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High risk of SARS-CoV-2 infection among frontline healthcare workers in Northeast Brazil: a respondent-driven sampling approach

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High risk of SARS-CoV-2 infection among frontline healthcare workers in Northeast Brazil: a respondent-driven sampling approach

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Abstract

Introduction: The disparities in the risk of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection among frontline health care workers (HCWs) and the unique work circumstances are poorly documented for low-and middle-income countries.

Methods: We assessed the frequency of SARS-CoV-2 infection, personal protective equipment (PPE) shortages, PPE use, and accidents involving biological material among HCWs in the Recife metropolitan area, Northeast Brazil. Using respondent driven sampling (RDS), we included HCWs attending suspected or confirmed COVID-19 patients from May 2020 to February 2021.

Results: We analyzed 1,525 HCWs (527 physicians, 471 registered nurses, 263 nursing assistants/technicians, and 264 physical therapists). Women predominated in all categories (81.1%). Nurses were older and had more comorbidities (hypertension and overweight/obesity) than the other HCWs. The overall prevalence of SARS-CoV-2 infection was 61.8% after adjustment for the cluster random effect, weighted by network, and reference population size. The independent risk factors for a positive RT-PCR test were being a nursing assistant (OR adjusted: 2.56), not always using all recommended PPE in routine practice (ORadj: 2.15), and reporting a splash of biological fluid/respiratory secretion in the eyes (ORadj: 3.37).

Conclusions: The high risk of infection among HCWs reflects PPE shortages and younger, possibly less experienced, frontline HCWs. There were disparities in the risk of SARS-CoV-2 infection among HCWs, with nursing assistants being the most vulnerable, possibly due to their longer and frequent contact with COVID-19 patients.

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Strengths and limitations of this study

- One of the strengths of this study is that the design enables the health care system and community in general to get a comprehensive picture of the physicians, nurses, nursing assistants, and physical therapists at the frontline during the COVID-19 pandemic in Northeast Brazil.
- Using respondent driven sampling (RDS) methodology allowed the inclusion of frontliners from different healthcare settings, in the private and public health sector. The results captured the full extent of characteristics of the workforce and the risk factors for infection during the pandemic in our setting. There was also an advantage of applying an online questionnaire which avoided face-to-face interviews. This fieldwork approach was appropriated during the lockdown and/or social distancing restrictions. It also aimed at reducing errors in data transcription, and in obtaining timely results.
- This study had some limitations inherent of RDS methodology regarding the representativeness of the participants recruited. We also acknowledge that there was also an imbalance in recruitment among the HCW categories. In our study physicians and nurses were more rapidly enrolled by RDS methodology than nursing assistants and physical therapists at the frontline.

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Introduction

The unprecedented rapid spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and its potentially severe outcomes have highly impacted the healthcare system, the global economy, and security.[1,2] According to the World Health Organization (WHO), the global cumulative number of confirmed coronavirus disease 2019 (COVID-19) cases had reached approximately 190.5 million with four million deaths by July 19, 2021.[3] In Brazil, approximately 19 million COVID-19 cases and 514,000 related deaths were reported within the same period. These figures represent almost 10% and 13% of the global COVID-19 cases and registered deaths, respectively, yet the Brazilian population represents approximately 2.5% of the global population. 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.[4]

Healthcare workers (HCWs) are considered a high-risk group due to the nature of their work. An Anglo-American prospective cohort that included approximately 100,000 HCWs showed a 3.4-fold higher risk of COVID-19 among frontline workers compared with the general community.[5] This comprehensive study used an online survey with the advantage of potentially avoiding personal contact during the pandemic, as well as allowing timely responses and dissemination of results.[5] A systematic review and meta-analysis, covering the period from the inception of the pandemic to July 2020, included 46 studies: approximately 70% were conducted in Europe (n=31), nine in the USA, six in Asia, and none in Latin America. Among symptomatic HCWs, the pooled overall prevalence of SARS-CoV-2 infection was 19% using reverse transcription-polymerase chain reaction (RT-PCR).[6]

In the Americas, 569,304 COVID-19 cases, including 2,506 deaths, had been reported among HCWs by August 2020.[7] According to public health surveillance, approximately 32% of Mexico City HCWs (n=11,226) had been infected with SARS-CoV-2 by July 2020.[8] Additionally, cross-sectional studies conducted in Brazil, Colombia, and Ecuador revealed lack of personal protective equipment (PPE) among 70% of frontline workers in the early pandemic response.[9] In Brazil, studies conducted using RT-PCR in teaching hospitals showed a varying prevalence of SARS-CoV-2 infection (42.4%–15%).[10,11,12] However, information on the prevalence of SARS-CoV-2 infection among frontline HCWs and risk factors for most regions of Brazil is limited.

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

Methods

Study design

This prospective study assessed the frequency of infected HCWs and their risk factors, using the respondent-driven sampling (RDS) methodology, 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 frontline HCWs attending emergency rooms, hospitals, and new field hospitals. RDS approach is based upon direct participant involvement.

The baseline findings are described following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for RDS.[13]

Setting

The study was conducted in the Recife metropolitan region, Pernambuco State, Northeast Brazil, where the first COVID-19 case was reported on March 12, 2020 The peak of the pandemic was during the 21st epidemiologic week in 2020.[14,15] This densely populated region comprises 15 municipalities with approximately four million inhabitants, corresponding to 42% of the state population.[16] The Brazilian unified health system (Sistema Unico de Saude—SUS) has provided universal coverage since 1990, with heterogeneity among the regions.[17]

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 formative research was valuable to adequate the research questions considering participants' priorities, experience, and preferences. Also the chosen methodology RDS requires direct involvement of the study

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participants in the recruitment and in indicating other members of the network. Therefore, the participants had an active role in the enrollment of other participants and in the development of the field work. This project was planned in collaboration with the official health care 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 HCWs attending suspected or confirmed COVID-19 patients from May 21, 2020 to February 10, 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 1,100 HCWs, considering a 95% confidence level (CI) to estimate a 40% prevalence of infections 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 COVID-19 patients?", 2) "How many of those colleagues have been in professional contact with you in the last two weeks?," and 3) "How many of them are close to you and you would invite to participate in this study?."

*Variabl*es

The variables collected were adapted from the WHO interim guidance (March 2020) on health workers' exposure risk assessment and management in the context of the COVID-19 pandemic. 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.

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(5) Adherence to IPC when performing aerosol-generating procedures (AGPs) using the abovementioned 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—I) during the period of healthcare interaction and II) 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).[18] The outcome was a self-reported positive RT-PCR test for SARS-CoV-2.

Data collection

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

Providing electronic informed consent was mandatory to participate and access the questionnaire. The project was approved by the National Ethics Committee (CONEP; CAAE: 30629220.8.0000.0008).

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 to 150 for outlier correction.[19] 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 chi-squared 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, version 15.0 (StataCorp LLC, College Station, TX, USA).

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Role of the funding source

The funding source had no involvement in any stage of the project.

Results

Participants

We recruited 2,474 health care workers and 1,525 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 HCWs 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% of the sample after adjustment to the reference population and for the study design (Table 1). Women also predominated in all professional categories, with the lowest percentage among physicians (63.4%) and the highest among nurses (86.7%) and nursing assistants (85.5%). The age distribution was as follows: 32.7% and 35.6% 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% and 45.0%, respectively, of those 20–29 years old. Comorbidities affected 30.0% of the studied population. Overweight/obesity (12.6%) and hypertension (11.9%) were the most prevalent comorbidities among nursing assistants and nurses than among the other categories. In total, 71.4% of HCWs attended COVID-19 cases exclusively in the public sector, including hospitals, emergency units, ambulance services, and primary care units. Most HCWs (73.5%) worked either in emergency rooms or ICU. Notably, 55.8% of the physicians and 37.8% of the physical therapists indicated working in three or more institutions during the pandemic (Table 1).

Overall, 78.0% of the participants received training on the use of PPE. Physical therapists (87.0%) and nursing assistants (81.1%) received a higher and similar frequency of training compared to the other categories. Almost half of the HCWs (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% for single-use gloves to 29.9% for face shields. Most HCWs (82.2%) reported performing AGPs on COVID-19 patients. Almost all participants reported having always used single-use gloves (98.4%) and N95 respirators (86.4%) during AGPs. The N95/PPF2 respirator was reused for more than seven days by approximately 28.3% of the participants, with highest and lowest frequencies reported by

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physicians (49.3%) and nursing assistants (20.6%), respectively. Overall, 63.7% of the HCWs 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.” HCWs reported 186 episodes of exposure to biological fluids/respiratory secretions during healthcare interaction with COVID-19 patients. Accidents were more frequent among physicians (13.9%) and less frequent among physical therapists (7.6%) (Table 2).

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). HCWs 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 (Supplementary Table 1).

For the tested HCWs, mostly symptomatic, the overall self-reported SARS-CoV-2 infection was 61.8% after adjustment for random cluster effects, weighted by network and population size. The highest infection positivity was among nursing assistants (70.0%), followed by physicians (55.0%), physical therapists (54.7%), and nurses (48.1%), 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 HCWs (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 HCWs, 10% (n=41) were hospitalized.

In a bivariate analysis, the nursing assistant category was positively associated with infection (odds ratio [OR]=2.77, p<0.001) compared to nurses. Reporting any accident involving body fluid/respiratory secretion was associated with infection (OR=2.67, p<0.014). When considering each accident, splashes in the eyes were a stronger predictor of infection (OR=4.07, p<0.031). During routine assistance of COVID-19 patients, not always wearing the complete

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set of recommended PPE items was associated with infection (OR=2.14; *p*=0.013) when compared to always using PPE. Not always using the complete recommended PPE items during AGPs was also associated with infection (OR=1.69; *p*=0.063) when compared with always using PPE (Supplementary Table 2).

In the final multivariate logistic regression model, the following were risk factors for infection: being a nursing assistant (OR adjusted=2.56, *p*=0.002), not always having used PPE during care of patients with COVID-19 (OR adjusted=2.15, *p*=0.044), and having suffered a splash to the eyes (OR adjusted=3.37, *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 frontline were younger and mainly worked in the Intensive Care Units 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 hospitalization and death.[20]

To our knowledge, our study depicted one of the highest frequencies of SARS-CoV-2 infections among HCWs. 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 frontline HCWs. Thus far, there has been no mass RT-PCR testing strategy for the Brazilian population despite WHO recommendations.[21] 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.[22] In Southeast Brazil, a high prevalence of SARS-CoV-2 infection (42%) tested by RT-PCR was found among symptomatic HCWs at a teaching hospital in Sao Paulo, from March to May 2020.[10] Another study found a prevalence of 14% (701 out of 4,987) using RT-PCR in a group composed of mainly symptomatic HCWs, at a hospital in the south of Brazil from April to June 2020.[12] 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.

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Our study found a 7% prevalence of infection (by RT-PCR) among the 105 asymptomatic HCWs, which is similar to the overall 5% prevalence of infection found by a large screening study for SARS-CoV-2 infection in the metropolitan area of Mexico City.[23] As expected, these results reflect the positive predictive value of clinical manifestations. Although seroprevalence studies cannot be directly compared to our findings, the frequencies of SARS-CoV-2 infection among HCWs 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.[11,24] 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.[25]

Critical aspects for the high risk of SARS-CoV-2 infection included shortage of PPE items reported by approximately half the HCWs. Moreover, 22% of HCWs 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- and medium-income countries like Brazil but also in high-income countries at the beginning of the pandemic.[26] At the individual level, one-fourth of the HCWs reported that PPE was not always used according to the WHO recommendations.[21] When performing AGPs, the nursing staff had the highest frequency (over 35%) of not fully adhering to complete PPE.[27] Furthermore, 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.[28] 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.[29] These accidents with biological fluids should be further investigated in other studies, as recommended by the WHO guidelines.[18] The prevalence among HCWs in the current study was at least 20-fold higher when compared to 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.[30] Therefore, there is strong evidence that HCWs are at a high risk of SARS-CoV-2 infection in low- and medium-income settings, such as Northeast Brazil.

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To the best of our knowledge, this is the largest Latin American study of HCWs 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.[18] One advantage of using the RDS methodology was that it allowed the inclusion of frontline HCWs from different healthcare settings, including the private and public health services, providing a more comprehensive picture of frontline HCWs during the pandemic. Furthermore, as HCWs 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.

This study had some limitations. First, 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-minute online questionnaire. Physicians and nurses were also a more vocal category early in the pandemic, publicizing 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 unfavorable socio-economic conditions when compared to 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. The current study did not discriminate the source of SARS-CoV-2 infection among HCWs. Accidents involving biological fluids should be further investigated in other studies to validate this finding.

Finally, our findings provide a comprehensive picture of the factors associated with SARS-CoV-2 infection among HCWs. This study highlighted the high prevalence of SARS-CoV-2 infection among all HCW categories, with nursing assistants being the most affected.

Data availability statement

Proposals for the dataset (de-identified 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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Ethics statements

Providing electronic informed consent was mandatory to participate and access the questionnaire. The project was approved by the National Ethics Committee (CONEP; CAAE: 30629220.8.0000.0008).

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Author contributions

MFPMA, WVS, CMTM, RAAX, DBMF, TB, CK, and LRFSK contributed to the study concept and design. CB, MNX, CNLM, GDMA, CBS, CAM, NTSF, JMG, CLFN, and JMVB contributed to the acquisition of data. MFPMA, URM, WVS, CLS, PRBSJ, and CRP contributed to the data analysis and creation of tables and figures. MFPMA, WVS, CMTM, RAAX, DMF, TVBA, MASMV, LNGCL, CB, and LNC contributed to data interpretation. MFPMA, WVS, URM have verified the underlying data. CMTM, MFPMA, WVS, 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.

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Declaration of interests

We declare no competing interests.

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Table 1. Demographic, clinical, and working baseline characteristics of health care workers in the metropolitan region of Recife, Northeast Brazil, 2020 to 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	58.6–67.9	86.7	82.7–89.9	85.5	79.8–89.7	70.3	63.6–76.3	81.1	77.8–84.1
Male	36.6	32.1–41.4	13.2	10.1–17.3	14.5	10.2–20.2	29.7	23.7–36.4	18.9	15.9–22.2
Age, years										
< 30	56.6	51.7–61.4	25.8	21.6–30.6	26.9	20.8–33.9	45.1	38.3–52.1	32.7	28.8–36.9
30– 39	34.1	29.6–38.9	37.3	32.5–42.4	34.5	28.0–41.6	45.3	38.5–52.4	35.6	31.5–40.0
≥ 40	9.3	6.8–12.6	36.9	32.1–41.9	38.6	32.0–45.7	9.6	6.2–14.4	31.7	27.6–36.0
Any comorbidity										
Any	23.3	19.5–27.6	33.9	29.2–38.8	32.0	25.8–38.9	19.0	14.1–25.1	30.1	26.1–34.3
None	76.7	72.4–80.5	66.1	61.2–70.8	68.0	61–74.2	81.0	74.9–85.9	69.9	65.7–73.8
Diabetes	1.0	0.4–2.6	2.1	1.1–4.1	2.0	0.8–5.1	0.4	0.1–3.1	1.8	0.9–3.4
Hypertension	4.0	2.5–6.4	13.2	10.0–17.1	14.4	10.1–19.9	4.8	2.5–8.9	11.9	9.2–15.1
Overweight/Obesity	7.3	5.3–10.0	11.1	8.2–14.6	14.9	10.6–20.4	8.9	5.6–13.7	12.6	9.9–15.9
Heart disease	0.4	0.1–1.3	1.2	0.5–3.0	0.9	0.2–3.5	0.0	..	0.1	0.3–2.1
Kidney disease	0.0	..	0.2	0.03–1.5	0.1	0.02–1.1	0.8	0.2–3.1	0.2	0.1–0.6
Others comorbidities	13.1	10.1–16.7	14.8	11.6–18.8	9.4	5.9–14.7	6.9	4.2–11.4	10.8	8.4–13.8
Number of workplaces										
< 3	44.2	39.4–49.0	91.8	88.4–94.2	95.2	92.0–97.2	62.2	55.2–68.7	84.2	82.1–86.1
≥ 3	55.8	51.0–60.6	8.2	5.8–11.6	4.8	2.8–8.0	37.8	31.3–44.8	15.8	13.9–17.9
Missing	2		0		1		0		3	
Institution provider										
Private	5.2	3.5–7.8	7.2	4.8–10.5	7.0	4.1–11.5	14.8	10.4–20.5	7.2	5.3–9.8
Public	44.5	39.7–49.3	81.2	76.8–85.0	79.8	73.5–85.0	35.2	28.9–42.2	71.4	67.6–74.9
Both	50.3	45.5–55.2	11.6	8.7–15.4	13.2	9.1–18.9	50.0	43–56.9	21.4	18.4–24.7
Work setting										
Outpatient/Inpatient clinics	12.0	9.1–15.6	41.6	36.6–46.8	27.7	21.6–34.7	11.5	7.6–17.0	26.5	22.7–30.8
ICU/Emergency	88.0	84.4–90.9	58.4	53.2–63.4	72.3	65.3–78.4	88.5	83.0–92.4	73.5	69.2–77.3

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. CI, confidence interval; ICU, intensive care unit

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Table 2. Adherence to infection prevention and control during healthcare interactions with COVID-19 patients 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	64.2–73.2	72.3	67.4–76.7	81.1	74.8–86.1	87.0	81.6–91.0	78.0	74.2–81.3
No	31.1	26.8–35.8	27.7	23.3–32.6	18.9	13.9–25.2	13.0	9.0–18.4	22.0	18.7–25.8
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	69.6–78.1	84.4	80.3–87.8	95.4	90.9–97.7	96.1	92.1–98.1	90.1	87.7–92.0
Not always	25.9	21.9–30.4	15.6	12.2–19.7	4.6	2.3–9.1	3.9	1.9–7.9	9.9	8.0–12.3
Missing	2		2		0		1		5	
Surgical mask										
Always	45.3	40.6–50.2	58.6	53.5–63.6	51.0	43.8–58.1	36.9	30.3–44.0	50.5	46.0–54.9
Not always	54.7	49.8–59.4	41.4	36.4–46.5	49.0	41.9–56.1	63.1	56.0–69.6	49.5	45.1–53.9
Missing	2		2		0		1		5	
N95 respirator										
Always	64.4	59.6–68.9	57.4	52.3–62.4	66.3	59.1–72.9	87.3	81.6–91.4	65.9	61.4–70.0
Not always	35.6	31.1–40.3	42.6	37.6–47.7	33.7	27.1–40.9	12.7	8.6–18.4	34.1	30.0–38.6
Missing	2		2		0		1		5	
Face shield										
Always	19.6	16.0–23.9	28.8	24.4–33.7	31.6	25.3–38.6	42.4	35.7–49.3	29.9	25.9–34.2
Not always	80.4	76.1–84.0	71.2	66.3–75.6	68.4	61.4–74.7	57.6	50.7–64.3	70.1	65.8–74.1
Missing	2		2		0		1		5	
Goggles/protective glasses										
Always	18.7	15.3–22.7	24.6	20.4–29.3	38.3	31.6–45.4	45.6	38.7 - 52.6	33.2	29.1–37.6
Not always	81.3	77.2–84.7	75.4	70.7–79.5	61.7	54.6–68.4	54.4	47.4–61.3	66.8	62.3–70.9
Missing	2		2		0		1		5	
Disposable gown										

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Always	48.0	43.3–52.9	50.8	45.6–55.9	63.8	56.6–70.4	67.2	60.3–73.3	59.2	54.8–63.5
Not always	52.0	47.1–56.7	49.2	44.1–54.4	36.2	29.5–43.4	32.8	26.7–39.7	40.8	36.5–45.2
Missing	2		2		0		1		5	
Waterproof apron										
Always	30.5	26.2–35.2	38.6	33.7–43.7	48.9	41.6–56.3	62.6	55.3–69.4	44.9	40.5–49.5
Not always	69.5	64.8–73.8	61.4	56.3–66.3	51.1	43.7–58.4	37.4	30.6–44.7	55.1	50.5–59.5
Missing	14		11		11		18		54	
During provision of routine assistance to COVID-19 patients, did you wear all PPE items as recommended by the WHO?										
Always	89.6	86.2–92.3	79.2	74.7–83.1	70.0	63.1–76.1	69.0	62.2–75.1	74.7	70.5–78.5
Not always	10.4	7.7–13.8	20.8	16.9–25.3	30.0	23.9–36.9	31.0	24.9–37.8	25.3	21.5–29.5
Missing	2		2		0		1		5	
Participated in AGP*										
Yes	79.6	75.3–83.2	75.6	70.8–79.8	83.4	77–88.3	95.8	91.7–97.8	82.2	78.4–85.5
No	20.4	16.8–24.7	24.4	20.2–29.2	16.6	11.7 - 23	4.2	2.1–8.3	17.8	14.5–21.6
Missing	1		1		1		2		5	
While participating in AGPs, have you used:										
Single Gloves										
Always	97.8	95.5–98.9	97.7	95.1–99	98.5	94.2–99.6	99.7	98.1–99.9	98.4	96.4–99.3
Not always	2.2	1.1–4.5	2.3	1–4.9	1.5	0.4–5.8	0.3	0.04–1.9	1.6	0.7–3.6
Missing	0		0		0		1		1	
Surgical mask										
Always	61.5	56.2–66.6	49.9	44.1–55.7	46.5	38.9–54.3	60.2	52.9–67.1	50.5	45.6–55.3
Not always	38.5	33.4–43.8	50.1	44.3–55.9	53.5	45.7–61.1	39.8	32.9–47.1	49.5	44.7–54.4
Missing	0		0		0		1		1	
N95 respirator										
Always	92.4	89–94.9	85.0	80.3–88.8	84.2	77.8–89.1	93.3	88.2–96.3	86.4	82.5–89.5
Not always	7.6	3.1–11	15.0	11.2–19.7	15.7	10.9–22.2	6.7	3.7–11.8	13.6	10.5–17.5
Missing	0		0		0		1		1	
Face shield										

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Always	51.6	46.2–56.9	48.3	42.6–54.1	48.0	40.3–55.7	41.4	34.5–48.6	48.1	43.2–53.0
Not always	48.4	43.1–53.8	51.7	45.8–57.4	52.0	44.2–59.7	58.6	51.4–65.5	51.9	47.0–56.8
Missing	0		0		0		1		1	
Goggles/Protective glasses										
Always	62.5	57.1–67.6	59.3	53.5–64.9	51.4	43.6–59.1	47.1	40–54.3	54.0	49.1–58.9
Not always	37.5	32.4–42.8	40.7	35.1–46.5	48.6	40.9–56.4	52.9	45.7 - 60	46.0	41.1–50.9
Missing	0		0		0		1		1	
Disposable gown										
Always	60.3	55.0–65.4	60.1	54.3 - 65.7	64.0	60.3–74.9	68.3	61.3–74.4	65.6	60.8–70.1
Not always	39.7	34.6–45.0	39.9	34.3–45.7	32.0	25.1–39.7	31.7	25.6–38.7	34.4	29.9–39.2
Missing	0		0		0		1		1	
Waterproof apron										
Always	55.2	49.7–60.6	60.7	54.8–66.3	62.5	54.4–69.9	74.6	67.4–80.7	61.9	57.0–66.7
Not always	44.8	39.4–50.3	39.3	33.7–45.2	37.5	30.1–45.6	25.4	19.3–32.6	38.1	33.3–43.0
Missing	9		7		9		17		42	
When performing an AGP in COVID-19 patients, did you wear all recommended PPE items as in WHO guidance?										
Always	66.0	60.0–71.4	58.0	51.4–64.3	63.8	54.1–72.6	74.7	64.2–82.8	63.7	57.8–69.2
Not always	34.0	28.6–40.0	42.0	35.7–48.6	36.2	27.4–45.9	25.3	17.2–35.8	36.3	30.8–42.2
Missing	0		0		0		1		1	
Duration of N95 respirator use										
< 8 days	50.7	45.8–55.6	71.4	66.6–75.8	79.4	73.0–84.6	54.6	47.6–61.5	71.7	67.9–75.3
≥ 8 days	49.3	44.4–54.2	28.6	24.2–33.4	20.6	15.4–27.0	45.4	38.5–52.4	28.3	24.7–32.1
Missing	9		5		8		4		26	
Any accident involving body fluid/respiratory secretion										
Yes	13.9	11–17.4	10.8	7.9–14.5	11.7	7.9–17.1	7.6	4.9–11.7	11.6	9.1–14.8
No	86.1	82.6–89	89.2	85.5–92.1	88.3	82.9–92.1	92.4	88.3–95.1	88.4	85.2–90.9
Organ involved										
Splash in the Mouth	1.9	1.02–3.8	1.9	0.85–4.3	0.2	0.04–1.5	0.7	0.2–3.1	0.8	0.5–1.4
Splash on the Skin	2.4	1.4–3.9	3.4	1.9–6.0	1.3	0.5–3.2	3.9	1.9–7.7	2.0	1.3–3.0
Splash on the Eyes	2.3	1.4–3.9	3.5	1.9–6.1	2.1	0.8–5.8	2.5	1.2–5.0	2.4	1.4–4.2

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Puncture/sharps	8.2	5.9–11.3	3.0	1.7–5.3	8.2	4.9–13.4	0.0	-	6.7	4.6–9.7
Self-perception of risk										
None/Low	21.6	17.9–25.9	24.9	20.7–29.6	21.9	16.3–28.7	17.2	12.5–23.3	22.0	18.5–26.1
Medium/High	78.4	74.1–82.1	75.1	70.3–79.3	78.1	71.3–83.7	82.8	76.7–87.5	78.0	73.8–81.5
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; COVID-19, coronavirus disease 2019; CI, confidence interval; ICU, intensive care unit; PPE, personal protective equipment; WHO, World Health Organization

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

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

Adjusted for cluster random effect and weighted by network and population size
COVID-19, coronavirus disease 2019; CI, confidence interval; PPE, personal protective equipment

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Figure Legends

Figure 1. Respondent-driven sampling recruitment chains.

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

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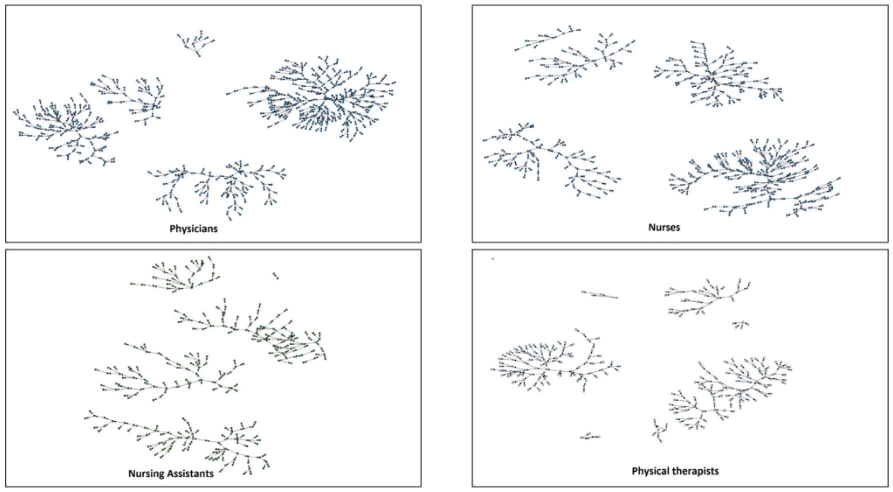

Figure 1. Respondent-driven sampling recruitment chains

338x190mm (170 x 170 DPI)


80·0
70·0
60·0
50·0
40·0
30·0
(%)
55·0
48·1
70·0
54·7
61·8
Lower Limit
Upper Limit
Prevalence(%)
Physician
Nurse
Nursing Assistant
Physical therapist
Overall
Occupation

Supplementary Table 1. Characteristics of the study population according to RT-PCR testing

		RT-PCR testing		*P*-value
		Yes (%)	**No (%)**	
Occupation category				0·02
	Physician	269 (51·1)	257 (48·9)	
	Registered nurse	224(47·6)	247(52·4)	
	Nursing assistant	110 (42·0)	152 (58·0)	
	Physical therapist	108(41·2)	154(58·8)	
Sex				0·43
	Female	530 (46·2)	618 (53·8)	
	Male	181 (48·5)	192 (51·5)	
Age group, years				0·15
	< 30	523 (45·7)	622 (54·3)	
	≥ 30	188 (50·0)	188 (50·0)	
Any comorbidity				< 0·001
	Yes	246 (56·8)	187 (43·2)	
	No	465 (42·7)	623 (57·3)	
Number of workplaces (hospitals/clinics)				< 0·01
	<3	247 (54·0)	210 (46·0)	
	≥3	462 (43·5)	599 (56·5)	
Work setting				0·39
	Emerg/ICU	565 (47·3)	629 (52·7)	
	Outpat/Inpatients	146 (44·7)	181 (55·3)	
Institution provider				< 0·001
	Private	48 (42·1)	66 (57·9)	
	Public	393 (43·0)	522 (57·0)	
	Both	270 (54·9)	222 (45·1)	
Performed aerossol generating procedure				0·36
	Yes	600 (47·3)	669 (52·7)	
	No	110 (44·5)	137 (55·5)	
	Missing	1 (20·0)	4 (80·0)	
Same N95 respirator, use duration, days				0·023
	≤ 7	458 (49·00	476 (51·0)	
	> 7	243 (43·0)	322 (57·0)	
Self-perceived risk				0·85
	None/Low	36 (45·1)	43 (54·9)	
	Medium/High	665 (46·7)	760 (53·3)	
Accident involving biological fluid/respiratory secretion				0·644
	Yes	84 (45·2)	102 (54·8)	
	No	627 (47·0)	708 (53·0)	
Sick leave due to COVID-19 symptoms				< 0·001
	Yes	576 (79·7)	147 (20·3)	
	No	130 (16·5)	659 (83·5)	
Had COVID-19-like symptoms/signs				< 0·001
	Yes	601 (68·2)	280 (31·8)	
	No	110 (17·0)	530 (82·8)	

COVID-19, coronavirus disease 2019; RT-PCR, reverse transcription polymerase chain reaction

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Supplementary Table 2. Potential risk factors for reporting a positive PCR COVID-19 result among front line healthcare professionals

	Odds Ratio	95% CI	*P*-value
Sex			
Female	1.0	..	..
Male	1.35	0.78–2.34	0.288
Age, years	1.03	0.65–1.64	0.889
Occupation			
Nurse	1.0	..	..
Physical therapist	1.42	0.88–2.27	0.148
Physician	1.32	0.91–1.91	0.142
Nursing Assistant	2.77	1.64–4.67	<0.001
Any comorbidity	1.19	0.75–1.90	0.454
Number of workplaces			
< 3	1.0	..	..
≥ 3	0.83	0.53–1.30	0.428
Institution provider			
Private	1.0	..	..
Public	0.92	0.42–2.02	0.844
Both	0.93	0.41–2.10	0.863
Work setting			
Outpatient /Inpatient clinics	1.0	..	..
ICU/Emergency	1.54	0.92–2.60	0.102
Training on PPE use	1.06	0.62–1.80	0.829
Any accident involving body fluid/respiratory secretion	2.67	1.22–5.82	0.014
Splash in the mouth			
No accident	1.0	..	..
Yes	3.84	0.64–22.95	0.140
Other accident	2.30	0.85–6.23	0.102
Splash on the skin			
No accident	1.0	..	..
Yes	1.86	0.54–6.44	0.328
Other accident	2.50	0.80–7.85	0.116
Splash in the eyes			
No accident	1.0	..	..
Yes	4.07	1.14–14.55	0.031
Other accident	2.07	0.71-6.08	0.184
Puncture/sharp accident			
No accident	1.0	..	..
Yes	2.25	0.51–9.89	0.282
Other accident	2.51	1.10–5.72	0.028
Duration N95 respirator use			
< 8 days	..	..	..
≥ 8 days	0.96	0.59–1.55	0.869
Used All PPE items during AGP#			
Did not Always use	1.68	0.97–2.92	0.063

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Used all PPE items while assisting COVID-19 patients			
Yes	1.0	..	..
No	2.14	1.18–3.88	0.013
Time on the front-line, days	0.997	0.994–1.000	0.042

Adjusted for cluster random effect and weighted by network and population size.

AGP, aerosol-generating procedure; COVID-19, coronavirus disease 2019; CI, confidence interval; ICU, intensive care unit; PPE, personal protective equipment

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Tabela 1. STROBE-RDS Statement Checklist for the manuscript title "High risk of SARS-CoV-2 infection among frontline healthcare workers in Northeast Brazil: a respondent-driven sampling approach"

Item	#	STROBE-RDS checklist	Main Document
Title and abstract	1	(a) Indicate ''respondent-driven sampling'' in the title or abstract	Done, RDS in the Title and abstract
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Pg. 1, lines 5-17. Abstract included methods, results and conclusions.
Introduction			
Background/ rationale	2	Explain the scientific background and rationale for the investigation being reported	Introduction, paragraph 1-3 Done
Objectives	3	State specific objectives, including any prespecified hypotheses	Introduction, paragraph 4
Methods			
Study design	4	(a) Present key elements of study design early in the article	Done, Methods, paragraph 1
		(b) State why RDS was chosen as the sampling method	Methods, paragraph 1 "RDS was chosen as a sampling approach for two main reasons: restrictions in conducting face-to-face interviews .."
Setting	5	(a) Describe the setting, locations, and relevant dates, including periods of recruitment and data collection	Done. Methods, paragraph 3 and 5
		(b) Describe formative research findings used to inform RDS study	Done Methods, paragraph 4
Participants	6	(a) Give the eligibility criteria and the sources and methods of selection of participants. Describe how participants were trained/instructed to recruit others, number of coupons issued per person, any time limits for referral	Done Methods, paragraph 5
		(b) Describe methods of seed selection and state number at start of study and number added later	Methods, paragraph 6 and 7
		(c) State if there was any variation in study procedures during data collection (e.g., changing numbers of coupons per recruiter, interruptions in sampling, or (stopping recruitment chains)	Done
		(d) Report wording of personal network size question(s)	Done. Methods, paragraph 7
		(e) Describe incentives for participation and recruitment	No incentives were offered.

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			pg8 line 6. “This study did not offer any incentive.”
Variables	7	(a) If applicable, clearly define all outcomes, correlates, predictors, potential confounders, effect modifiers, and diagnostic criteria	Done. Methods, pg 8; “The variables collected were adapted from the WHO interim guidance”
		(b) State recruitment relationship was tracked	Figure 1 “Respondent-driven sampling recruitment chains”
Data sources/ measurement	8	(a) For each variable of interest, give sources of data and details of methods of measurement. Describe comparability of measurement methods if there is more than one group	Done. Methods, pg 8; the variables of interest were specified.
		(b) Describe methods to assess eligibility and reduce repeat enrollment (e.g., coupon manager software, biometrics)	Methods, pg 9. Data collection. “Data were collected using a web-based software platform by FITec (Recife, Pernambuco, Brazil). The HCWs answered the questionnaire by accessing a link that could be opened on a smartphone or a computer browser.”
Bias	9	Describe any efforts to address potential sources of bias	Not done
Study size	10	Explain how the study size was arrived at	Methods, “We calculated a sample size of 1,100 HCWs, considering a 95% confidence level (CI) to estimate a 40% prevalence of

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			infections with a 5% error and a design effect of three.”
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Methods, section “variable” and “Data analysis”,
Statistical methods	12	(a) Describe all statistical methods, including those to account for sampling strategy (e.g., the estimator used) and, if applicable, those used to control for confounding	Methods, section “Data analysis”
		(b) State data analysis software, version number, and specific analysis settings used	Methods, section “Data analysis”
		(c) Describe any methods used to examine subgroups and interactions	Not applicable
		(d) Explain how missing data were addressed	Methods, section “Data analysis”
		(e) Describe any sensitivity analyses	Not done
		(f) Report any criteria used to support statements on whether estimator conditions or assumptions were appropriate	Not done
		(g) Explain how seeds were handled in analysis	Done, pg 9 “Data analysis” The seeds were used to define the cluster of the study.
Results			
Participants	13	(a) Report the numbers of individuals at each stage of the study, for example, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, and analyzed	Done. Results, Text, first paragraph
		(b) Give reasons for nonparticipation at each stage (e.g., not eligible, does not consent, decline to recruit others)	Done
		(c) Consider use of a flow diagram	Not included as Flowchart due to limited number of Figures of the Journal
		(d) Report number of coupons issued and returned	Not applicable
		(e) Report number of recruits by seed and number of RDS recruitment waves for each seed. Consider showing graph of entire recruitment network	Done Figure 1. Presents RDS recruitment chains.
		(f) Report recruitment challenges (e.g., commercial exchange of coupons, imposters, duplicate recruits) and how addressed	Not Done
		(g) Consider reporting estimated design effect for outcomes of interest	Done Figure 2 shows prevalence adjusted “for

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			random cluster effects" Pq 11
Descriptive data	14	(a) Give characteristics of study participants (e.g., demographic, clinical, social) and, if applicable, information on correlates and potential confounders. Report unweighted sample size and percentages, estimated population proportions or means with estimated precision (e.g., 95% confidence interval)	Done Table 1 and table 2
		(b) Indicate the number of participants with missing data for each variable of interest	Done. Missing Data presented for each variable (Tables 1 and 2)
Outcome data	15	If applicable, report number of outcome events or summary measures	Done. Presented in Figure 2.
Main results	16	(a) Give unadjusted and study design adjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence intervals). Make clear which confounders were adjusted for and why they were included	Done. Results section and Tables 3
		(b) Report category boundaries when continuous variables were categorized	Not applicable
		(c) If adjustment of primary outcome leads to marked changes, report information on factors influencing the adjustments (e.g., personal network sizes, recruitment patterns by group, key confounders)	The adjustment only modified slightly not affecting the general results
Other analyses	17	Report other analyses done for example, analyses of subgroups and interactions, sensitivity analyses, different RDS estimators and definitions of personal network size	All analyses were reported
Discussion			
Key results	18	Summarize key results with reference to study objectives	Done. Discussion, paragraph 1
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Done. Discussion, paragraph 7
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Discussion, paragraph 2-5
Generalizability	21	Discuss the generalizability (external validity) of the study results	Discussion, paragraph 6 and 8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	page 16, funding section

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

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

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Abstract

Objectives: We assessed the prevalence of severe acute respiratory syndrome coronavirus (SARS-CoV-2) infection, personal protective equipment (PPE) shortages and occurrence of biological accidents among frontline health care workers (HCW).

Design, setting and participants: Using respondent driven sampling (RDS), the study recruited distinct categories of HCW attending suspected or confirmed COVID-19 patients 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 analyzed 1,525 HCW: 527 physicians, 471 registered nurses, 263 nursing assistants, and 264 physical therapists. Women predominated in all categories (81.1%; 95% CI: 77.8% - 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%-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 (ORadjusted: 2.56; 95% CI: 1.42 - 4.61), not always using all recommended PPE while assisting patients with COVID-19 (ORadj: 2.15; 95% CI: 1.02 - 4.53) and reporting a splash of biological fluid/respiratory secretion in the eyes (ORadj: 3.37; 95% CI: 1.10 – 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 health care facility environments, specific training and supervision to cope with public health emergencies.

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Strengths and limitations of this study

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

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Introduction

The unprecedented rapid spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and its potentially severe outcomes have highly impacted the healthcare system, the global economy, and security.[1,2] According to the World Health Organization (WHO), the global cumulative number of confirmed coronavirus disease 2019 (COVID-19) cases had reached approximately 364.2 million and 5.6 million deaths by January 28, 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 hospital system with 678 235 patients' admission 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 (February 25, 2020 to November 5, 2020) to 39.3% in the second wave (November 6, 2020, to April 30, 2021). The northeast and north states of the country concentrate the worst in-hospital mortality rates, which are 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 COVID-19 among frontline workers compared with the general community.[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 test.[7] Another systematic review and metanalysis suggested that exposure in settings with familiar contact increases SARS-CoV-2 transmission. However, to explore the transmission pattern in health facilities, workplace and social settings is still challenging due to limited data so far.[8] These previous reviews did not include studies from Brazil.

In the Americas, 569,304 COVID-19 cases, including 2,506 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 frontline workers in the early pandemic response.[11]

In line with the previous studies a survey among HCW reported PPE shortage in the first COVID-19 wave in Brazil 2020[12], and the inadequate working conditions were also reported by the media[13]. In Brazil, prevalence of SARS-CoV-2 infection using RT-PCR in teaching hospitals varied from 15% to 42.4% among symptomatic HCW in the south region and southeast regions, respectively.[14,15,16] However, information on the prevalence of SARS-CoV-2 infection among frontline 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, 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 frontline HCW attending emergency rooms, hospitals, and new field hospitals. RDS approach is based upon direct participant involvement.

The baseline findings are described following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) 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 March 12, 2020. The peak of the pandemic was during the 21st epidemiologic week in 2020.[19,20] This densely populated region comprises 15 municipalities with approximately four million inhabitants, corresponding to 42% of the state population.[21] The Brazilian unified health system (Sistema Unico de Saude—SUS) 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.

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Participants and Public Involvement

Participants and/or the public were not involved in the design. However, the formative research 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 health care 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 COVID-19 patients from May 21, 2020 to February 10, 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 1,100 HCW, considering a 95% confidence level (CI) to estimate a 40% prevalence of infections 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 COVID-19 patients?", 2) "How many of those colleagues have been in professional contact with you in the last two weeks?," and 3) "How many of them are close to you and you would invite to participate in this study?."

*Variabl*es

We applied the WHO questionnaire developed as an operational tool to determine the risk of COVID-19 virus infection among HCW exposed to a COVID-19 patient in a health care 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:

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(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: i) always as recommended (more than 95% of the time); ii) most of the time (ranging from 50% to 95%); iii) occasionally (1-49%); iv) never; v) unavailable.

(5) Adherence to IPC when performing aerosol-generating procedures (AGPs) using the abovementioned 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—I) during the period of healthcare interaction and II) 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 criterion to assess SARS-CoV-2 infection among HCW was a positive self-reported PCR test. Serologic tests were not considered as diagnostic criteria.

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.

Providing electronic informed consent was mandatory to participate and access the questionnaire. The project was approved by the National Ethics Committee (CONEP; CAAE: 30629220.8.0000.0008).

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,

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we limited the network size to 3 to 150 for outlier correction.[24] 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 chi-squared 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, version 15.0 (StataCorp LLC, College Station, TX, USA).

Role of the funding source

The funding source had no involvement in any stage of the project.

Results

Participants

We recruited 2,474 health care workers and 1,525 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% – 84.1%) of the sample after adjustment to the reference 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% – 67.9%) and the highest among nurses (86.7%; 95% CI: 82.7% – 89.9%) and nursing assistants (85.5%; 95% CI: 79.8% – 89.7%). The age distribution was as follows: 32.7% (95% CI: 28.8% – 36.9%) and 35.6% (95% CI: 31.5% – 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% – 61.4%) and 45.1% (95% CI: 38.3% – 52.1%), respectively, of those 20–29 years old. Comorbidities affected

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30.1% (95% IC: 26.1% – 34.3%) of the studied population. Overweight/obesity (12.6%; 95% CI: 9.9% – 15.9%) and hypertension (11.9%; 95% CI: 9.2% – 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% – 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% – 77.3%) worked either in emergency rooms or ICU. Notably, 55.8% (95% CI: 51.0% – 60.6%) of the physicians and 37.8% (95% CI: 31.3% – 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% – 81.3%) of the participants received training on the use of PPE. Physical therapists (87.0%; 95% CI: 81.6% – 91.0%) and nursing assistants (81.1%; 95% CI: 74.8% – 86.1%) received a higher and similar frequency of training compared to 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% – 92.0%) for single-use gloves to 29.9% (95% CI: 25.9% – 34.2%) for face shields. Most HCW (82.2%; 95% CI: 78.4% – 85.5%) reported performing AGPs on COVID-19 patients. Almost all participants reported having always used single-use gloves (98.4%; 95% CI: 96.4% – 99.3%) and N95 respirators (86.4%; 95% CI: 82.5% – 89.5%) during AGPs. The N95/PPF2 respirator was reused for more than seven days by approximately 28.3% (95% CI: 24.7% – 32.1%) of the participants, with highest and lowest frequencies reported by physicians (49.3%; 95% CI: 44.4% – 54.2%) and nursing assistants (20.6%; 95% CI: 15.4% – 27.0%), respectively. Overall, 63.7% (95% CI: 57.8% – 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 COVID-19 patients. Accidents were more frequent among physicians (13.9%; 95% CI: 11.0% – 17.4%) and less frequent among physical therapists (7.6%; 95% CI: 4.9% – 11.7%) (Table 2).

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

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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 (Supplementary Table 1).

For the tested HCW, mostly symptomatic, the overall self-reported SARS-CoV-2 infection was 61.8% (95% CI: 55.7%-67.5%) compared with 14.9% (CI: 4.9%-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%-79.1%), followed by physicians (55.0%; 95%CI: 47.5%-62.3%), physical therapists (54.7%; 95%CI: 43.1%-65.7%), and nurses (48.1%; 95%CI: 40.3%-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 hospitalized.

In a bivariate analysis, the nursing assistant category was positively associated with infection (odds ratio [OR]=2.77; 95% CI: 1.64–4.67, p<0.001) compared to nurses. Reporting any accident involving body fluid/respiratory secretion was associated with infection (OR=2.67; 95% CI: 1.22–5.82, p<0.014). When considering each accident, splashes in the eyes were a stronger predictor of infection (OR=4.07; 95% CI: 1.14–14.55, p<0.031). During routine assistance of COVID-19 patients, not always wearing the complete set of recommended PPE items was associated with infection (OR=2.14; 95% CI: 1.18–3.88, p=0.013) when compared to always using PPE. Not always using the complete recommended PPE items during AGPs was also associated with infection (OR=1.68; 95% CI: 0.97–2.92, p=0.063) when compared with always using PPE (Supplementary Table 2).

In the final multivariate logistic regression model, the following were risk factors for infection: being a nursing assistant (OR adjusted=2.56; 95% CI: 1.42–4.61, p=0.002), not always having used PPE during care of patients with COVID-19 (OR adjusted=2.15; 95% CI: 1.02–4.53, p=0.044), and having suffered a splash to the eyes (OR adjusted=3.37; 95% CI: 1.10–10.34, p=0.034) (Table 3).

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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 frontline were younger and mainly worked in the Intensive Care Units 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 frontliners 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 hospitalization and death.[25]

To our knowledge, our study depicted one of the highest frequencies of SARS-CoV-2 infections among HCW, being nursing assistant the most vulnerable category. In consonant with this finding, nursing assistant 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 frontline HCW. Thus far, there has been no mass RT-PCR testing strategy for the Brazilian population despite WHO recommendations.[26] 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.[27] 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 4,987) 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.

Seroprevalence studies cannot be directly compared to our findings, 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.[28,29] 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-

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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.[30]

In our setting, critical aspects for the high risk of SARS-CoV-2 infection included 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- and medium-income countries like Brazil but also in high-income countries at the beginning of the pandemic.[31] At the individual level, one-fourth of the HCW reported that PPE was not always used according to the WHO recommendations.[26] When performing AGPs, the nursing staff had the highest frequency (over 35%) of not fully adhering to complete PPE.[32] However, not always used the recommended PPE during performance of AGPs was not associated with PCR positive report in our analysis. This finding is in line with a recent study questioning the concept of aerosol-generating procedures for risk-stratifying patients since most procedures considered as AGPs do not meaningfully increase respiratory aerosols.[33] 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.[34] 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.[35] 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 to 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.[36] Therefore, there is strong evidence that HCW are at a high risk of SARS-CoV-2 infection in low- 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]

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The advantage of using 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 frontline 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.

This study has some limitations. 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 frontline 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 of 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 minimize 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 frontliners attending suspected or confirmed Covid-19 patients. In fact, only 15.2% of them referred to have had contact with COVID-19 cases simultaneously in health-care facilities and at the household (data not shown). In our analysis the risk factors associated with infection were higher among nursing assistant; HCW not using all PPE items as recommended to professionals reporting an accident during their activities. It is likely that the high frequency of infection among frontline HCW was presumably healthcare associated infections in line with our findings, with the scenario of shortage of PPE and the high health care 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-minute online questionnaire. Physicians and nurses were also a more vocal category early in the pandemic, publicizing the constraints/pressure of the workplace. Conversely, nursing assistants, as routine

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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 socio-economic conditions when compared to 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 health care facility environments, specific training and supervision to cope with public health emergencies.

Data availability statement

Proposals for the dataset (de-identified 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.

Ethics statements

All participants provided electronic informed consent in the web-based platform. HCW could only access the questionnaire after giving the on-line Informed Consent Form (ICF). In our study we applied the ICF in agreement with both: the requirements of the National Ethics Committee (CONEP, 30629220.8.0000.0008); and with the current protocols for electronic survey.

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Author contributions

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MFPMA, WVS, CMTM, RAAX, DBMF, TB, CK, and LRFSK contributed to the study concept and design. CB, MNX, CNLM, GDMA, CBS, CAM, NTSF, JMG, CLFN, and JMVB contributed to the acquisition of data. MFPMA, URM, WVS, CLS, PRBSJ, and CRP contributed to the data analysis and creation of tables and figures. MFPMA, WVS, CMTM, RAAX, DMF, TVBA, MASMV, LNGCL, CB, and LNC contributed to data interpretation. MFPMA, WVS, URM have verified the underlying data. CMTM, MFPMA, WVS, 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.

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Declaration of interests

We declare no competing interests.

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Table 1. Demographic, clinical, and working baseline characteristics of health care workers in the metropolitan region of Recife, Northeast Brazil, 2020 to 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	58.6–67.9	86.7	82.7–89.9	85.5	79.8–89.7	70.3	63.6–76.3	81.1	77.8–84.1
Male	36.6	32.1–41.4	13.2	10.1–17.3	14.5	10.2–20.2	29.7	23.7–36.4	18.9	15.9–22.2
Age, years										
< 30	56.6	51.7–61.4	25.8	21.6–30.6	26.9	20.8–33.9	45.1	38.3–52.1	32.7	28.8–36.9
30– 39	34.1	29.6–38.9	37.3	32.5–42.4	34.5	28.0–41.6	45.3	38.5–52.4	35.6	31.5–40.0
≥ 40	9.3	6.8–12.6	36.9	32.1–41.9	38.6	32.0–45.7	9.6	6.2–14.4	31.7	27.6–36.0
Any comorbidity										
Any	23.3	19.5–27.6	33.9	29.2–38.8	32.0	25.8–38.9	19.0	14.1–25.1	30.1	26.1–34.3
None	76.7	72.4–80.5	66.1	61.2–70.8	68.0	61–74.2	81.0	74.9–85.9	69.9	65.7–73.8
Diabetes	1.0	0.4–2.6	2.1	1.1–4.1	2.0	0.8–5.1	0.4	0.1–3.1	1.8	0.9–3.4
Hypertension	4.0	2.5–6.4	13.2	10.0–17.1	14.4	10.1–19.9	4.8	2.5–8.9	11.9	9.2–15.1
Overweight/Obesity	7.3	5.3–10.0	11.1	8.2–14.6	14.9	10.6–20.4	8.9	5.6–13.7	12.6	9.9–15.9
Heart disease	0.4	0.1–1.3	1.2	0.5–3.0	0.9	0.2–3.5	0.0	..	0.1	0.3–2.1
Kidney disease	0.0	..	0.2	0.03–1.5	0.1	0.02–1.1	0.8	0.2–3.1	0.2	0.1–0.6
Others comorbidities	13.1	10.1–16.7	14.8	11.6–18.8	9.4	5.9–14.7	6.9	4.2–11.4	10.8	8.4–13.8
Number of workplaces										
< 3	44.2	39.4–49.0	91.8	88.4–94.2	95.2	92.0–97.2	62.2	55.2–68.7	84.2	82.1–86.1
≥ 3	55.8	51.0–60.6	8.2	5.8–11.6	4.8	2.8–8.0	37.8	31.3–44.8	15.8	13.9–17.9
Missing	2		0		1		0		3	
Institution provider										
Private	5.2	3.5–7.8	7.2	4.8–10.5	7.0	4.1–11.5	14.8	10.4–20.5	7.2	5.3–9.8
Public	44.5	39.7–49.3	81.2	76.8–85.0	79.8	73.5–85.0	35.2	28.9–42.2	71.4	67.6–74.9
Both	50.3	45.5–55.2	11.6	8.7–15.4	13.2	9.1–18.9	50.0	43–56.9	21.4	18.4–24.7
Work setting										
Outpatient/Inpatient clinics	12.0	9.1–15.6	41.6	36.6–46.8	27.7	21.6–34.7	11.5	7.6–17.0	26.5	22.7–30.8
ICU/Emergency	88.0	84.4–90.9	58.4	53.2–63.4	72.3	65.3–78.4	88.5	83.0–92.4	73.5	69.2–77.3

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. CI, confidence interval; ICU, intensive care unit

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Table 2. Adherence to infection prevention and control during healthcare interactions with COVID-19 patients 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	64.2–73.2	72.3	67.4–76.7	81.1	74.8–86.1	87.0	81.6–91.0	78.0	74.2–81.3
No	31.1	26.8–35.8	27.7	23.3–32.6	18.9	13.9–25.2	13.0	9.0–18.4	22.0	18.7–25.8
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	69.6–78.1	84.4	80.3–87.8	95.4	90.9–97.7	96.1	92.1–98.1	90.1	87.7–92.0
Not always	25.9	21.9–30.4	15.6	12.2–19.7	4.6	2.3–9.1	3.9	1.9–7.9	9.9	8.0–12.3
Missing	2		2		0		1		5	
Surgical mask										
Always	45.3	40.6–50.2	58.6	53.5–63.6	51.0	43.8–58.1	36.9	30.3–44.0	50.5	46.0–54.9
Not always	54.7	49.8–59.4	41.4	36.4–46.5	49.0	41.9–56.1	63.1	56.0–69.6	49.5	45.1–53.9
Missing	2		2		0		1		5	
N95 respirator										
Always	64.4	59.6–68.9	57.4	52.3–62.4	66.3	59.1–72.9	87.3	81.6–91.4	65.9	61.4–70.0
Not always	35.6	31.1–40.3	42.6	37.6–47.7	33.7	27.1–40.9	12.7	8.6–18.4	34.1	30.0–38.6
Missing	2		2		0		1		5	
Face shield										
Always	19.6	16.0–23.9	28.8	24.4–33.7	31.6	25.3–38.6	42.4	35.7–49.3	29.9	25.9–34.2
Not always	80.4	76.1–84.0	71.2	66.3–75.6	68.4	61.4–74.7	57.6	50.7–64.3	70.1	65.8–74.1
Missing	2		2		0		1		5	
Goggles/protective glasses										
Always	18.7	15.3–22.7	24.6	20.4–29.3	38.3	31.6–45.4	45.6	38.7 - 52.6	33.2	29.1–37.6
Not always	81.3	77.2–84.7	75.4	70.7–79.5	61.7	54.6–68.4	54.4	47.4–61.3	66.8	62.3–70.9
Missing	2		2		0		1		5	
Disposable gown										

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Always	48.0	43.3–52.9	50.8	45.6–55.9	63.8	56.6–70.4	67.2	60.3–73.3	59.2	54.8–63.5
Not always	52.0	47.1–56.7	49.2	44.1–54.4	36.2	29.5–43.4	32.8	26.7–39.7	40.8	36.5–45.2
Missing	2		2		0		1		5	
Waterproof apron										
Always	30.5	26.2–35.2	38.6	33.7–43.7	48.9	41.6–56.3	62.6	55.3–69.4	44.9	40.5–49.5
Not always	69.5	64.8–73.8	61.4	56.3–66.3	51.1	43.7–58.4	37.4	30.6–44.7	55.1	50.5–59.5
Missing	14		11		11		18		54	
During provision of routine assistance to COVID-19 patients, did you wear all PPE items as recommended by the WHO?										
Always	89.6	86.2–92.3	79.2	74.7–83.1	70.0	63.1–76.1	69.0	62.2–75.1	74.7	70.5–78.5
Not always	10.4	7.7–13.8	20.8	16.9–25.3	30.0	23.9–36.9	31.0	24.9–37.8	25.3	21.5–29.5
Missing	2		2		0		1		5	
Participated in AGP*										
Yes	79.6	75.3–83.2	75.6	70.8–79.8	83.4	77–88.3	95.8	91.7–97.8	82.2	78.4–85.5
No	20.4	16.8–24.7	24.4	20.2–29.2	16.6	11.7 - 23	4.2	2.1–8.3	17.8	14.5–21.6
Missing	1		1		1		2		5	
While participating in AGPs, have you used:										
Single Gloves										
Always	97.8	95.5–98.9	97.7	95.1–99	98.5	94.2–99.6	99.7	98.1–99.9	98.4	96.4–99.3
Not always	2.2	1.1–4.5	2.3	1–4.9	1.5	0.4–5.8	0.3	0.04–1.9	1.6	0.7–3.6
Missing	0		0		0		1		1	
Surgical mask										
Always	61.5	56.2–66.6	49.9	44.1–55.7	46.5	38.9–54.3	60.2	52.9–67.1	50.5	45.6–55.3
Not always	38.5	33.4–43.8	50.1	44.3–55.9	53.5	45.7–61.1	39.8	32.9–47.1	49.5	44.7–54.4
Missing	0		0		0		1		1	
N95 respirator										
Always	92.4	89–94.9	85.0	80.3–88.8	84.2	77.8–89.1	93.3	88.2–96.3	86.4	82.5–89.5
Not always	7.6	3.1–11	15.0	11.2–19.7	15.7	10.9–22.2	6.7	3.7–11.8	13.6	10.5–17.5
Missing	0		0		0		1		1	
Face shield										

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Always	51.6	46.2–56.9	48.3	42.6–54.1	48.0	40.3–55.7	41.4	34.5–48.6	48.1	43.2–53.0
Not always	48.4	43.1–53.8	51.7	45.8–57.4	52.0	44.2–59.7	58.6	51.4–65.5	51.9	47.0–56.8
Missing	0		0		0		1		1	
Goggles/Protective glasses										
Always	62.5	57.1–67.6	59.3	53.5–64.9	51.4	43.6–59.1	47.1	40–54.3	54.0	49.1–58.9
Not always	37.5	32.4–42.8	40.7	35.1–46.5	48.6	40.9–56.4	52.9	45.7 - 60	46.0	41.1–50.9
Missing	0		0		0		1		1	
Disposable gown										
Always	60.3	55.0–65.4	60.1	54.3 - 65.7	64.0	60.3–74.9	68.3	61.3–74.4	65.6	60.8–70.1
Not always	39.7	34.6–45.0	39.9	34.3–45.7	32.0	25.1–39.7	31.7	25.6–38.7	34.4	29.9–39.2
Missing	0		0		0		1		1	
Waterproof apron										
Always	55.2	49.7–60.6	60.7	54.8–66.3	62.5	54.4–69.9	74.6	67.4–80.7	61.9	57.0–66.7
Not always	44.8	39.4–50.3	39.3	33.7–45.2	37.5	30.1–45.6	25.4	19.3–32.6	38.1	33.3–43.0
Missing	9		7		9		17		42	
When performing an AGP in COVID-19 patients, did you wear all recommended PPE items as in WHO guidance?										
Always	66.0	60.0–71.4	58.0	51.4–64.3	63.8	54.1–72.6	74.7	64.2–82.8	63.7	57.8–69.2
Not always	34.0	28.6–40.0	42.0	35.7–48.6	36.2	27.4–45.9	25.3	17.2–35.8	36.3	30.8–42.2
Missing	0		0		0		1		1	
Duration of N95 respirator use										
< 8 days	50.7	45.8–55.6	71.4	66.6–75.8	79.4	73.0–84.6	54.6	47.6–61.5	71.7	67.9–75.3
≥ 8 days	49.3	44.4–54.2	28.6	24.2–33.4	20.6	15.4–27.0	45.4	38.5–52.4	28.3	24.7–32.1
Missing	9		5		8		4		26	
Any accident involving body fluid/respiratory secretion										
Yes	13.9	11–17.4	10.8	7.9–14.5	11.7	7.9–17.1	7.6	4.9–11.7	11.6	9.1–14.8
No	86.1	82.6–89	89.2	85.5–92.1	88.3	82.9–92.1	92.4	88.3–95.1	88.4	85.2–90.9
Organ involved										
Splash in the Mouth	1.9	1.02–3.8	1.9	0.85–4.3	0.2	0.04–1.5	0.7	0.2–3.1	0.8	0.5–1.4
Splash on the Skin	2.4	1.4–3.9	3.4	1.9–6.0	1.3	0.5–3.2	3.9	1.9–7.7	2.0	1.3–3.0
Splash on the Eyes	2.3	1.4–3.9	3.5	1.9–6.1	2.1	0.8–5.8	2.5	1.2–5.0	2.4	1.4–4.2

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Puncture/sharps	8.2	5.9–11.3	3.0	1.7–5.3	8.2	4.9–13.4	0.0	-	6.7	4.6–9.7
Self-perception of risk										
None/Low	21.6	17.9–25.9	24.9	20.7–29.6	21.9	16.3–28.7	17.2	12.5–23.3	22.0	18.5–26.1
Medium/High	78.4	74.1–82.1	75.1	70.3–79.3	78.1	71.3–83.7	82.8	76.7–87.5	78.0	73.8–81.5
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; COVID-19, coronavirus disease 2019; CI, confidence interval; ICU, intensive care unit; PPE, personal protective equipment; WHO, World Health Organization

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

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

Adjusted for cluster random effect and weighted by network and population size
COVID-19, coronavirus disease 2019; CI, confidence interval; PPE, personal protective equipment

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Figure Legends

Figure 1. Respondent-driven sampling recruitment chains.

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

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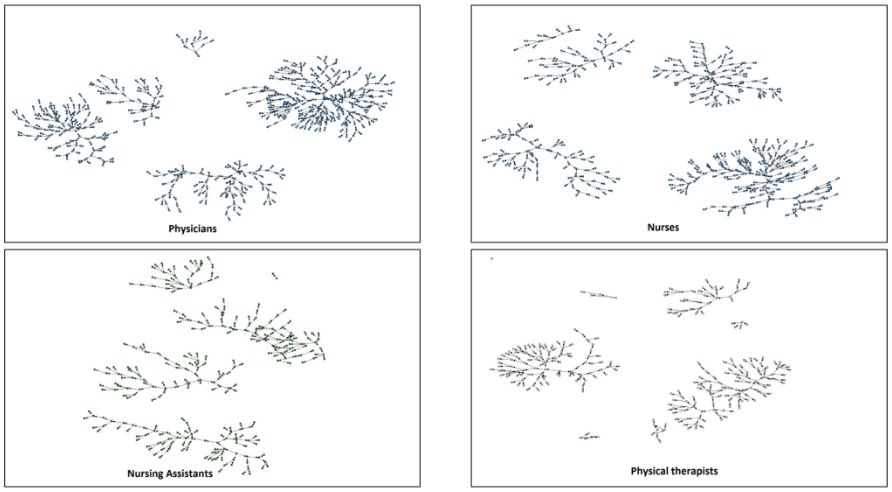

Figure 1. Respondent-driven sampling recruitment chains

338x190mm (170 x 170 DPI)


80·0
70·0
60·0
50·0
40·0
30·0
(%)
55·0
48·1
70·0
54·7
61·8
Lower Limit
Upper Limit
Prevalence(%)
Physician
Nurse
Nursing Assistant
Physical therapist
Overall
Occupation

Supplementary Table 1. Characteristics of the study population according to RT-PCR testing

		RT-PCR testing		*P*-value
		Yes (%)	**No (%)**	
Occupation category				0·02
	Physician	269 (51·1)	257 (48·9)	
	Registered nurse	224(47·6)	247(52·4)	
	Nursing assistant	110 (42·0)	152 (58·0)	
	Physical therapist	108(41·2)	154(58·8)	
Sex				0·43
	Female	530 (46·2)	618 (53·8)	
	Male	181 (48·5)	192 (51·5)	
Age group, years				0·15
	< 30	523 (45·7)	622 (54·3)	
	≥ 30	188 (50·0)	188 (50·0)	
Any comorbidity				< 0·001
	Yes	246 (56·8)	187 (43·2)	
	No	465 (42·7)	623 (57·3)	
Number of workplaces (hospitals/clinics)				< 0·01
	<3	247 (54·0)	210 (46·0)	
	≥3	462 (43·5)	599 (56·5)	
Work setting				0·39
	Emerg/ICU	565 (47·3)	629 (52·7)	
	Outpat/Inpatients	146 (44·7)	181 (55·3)	
Institution provider				< 0·001
	Private	48 (42·1)	66 (57·9)	
	Public	393 (43·0)	522 (57·0)	
	Both	270 (54·9)	222 (45·1)	
Performed aerossol generating procedure				0·36
	Yes	600 (47·3)	669 (52·7)	
	No	110 (44·5)	137 (55·5)	
	Missing	1 (20·0)	4 (80·0)	
Same N95 respirator, use duration, days				0·023
	≤ 7	458 (49·00	476 (51·0)	
	> 7	243 (43·0)	322 (57·0)	
Self-perceived risk				0·85
	None/Low	36 (45·1)	43 (54·9)	
	Medium/High	665 (46·7)	760 (53·3)	
Accident involving biological fluid/respiratory secretion				0·644
	Yes	84 (45·2)	102 (54·8)	
	No	627 (47·0)	708 (53·0)	
Sick leave due to COVID-19 symptoms				< 0·001
	Yes	576 (79·7)	147 (20·3)	
	No	130 (16·5)	659 (83·5)	
Had COVID-19-like symptoms/signs				< 0·001
	Yes	601 (68·2)	280 (31·8)	
	No	110 (17·0)	530 (82·8)	

COVID-19, coronavirus disease 2019; RT-PCR, reverse transcription polymerase chain reaction

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Supplementary Table 2. Potential risk factors for reporting a positive PCR COVID-19 result among front line healthcare professionals

	Odds Ratio	95% CI	*P*-value
Sex			
Female	1.0	..	..
Male	1.35	0.78–2.34	0.288
Age, years	1.03	0.65–1.64	0.889
Occupation			
Nurse	1.0	..	..
Physical therapist	1.42	0.88–2.27	0.148
Physician	1.32	0.91–1.91	0.142
Nursing Assistant	2.77	1.64–4.67	<0.001
Any comorbidity	1.19	0.75–1.90	0.454
Number of workplaces			
< 3	1.0	..	..
≥ 3	0.83	0.53–1.30	0.428
Institution provider			
Private	1.0	..	..
Public	0.92	0.42–2.02	0.844
Both	0.93	0.41–2.10	0.863
Work setting			
Outpatient /Inpatient clinics	1.0	..	..
ICU/Emergency	1.54	0.92–2.60	0.102
Training on PPE use	1.06	0.62–1.80	0.829
Any accident involving body fluid/respiratory secretion	2.67	1.22–5.82	0.014
Splash in the mouth			
No accident	1.0	..	..
Yes	3.84	0.64–22.95	0.140
Other accident	2.30	0.85–6.23	0.102
Splash on the skin			
No accident	1.0	..	..
Yes	1.86	0.54–6.44	0.328
Other accident	2.50	0.80–7.85	0.116
Splash in the eyes			
No accident	1.0	..	..
Yes	4.07	1.14–14.55	0.031
Other accident	2.07	0.71-6.08	0.184
Puncture/sharp accident			
No accident	1.0	..	..
Yes	2.25	0.51–9.89	0.282
Other accident	2.51	1.10–5.72	0.028
Duration N95 respirator use			
< 8 days	..	..	..
≥ 8 days	0.96	0.59–1.55	0.869
Used All PPE items during AGP#			
Did not Always use	1.68	0.97–2.92	0.063

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Used all PPE items while assisting COVID-19 patients			
Yes	1.0	..	..
No	2.14	1.18–3.88	0.013
Time on the front-line, days	0.997	0.994–1.000	0.042

Adjusted for cluster random effect and weighted by network and population size.

AGP, aerosol-generating procedure; COVID-19, coronavirus disease 2019; CI, confidence interval; ICU, intensive care unit; PPE, personal protective equipment

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Tabela 1. STROBE-RDS Statement Checklist for the manuscript title "High risk of SARS-CoV-2 infection among frontline healthcare workers in Northeast Brazil: a respondent-driven sampling approach"

Item	#	STROBE-RDS checklist	Main Document
Title and abstract	1	(a) Indicate ''respondent-driven sampling'' in the title or abstract	Page:1/ Line: 1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Page:3/ Line:2-23
Introduction			
Background/ rationale	2	Explain the scientific background and rationale for the investigation being reported	Page:5/ Line: 2-34; Page:6/ Line: 1-6
Objectives	3	State specific objectives, including any prespecified hypotheses	Page:6/ Line: 7-9
Methods			
Study design	4	(a) Present key elements of study design early in the article	Page:6/ Line: 13-18
		(b) State why RDS was chosen as the sampling method	Page:6/ Line: 15-17
Setting	5	(a) Describe the setting, locations, and relevant dates, including periods of recruitment and data collection	Page:6/ Line: 23-28 Page:7/ Line: 13-14
		(b) Describe formative research findings used to inform RDS study	Page:6/ Line: 31-34
Participants	6	(a) Give the eligibility criteria and the sources and methods of selection of participants. Describe how participants were trained/instructed to recruit others, number of coupons issued per person, any time limits for referral	Page:7/ Line: 13-18
		(b) Describe methods of seed selection and state number at start of study and number added later	Page:7/ Line: 19-25
		(c) State if there was any variation in study procedures during data collection (e.g., changing numbers of coupons per recruiter, interruptions in sampling, or (stopping recruitment chains)	Page:7/ Line: 17
		(d) Report wording of personal network size question(s)	Page:7/ Line: 21-25
		(e) Describe incentives for participation and recruitment	Page:7/ Line: 17-18
Variables	7	(a) If applicable, clearly define all outcomes, correlates, predictors, potential confounders, effect modifiers, and diagnostic criteria	Page:7/ Line: 28-32 Page:8/ Line: 1-20
		(b) State recruitment relationship was tracked	Page:9/ Line: 22-23
Data sources/ measurement	8	(a) For each variable of interest, give sources of data and details of methods of measurement. Describe comparability of measurement methods if there is more than one group	Page:8/ Line: 31-34 Page:9/ Line: 1-10
		(b) Describe methods to assess eligibility and reduce repeat enrollment (e.g., coupon manager software, biometrics)	Page:8/ Line: 23-25
Bias	9	Describe any efforts to address potential sources of bias	Not done
Study size	10	Explain how the study size was arrived at	Page:7/ Line: 19-20
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page:7/ Line: 28-32 Page:8/ Line: 1-16 Page:8/ Line: 31-34 Page:9/ Line: 1-10
Statistical methods	12	(a) Describe all statistical methods, including those to account for sampling strategy (e.g., the estimator used) and, if applicable, those used to control for confounding	Page:8/ Line: 31-34 Page:9/ Line: 1-10
		(b) State data analysis software, version number, and specific analysis settings used	Page:9/ Line: 11-12
		(c) Describe any methods used to examine subgroups and interactions	Not applicable
		(d) Explain how missing data were addressed	Page: 9/ Line: 1-3
		(e) Describe any sensitivity analyses	Not done
		(f) Report any criteria used to support statements on whether estimator conditions or assumptions were appropriate	Not done
		(g) Explain how seeds were handled in analysis	Page:9/ Line: 3-4
Results			
Participants	13	(a) Report the numbers of individuals at each stage of the study, for example, numbers potentially eligible,	Page:9/ Line: 19-23

		examined for eligibility, confirmed eligible, included in the study, and analyzed	
		(b) Give reasons for nonparticipation at each stage (e.g., not eligible, does not consent, decline to recruit others)	Page:9/ Line: 21-22
		(c) Consider use of a flow diagram	Not included as Flowchart due to limited number of Figures of the Journal
		(d) Report number of coupons issued and returned	Not applicable
		(e) Report number of recruits by seed and number of RDS recruitment waves for each seed. Consider showing graph of entire recruitment network	Page:9/ Line: 22-23 Figure 1
		(f) Report recruitment challenges (e.g., commercial exchange of coupons, imposters, duplicate recruits) and how addressed	Not Done
		(g) Consider reporting estimated design effect for outcomes of interest	Page:11/ Line:7-13
Descriptive data	14	(a) Give characteristics of study participants (e.g., demographic, clinical, social) and, if applicable, information on correlates and potential confounders. Report unweighted sample size and percentages, estimated population proportions or means with estimated precision (e.g., 95% confidence interval)	Page:9/ Line: 26-34 Page:10/ Line: 1-32
		(b) Indicate the number of participants with missing data for each variable of interest	Page: 20-24
Outcome data	15	If applicable, report number of outcome events or summary measures	Page:11/ Line: 7-13
Main results	16	(a) Give unadjusted and study design adjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence intervals). Make clear which confounders were adjusted for and why they were included	Page:11/ Line: 19-33
		(b) Report category boundaries when continuous variables were categorized	Not applicable
		(c) If adjustment of primary outcome leads to marked changes, report information on factors influencing the adjustments (e.g., personal network sizes, recruitment patterns by group, key confounders)	The adjustment only modified slightly not affecting the general results
Other analyses	17	Report other analyses done for example, analyses of subgroups and interactions, sensitivity analyses, different RDS estimators and definitions of personal network size	All analyses were reported
Discussion			
Key results	18	Summarize key results with reference to study objectives	Page:12/ Line: 2-14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page:14/ Line: 9-34 Page:15/ Line: 1-7
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page:12/ Line: 14-33 Page:13/ Line: 1-34
Generalizability	21	Discuss the generalizability (external validity) of the study results	Page:13/ Line:30-34 Page:14/ Line: 1-8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page:16/ Line: 13-16

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

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

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Abstract

Objectives: We assessed the prevalence of severe acute respiratory syndrome coronavirus (SARS-CoV-2) infection, personal protective equipment (PPE) shortages and occurrence of biological accidents among frontline health care workers (HCW).

Design, setting and participants: Using respondent driven sampling (RDS), the study recruited distinct categories of HCW attending suspected or confirmed COVID-19 patients 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 analyzed 1,525 HCW: 527 physicians, 471 registered nurses, 263 nursing assistants, and 264 physical therapists. Women predominated in all categories (81.1%; 95% CI: 77.8% - 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%-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 (ORadjusted: 2.56; 95% CI: 1.42 - 4.61), not always using all recommended PPE while assisting patients with COVID-19 (ORadj: 2.15; 95% CI: 1.02 - 4.53) and reporting a splash of biological fluid/respiratory secretion in the eyes (ORadj: 3.37; 95% CI: 1.10 – 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 health care facility environments, specific training and supervision to cope with public health emergencies.

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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 health care professionals who attended Covid-19 patients 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 respondent-driven sampling 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.

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Introduction

The unprecedented rapid spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and its potentially severe outcomes have greatly impacted the healthcare system, the global economy, and security.[1,2] According to the World Health Organization (WHO), the global cumulative number of confirmed coronavirus disease 2019 (COVID-19) cases had reached approximately 364.2 million infections and 5.6 million deaths by January 28, 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 (February 25, 2020 to November 5, 2020) to 39.3% in the second wave (November 6, 2020, to April 30, 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 frontline 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 metanalysis 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 2,506 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

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protective equipment (PPE) among 70% of frontline 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 region and southeast regions, respectively.[14,15,16] However, information on the prevalence of SARS-CoV-2 infection among frontline 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 frontline HCW attending emergency rooms, hospitals, and new field hospitals. RDS approach is based upon direct participant involvement.

The baseline findings are described following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) 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 March 12, 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 four million inhabitants, corresponding to 42% of the state population.[21] The Brazilian unified health system (Sistema Unico de Saude—SUS) 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

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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 formative research 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 health care 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 COVID-19 patients from May 21, 2020 to February 10, 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 1,100 HCW, considering a 95% confidence level (CI) to estimate a 40% prevalence of infections 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 COVID-19 patients?", 2) "How many of those colleagues have been in professional contact with you in the last two weeks?," and 3) "How many of them are close to you and you would invite to participate in this study?."

*Variabl*es

We applied the WHO questionnaire developed as an operational tool to determine the risk of COVID-19 virus infection among HCW exposed to a COVID-19 patient in a health care facility. This questionnaire was developed as an interim guidance for risk assessment by the

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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: i) always as recommended (more than 95% of the time); ii) most of the time (ranging from 50% to 95%); iii) occasionally (1-49%); iv) never; v) unavailable.

(5) Adherence to IPC when performing aerosol-generating procedures (AGPs) using the abovementioned 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—I) during the period of healthcare interaction and II) 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 LACEN, which is the public health 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.

Providing electronic informed consent was mandatory to participate and access the questionnaire. The project was approved by the National Ethics Committee (CONEP; CAAE: 30629220.8.0000.0008).

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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 to 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 chi-squared 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, version 15.0 (StataCorp LLC, College Station, TX, USA).

Role of the funding source

The funding source had no involvement in any stage of the project.

Results

Participants

We recruited 2,474 health care workers and 1,525 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% – 84.1%) of the sample after adjustment to the reference 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% – 67.9%) and the highest among nurses (86.7%; 95% CI: 82.7% – 89.9%) and nursing

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assistants (85.5%; 95% CI: 79.8% – 89.7%). The age distribution was as follows: 32.7% (95% CI: 28.8% – 36.9%) and 35.6% (95% CI: 31.5% – 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% – 61.4%) and 45.1% (95% CI: 38.3% – 52.1%), respectively, of those 20–29 years old. Comorbidities affected 30.1% (95% IC: 26.1% – 34.3%) of the studied population. Overweight/obesity (12.6%; 95% CI: 9.9% – 15.9%) and hypertension (11.9%; 95% CI: 9.2% – 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% – 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% – 77.3%) worked either in emergency rooms or ICU. Notably, 55.8% (95% CI: 51.0% – 60.6%) of the physicians and 37.8% (95% CI: 31.3% – 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% – 81.3%) of the participants received training on the use of PPE. Physical therapists (87.0%; 95% CI: 81.6% – 91.0%) and nursing assistants (81.1%; 95% CI: 74.8% – 86.1%) received a higher and similar frequency of training compared to 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% – 92.0%) for single-use gloves to 29.9% (95% CI: 25.9% – 34.2%) for face shields. Most HCW (82.2%; 95% CI: 78.4% – 85.5%) reported performing AGPs on COVID-19 patients. Almost all participants reported having always used single-use gloves (98.4%; 95% CI: 96.4% – 99.3%) and N95 respirators (86.4%; 95% CI: 82.5% – 89.5%) during AGPs. The N95/PPF2 respirator was reused for more than seven days by approximately 28.3% (95% CI: 24.7% – 32.1%) of the participants, with highest and lowest frequencies reported by physicians (49.3%; 95% CI: 44.4% – 54.2%) and nursing assistants (20.6%; 95% CI: 15.4% – 27.0%), respectively. Overall, 63.7% (95% CI: 57.8% – 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

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interaction with COVID-19 patients. Accidents were more frequent among physicians (13.9%; 95% CI: 11.0% – 17.4%) and less frequent among physical therapists (7.6%; 95% CI: 4.9% – 11.7%) (Table 2).

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 (Supplementary Table 1).

For the tested HCW, mostly symptomatic, the overall self-reported SARS-CoV-2 infection was 61.8% (95% CI: 55.7%-67.5%) compared with 14.9% (CI: 4.9%-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%-79.1%), followed by physicians (55.0%; 95%CI: 47.5%-62.3%), physical therapists (54.7%; 95%CI: 43.1%-65.7%), and nurses (48.1%; 95%CI: 40.3%-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 hospitalized.

In a bivariate analysis, the nursing assistant category was positively associated with infection (odds ratio [OR]=2.77; 95% CI: 1.64–4.67, p<0.001) compared to nurses. Reporting any accident involving body fluid/respiratory secretion was associated with infection (OR=2.67; 95% CI: 1.22–5.82, p<0.014). When considering each accident, splashes in the eyes were a stronger predictor of infection (OR=4.07; 95% CI: 1.14–14.55, p<0.031). During routine assistance of COVID-19 patients, not always wearing the complete set of recommended PPE items was associated with infection (OR=2.14; 95% CI: 1.18–3.88, p=0.013) when compared to always using PPE. Not always using the complete recommended PPE items during AGPs was also associated with infection (OR=1.68; 95% CI: 0.97–2.92, p=0.063) when compared with always using PPE (Supplementary Table 2).

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In the final multivariate logistic regression model, the following were risk factors for infection: being a nursing assistant (OR adjusted=2.56; 95% CI: 1.42–4.61, p=0.002), not always having used PPE during care of patients with COVID-19 (OR adjusted=2.15; 95% CI: 1.02–4.53, p=0.044), and having suffered a splash to the eyes (OR adjusted=3.37; 95% CI: 1.10–10.34, 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 frontline were younger and mainly worked in the Intensive Care Units 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 frontliners 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 hospitalization 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 frontline 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 4,987) 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.

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Finding of seroprevalence studies cannot be directly compared to 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- and medium-income countries like 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 aerosol-generating procedures (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 to 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

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evidence that HCW are at a high risk of SARS-CoV-2 infection in low- 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 frontline 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 frontline 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 of 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 minimize 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 frontliners attending suspected or confirmed Covid-19 patients. In fact, only 15.2% of them referred to

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have had contact with COVID-19 cases simultaneously in health-care 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 frontline HCW was presumably healthcare associated infections in line with our findings, with the scenario of shortage of PPE and the high health care 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-minute online questionnaire. Physicians and nurses were also a more vocal category early in the pandemic, publicizing 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 socio-economic conditions when compared to 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 health care facility environments, specific training and supervision to cope with public health emergencies.

Data availability statement

Proposals for the dataset (de-identified 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.

Ethics statements

All participants provided electronic informed consent in the web-based platform. HCW could only access the questionnaire after giving the on-line Informed Consent Form (ICF). In our

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study we applied the ICF in agreement with both: the requirements of the National Ethics Committee (CONEP, 30629220.8.0000.0008); and with the current protocols for electronic survey.

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Author contributions

MFPMA, WVS, CMTM, RAAX, DBMF, TB, CK, and LRFSK contributed to the study concept and design. CB, MNX, CNLM, GDMA, CBS, CAM, NTSF, JMG, CLFN, and JMVB contributed to the acquisition of data. MFPMA, URM, WVS, CLS, PRBSJ, and CRP contributed to the data analysis and creation of tables and figures. MFPMA, WVS, CMTM, RAAX, DMF, TVBA, MASMV, LNGCL, CB, and LNC contributed to data interpretation. MFPMA, WVS, URM have verified the underlying data. CMTM, MFPMA, WVS, 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.

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Declaration of interests

We declare no competing interests.

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Table 1. Demographic, clinical, and working baseline characteristics of health care workers in the metropolitan region of Recife, Northeast Brazil, 2020 to 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	58.6–67.9	86.7	82.7–89.9	85.5	79.8–89.7	70.3	63.6–76.3	81.1	77.8–84.1
Male	36.6	32.1–41.4	13.2	10.1–17.3	14.5	10.2–20.2	29.7	23.7–36.4	18.9	15.9–22.2
Age, years										
< 30	56.6	51.7–61.4	25.8	21.6–30.6	26.9	20.8–33.9	45.1	38.3–52.1	32.7	28.8–36.9
30– 39	34.1	29.6–38.9	37.3	32.5–42.4	34.5	28.0–41.6	45.3	38.5–52.4	35.6	31.5–40.0
≥ 40	9.3	6.8–12.6	36.9	32.1–41.9	38.6	32.0–45.7	9.6	6.2–14.4	31.7	27.6–36.0
Any comorbidity										
Any	23.3	19.5–27.6	33.9	29.2–38.8	32.0	25.8–38.9	19.0	14.1–25.1	30.1	26.1–34.3
None	76.7	72.4–80.5	66.1	61.2–70.8	68.0	61–74.2	81.0	74.9–85.9	69.9	65.7–73.8
Diabetes	1.0	0.4–2.6	2.1	1.1–4.1	2.0	0.8–5.1	0.4	0.1–3.1	1.8	0.9–3.4
Hypertension	4.0	2.5–6.4	13.2	10.0–17.1	14.4	10.1–19.9	4.8	2.5–8.9	11.9	9.2–15.1
Overweight/Obesity	7.3	5.3–10.0	11.1	8.2–14.6	14.9	10.6–20.4	8.9	5.6–13.7	12.6	9.9–15.9
Heart disease	0.4	0.1–1.3	1.2	0.5–3.0	0.9	0.2–3.5	0.0	..	0.1	0.3–2.1
Kidney disease	0.0	..	0.2	0.03–1.5	0.1	0.02–1.1	0.8	0.2–3.1	0.2	0.1–0.6
Others comorbidities	13.1	10.1–16.7	14.8	11.6–18.8	9.4	5.9–14.7	6.9	4.2–11.4	10.8	8.4–13.8
Number of workplaces										
< 3	44.2	39.4–49.0	91.8	88.4–94.2	95.2	92.0–97.2	62.2	55.2–68.7	84.2	82.1–86.1
≥ 3	55.8	51.0–60.6	8.2	5.8–11.6	4.8	2.8–8.0	37.8	31.3–44.8	15.8	13.9–17.9
Missing	2		0		1		0		3	
Institution provider										
Private	5.2	3.5–7.8	7.2	4.8–10.5	7.0	4.1–11.5	14.8	10.4–20.5	7.2	5.3–9.8
Public	44.5	39.7–49.3	81.2	76.8–85.0	79.8	73.5–85.0	35.2	28.9–42.2	71.4	67.6–74.9
Both	50.3	45.5–55.2	11.6	8.7–15.4	13.2	9.1–18.9	50.0	43–56.9	21.4	18.4–24.7
Work setting										
Outpatient/Inpatient clinics	12.0	9.1–15.6	41.6	36.6–46.8	27.7	21.6–34.7	11.5	7.6–17.0	26.5	22.7–30.8
ICU/Emergency	88.0	84.4–90.9	58.4	53.2–63.4	72.3	65.3–78.4	88.5	83.0–92.4	73.5	69.2–77.3

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. CI, confidence interval; ICU, intensive care unit

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Table 2. Adherence to infection prevention and control during healthcare interactions with COVID-19 patients 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	64.2–73.2	72.3	67.4–76.7	81.1	74.8–86.1	87.0	81.6–91.0	78.0	74.2–81.3
No	31.1	26.8–35.8	27.7	23.3–32.6	18.9	13.9–25.2	13.0	9.0–18.4	22.0	18.7–25.8
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	69.6–78.1	84.4	80.3–87.8	95.4	90.9–97.7	96.1	92.1–98.1	90.1	87.7–92.0
Not always	25.9	21.9–30.4	15.6	12.2–19.7	4.6	2.3–9.1	3.9	1.9–7.9	9.9	8.0–12.3
Missing	2		2		0		1		5	
Surgical mask										
Always	45.3	40.6–50.2	58.6	53.5–63.6	51.0	43.8–58.1	36.9	30.3–44.0	50.5	46.0–54.9
Not always	54.7	49.8–59.4	41.4	36.4–46.5	49.0	41.9–56.1	63.1	56.0–69.6	49.5	45.1–53.9
Missing	2		2		0		1		5	
N95 respirator										
Always	64.4	59.6–68.9	57.4	52.3–62.4	66.3	59.1–72.9	87.3	81.6–91.4	65.9	61.4–70.0
Not always	35.6	31.1–40.3	42.6	37.6–47.7	33.7	27.1–40.9	12.7	8.6–18.4	34.1	30.0–38.6
Missing	2		2		0		1		5	
Face shield										
Always	19.6	16.0–23.9	28.8	24.4–33.7	31.6	25.3–38.6	42.4	35.7–49.3	29.9	25.9–34.2
Not always	80.4	76.1–84.0	71.2	66.3–75.6	68.4	61.4–74.7	57.6	50.7–64.3	70.1	65.8–74.1
Missing	2		2		0		1		5	
Goggles/protective glasses										
Always	18.7	15.3–22.7	24.6	20.4–29.3	38.3	31.6–45.4	45.6	38.7 - 52.6	33.2	29.1–37.6
Not always	81.3	77.2–84.7	75.4	70.7–79.5	61.7	54.6–68.4	54.4	47.4–61.3	66.8	62.3–70.9
Missing	2		2		0		1		5	
Disposable gown										

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Always	48.0	43.3–52.9	50.8	45.6–55.9	63.8	56.6–70.4	67.2	60.3–73.3	59.2	54.8–63.5
Not always	52.0	47.1–56.7	49.2	44.1–54.4	36.2	29.5–43.4	32.8	26.7–39.7	40.8	36.5–45.2
Missing	2		2		0		1		5	
Waterproof apron										
Always	30.5	26.2–35.2	38.6	33.7–43.7	48.9	41.6–56.3	62.6	55.3–69.4	44.9	40.5–49.5
Not always	69.5	64.8–73.8	61.4	56.3–66.3	51.1	43.7–58.4	37.4	30.6–44.7	55.1	50.5–59.5
Missing	14		11		11		18		54	
During provision of routine assistance to COVID-19 patients, did you wear all PPE items as recommended by the WHO?										
Always	89.6	86.2–92.3	79.2	74.7–83.1	70.0	63.1–76.1	69.0	62.2–75.1	74.7	70.5–78.5
Not always	10.4	7.7–13.8	20.8	16.9–25.3	30.0	23.9–36.9	31.0	24.9–37.8	25.3	21.5–29.5
Missing	2		2		0		1		5	
Participated in AGP*										
Yes	79.6	75.3–83.2	75.6	70.8–79.8	83.4	77–88.3	95.8	91.7–97.8	82.2	78.4–85.5
No	20.4	16.8–24.7	24.4	20.2–29.2	16.6	11.7 - 23	4.2	2.1–8.3	17.8	14.5–21.6
Missing	1		1		1		2		5	
While participating in AGPs, have you used:										
Single Gloves										
Always	97.8	95.5–98.9	97.7	95.1–99	98.5	94.2–99.6	99.7	98.1–99.9	98.4	96.4–99.3
Not always	2.2	1.1–4.5	2.3	1–4.9	1.5	0.4–5.8	0.3	0.04–1.9	1.6	0.7–3.6
Missing	0		0		0		1		1	
Surgical mask										
Always	61.5	56.2–66.6	49.9	44.1–55.7	46.5	38.9–54.3	60.2	52.9–67.1	50.5	45.6–55.3
Not always	38.5	33.4–43.8	50.1	44.3–55.9	53.5	45.7–61.1	39.8	32.9–47.1	49.5	44.7–54.4
Missing	0		0		0		1		1	
N95 respirator										
Always	92.4	89–94.9	85.0	80.3–88.8	84.2	77.8–89.1	93.3	88.2–96.3	86.4	82.5–89.5
Not always	7.6	3.1–11	15.0	11.2–19.7	15.7	10.9–22.2	6.7	3.7–11.8	13.6	10.5–17.5
Missing	0		0		0		1		1	
Face shield										

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Always	51.6	46.2–56.9	48.3	42.6–54.1	48.0	40.3–55.7	41.4	34.5–48.6	48.1	43.2–53.0
Not always	48.4	43.1–53.8	51.7	45.8–57.4	52.0	44.2–59.7	58.6	51.4–65.5	51.9	47.0–56.8
Missing	0		0		0		1		1	
Goggles/Protective glasses										
Always	62.5	57.1–67.6	59.3	53.5–64.9	51.4	43.6–59.1	47.1	40–54.3	54.0	49.1–58.9
Not always	37.5	32.4–42.8	40.7	35.1–46.5	48.6	40.9–56.4	52.9	45.7 - 60	46.0	41.1–50.9
Missing	0		0		0		1		1	
Disposable gown										
Always	60.3	55.0–65.4	60.1	54.3 - 65.7	64.0	60.3–74.9	68.3	61.3–74.4	65.6	60.8–70.1
Not always	39.7	34.6–45.0	39.9	34.3–45.7	32.0	25.1–39.7	31.7	25.6–38.7	34.4	29.9–39.2
Missing	0		0		0		1		1	
Waterproof apron										
Always	55.2	49.7–60.6	60.7	54.8–66.3	62.5	54.4–69.9	74.6	67.4–80.7	61.9	57.0–66.7
Not always	44.8	39.4–50.3	39.3	33.7–45.2	37.5	30.1–45.6	25.4	19.3–32.6	38.1	33.3–43.0
Missing	9		7		9		17		42	
When performing an AGP in COVID-19 patients, did you wear all recommended PPE items as in WHO guidance?										
Always	66.0	60.0–71.4	58.0	51.4–64.3	63.8	54.1–72.6	74.7	64.2–82.8	63.7	57.8–69.2
Not always	34.0	28.6–40.0	42.0	35.7–48.6	36.2	27.4–45.9	25.3	17.2–35.8	36.3	30.8–42.2
Missing	0		0		0		1		1	
Duration of N95 respirator use										
< 8 days	50.7	45.8–55.6	71.4	66.6–75.8	79.4	73.0–84.6	54.6	47.6–61.5	71.7	67.9–75.3
≥ 8 days	49.3	44.4–54.2	28.6	24.2–33.4	20.6	15.4–27.0	45.4	38.5–52.4	28.3	24.7–32.1
Missing	9		5		8		4		26	
Any accident involving body fluid/respiratory secretion										
Yes	13.9	11–17.4	10.8	7.9–14.5	11.7	7.9–17.1	7.6	4.9–11.7	11.6	9.1–14.8
No	86.1	82.6–89	89.2	85.5–92.1	88.3	82.9–92.1	92.4	88.3–95.1	88.4	85.2–90.9
Organ involved										
Splash in the Mouth	1.9	1.02–3.8	1.9	0.85–4.3	0.2	0.04–1.5	0.7	0.2–3.1	0.8	0.5–1.4
Splash on the Skin	2.4	1.4–3.9	3.4	1.9–6.0	1.3	0.5–3.2	3.9	1.9–7.7	2.0	1.3–3.0
Splash on the Eyes	2.3	1.4–3.9	3.5	1.9–6.1	2.1	0.8–5.8	2.5	1.2–5.0	2.4	1.4–4.2

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Puncture/sharps	8.2	5.9–11.3	3.0	1.7–5.3	8.2	4.9–13.4	0.0	-	6.7	4.6–9.7
Self-perception of risk										
None/Low	21.6	17.9–25.9	24.9	20.7–29.6	21.9	16.3–28.7	17.2	12.5–23.3	22.0	18.5–26.1
Medium/High	78.4	74.1–82.1	75.1	70.3–79.3	78.1	71.3–83.7	82.8	76.7–87.5	78.0	73.8–81.5
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; COVID-19, coronavirus disease 2019; CI, confidence interval; ICU, intensive care unit; PPE, personal protective equipment; WHO, World Health Organization

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

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

Adjusted for cluster random effect and weighted by network and population size
COVID-19, coronavirus disease 2019; CI, confidence interval; PPE, personal protective equipment

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Figure Legends

Figure 1. Respondent-driven sampling recruitment chains.

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

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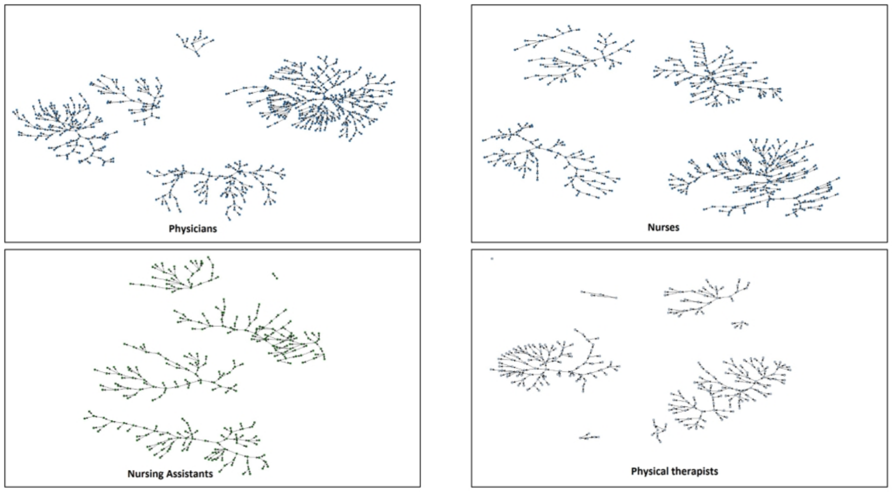

Figure 1. Respondent-driven sampling recruitment chains

338x190mm (170 x 170 DPI)


80·0
70·0
60·0
50·0
40·0
30·0
(%)
55·0
48·1
70·0
54·7
61·8
Lower Limit
Upper Limit
Prevalence(%)
Physician
Nurse
Nursing Assistant
Physical therapist
Overall
Occupation

Supplementary Table 1. Characteristics of the study population according to RT-PCR testing

		RT-PCR testing		*P*-value
		Yes (%)	**No (%)**	
Occupation category				0·02
	Physician	269 (51·1)	257 (48·9)	
	Registered nurse	224(47·6)	247(52·4)	
	Nursing assistant	110 (42·0)	152 (58·0)	
	Physical therapist	108(41·2)	154(58·8)	
Sex				0·43
	Female	530 (46·2)	618 (53·8)	
	Male	181 (48·5)	192 (51·5)	
Age group, years				0·15
	< 30	523 (45·7)	622 (54·3)	
	≥ 30	188 (50·0)	188 (50·0)	
Any comorbidity				< 0·001
	Yes	246 (56·8)	187 (43·2)	
	No	465 (42·7)	623 (57·3)	
Number of workplaces (hospitals/clinics)				< 0·01
	<3	247 (54·0)	210 (46·0)	
	≥3	462 (43·5)	599 (56·5)	
Work setting				0·39
	Emerg/ICU	565 (47·3)	629 (52·7)	
	Outpat/Inpatients	146 (44·7)	181 (55·3)	
Institution provider				< 0·001
	Private	48 (42·1)	66 (57·9)	
	Public	393 (43·0)	522 (57·0)	
	Both	270 (54·9)	222 (45·1)	
Performed aerossol generating procedure				0·36
	Yes	600 (47·3)	669 (52·7)	
	No	110 (44·5)	137 (55·5)	
	Missing	1 (20·0)	4 (80·0)	
Same N95 respirator, use duration, days				0·023
	≤ 7	458 (49·00	476 (51·0)	
	> 7	243 (43·0)	322 (57·0)	
Self-perceived risk				0·85
	None/Low	36 (45·1)	43 (54·9)	
	Medium/High	665 (46·7)	760 (53·3)	
Accident involving biological fluid/respiratory secretion				0·644
	Yes	84 (45·2)	102 (54·8)	
	No	627 (47·0)	708 (53·0)	
Sick leave due to COVID-19 symptoms				< 0·001
	Yes	576 (79·7)	147 (20·3)	
	No	130 (16·5)	659 (83·5)	
Had COVID-19-like symptoms/signs				< 0·001
	Yes	601 (68·2)	280 (31·8)	
	No	110 (17·0)	530 (82·8)	

COVID-19, coronavirus disease 2019; RT-PCR, reverse transcription polymerase chain reaction

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Supplementary Table 2. Potential risk factors for reporting a positive PCR COVID-19 result among front line healthcare professionals

	Odds Ratio	95% CI	*P*-value
Sex			
Female	1.0	..	..
Male	1.35	0.78–2.34	0.288
Age, years	1.03	0.65–1.64	0.889
Occupation			
Nurse	1.0	..	..
Physical therapist	1.42	0.88–2.27	0.148
Physician	1.32	0.91–1.91	0.142
Nursing Assistant	2.77	1.64–4.67	<0.001
Any comorbidity	1.19	0.75–1.90	0.454
Number of workplaces			
< 3	1.0	..	..
≥ 3	0.83	0.53–1.30	0.428
Institution provider			
Private	1.0	..	..
Public	0.92	0.42–2.02	0.844
Both	0.93	0.41–2.10	0.863
Work setting			
Outpatient /Inpatient clinics	1.0	..	..
ICU/Emergency	1.54	0.92–2.60	0.102
Training on PPE use	1.06	0.62–1.80	0.829
Any accident involving body fluid/respiratory secretion	2.67	1.22–5.82	0.014
Splash in the mouth			
No accident	1.0	..	..
Yes	3.84	0.64–22.95	0.140
Other accident	2.30	0.85–6.23	0.102
Splash on the skin			
No accident	1.0	..	..
Yes	1.86	0.54–6.44	0.328
Other accident	2.50	0.80–7.85	0.116
Splash in the eyes			
No accident	1.0	..	..
Yes	4.07	1.14–14.55	0.031
Other accident	2.07	0.71-6.08	0.184
Puncture/sharp accident			
No accident	1.0	..	..
Yes	2.25	0.51–9.89	0.282
Other accident	2.51	1.10–5.72	0.028
Duration N95 respirator use			
< 8 days	..	..	..
≥ 8 days	0.96	0.59–1.55	0.869
Used All PPE items during AGP#			
Did not Always use	1.68	0.97–2.92	0.063

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Used all PPE items while assisting COVID-19 patients			
Yes	1.0	..	..
No	2.14	1.18–3.88	0.013
Time on the front-line, days	0.997	0.994–1.000	0.042

Adjusted for cluster random effect and weighted by network and population size.

AGP, aerosol-generating procedure; COVID-19, coronavirus disease 2019; CI, confidence interval; ICU, intensive care unit; PPE, personal protective equipment

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Tabela 1. STROBE-RDS Statement Checklist for the manuscript title "High risk of SARS-CoV-2 infection among frontline healthcare workers in Northeast Brazil: a respondent-driven sampling approach"

Item	#	STROBE-RDS checklist	Main Document
Title and abstract	1	(a) Indicate ''respondent-driven sampling'' in the title or abstract	Page:1/ Line: 1-2
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	Page:3/ Line:2-23
Introduction			
Background/ rationale	2	Explain the scientific background and rationale for the investigation being reported	Page:5/ Line: 2-34; Page:6/ Line: 1-6
Objectives	3	State specific objectives, including any prespecified hypotheses	Page:6/ Line: 7-9
Methods			
Study design	4	(a) Present key elements of study design early in the article	Page:6/ Line: 13-18
		(b) State why RDS was chosen as the sampling method	Page:6/ Line: 15-17
Setting	5	(a) Describe the setting, locations, and relevant dates, including periods of recruitment and data collection	Page:6/ Line: 23-28 Page:7/ Line: 13-14
		(b) Describe formative research findings used to inform RDS study	Page:6/ Line: 31-34
Participants	6	(a) Give the eligibility criteria and the sources and methods of selection of participants. Describe how participants were trained/instructed to recruit others, number of coupons issued per person, any time limits for referral	Page:7/ Line: 13-18
		(b) Describe methods of seed selection and state number at start of study and number added later	Page:7/ Line: 19-25
		(c) State if there was any variation in study procedures during data collection (e.g., changing numbers of coupons per recruiter, interruptions in sampling, or (stopping recruitment chains)	Page:7/ Line: 17
		(d) Report wording of personal network size question(s)	Page:7/ Line: 21-25
		(e) Describe incentives for participation and recruitment	Page:7/ Line: 17-18
Variables	7	(a) If applicable, clearly define all outcomes, correlates, predictors, potential confounders, effect modifiers, and diagnostic criteria	Page:7/ Line: 28-32 Page:8/ Line: 1-20
		(b) State recruitment relationship was tracked	Page:9/ Line: 22-23
Data sources/ measurement	8	(a) For each variable of interest, give sources of data and details of methods of measurement. Describe comparability of measurement methods if there is more than one group	Page:8/ Line: 31-34 Page:9/ Line: 1-10
		(b) Describe methods to assess eligibility and reduce repeat enrollment (e.g., coupon manager software, biometrics)	Page:8/ Line: 23-25
Bias	9	Describe any efforts to address potential sources of bias	Not done
Study size	10	Explain how the study size was arrived at	Page:7/ Line: 19-20
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page:7/ Line: 28-32 Page:8/ Line: 1-16 Page:8/ Line: 31-34 Page:9/ Line: 1-10
Statistical methods	12	(a) Describe all statistical methods, including those to account for sampling strategy (e.g., the estimator used) and, if applicable, those used to control for confounding	Page:8/ Line: 31-34 Page:9/ Line: 1-10
		(b) State data analysis software, version number, and specific analysis settings used	Page:9/ Line: 11-12
		(c) Describe any methods used to examine subgroups and interactions	Not applicable
		(d) Explain how missing data were addressed	Page: 9/ Line: 1-3
		(e) Describe any sensitivity analyses	Not done
		(f) Report any criteria used to support statements on whether estimator conditions or assumptions were appropriate	Not done
		(g) Explain how seeds were handled in analysis	Page:9/ Line: 3-4
Results			
Participants	13	(a) Report the numbers of individuals at each stage of the study, for example, numbers potentially eligible,	Page:9/ Line: 19-23

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		examined for eligibility, confirmed eligible, included in the study, and analyzed	
		(b) Give reasons for nonparticipation at each stage (e.g., not eligible, does not consent, decline to recruit others)	Page:9/ Line: 21-22
		(c) Consider use of a flow diagram	Not included as Flowchart due to limited number of Figures of the Journal
		(d) Report number of coupons issued and returned	Not applicable
		(e) Report number of recruits by seed and number of RDS recruitment waves for each seed. Consider showing graph of entire recruitment network	Page:9/ Line: 22-23 Figure 1
		(f) Report recruitment challenges (e.g., commercial exchange of coupons, imposters, duplicate recruits) and how addressed	Not Done
		(g) Consider reporting estimated design effect for outcomes of interest	Page:11/ Line:7-13
Descriptive data	14	(a) Give characteristics of study participants (e.g., demographic, clinical, social) and, if applicable, information on correlates and potential confounders. Report unweighted sample size and percentages, estimated population proportions or means with estimated precision (e.g., 95% confidence interval)	Page:9/ Line: 26-34 Page:10/ Line: 1-32
		(b) Indicate the number of participants with missing data for each variable of interest	Page: 20-24
Outcome data	15	If applicable, report number of outcome events or summary measures	Page:11/ Line: 7-13
Main results	16	(a) Give unadjusted and study design adjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence intervals). Make clear which confounders were adjusted for and why they were included	Page:11/ Line: 19-33
		(b) Report category boundaries when continuous variables were categorized	Not applicable
		(c) If adjustment of primary outcome leads to marked changes, report information on factors influencing the adjustments (e.g., personal network sizes, recruitment patterns by group, key confounders)	The adjustment only modified slightly not affecting the general results
Other analyses	17	Report other analyses done for example, analyses of subgroups and interactions, sensitivity analyses, different RDS estimators and definitions of personal network size	All analyses were reported
Discussion			
Key results	18	Summarize key results with reference to study objectives	Page:12/ Line: 2-14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page:14/ Line: 9-34 Page:15/ Line: 1-7
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page:12/ Line: 14-33 Page:13/ Line: 1-34
Generalizability	21	Discuss the generalizability (external validity) of the study results	Page:13/ Line:30-34 Page:14/ Line: 1-8
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page:16/ Line: 13-16

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