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Not always	69.5	64.8 to 73.8	61.4	56.3 to 66.3	51.1	43.7 to 58.4	37.4	30.6 to 44.7	55.1	50.5 to 59.5
Missing	14		11		11		18		54	
During provision of routine assistance to patients with COVID-19, did you wear all PPE items as recommended by the WHO?										
Always	89.6	86.2 to 92.3	79.2	74.7 to 83.1	70.0	63.1 to 76.1	69.0	62.2 to 75.1	74.7	70.5 to 78.5
Not always	10.4	7.7 to 13.8	20.8	16.9 to 25.3	30.0	23.9 to 36.9	31.0	24.9 to 37.8	25.3	21.5 to 29.5
Missing	2		2		0		1		5	
Participated in AGPs										
Yes	79.6	75.3 to 83.2	75.6	70.8 to 79.8	83.4	77 to 88.3	95.8	91.7 to 97.8	82.2	78.4 to 85.5
No	20.4	16.8 to 24.7	24.4	20.2 to 29.2	16.6	11.7 to 23	4.2	2.1 to 8.3	17.8	14.5 to 21.6
Missing	1		1		1		2		5	
While participating in AGPs, have you used:										
Single Gloves										
Always	97.8	95.5 to 98.9	97.7	95.1 to 99	98.5	94.2 to 99.6	99.7	98.1 to 99.9	98.4	96.4 to 99.3
Not always	2.2	1.1 to 4.5	2.3	1 to 4.9	1.5	0.4 to 5.8	0.3	0.04 to 1.9	1.6	0.7 to 3.6
Missing	0		0		0		1		1	
Surgical mask										
Always	61.5	56.2 to 66.6	49.9	44.1 to 55.7	46.5	38.9 to 54.3	60.2	52.9 to 67.1	50.5	45.6 to 55.3
Not always	38.5	33.4 to 43.8	50.1	44.3 to 55.9	53.5	45.7 to 61.1	39.8	32.9 to 47.1	49.5	44.7 to 54.4
Missing	0		0		0		1		1	
N95 respirator										
Always	92.4	89 to 94.9	85.0	80.3 to 88.8	84.2	77.8 to 89.1	93.3	88.2 to 96.3	86.4	82.5 to 89.5
Not always	7.6	3.1 to 11	15.0	11.2 to 19.7	15.7	10.9 to 22.2	6.7	3.7 to 11.8	13.6	10.5 to 17.5
Missing	0		0		0		1		1	
Face shield										
Always	51.6	46.2 to 56.9	48.3	42.6 to 54.1	48.0	40.3 to 55.7	41.4	34.5 to 48.6	48.1	43.2 to 53.0
Not always	48.4	43.1 to 53.8	51.7	45.8 to 57.4	52.0	44.2 to 59.7	58.6	51.4 to 65.5	51.9	47.0 to 56.8
Missing	0		0		0		1		1	
Goggles/Protective glasses										
Always	62.5	57.1 to 67.6	59.3	53.5 to 64.9	51.4	43.6 to 59.1	47.1	40 to 54.3	54.0	49.1 to 58.9
Not always	37.5	32.4 to 42.8	40.7	35.1 to 46.5	48.6	40.9 to 56.4	52.9	45.7 to 60	46.0	41.1 to 50.9
Missing	0		0		0		1		1	

Continued

Table 2 Continued

	Physicians (n=527)		Nurses (n=471)		Nursing assistants (n=263)		Physical therapists (n=264)		Total	
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Disposable gown										
Always	60.3	55.0 to 65.4	60.1	54.3 to 65.7	64.0	60.3 to 74.9	68.3	61.3 to 74.4	65.6	60.8 to 70.1
Not always	39.7	34.6 to 45.0	39.9	34.3 to 45.7	32.0	25.1 to 39.7	31.7	25.6 to 38.7	34.4	29.9 to 39.2
Missing	0		0		0		1		1	
Waterproof apron										
Always	55.2	49.7 to 60.6	60.7	54.8 to 66.3	62.5	54.4 to 69.9	74.6	67.4 to 80.7	61.9	57.0 to 66.7
Not always	44.8	39.4 to 50.3	39.3	33.7 to 45.2	37.5	30.1 to 45.6	25.4	19.3 to 32.6	38.1	33.3 to 43.0
Missing	9		7		9		17		42	
When performing an AGP in patients with COVID-19, did you wear all recommended PPE items as in WHO guidance?										
Always	66.0	60.0 to 71.4	58.0	51.4 to 64.3	63.8	54.1 to 72.6	74.7	64.2 to 82.8	63.7	57.8 to 69.2
Not always	34.0	28.6 to 40.0	42.0	35.7 to 48.6	36.2	27.4 to 45.9	25.3	17.2 to 35.8	36.3	30.8 to 42.2
Missing	0		0		0		1		1	
Duration of N95 respirator use										
<8 days	50.7	45.8 to 55.6	71.4	66.6 to 75.8	79.4	73.0 to 84.6	54.6	47.6 to 61.5	71.7	67.9 to 75.3
≥8 days	49.3	44.4 to 54.2	28.6	24.2 to 33.4	20.6	15.4 to 27.0	45.4	38.5 to 52.4	28.3	24.7 to 32.1
Missing	9		5		8		4		26	
Any accident involving body fluid/respiratory secretion										
Yes	13.9	11 to 17.4	10.8	7.9 to 14.5	11.7	7.9 to 17.1	7.6	4.9 to 11.7	11.6	9.1 to 14.8
No	86.1	82.6 to 89	89.2	85.5 to 92.1	88.3	82.9 to 92.1	92.4	88.3 to 95.1	88.4	85.2 to 90.9
Organ involved										
Splash in the Mouth	1.9	1.02 to 3.8	1.9	0.85 to 4.3	0.2	0.04 to 1.5	0.7	0.2 to 3.1	0.8	0.5 to 1.4
Splash on the Skin	2.4	1.4 to 3.9	3.4	1.9 to 6.0	1.3	0.5 to 3.2	3.9	1.9 to 7.7	2.0	1.3 to 3.0
Splash on the Eyes	2.3	1.4 to 3.9	3.5	1.9 to 6.1	2.1	0.8 to 5.8	2.5	1.2 to 5.0	2.4	1.4 to 4.2
Puncture/sharps	8.2	5.9 to 11.3	3.0	1.7 to 5.3	8.2	4.9 to 13.4	0.0	–	6.7	4.6 to 9.7
Self-perception of risk										
None/Low	21.6	17.9 to 25.9	24.9	20.7 to 29.6	21.9	16.3 to 28.7	17.2	12.5 to 23.3	22.0	18.5 to 26.1
Medium/High	78.4	74.1 to 82.1	75.1	70.3 to 79.3	78.1	71.3 to 83.7	82.8	76.7 to 87.5	78.0	73.8 to 81.5
Missing	9		2		6		4		21	

Frequency for each professional category: adjusted for cluster random effect and weighted by network size. Total frequency: adjusted for cluster random effect and weighted by network and population size.
AGPs, aerosol-generating procedures; ICU, intensive care unit; PPE, personal protective equipment.

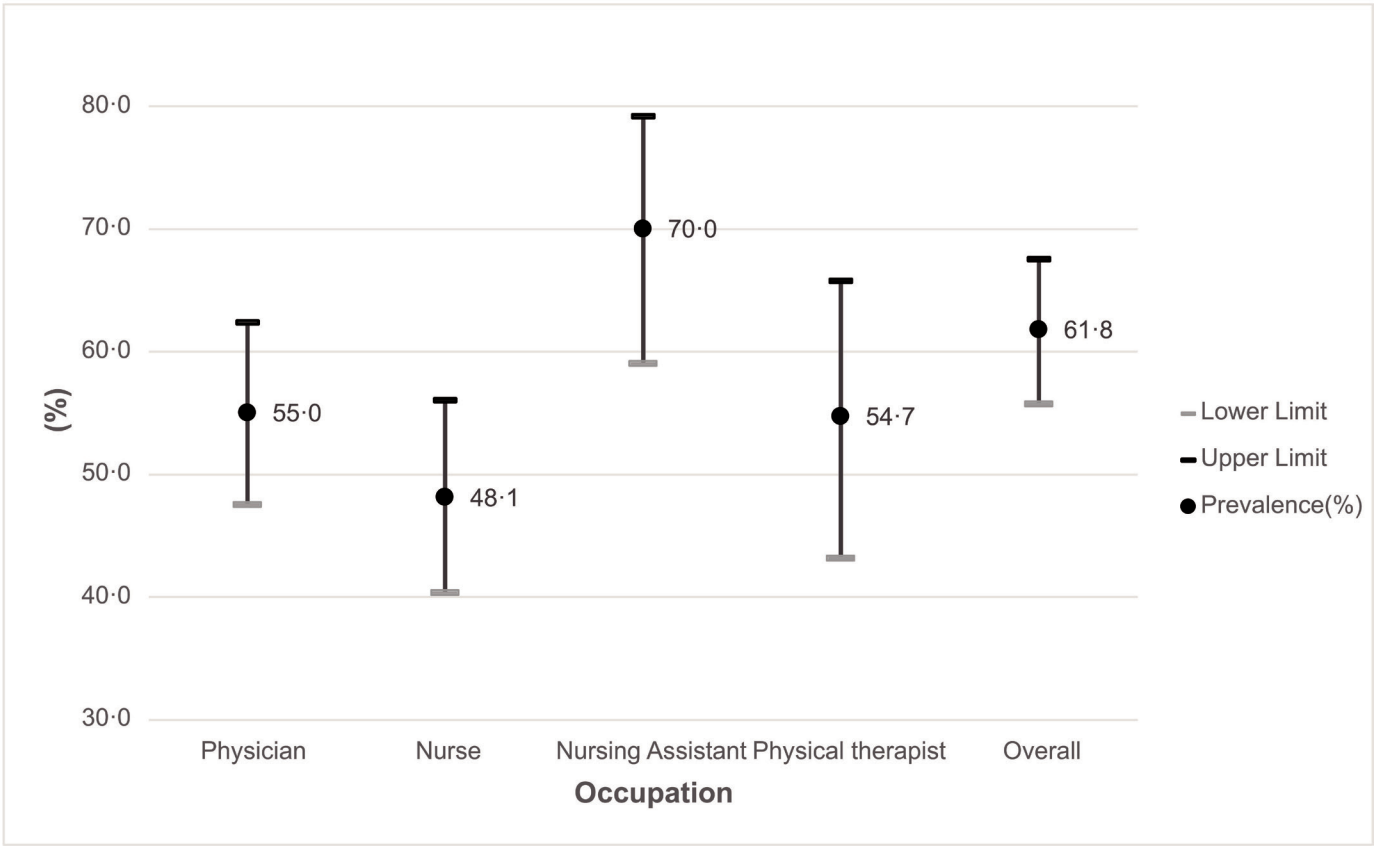

Figure 2 Frequencies of self-reported SARS-CoV-2 infection by healthcare categories.

The frequency of COVID-19 testing varied from 41.2% for physical therapists to 51.1% for physicians. Individuals with any comorbidity were more likely to get tested (56.8%) than those without comorbidities (p<0.001). HCW who worked in three or more health services were also more likely to get tested (54.9%) than those who worked in only one health service (42.1%) (p<0.001). There was no statistical difference in the likelihood of testing, according to sex, age group (<30 versus≥30 years old), work setting (outpatients, inpatients, and emergency rooms and ICU), self-perception of risk (no risk to high risk of exposure), reported accidents with biological fluid/respiratory secretion, and when performing AGPs (online supplemental table S1).

For the tested HCW, mostly symptomatic, the overall self-reported SARS-CoV-2 infection was 61.8% (95% CI: 55.7% to 67.5%) compared with 14.9% (CI: 4.9% to 37.5%) among asymptomatic, after adjustment for random cluster effects, weighted by network and population size. The highest infection positivity was among nursing assistants (70.0%; 95% CI: 59.0% to 79.1%), followed by physicians (55.0%; 95% CI: 47.5% to 62.3%), physical therapists (54.7%; 95% CI: 43.1% to 65.7%) and nurses (48.1%; 95% CI: 40.3% to 56.0%), adjusted for random cluster effects (figure 2). RT-PCR screening was performed mainly among symptomatic cases in all categories, ranging from 81.8% to 91.8% for physicians and nursing assistants, respectively.

Almost half of the HCW (47.8%) reported taking sick leave due to COVID-19, with a similar trend among the other categories (p=0.159). The median length of health leave was 14 days for all professional categories, reflecting a standard procedure. Of 399 symptomatic SARS-CoV-2 infected HCW, 10% (n=41) were hospitalised.

In a bivariate analysis, the nursing assistant category was positively associated with infection (OR=2.77; 95% CI: 1.64 to 4.67, p<0.001) compared with nurses. Reporting any accident involving body fluid/respiratory secretion was associated with infection (OR=2.67; 95% CI: 1.22 to 5.82, p<0.014). When considering each accident, splashes in the eyes were a stronger predictor of infection (OR=4.07; 95% CI: 1.14 to 14.55, p<0.031). During routine assistance of patients with COVID-19, not always wearing the complete set of recommended PPE items was associated with infection (OR=2.14; 95% CI: 1.18 to 3.88, p=0.013) when compared with always using PPE. Not always using the complete recommended PPE items during AGPs was also associated with infection (OR=1.68; 95% CI: 0.97 to 2.92, p=0.063) when compared with always using PPE (online supplemental table S2).

In the final multivariate logistic regression model, the following were the risk factors for infection: being a nursing assistant (OR adjusted=2.56; 95% CI: 1.42 to 4.61, p=0.002), not always having used PPE during care of patients with COVID-19 (OR adjusted=2.15; 95% CI: 1.02 to 4.53, p=0.044) and having suffered a splash to the

Table 3 Final multivariate model for factors associated with reported positive PCR COVID-19 results

	OR	95% CI	P value
Occupation			
Nurse	1.0	––	–
Physical therapist	1.47	0.80 to 2.72	0.214
Physician	1.20	0.76 to 1.90	0.426
Nursing assistant	2.56	1.42 to 4.61	0.002
Splash on the eyes			
No accident	1.0	–	–
Yes	3.37	1.10 to 10.34	0.034
Any accident	1.59	0.51 to 4.90	0.421
Used all PPE items while assisting patients with COVID-19			
Yes	1.0	–	–
No	2.15	1.02 to 4.53	0.044

Adjusted for cluster random effect and weighted by network and population size.
PPE, personal protective equipment.

eyes (OR adjusted=3.37; 95% CI: 1.10 to 10.34, p=0.034) (table 3).

DISCUSSION

The current study showed substantial heterogeneity in demographic and self-referred comorbidities between HCW categories during the COVID-19 pandemic. Of note, physicians and physical therapists at the front-line were younger and mainly worked in the ICU and emergency rooms when compared with nurses. This reflects the expansion of the healthcare workforce with the inclusion of younger physicians and physical therapists, possibly inexperienced professionals, forcibly driven to work as front liners in a high-risk environment. Nurses and nursing assistants were older and reported more comorbidities, particularly hypertension and overweight/obesity. According to the accumulated evidence, the public health strategy was to prevent exposure among older age groups and/or individuals with comorbidities, as older age and comorbidities are strong prognostic factors for hospitalisation and death.[26]

To the best of our knowledge, our study depicted one of the highest frequencies of SARS-CoV-2 infections among HCW, with nursing assistants being the most vulnerable category. In consonance with this finding, nursing assistants also had the highest prevalence of infection comparing with the other staff in a university hospital in the Southeast of Brazil.[16] One likely explanation is that most of the participants tested were symptomatic, reflecting the policy of making RT-PCR tests for COVID-19 diagnosis available to front-line HCW. Thus far, there has been no mass RT-PCR testing strategy for the Brazilian population despite WHO recommendations.[27] Worldwide, the prevalence closest to that of our study was 55%, by RT-PCR among 177 symptomatic medical residents in New York city at the beginning of the COVID-19 pandemic.[28] In Southeast Brazil, a high prevalence of SARS-CoV-2 infection (42%) tested by RT-PCR was found among symptomatic HCW at a teaching hospital in Sao Paulo, from March to May 2020.[15] Another study found a prevalence of 14% (701 out of 4987) using RT-PCR in a group composed of mainly symptomatic HCW, at a hospital in the South of Brazil from April to June 2020.[14] This variation might be attributable to the dynamics of the pandemic in different regions of the country, the availability/quality of PPE, and training in different healthcare settings.

Finding of seroprevalence studies cannot be directly compared with our results. The frequencies of SARS-CoV-2 infection among HCW in São Paulo city ranged from 5.5% (IgG ELISA) in a private hospital to 14% (IgG/IgM antibody, WONDFO) in a large public hospital in 2020.[29 30] Both hospital settings stated that they adopted high-quality hospital infection control and provided complete PPE in the early stages of the COVID-19 pandemic. This may reflect especially high-quality healthcare facilities in more developed regions of the country and the rates reported were similar to those reported in another meta-analysis of seroprevalence studies.[31]

In our setting, critical aspects for the high risk of SARS-CoV-2 infection included a shortage of PPE items reported by approximately half the HCW. Moreover, 22% of HCW reported not been trained on PPE use. The lack of preparedness of the health workforce to respond to the COVID-19 pandemic was not only encountered by low-income and medium-income countries such as Brazil but also in high-income countries at the beginning of the pandemic.[32] At the individual level, one-fourth of the HCW reported that PPE was not always used according to the WHO recommendations.[27] When performing AGPs, the nursing staff had the highest frequency (over 35%) of not fully adhering to complete PPE.[33] However, not always using the recommended PPE during performance of AGPs was not associated with PCR positive reports in our analysis. This finding is in line with a recent study questioning the concept of AGPs for risk-stratifying patients, since most procedures considered as AGPs do not meaningfully increase respiratory aerosols.[34] In the current study, not using the recommended PPE during routine attendance of COVID-19 cases caused a 2.2-fold increased risk of a SARS-CoV-2 positive RT-PCR test result. Accidents with biological fluids occurred in all categories; however, they were most frequently reported among physicians, the youngest, and perhaps the group with the least experience working in critical conditions. Reporting an accident with biological fluids, such as a splash in the eye, was positively associated with infection in the final multivariable model. Although it is uncertain whether viruses occasionally present in biofluids are infectious, these fluids should be considered potentially infectious.[35] Moreover, the eye has been considered a possible route of

SARS-CoV-2 entry through drainage via the nasolacrimal duct to the upper respiratory tract.[36] These accidents with biological fluids should be further investigated in other studies, as recommended by the WHO guidelines.[23] The prevalence among HCW in the current study was at least 20-fold higher when compared with the 3.2% seroprevalence in a population-based survey using SARS-CoV-2 antibody rapid tests conducted during the first wave of the pandemic in the same region.[37] Therefore, there is strong evidence that HCW are at a high risk of SARS-CoV-2 infection in low-income and medium-income settings, such as Northeast Brazil.

To the best of our knowledge, this is the largest South American study of HCW during the COVID-19 pandemic, with the inclusion of the four main healthcare professionals in the public and private sectors and multiple levels of health services. Previous investigations conducted in Brazil were mainly restricted to one hospital setting and did not apply the WHO questionnaire.[23]

The advantage of using the respondent-driven sampling technique was that it allowed the inclusion of HCW from different healthcare settings, including the private and public health services, providing a more comprehensive picture of front-line HCW during the pandemic. Furthermore, as HCW worked in more than one health service and/or in newly implemented 'field hospitals/units', this strategy allowed us to capture the full extent of characteristics of the workforce and the risk factors for infection. Another advantage of applying an online questionnaire was to avoid face-to-face interviews during the lockdown and/or social distancing restrictions, reduce errors in data transcription, and obtain timely results.

We acknowledge as a potential limitation that our result was based on self-report COVID-19 results. In fact, this outcome is in consonance with previously large-scale online surveys published during COVID-19 pandemic.[6 38 39] HCW have the ability by their professional training for reporting a positive PCR test for COVID-19. It is important to mention that during this study period, the most available test was the PCR-based nasal swab, mainly performed by the reference laboratory in charge of the COVID-19 public health response regionally. Nevertheless, some misclassification of the outcome cannot be excluded.

Respondent-driven sampling study are traditionally designed for 'hard-to-reach population' in a lack of a sampling frame.[17] In the study setting, the population of health professionals at front line although not a hard-to-reach population was made more difficult to access due a lack of sampling frame and the enormous time burden on the staff. Therefore, we did not access this population in a probabilistic sampling, but via the chain referral samples (social network), which potentially induce selection bias. Despite this limitation, inherent of RDS technique, the study had several waves of recruitment chains, achieving a large and heterogeneous sample. In addition, we estimated the weighted prevalence of SARS-CoV-2 infection considering the social network size to minimise the potential selection bias introduced by the study design. Another limitation is that the study was not designed as genomic surveillance or contact tracing to distinguish the setting of the transmission. However, the participants were front liners attending suspected or confirmed patients with COVID-19. In fact, only 15.2% of them referred to have had contact with COVID-19 cases simultaneously in healthcare facilities and at the household (data not shown). In our analysis, the risk factors associated with infection were higher among nursing assistants; HCW not using all PPE items as recommended, and to professionals reporting an accident during their activities. It is likely that the high frequency of infections among front-line HCW was presumably healthcare associated infections in line with our findings, with the scenario of shortage of PPE and the high healthcare pressure during the first pandemic wave. Nevertheless, the source of SARS-CoV-2 infection could not be ascertained in this study.

There was an imbalance in recruitment among the HCW categories; physicians and nurses were more rapidly enrolled by RDS than nursing assistants. One possible explanation is that physicians and nurses seem to understand research methodology better and/or to have either better smartphones or data plans required to answer the approximately 15 min online questionnaire. Physicians and nurses were also a more vocal category early in the pandemic, publicising the constraints/pressure of the workplace. Conversely, nursing assistants, as routine healthcare assistants, spend more time providing direct patient care and have low wages. They could also be less confident/willing to participate due to work overload or unfavourable socioeconomic conditions when compared with the other categories that require university degrees. Additionally, disclosure of the work environment concerning PPE and infection control prevention may be problematic for nursing assistants whose jobs are less stable and more prone to replacement in our setting. Accidents involving biological fluids should be further investigated in other studies to validate this finding.

The study shows the high frequency of SARS-CoV2 infection among HCW presumably due to workplace exposures. In our setting, nursing assistants comprised the most vulnerable category. Our findings highlight the need for improving healthcare facility environments, specific training and supervision to cope with public health emergencies.

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Acknowledgements We thank HCW for their participation. We acknowledge the Institute of Health Technology Assessment and MCTIC/CNPq/FNDCT/MS/SCTIE/Decit Nº 07/2020 for support and FITec (Brazil) for the web-based software platform. The following researchers received scholarship (CNPq-Pq): 308974/2018-2 to CMTM, 309722/2017-9 to RAAX, 301905/2017-7 to MFPMA, no. 30735/2018-1 to CB and 303661/2017-8 to WVdS. CRP received scholarship from CNPq, EV-1 no. 315877/2020-0. We thank all participants for their important contribution in this project. We would like to thank Editage (www.editage.com) for English language editing.

Contributors MdFPMdA, WVdS, CMTM, RAdAX, DdBM-F, TVBdA, CK and LRFSK contributed to the study concept and design. MdFPMdA is the principal investigator and the guarantor of the study. CB, MNX, CNLdM, GDMdA, CB-S, CAM, NTdS-F, JMG, CLF-N and JMVB contributed to the acquisition of data. MdFPMdA, URM, WVdS, CLS, PRBdS-J and CRP contributed to the data analysis and creation of tables and figures. MdFPMdA, WVdS, CMTM, RAdAX, DdBM-F, TVBdA, MASMV, LNGCL, CB and LNC contributed to data interpretation. MdFPMdA, WVdS and URM have verified the underlying data. CMTM, MdFPMdA, WVdS and CRP drafted the initial manuscript and all other coauthors contributed scientific inputs equally towards the interpretation of the findings and the final draft of the manuscript. All authors confirm that they had full access to all the data in the study and accept responsibility to submit for publication.

Funding This investigation was funded by Health Technology Assessment Institute (IATS) and by MCTIC/CNPq/FNDCT/MS/SCTIE/Decit Nº 07/2020.

Competing interests None declared.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Consent obtained directly from patient(s).

Ethics approval This study involves human participants. Providing electronic informed consent was mandatory to participate and access the questionnaire. The project was approved by the National Ethics Committee of Brazil (CONEP; CAAE: 30629220.8.0000.0008). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Proposals for the dataset (deidentified participant data, data dictionary) should be directed to the corresponding author: turchicm@gmail.com. To gain access, data requestors will need to present their plan of analysis and sign a data access agreement.

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