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Cross-sectional study of personal protective equipment use, training and biosafety preparedness among healthcare workers during the first months of the SARS-CoV-2 pandemic in Brazil

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Cross-sectional study of personal protective equipment use, training and biosafety preparedness among healthcare workers during the first months of the SARS-CoV-2 pandemic in Brazil

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ABSTRACT

Objectives Brazil has high rates of COVID-19 and tuberculosis among healthcare workers (HCWs). Personal protective equipment (PPE) is essential for their protection. We aimed to evaluate PPE use, training, and preparedness among HCWs in the early months of the SARS-CoV-2 pandemic in Brazil.

Methods A cross-sectional study was performed using questionnaires available to HCWs through a website created to provide PPE guidelines. χ^2 test and robust Poisson regression identified factors associated with HCWs treating COVID-19 patients (TCOVID-19), lack of training on PPE use and N95 respirator reuse. The speech content of open-ended questions was analysed.

Results We analysed 1410 questionnaires collected from April to July 2020 representing 526 Brazilian cities. HCWs-TCOVID-19 had fewer years of work experience, were more likely to reuse PPE, and reported higher stress levels and lower biosafety at the workplace than HCWs not TCOVID-19 patients. Fearful concerns, limited PPE access and pandemic unpreparedness were common among HCWs. Lack of PPE training was associated with the profession and no N95 respirator fit tests. N95 reuse during the pandemic, common to 78% of the HCWs, was associated with the reuse of PPE during the pandemic and reuse of N95 before the pandemic.

Conclusions We report the unpreparedness of HCWs and institutions to handle the pandemic, with low rates of training and N95 respirator fit testing and high PPE reuse. N95 reuse was a pre-established practice. This chronic unpreparedness to deal with airborne pathogens may have contributed to one of the highest global rates of tuberculosis and COVID-19 among HCWs.

INTRODUCTION

The WHO declared COVID-19 a pandemic on 11 March 2020. Until 10 March 2023, Brazil accounted for more than 37 million cases and 699 276 deaths, occupying the third position in the number of cases and second in number

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ The health of Brazilian healthcare workers (HCWs) was severely affected by the SARS-CoV-2 pandemic and the country reports one of the highest numbers of tuberculosis among HCWs; both diseases are airborne.
- ⇒ Improper use, maintenance and disposal of personal protective equipment (PPE) can increase the risk of HCWs contracting SARS-CoV-2 and other airborne pathogens.

WHAT THIS STUDY ADDS

- ⇒ The use, preparedness and perception of PPE among 1410 HCWs from 526 cities was assessed in the early months of the SARS-CoV-2 pandemic in Brazil.
- ⇒ Results reveal a scenario of pandemic unpreparedness, characterised by the lack of PPE training and N95 respirators fit tests, reuse of disposable PPE, N95 respirator reuse, as well as high stress and low biosafety perception by HCWs at their workplace.
- ⇒ Problems associated with PPE were not exclusively related to the pandemic period but pre-established practices.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ Our study identified significant issues related to biosafety measures in Brazil, particularly those under state regulation, indicating a lack of enforcement or comprehensive guidelines for respiratory protection programmes, which has negatively impacted the health of HCWs.
- ⇒ Findings provide valuable evidence that can be used to develop evidence-based strategies to enhance the biosafety of Brazilian HCWs, better equipping them to respond to both current and future pandemics, through structural, educational and behavioural changes.

of deaths globally.¹ During the first year of the pandemic, vaccines were unavailable. Many healthcare workers (HCWs) were infected, and it is estimated that between 80 000 and 180

000 HCWs died worldwide between January 2020 and May 2021.² Brazil has more than 5 million registered HCWs.³ By September 2021, 568 358 cases of SARS (Severe acute respiratory syndrome) were reported, and COVID-19 was the cause of 95% of HCWs' hospitalisations for SARS that led to death.⁴ Data on the actual number of deaths due to COVID-19 in Brazilian HCWs are fragmented and inaccurate. The WHO estimates that the country accounts for the second largest death toll of HCWs due to COVID-19, with 9769 HCWs deaths from January 2020 to May 2021.² In contrast, a survey from the Brazilian National Registry indicates 24.5% excess deaths in HCWs from March 2020 to February 2021 compared with the same period of 2019 (from 3571 to 4446 deaths), with 1411 deaths registered due to COVID-19.⁵ Noteworthy, Brazil also reports one of the highest absolute numbers of HCWs with tuberculosis, another airborne disease. Around 1000 cases are reported annually, behind China and India only.^{6,7}

Increased risk of SARS-CoV-2 infection by HCWs has been associated with personal protective equipment (PPE) availability, workplace conditions, profession, contact with COVID-19 patients and the availability of diagnostic tests.⁸ HCWs are at high risk of infection due to prolonged exposure and intimate contact with SARS-CoV-2 infected patients, particularly during invasive procedures with aerosol formation.⁹ To protect HCWs from biological hazards in the workplace, a hierarchy hazard control system through collective and individual biosecurity measures is usually adopted. This system ensures collective protection, such as risk elimination and replacement, followed by engineering and administrative measures and the correct use of PPE.¹⁰ Although PPE is the last biosecurity measure, it is an indispensable tool to protect HCWs from infection.¹⁰

When the SARS-CoV-2 emerged, HCWs changed their everyday measures to ensure protection from respiratory and contact transmission of the virus, mainly using PPE. The scarcity of PPE that ensued worldwide and in Brazil^{11,12} put into evidence the lack of preparedness to fight a respiratory pandemic. Aware of the risks that the SARS-CoV-2 pandemic posed to the HCWs in Brazil, in April 2020, biosafety experts from the University of São Paulo created a website (EPISaúde, www.episaude.org) to provide free information on how to properly use and discard PPE in the context of COVID-19 transmission. Here, we report the results of a survey with HCWs conducted through this platform from 24 April 2020 to 14 July 2020. Our objective was to evaluate the HCWs' perception of PPE use, preparedness and training in the early months of the SARS-CoV-2 pandemic in Brazil. We also report for the first time a speech content analysis of statements provided by Brazilian HCWs at the time of the survey.

METHODS

Study design and questionnaire

A cross-sectional study through convenience sampling was performed by evaluating structured questionnaires available to HCWs on the EPISaúde website (www.episaude.org).

The platform was launched in April 2020 and advertised through electronic news media and WhatsApp messenger groups of HCWs. As of June 2020, more than 220 000 people had accessed the platform. A link inviting HCWs to participate in the study was on the front page of the website. Participation in the survey was voluntary and considered after participants provided informed consent through electronic signature. HCWs could remain anonymous. The questionnaires were collected from 24 April 2020 to 14 July 2020. The only eligibility criterion was that respondents had to confirm to be HCWs or other healthcare-associated personnel (e.g., hospital administrative staff, ambulance drivers). To facilitate, all respondents who confirmed being HCWs or healthcare-associated personnel will be called HCWs hereafter. Questionnaires from respondents from other countries were excluded from the study (n=10), as our focus was to characterise the Brazilian scenario.

The questionnaire contained multiple-choice questions, ranked response questions and open-ended questions. There were demographic questions, such as sex (female or male), age (open-ended question), geographical region of their workplace (state and city), profession (open-ended question), job sector (public sector, private sector, or both), workplace (public hospital, private hospital, primary healthcare/emergency or ambulatory facility (UBS-Basic Health Unit, UPA-Emergency Care Unit, AMA-Outpatient Medical Care), laboratory, private clinic, health surveillance service, others; more than one answer was allowed), and years of working experience (up to 4 years, 5–10 years, 11–20 years, 21 or more years). They were also asked if they were directly attending and/or taking care of suspected and/or confirmed COVID-19 patients at the time of the survey.

Questions regarding PPE use and training included access to PPE before (yes or no) and during (yes or no) the pandemic and which types (a list of PPE was given, online supplemental S1 table); reason for not having access to PPE during the pandemic (open-ended question); use of PPE at the workplace during the pandemic (yes or no) and which types (a list of PPE was given, online supplemental S1 table); reuse of disposable PPE before (yes or no) and during (yes or no) the pandemic and which types (a list of PPE was given, online supplemental S1 table); reuse of N95 respirator before (yes or no) and during (yes or no) the pandemic; frequency of training for the use, maintenance and disposal of PPE over the past 5 years (from 0X to $\geq 5X$); place of PPE training (current or previous workplace, graduate school, undergraduate school, by their own; more than one answer was allowed); frequency of N95 respirator fit tests over the past 5 years (from 0X to $\geq 5X$); type of PPE used in their workplace for respiratory protection during the pandemic (surgical mask, N95 respirator, reusable N95 respirator, motorised respirator, homemade mask or no respiratory protection; more than one answer was allowed).

Ranked response questions included (on a scale of 0–10): perceived level of stress by HCWs during the

SARS-CoV-2 pandemic, how safe the HCWs felt at their workplace regarding SARS-CoV-2 infection (ie, perceived biosafety level at the workplace) and how much HCWs believed the lack of PPE, lack of PPE training, and cost of PPE impacted their infection risk at their workplace. At the end of the questionnaire, there was an optional open-ended question for HCWs to answer if there was anything they would like to share. The questionnaire is available in online supplemental S1 file.

The authors KM, JK, TO, APDB and AMGS had access to the names of respondents who opted to provide it, and these were kept confidential in two password-protected computers.

Patient and public involvement

HCWs answers started to be collected on 24 April 2020, when the electronic questionnaire became available on the website. Respondents were not asked to assess the time required to answer the questionnaire but were informed of the approximate necessary time to answer all questions. They were also informed of the research questions during participation consent. Respondents were not involved in the design, conduct, reporting or dissemination plans of this research.

Statistical analyses

Comparison of HCWs based on exposure to COVID-19 patients

The data were compiled with Microsoft Excel and uploaded and analysed in Prism V.9.1.1. (GraphPad Software, USA) and IBM SPSS Statistics for Windows, V.26 (IBM). Respondents were divided into two groups: those who answered 'yes' to the question of attending and/or taking care of suspected and/or confirmed cases of COVID-19 (hereafter called HCWs treating COVID-19 (TCOVID-19) or HCWs TCOVID-19 patients) and those who answered 'no' to the question of attending and/or taking care of suspected and/or confirmed cases of COVID-19 (hereafter called HCWs not TCOVID-19 (NTCOVID-19) or HCWs NTCOVID-19 patients). χ^2 test was used to compare the differences between these two HCW groups across the following selected independent categorical variables: sex; profession; job sector; workplace; years of work experience; access to PPE before and during the pandemic; use of PPE at the workplace during the pandemic; reuse of disposable PPE before and during the pandemic; reuse of N95 respirator before and during the pandemic; training for the use, maintenance and disposal of PPE over the past 5 years and N95 respirator fit tests over the past 5 years. Results were considered significant when $p \leq 0.05$. The total missing data for the selected dataset was only 2.12%, including three variables: profession (n=1) and N95 respirator fit test (n=29). It is possible that the 29 HCWs were unaware of what N95 respirator fit tests are.

To support some of the findings of the χ^2 test described above, data on the access to and reuse of different types of PPE before and during the pandemic; frequency of training on the use, maintenance and disposal of PPE

over the past 5 years; place of PPE training; frequency of N95 respirator fit tests over the past 5 years; and type of PPE used in their workplace for respiratory protection during the pandemic were compiled according to the TCOVID-19 and NTCOVID-19 groups.

Next, the following ordinal categories were compared between HCWs TCOVID and NTCOVID using Mann-Whitney U test (two tailed): perceived level of stress during the pandemic; perceived level of biosafety during the pandemic at the workplace; perceived levels of the impact of the lack of PPE, lack of PPE training and PPE cost on HCW's infection risk at the workplace. Results were considered statistically significant when $p \leq 0.05$.

Speech content analysis

Open-ended questions from the questionnaire were analysed using inductive quantitative and qualitative content analyses. Open-ended questions of the questionnaire included: 'Is there anything else you would like to share with us?' and 'If you did not have access to any of the listed PPE, describe why'. Content analyses were performed according to the following steps: preparation, organisation and description based on available guidelines.^{13 14} Each statement or answer was considered an analysis unit and separated into categories and subcategories. More than one category was considered for each analysis unit. All classification of responses was conducted by the author KM and checked by APDB.

Factors associated with lack of PPE training and reuse of N95 respirator

Based on the results obtained when comparing HCWs TCOVID-19 and NTCOVID-19 and on the speech content analysis, the lack of PPE training and reuse of disposable N95 respirator were explored in two separate robust Poisson regression analyses using R software V.4.1.1. First, HCWs who had at least one training for the use, maintenance and disposal of PPE over the past 5 years were compared with HCWs who did not have PPE training over the past 5 years to identify variables statistically associated with the lack of PPE training. Second, respondents using disposable N95 respirators as respiratory protection in the workplace (n=1010) were divided into HCWs reusing and not reusing disposable N95 respirators during that pandemic and compared to identify variables associated with the N95 respirator reuse. The same variables described above in the comparison between HCWs TCOVID and NTCOVID (plus geographic region) were tested using robust Poisson regression. The main model was tested against a null model using the corrected Akaike information criterion. Multicollinearity of the model was evaluated using variance inflation factors (VIF). Prevalence ratio (PR) and 95% CI for PR were calculated. Constant variables were not detected. Collinearity was detected for 'workplace' (VIF=11.38) in the N95 respirator reuse analysis; this variable was then excluded. Rows with missing data were skipped during the statistical analysis.

RESULTS

Summary of responses

Time of the survey and demographics of the surveyed population

A total of 1410 questionnaires were received from respondents working in Brazil and most (90%) were obtained by the beginning of May 2020. At that time, Brazil was in its 17th epidemiological week of the pandemic, with 40 581 cases and 2575 deaths reported. The disease was predominantly occurring in large urban centres, particularly in state capitals. The highest COVID-19 incidence was happening in the states of Amazonas, Amapá, Roraima, Ceará and São Paulo.¹⁵

Most questionnaires were from female HCWs (83.5%, [table 1](#)) and the average age was 44 years old (SD: 10, from 19 to 72 years). The questionnaires were received from respondents working in 526 cities, comprising all 26 Brazilian states and the Federal District. São Paulo was the most represented state (316; 22.41%), followed by Rio de Janeiro (215; 15.25%), Minas Gerais (110; 7.80%), Bahia (106; 7.52%) and Pernambuco (76; 5.39%). Other states represented less than 5% of the respondents each. Three respondents did not type a valid city/state response (i.e., were considered as missing data). States were then compiled by regions, with 48.6% (n=685) of the respondents being from the Southeast region, 27.9% (n=394) being from the Northeast region, 9.0% (n=127) being from the South region, 8.2% (n=116) being from the Midwest region and 6.0% (n=85) being from the North region.

Professional characterisation of the surveyed population

Respondents were of 64 different professions, with 79.7% composed of nurses, nurse technicians, dentists, physicians and physical therapists ([table 1](#)). Other professions accounted for less than 5% of the respondents each. Most HCWs worked in the public sector (58%), in public hospitals and UBS/UPA/AMA ([table 1](#)). Proportions of HCWs in each category of the variable 'years of work experience' were similar, although lower for those with only up to 4 years of experience ([table 1](#)).

Comparison between HCWs TCOVID-19 and HCWs NTCOVID-19

Professional characteristics

About half of the HCWs (812/1410; 57.6%) reported they were attending/taking care of confirmed and/or suspected COVID-19 patients (HCWs TCOVID-19) at the time of the survey ([table 1](#)). Being from TCOVID-19 or NTCOVID-19 groups was statistically associated with the profession, job sector, workplace and years of work experience ([table 1](#)). Overall, the most frequent profile of the HCW TCOVID-19 at the time of the survey was of nurses, nurse technicians and physicians working in hospitals and UBS/UPA/AMA and having less than 20 years of work experience. In addition, the proportion of HCWs working in the public sector was higher in the TCOVID-19 group (64.4% than in the NTCOVID-19 group (49.3%), while the proportion of HCWs working

in the private sector was higher in the NTCOVID-19 group (32.6%) than in the TCOVID-19 group (17.7%).

PPE access and reuse

Being from TCOVID-19 or NTCOVID-19 groups was statistically associated with access to PPE before and during the pandemic, the use of PPE during the pandemic, the reuse of disposable PPE before and during the pandemic and reuse of N95 respirators during the pandemic ([table 1](#)). Although more than 95% of the HCWs had access to PPE in their workplace before and during the pandemic, the proportions of HCWs with access to PPE in both periods were higher in the TCOVID-19 group (96.9% and 99.1%, respectively) than in the NTCOVID-19 group (94.1% and 95.2%, respectively) ([table 1](#)). This association being significant before and during the pandemic suggests that access is influenced by profession, as professional composition of the groups is different. The proportions of HCWs reporting access to PPE were different depending on the PPE type and, except for gloves, were higher at the time of the survey than before the pandemic for both groups, with the highest differences seen with the N95 respirators and face shields (online supplemental figure S1A,S1B).

Reuse of disposable PPE was identified as common practice before and during the pandemic ([table 1](#)). Nevertheless, the proportion of HCWs reusing disposable PPE increased from about 50% before the pandemic to 63% at the time of the survey ([table 1](#)). This increase was led by HCWs TCOVID-19, as the proportion of HCWs reusing disposable PPE during the pandemic (70.1%) was higher in the TCOVID-19 group compared with the NTCOVID-19 group (52.5%) ([table 1](#)). HCWs TCOVID-19 reported an increase in the reuse of all PPE at the time of the survey compared with before, except for gloves and face shields (online supplemental figure S1C).

As with other PPE, the reuse of N95 respirators was common practice before the pandemic ([table 1](#)). Among those using N95 respirators (disposable or reusable, plastic types) before the pandemic (n=707), 57.6% were reusing the disposable N95 respirator. During the pandemic, this proportion of HCWs reusing disposable N95 respirators increased to 75.8% ([table 1](#)). The proportion of HCWs reusing the disposable N95 respirators during the pandemic was significantly higher in the TCOVID-19 group compared with the NTCOVID-19 group, alarmingly reaching 80% of this population ([table 1](#)).

Training for the use, maintenance and disposal of PPE and N95 respirator fit test

About half of the HCWs (57%) reported receiving training to use, maintain and dispose of PPE ([table 1](#)). The proportion of HCWs who received training (59.4%) was higher in the TCOVID-19 group than in the NTCOVID-19 group (53.2%). Among the HCWs who had training, most received training only once or twice over the past 5 years (HCWs TCOVID: 301/812, 37.1%; HCWs NTCOVID: 192/598, 32.1%) ([figure 1A](#)). The top source

Table 1 χ^2 test of selected independent variables comparing healthcare workers (HCWs) treating suspected and/or confirmed COVID-19 patients (HCWs TCOVID-19) and HCWs not treating these patients (HCWs NTCOVID-19)

Variables	Descriptive statistics			P value	
	NTCOVID-19 (n=598)	TCOVID-19 (n=812)	Total (n=1410)		
Sex					
Female	492 (82.3%)	685 (84.4%)	1177 (83.5%)	0.310	
Male	106 (17.7%)	127 (15.6%)	233 (16.5%)		
Profession*					
Nurse	119 (19.9%)	295 (36.3%)	414 (29.4%)	<0.001	
Nurse technician	61 (10.2%)	187 (23.0%)	248 (17.6%)		
Physician	64 (10.7%)	124 (15.3%)	188 (13.3%)		
Dentist	172 (28.8%)	35 (4.3%)	207 (14.7%)		
Physical therapist	38 (6.4%)	28 (3.4%)	66 (4.7%)		
Others	144 (24.1%)	142 (17.5%)	286 (20.3%)		
Job sector					
Public	295 (49.3%)	523 (64.4%)	818 (58.0%)		<0.001
Private	195 (32.6%)	144 (17.7%)	339 (24.0%)		
Both	108 (18.1%)	145 (17.9%)	253 (18.0%)		
Workplace					
Public hospital	107 (17.9%)	241 (29.7%)	348 (24.7%)	<0.001	
Private hospital	20 (3.3%)	79 (9.7%)	99 (7.0%)		
UBS/UPA/AMA	68 (11.4%)	160 (19.7%)	228 (16.2%)		
Laboratory	11 (1.8%)	16 (2.0%)	27 (1.9%)		
Private clinic	121 (20.2%)	11 (1.4%)	132 (9.4%)		
Health surveillance	9 (1.5%)	4 (0.5%)	13 (0.9%)		
≥2 of the options	162 (27.1%)	244 (30.0%)	406 (28.8%)		
Others	100 (16.7%)	57 (7.0%)	157 (11.1%)		
Years of work experience					
0–4 years	72 (12.0%)	158 (19.5%)	230 (16.3%)	<0.001	
5–10 years	103 (17.2%)	207 (25.5%)	310 (22.0%)		
11–20 years	152 (25.4%)	252 (31.0%)	404 (28.7%)		
21 years or more	271 (45.3%)	195 (24.0%)	466 (33.0%)		
Access to PPE before the pandemic					
Yes	563 (94.1%)	787 (96.9%)	1350 (95.7%)	0.011	
No	35 (5.9%)	25 (3.1%)	60 (4.3%)		
Access to PPE during the pandemic					
Yes	569 (95.2%)	805 (99.1%)	1374 (97.4%)	<0.001	
No	29 (4.8%)	7 (0.9%)	36 (2.6%)		
Using PPE during the pandemic					
Yes	551 (92.1%)	795 (97.9%)	1346 (95.5%)	<0.001	
No	47 (7.9%)	17 (2.1%)	64 (4.5%)		
Reuse of disposable PPE before the pandemic					
Yes	279 (46.7%)	425 (52.3%)	704 (49.9%)	0.036	
No	319 (53.3%)	387 (47.7%)	706 (50.1%)		
Reuse of disposable PPE during the pandemic					
Yes	314 (52.5%)	569 (70.1%)	883 (62.6%)	<0.001	
No	284 (47.5%)	243 (29.9%)	527 (37.4%)		
Reuse of N95 before the pandemic†					

Continued

Table 1 Continued

Variables	Descriptive statistics			P value
	NTCOVID-19 (n=598)	TCOVID-19 (n=812)	Total (n=1410)	
Yes	118 (54.1%)	289 (59.1%)	407 (57.6%)	
No	93 (42.7%)	185 (37.8%)	278 (39.3%)	
Use reusable-type N95	7 (3.2%)	15 (3.1%)	22 (3.1%)	0.214
Reuse of N95 during the pandemic‡				
Yes	261 (68.1%)	531 (80.2%)	792 (75.8%)	
No	108 (28.2%)	110 (16.6%)	218 (20.9%)	
Use reusable-type N95	14 (3.7%)	21 (3.2%)	35 (3.3%)	<0.001
Training for the use, maintenance and disposal of PPE				
Yes	318 (53.2%)	482 (59.4%)	800 (56.7%)	
No	280 (46.8%)	330 (40.6%)	610 (43.3%)	0.022
N95 respirator fit test§				
Yes	47 (7.9%)	132 (16.3%)	179 (12.7%)	
No	530 (88.6%)	672 (82.8%)	1202 (85.2%)	<0.001

*1 missing.
†380 did not use N95 respirators before the pandemic.
‡250 were not using N95 respirators at the time of the survey.
§29 missing.
¶p-values in bold are statistically significant
AMA, outpatient medical care; NTCOVID-19, not TCOVID-19; PPE, personal protective equipment; TCOVID-19, treating COVID-19 patients; UBS, basic health unit; UPA, emergency care unit.

of training was their current workplace institution, followed by self-taught training (figure 1B).

Surprisingly, the vast majority of HCWs (85.2%) did not have an N95 respirator fit test performed over the past 5 years (table 1; figure 1C). Although short of desirable, the proportion of HCWs who had an N95 respirator fit test done (16.3%) was higher in the TCOVID-19 group compared with the NTCOVID-19 group (7.9%) (table 1). Considering HCWs TCOVID-19 that reported using the N95 respirator as respiratory protection in the workplace (n=641), 81.3% (521/641) never performed an N95 respirator fit test over the past 5 years.

Respiratory protection used by HCWs at the workplace during the pandemic

HCWs were asked the types of respiratory PPE they were using at the workplace during the pandemic. Surgical masks were the main respiratory protection used by HCWs at their workplace (HCWs TCOVID: 629/812, 77.4%; HCWs NTCOVID: 442/598, 73.9%; figure 1D). The proportion of HCWs TCOVID-19 using N95 respirators (563/812, 69.3%) was higher than HCWs NTCOVID-19 (281/598, 47%; figure 1D). Remarkably, 13% (106/812) of the HCWs TCOVID-19 and 22.1% (132/598) of the HCWs NTCOVID-19 still reported using homemade masks in their workplace at the time of the survey (figure 1D).

Ranked responses

HCWs TCOVID-19 reported statistically higher levels of stress during the pandemic and feeling less safe in their workplace regarding the risk of SARS-CoV-2 infection

than HCWs NTCOVID-19 (figure 1E,F). Both HCWs TCOVID-19 and NTCOVID-19 perceived high impact levels (level>8) of the lack of PPE or training on PPE use, and PPE cost on their infection risk at the workplace (figure 1G–I).

Speech content analysis

Personal statements of HCWs

A total of 352 statements were received in response to 'Is there anything else you would like to share with us?', being 116 (32.95%) from nurses, 65 (18.47%) from nursing technicians, 40 each (11.36%) from dentists and physicians, 18 (5.11%) from physical therapists and 13 (3.69%) from pharmacists. Issues involving the lack of PPE; concerns of being neglected, under infection risk and work overload; pandemic unpreparedness and general testimonies were the main topics raised (table 2). Other common features identified were inappropriate or non-standard PPE, lack of credibility and trust, fear and uncertainty, lack of training, scarcity of COVID-19 diagnostic tests for HCWs, unpreparedness and requirement of guidelines. It was possible to identify HCWs reusing the N95 respirator for 7 to 30 consecutive days. Descriptions of subcategories and direct citations are available in online supplemental S2 table.

Reasons for not having access to PPE

In total, 440 (31.2%) HCWs answered why they did not have access to any of the PPE listed, being 115 (26.14%) nurses, 78 (17.73%) dentists, 73 (16.59%) nurse technicians, 68 (15.45%) physicians and 15 (3.41%) physical therapists. Reasons ranged from complete PPE

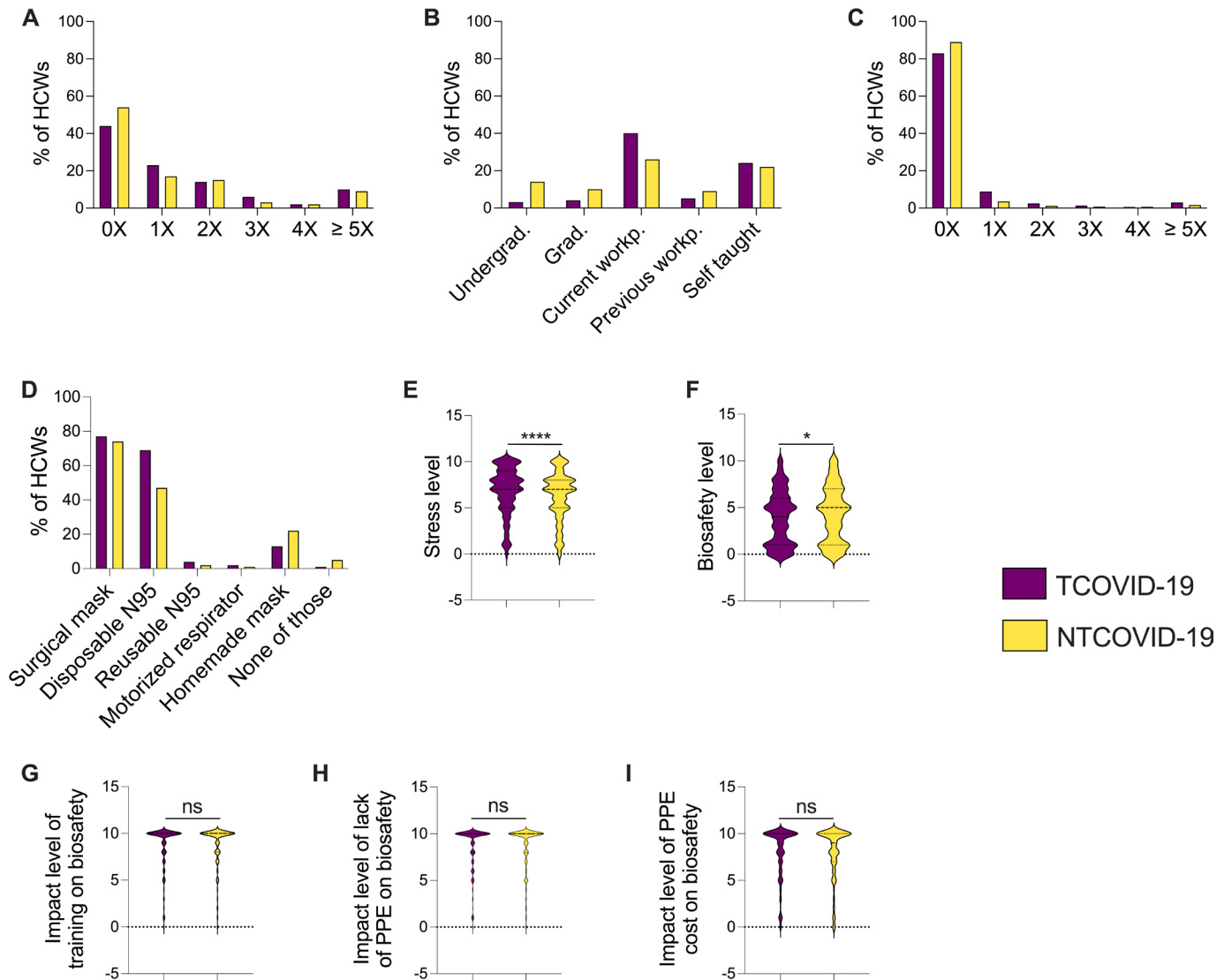


Figure 1 Training on PPE use, maintenance and disposal; N95 respirator fit tests; type of respiratory protection at the workplace and ranked responses of HCWs. (A) Frequency of training on PPE use, maintenance and disposal by HCWs over the past 5 years. (B) Place of training on PPE use, maintenance and disposal by HCWs. (C) Frequency of N95 respirator fit tests by HCWs over the past 5 years. (D) Type of respiratory protection used by HCWs in the workplace at the time of the survey. (E) Perceived stress level of HCWs during the pandemic (on a scale of 0, no stress, to 10, a lot of stress). (F) Perceived safety level reported by HCWs regarding SARS-CoV-2 infection risk in their workplace during the pandemic (on a scale of 0, not safe, to 10, very safe). (G) Perceived impact of lack of training regarding the use of PPE on the risk of infection by HCWs in the workplace (on a scale of 0, no impact, to 10, a lot of impact). (H) Perceived impact of the lack of PPE on the risk of infection by HCWs in the workplace (on a scale of 0, no impact, to 10, a lot of impact). (I) Perceived impact of PPE cost on the risk of infection by HCWs in the workplace (on a scale of 0, no impact, to 10, a lot of impact). * $p=0.033535$, **** $p=0.000013$. A total of 1410 HCWs responded to the questionnaire from 24 April 2020 to 14 July 2020. HCWs, healthcare workers; NS, not significant; NTCOVID-19, not TCOVID-19; PPE, personal protective equipment; TCOVID-19, treating COVID-19 patients.

unavailability at the workplace to not enough or inappropriate PPE, leading some HCWs even to buy their own PPE (table 3). Descriptions of subcategories and direct citations are available in online supplemental S3 table.

PPE training and reuse of N95 respirator during the pandemic

The findings of the initial bivariate analyses (table 1) and the speech content analyses showed that two important biosafety components were alarmingly affected in the surveyed population: PPE training and reuse of N95 respirators. Therefore, the same independent variables

listed in table 1 were tested for their association with lack of PPE training and N95 reuse using robust Poisson regression (tables 4 and 5).

Accordingly, lack of training for the use, maintenance and disposal of PPE was significantly associated with the profession and N95 respirator fit test (table 4). The prevalence of not having training for the use, maintenance and disposal of PPE was 1.35 times higher (95% CI 1.12 to 1.62) among nurse technicians and 1.50 times higher (95% CI 1.23 to 1.83) among physicians compared with

Table 2 Qualitative and quantitative analyses and the relative proportions of each category of statements by HCWs

Category	Description	N*	%
Issues involving the lack of PPE	HCWs addressed the main issues regarding the lack of PPE, such as the high cost and unavailability. They also talked about the way they handled it, by extended use or rationing	102/352	28.98
Concerns	HCWs talked about feeling neglected, work overload because of colleagues having SARS-CoV-2 infection and staying on sick leave and being required to use uncertified or low-quality PPE	98/352	27.84
Unpreparedness to handle the pandemic	HCWs reported the main difficulties while facing the pandemic, which includes unpreparedness, lack of training and inadequate workplace infrastructure and workflow to care for COVID-19 patients	90/352	25.57
Testimonies	HCWs discussed the importance of healthcare services and PPE availability to face the pandemic. They also reported that they had close contact with suspected or positive COVID-19 patients, that they were grateful for the biosafety information released in the EPISaúde platform, and made suggestions to improve the information provided	56/352	15.91
Demands	HCWs stated that they would like to have access to training courses and biosafety guidelines, in addition to healthcare institution inspection, better healthcare and psychological support to deal with the pandemic	37/352	10.51
How HCWs felt	HCWs reported their frustration, indignation and insecurity in the workplace during the COVID-19 pandemic, in addition to the difficulties of being apart from family members	37/352	10.51
PPE reuse	HCWs talked about PPE reuse in general and its risks. The vast majority addressed the reuse of N95 respirators, specifically	35/352	9.94
Other	HCWs described their symptoms and their activities and that they had to share protective goggles with colleagues. Additionally, some reported difficulty in gaining employment. Some said they were satisfied with the biosafety measures adopted or reported the difficulties faced during the pandemic, among others	32/352	9.09
Issues with COVID-19 diagnostic tests	Issues with COVID-19 diagnostic tests: HCWs reported it was hard to get a SARS-CoV-2 diagnostic test or receive the results, which took a long time to be available. Also, diagnostic tests were unavailable for HCWs who were on the front lines	28/352	7.95

*More than one category was considered for each analysis unit. HCWs, healthcare workers; PPE, personal protective equipment.

nurses. In addition, N95 respirator fit tests were likely strong components of PPE training, as the prevalence of not having training for the use, maintenance and disposal of PPE was 4.89 times higher (95% CI 4.51 to

5.30) among HCWs who did not perform an N95 respirator fit test compared with those who performed the test.



Table 3 Qualitative and quantitative analyses of answers provided by healthcare workers (HCWs) on why they did not have access to PPE (personal protective equipment)

Main category*	Secondary category	Tertiary category	Description	TCOVID-19	NTCOVID-19	Total	
Answered the question	PPE not available (213/389); 55%	Not available at institution	PPE, materials and equipment were unavailable at the institution	64/141 (45.39%)	25/72 (34.72%)	89/213 (41.78%)	
		Not provided	Institution, sector, state, county or city did not provide.	49/141 (34.75%)	16/72 (22.22%)	65/213 (30.52%)	
Did not answer the question, but provided comments	Institutional protocol	PPE shortage	Because of the shortage, not available for purchase.	31/141 (21.99%)	32/72 (44.44%)	73/213 (34.27%)	
		NA	They were not using due to institutional recommendations. The use of specific PPE was reserved for specific sectors, professionals or procedures.	42/68 (61.76%)	26/68 (38.24%)	68/398 (17.08%)	
		NA	Because they were not working in healthcare institutions at the time of survey.	1/36 (2.78%)	35/36 (97.22%)	36/389 (9.25%)	
		NA	HCWs stated it was not needed due to their working conditions or sector.	8/28 (28.57%)	20/28 (71.43%)	28/398 (7.03%)	
		NA	Although HCWs reported having access to PPE, there was insufficient quantity.	9/15 (60%)	6/15 (40%)	15/389 (3.86%)	
		NA	Because they did not work directly with positive or suspected COVID-19 patients. Some HCWs reported that they do not work directly with customer services.	2/13 (15.38%)	11/13 (84.61%)	13/389 (3.34%)	
		High cost	Financial reasons (12/389); 3%	The high cost impacted PPE acquisition.	5/6 (83.33%)	4/6 (66.67%)	9/12 (75%)
		Lack of funds	Lack of funds	The lack of financial resources impacted PPE acquisition.	1/6 (16.67%)	2/6 (33.33%)	3/12 (25%)
		NA	Inadequate PPE	HCWs reported the use of uncertified PPE, such as masks made of fabric, improvised face shields or reported the use of inappropriate and low-quality PPE	10/11 (90.91%)	1/11 (9.09%)	11/75 (14.67%)
		NA	Only some were available	HCWs informed which PPE they had access to or which one they did not have.	6/27 (22.22%)	21/27 (77.78%)	27/75 (36%)
NA	They had to buy their PPE	HCWs reported that they had to buy their PPE, exemplifying which PPE they had purchased.	17/23 (73.91%)	6/23 (26.09%)	23/75 (30.67%)		
NA	Other	HCWs described many different reasons why they did not use PPE that did not fit into other categories.	6/10 (60%)	4/10 (40%)	10/75 (13.33%)		

*More than one category was considered for each analysis unit. NA, not available; NTCOVID-19, not TCOVID-19; TCOVID, treating COVID-19 patients.

Table 4 Robust Poisson regression of selected independent variables comparing healthcare workers (HCWs) that had training for the use, maintenance and disposal of PPE in the past 5 years compared with those who did not

Variables	Descriptive statistics			Crude PR (95% CI)	Adjusted PR (95% CI)*
	Trained (n=800)	Not trained (n=610)	Total (n=1410)		
Profession†					
Nurse (ref)	275 (34.4%)	139 (22.8%)	414 (29.4%)		
Nurse technician	136 (17.0%)	112 (18.4%)	248 (17.6%)	1.4 (1.1 to 1.8)	1.3 (1.1 to 1.6)
Physician	93 (11.6%)	95 (15.6%)	188 (13.3%)	1.4 (1.1 to 1.9)	1.5 (1.2 to 1.8)
Dentist	119 (15.0%)	88 (14.4%)	207 (14.7%)	1.1 (0.8 to 1.60)	1.2 (1.0 to 1.5)
Physical therapist	37 (4.6%)	29 (4.7%)	66 (4.7%)	1.3 (0.8 to 1.9)	1.3 (0.9 to 1.9)
Others	139 (17.4%)	147 (24.1%)	286 (20.3%)	1.3 (1.0 to 1.7)	1.5 (1.3 to 1.8)
N95 respirator fit test‡					
Yes (ref)	160 (20.0%)	19 (3.1%)	179 (12.7%)		
No	626 (78.2%)	576 (94.4%)	1202 (85.2%)	4.2 (2.6 to 6.7)	4.9 (4.5 to 5.3)

Only statistically significant variables are shown. Full results are in online supplemental S4 table.

In bold are statistically significant results, compared with reference categories.

*Adjusted PRs are calculated only for significant variables in crude PR calculations.

†1 missing.

‡29 missing.

PPE, personal protective equipment; PR, prevalence ratio.

We then analysed only HCWs using disposable N95 respirators as respiratory protection in the workplace (n=1010) to identify variables associated with the reuse of disposable N95 respirators during the pandemic. The reuse of disposable PPE during the pandemic and the reuse of N95 respirators before the pandemic (table 5) were associated with the reuse of N95 respirators during the pandemic. The prevalence of reusing N95 respirators during the pandemic was 26% lower (PR 0.74, 95% CI 0.64 to 0.86) among individuals who did not reuse disposable PPE during the pandemic, and 29% lower (PR 0.71, 95% CI 0.61 to 0.83) among those who did not reuse N95 respirators before the pandemic. Even though the results were not statistically significant, it is noteworthy that a

higher proportion of HCWs TCOVID-19 were reusing N95 respirators during the pandemic (531/641, 82.84%) compared with HCWs NTCOVID-19 (261/269, 70.73%).

DISCUSSION

Results show that many HCWs and healthcare institutions in Brazil were not prepared to handle the biosafety risks of a respiratory pandemic. Because of the time of the survey (most questionnaires were sent by the beginning of May 2020), many healthcare facilities were still evaluating how to provide PPE and modify workflows; thus, current findings do not reflect the months that followed nor the current state of the pandemic. Yet, they represent

Table 5 Robust Poisson regression of selected independent variables comparing healthcare workers who reuse disposable N95 respirators during the pandemic compared with those who did not

Variables	Descriptive statistics			Crude PR (95% CI)	Adjusted PR (95% CI)*
	Do not reuse N95 (n=218)	Reuse N95 (n=792)	Total (n=1010)		
Reuse of disposable PPE during the pandemic					
Yes (ref)	106 (48.6%)	611 (77.2%)	717 (71.0%)		
No	112 (51.4%)	181 (22.8%)	293 (29.0%)	0.7 (0.6 to 0.9)	0.7 (0.6 to 0.9)
Reuse of N95 before the pandemic					
Yes (ref)	45 (20.6%)	329 (41.5%)	374 (37.0%)		
No	97 (44.5%)	150 (18.9%)	247 (24.5%)	0.7 (0.6 to 0.9)	0.7 (0.6 to 0.8)
Did not use N95	70 (32.1%)	310 (39.2%)	380 (37.6%)	0.9 (0.8 to 1.1)	0.9 (0.8 to 1.0)
Use reusable-type N95	6 (2.8%)	3 (0.4%)	9 (0.9%)	0.4 (0.1 to 1.2)	0.4 (0.1 to 1.2)

Only statistically significant variables are shown. Full results are in online supplemental S5 table.

In bold are statistically significant results, compared with reference categories.

*Adjusted PRs are calculated only for significant variables in crude PR calculations.

PR, prevalence ratio.

a historical moment of the early months of the SARS-CoV-2 pandemic in Brazil and can be used for planning and contingency strategies for future pandemics. Overall, this study corroborates with surveys showing that HCWs from Latin America suffered from a lack of governmental support, biosafety and related policies in their workplace.¹⁶ To our knowledge, this is also the first study to incorporate inductive content analysis of Brazilian HCWs statements in the context of the SARS-CoV-2 pandemic.

Dentists, comprising a large proportion of the surveyed population, are highly exposed to patients that may be unaware of a SARS-CoV-2 infection. Speech analysis showed their worrying need for information on how to adapt practices to increase their personal protection while working. Cross-sectional studies on dentists conducted early in the pandemic revealed significant impacts, including lack of specific training for patient interaction,¹⁷ substantial reduction in workload^{18–19} and recommendations to delay elective procedures to prioritise urgent care and conserve PPE supplies.²⁰ Our findings align with these, possibly explaining why most dentists did not treat patients suspected or positive for COVID-19. In the following months, the Brazilian Dental Health Council issued guidelines for the biosafety of dentists.²¹ The absence of such guidelines prior to the pandemic underscores unpreparedness for a respiratory viral pandemic in this healthcare sector, even though dentists are well accustomed to the use of PPE.

The proportion of most experienced HCWs (>21 years of experience) was higher in the group NTCOVID-19 compared with the group TCOVID-19. There may be three possible explanations for this finding. First, less experienced HCWs may lack training on PPE use, being inclined to access the EPISaúde website, biasing the results. Second, it is possible that less experienced HCWs were able to endure the more intense workloads associated with the front-line response than more senior HCWs. And third, older HCWs refrained from working with COVID-19 patients because they were at increased risk of severe disease and death by SARS-CoV-2.

A positive outcome of this study is that access to PPE increased during the pandemic. A significant increase was seen for N95 respirators and face shields, which means this was probably the first time certain HCWs were using these PPE. Considering that almost half of the respondents had never had PPE training, there were great chances that N95 respirators and the face shields were not being used correctly. The correct fit of N95 respirators guarantees efficient airborne protection, and the lack of training regarding their use by HCWs correlates with poor respirator fit.^{22–23} Unfortunately, more than 80% of the surveyed respondents had never performed an N95 respirator fit test over the past 5 years. The N95 respirator fit test was also not mentioned in HCWs' statements, which suggests a lack of knowledge about the test, especially considering that this topic was addressed in similar qualitative analyses from other countries.²⁴ A study in an Australian tertiary institution showed that

without a fit test, more than half of HCWs were using an N95 respirator that did not provide adequate airborne protection.²⁵ The Brazilian Health Agency (ANVISA) recommends annual fit tests and tests on changes in face shape or respirator models.²⁶ Thus, it should be investigated why the recommendations were not being followed by many healthcare institutions, because this may have contributed to the Brazilian HCWs' infection rate by SARS-CoV-2. Since the N95 respirator fit test and the PPE training are complementary and should take place regularly, it could be beneficial to execute them simultaneously, as they are necessary to ensure the safety of HCWs dealing with airborne pathogens in healthcare settings.

More than half of the HCWs using respiratory protection of N95-type were reusing disposable N95 respirators before the pandemic, and the percentage increased to around 80% during the pandemic, suggesting that this is a chronic issue in the Brazilian healthcare system. These HCWs righteously voiced their concerns about the reuse of N95 respirators in their statements. They also mentioned that the reuse of the same disposable N95 respirator was prolonged, ranging from 7 to 30 days. Brazil is a high tuberculosis burden country and the third country in the world with the greatest number of reported tuberculosis cases among HCWs,^{6–7} another important airborne disease. No study to date has been conducted to identify risk factors associated with the high TB burden among HCWs in Brazil. Results from this study emphasise the need to evaluate practices involving respiratory protection to prevent TB transmission. Lack of adequate infection control training, reuse of N95 respirator and inappropriate N95 respirator sealing and PPE handling have been identified as risk factors for infection of HCWs with other airborne pathogens worldwide, such as SARS-CoV-1.^{27–30}

It is inherently difficult to attribute infection specifically and only to the reuse of N95 respirators in HCWs. This practice is often accompanied by other poor infection control measures and high community transmission of the related pathogen, which can be confounding factors. In a randomised trial with 12 HCWs, the reuse of N95 respirators previously contaminated with the benign bacteriophage MS2 led to virus transfer to the face, hands and clothing of the HCWs, suggesting potential routes of transmission and infection if the respirator is reused.³¹ In addition, the prolonged use of N95 respirators may cause PPE to malfunction.³² While recommendations for extended use or limited reuse of respiratory protection in response to PPE shortages have been made during previous public health emergencies, these practices should not become routine. It is shocking that the reuse of disposable, single-use N95 respirators was common practice among the respondents of this study even before the pandemic, that N95 respirator fit tests were almost absent and that PPE training was deficient.

The lack of PPE that ensued in the early months of the pandemic in Brazil could have been at least partially prevented or less severe if the use of N95 respirators had

been widespread and performed correctly before the pandemic. Hospitals would have a robust stock, and the national industry would perhaps be more developed to produce this type of PPE and less dependant on external sources. Globally, the lack of PPE led to rationing recommendations, extended use and reuse when necessary.³³ At the time of the survey (April–July 2020), the N95 respirator was being indicated only during medical procedures predisposing to aerosol formation, which could explain why some HCWs TCOVID-19 did not have access to this PPE. Nevertheless, many HCWs expressed frustration about wearing the surgical mask instead of the N95 respirator. As shown in other studies conducted in Latin America,³⁴ not all HCWs TCOVID-19 had access to N95 respirators and reported their absence.

Most HCWs from this survey considered the lack of training as a high-impact factor for HCWs' infection risk at the workplace, extensively addressed this in their statements. Protocol deviations and self-contamination during PPE donning and doffing have been reported, emphasising the need for regular PPE training, as practice can reduce protocol deviations and, consequently, the risk of HCW infection.^{35–38} The COVID-19 pandemic created just-in-time training opportunities for HCWs, with many organisations developing training resources. However, a study showed that most of these resources did not address the knowledge necessary to effectively implement infection control measures.³⁹ COVID-19-associated training should not replace the need for formal training provided by universities, governmental agencies or healthcare facilities. It is also necessary to ensure that training is based on risk assessments and covers the needs of HCWs working in that specific setting.

The lack of information regarding the disease and PPE needs for specific procedures can lead to PPE misuse, lack of PPE and distorted perception of absence.³⁴ At the time of the survey, there were no clear recommendations on specific PPE use for handling COVID-19 patients. However, recommendations were available for other airborne transmission pathogens, such as SARS-CoV-1, H1N1 and tuberculosis.^{40 41} Most HCWs surveyed worked in the public sector. More than 70% of the Brazilian population depends on SUS, which is public. The SUS has been suffering from a lack of funding and resources for years, which interferes with PPE, equipment acquisition¹² and workforce. The lack of funding and work overload may help explain the lack of training for HCWs working in public institutions.

Limitations of this study

This survey is a snapshot of the early months of the pandemic and does not reflect the current state or what happened during the following months of 2020 and 2021. The surveyed population also does not represent all Brazilian HCWs and institutional realities. While we know the number of people that accessed the website, we had no control over how the news about the website spread throughout the country and the number of

people it reached. We had a higher representation of HCWs from the Southeast and Northeast regions, two of the three Brazilian regions most affected by COVID-19 at the time of the survey. Unfortunately, we did not have the same representation of respondents from the North, an important region affected at the time of the survey, which could be related to the distribution of the website news across the country. Brazil is a continental country with more than 5 million registered HCWs. To collect a representative sample of all Brazilian HCWs is very challenging. Therefore, a sample size was not precalculated for this study. Considering that respondents were attracted to the survey most likely because they were looking for information regarding PPE use, it is possible that the sampled population represents HCWs who needed information and lacked knowledge about PPE use and institutional support and training. Thus, results may be biased towards less informed HCWs, not representing the totality of the Brazilian scenario.

CONCLUSION

Many HCWs and healthcare institutions were unprepared to face the SARS-CoV-2 pandemic. This happened in spite of (1) a previous Brazilian Preparedness Guideline for Influenza,⁴¹ (2) SARS-CoV-2 reaching other countries before Brazil and (3) Brazil being a high burden country for other significant airborne diseases, such as tuberculosis. The way healthcare settings dealt with equipment and PPE acquisition, the high demand, problems in the international supply chain of PPE, and governmental failures to address these problems are some of the reasons leading to PPE shortage⁴² in the first semester of 2020, particularly of N95 respirators. However, our study shows that the lack of training, the negligible N95 respirator fit tests and PPE reuse are not exclusively related to the COVID-19 pandemic, yet a chronic problem of the Brazilian healthcare system.

To change this scenario and better handle future pandemics, structural, educational and behavioural changes are required in the Brazilian healthcare system and its professionals. Biosafety training should be mandatory in healthcare-related undergraduate and graduate courses and institutions, and continued education should be enforced. In addition to elaborating biosafety guidelines for specific pathogens and biosafety hazards, it is necessary to invest in teaching and training. It is also necessary to invest in and develop the national industry of PPE, to decrease the dependency on international sources, which could also be based on higher demand by decreasing PPE reuse. Furthermore, clear guidelines for training, the rational use of PPE, PPE stock management, risk assessment, and collective and individual biosafety measures should be developed and implemented in the SUS. These measures must become a reality now and should not wait until the next pandemic emerges; otherwise, we will face the same problems, and more lives will be lost.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and this study complied with the ethical precepts of Resolution No 466/12 of the National Health Council of Brazil and with C.N.S. Resolution No 510 of 2016 on research involving human beings. It was registered and approved by the Brazilian Platform of the Ministry of Health through the Ethics Committee of the Institute of Biomedical Sciences, University of São Paulo (protocol no CAAE 30886620.7.0000.5467). Participants gave informed consent to participate in the study before taking part.

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