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Parajára, Magda do Carmo; Silva, Juliana Ilídio da; Menezes-Júnior, Luiz Antônio Alves de; Sales, Aline Dayrell Ferreira; Friche, Amélia Augusta de Lima; Machado, Elaine Leandro; Silva, Luiz Sérgio; Andrade, Amanda Cristina de Souza; Freitas, Silvia Nascimento de; Caiaffa, Waleska Teixeira; Meireles, Adriana Lúcia

COVID-19: perfil de trabalhadores brasileiros em uma companhia de mineração e a dinâmica dos casos comunitários

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Magda do Carmo Parajára[a]
https://orcid.org/0000-0001-7019-1365

Juliana Ilídio da Silva[b]
https://orcid.org/0000-0002-0604-6662

Luiz Antônio Alves de Menezes-Júnior[a]
https://orcid.org/0000-0002-4497-5358

Aline Dayrell Ferreira Sales[c]
https://orcid.org/0000-0002-7848-6835

Amélia Augusta de Lima Friche[c,d]
https://orcid.org/0000-0002-2463-0539

Elaine Leandro Machado[c]
https://orcid.org/0000-0002-3226-3476

Luiz Sérgio Silva[c]
https://orcid.org/0000-0002-3517-6941

Amanda Cristina de Souza Andrade[b]
https://orcid.org/0000-0002-3366-4423

Silvia Nascimento de Freitas[a]
https://orcid.org/0000-0002-4119-0352

Waleska Teixeira Caiaffa[c]
https://orcid.org/0000-0001-5043-4980

Adriana Lúcia Meireles[a]
https://orcid.org/0000-0002-1447-953X

[a] Universidade Federal de Ouro Preto, Departamento de Nutrição Clínica e Social, Programa de Pós-Graduação em Saúde e Nutrição. Ouro Preto, MG, Brazil.

[b] Universidade Federal de Mato Grosso, Instituto de Saúde Coletiva, Programa de Pós-Graduação em Saúde Coletiva. Cuiabá, MT, Brazil.

[c] Universidade Federal de Minas Gerais, Faculdade de Medicina, Departamento de Medicina Preventiva e Social. Belo Horizonte, MG, Brazil.

[d] Universidade Federal de Minas Gerais, Faculdade de Medicina, Departamento de Fonoaudiologia. Belo Horizonte, MG, Brazil.

Contact:
Adriana Lúcia Meireles
E-mail:
adriana.meireles@ufop.edu.br

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COVID-19: profile of Brazilian workers of a mining company and the dynamic of community cases

COVID-19: perfil de trabalhadores brasileiros em uma companhia de mineração e a dinâmica dos casos comunitários

Abstract

Objective: to describe the COVID-19 clinical outcomes profile from mining workers and the cases dynamic within the mining units and their respective municipalities. Methods: *a cohort and ecological study using workers clinical-epidemiological, sociodemographic, and occupational secondary data of a multinational mining company, and of COVID-19 cases from five municipalities where the mining units were located, in Brazil, between March 2020 to April 2021. We calculated the cases cumulative incidence and the 7-day moving average (MA), and compared at the mining unit and respective municipality.* Results: *the study included 17,523 workers, 88.4% male, and 22.6% had at least one positive result for COVID-19. The workers most tested, with positive results, placed in quarantine, and with symptoms were female, middle-aged, living and working in Rio de Janeiro state, directly hired by the mining company, in shift-work, and in high-risk occupations. All mining units presented a cumulative incidence higher than their respective municipalities. Three municipalities showed peaks of COVID-19 with MA cases coinciding with an increase in cases among mining workers.* Conclusion: *approximately one-fifth of workers were diagnosed with COVID-19. The mining units had a similar temporal distribution of COVID-19 cases to the municipalities where they were located.*

Keywords: COVID-19; disease outbreaks; surveillance of the workers health; occupational health; occupational risks; epidemiology.

Resumo

Objetivo: *descrever o perfil de desfechos de COVID-19 em trabalhadores da mineração e a dinâmica dos casos nas unidades de mineração e seus respectivos municípios.* Métodos: *estudo de coorte e ecológico, com dados secundários clínico-epidemiológicos, sociodemográficos e ocupacionais de trabalhadores de mineradora multinacional no Brasil e de casos de COVID-19 nos cinco municípios onde as unidades estavam localizadas, de março de 2020 a abril de 2021. A incidência acumulada e média móvel (MM) de 7 dias dos casos foram calculadas e comparadas na unidade e respectivo município.* Resultados: *foram incluídos 17.523 trabalhadores; 88,4% eram do sexo masculino; e 22,6% tiveram pelo menos um resultado positivo. Os trabalhadores mais testados, com casos positivos, colocados em quarentena e com sintomas foram do sexo feminino, de meia-idade, morando e trabalhando no Rio de Janeiro, diretamente contratados pela mineradora, em turnos e ocupações de alto risco. Todas as unidades apresentaram uma incidência acumulada superior aos seus respectivos municípios. Três municípios apresentaram picos de COVID-19 com MM coincidindo com o aumento de casos entre trabalhadores de mineração.* Conclusão: *aproximadamente um quinto dos trabalhadores foram diagnosticados com COVID-19, e a distribuição temporal dos casos nas unidades de mineração foi semelhante àquela dos municípios onde estavam localizadas.*

Palavras-chave: *COVID-19; surtos de doenças; vigilância em saúde do trabalhador; saúde do trabalhador; riscos ocupacionais; epidemiologia.*

Introduction

The COVID-19 pandemic caused by the SARS-CoV-2 has disrupted social interactions, well-being, and working conditions[1,2]. Whereas many workers have been losing their jobs in Brazil[3], many of those considered non-essential have had to adapt to working from home, often experiencing increased work demands and workload[2]. On the other hand, essential workers who do not have the same opportunity to work from home may be at greater risk of contracting and transmitting COVID-19[4].

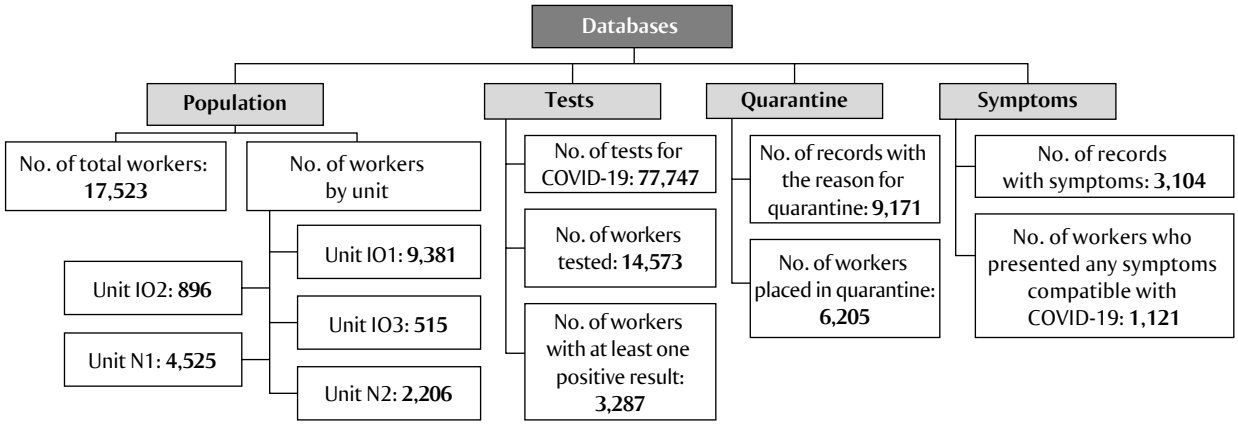
Mining was one of the activities considered essential in Brazil during the pandemic[5]. Mining workers were not exempt from the COVID-19 impacts on the work environment[6]. Although some industrial workers can perform their activities from home, others cannot. In some cases, they even need to work close to each other, increasing the chances of exposure to the virus[4,7]. Moreover, the concentration and mobility of workers from mining companies to their respective municipalities where the units are located affected the transmission dynamics of the disease in these areas[8,9].Health problems impact the extraction sector, including mining[10]. Miners can be exposed to a range of occupational hazards (e.g., psychosocial, ergonomic, biological, physical, and chemical) causing injuries, microbiological contamination, and acute and chronic diseases, especially respiratory disorders, such as pneumoconiosis, chronic obstructive pulmonary disease, and lung cancer, due to dust inhalation[10]. These work-related exposures, alongside sociodemographic and community context, can increase the risk of infection and severe outcomes related to COVID-19 among miners[9,11].

Considering the relevance of miners' health and the scarcity of studies investigating COVID-19 cases among mining workers and those from the community[9,12], simultaneously, this study aims to describe the clinical-epidemiological, sociodemographic, and occupational aspects regarding COVID-19 outcomes of workers from a multinational mining company in Brazil as well as the dynamic of cases in the municipalities where their units are installed.

Methods

Study design and data sources

This work comprises a cohort study with a follow-up of COVID-19 cases among workers from a multinational mining company in Brazil. Also, an ecological study was carried out to understand COVID-19 cases dynamics in the municipalities where the mining company's units were located. Secondary clinical-epidemiological, sociodemographic, and occupational data from administrative and medical databases of the multinational mining company were used (**Figure 1**). The databases comprised the period of March 2020 to April 2021. They included information on the number and type of tests to detect SARS-CoV-2, number of cases, number of workers placed in quarantine, and information on any symptoms related to COVID-19. Furthermore, the mining company provided data regarding the sociodemographic and occupational characteristics of all workers registered at the time when the database was made available.



*Note: the first positive test was considered regardless of the exam type: reverse transcription-polymerase chain reaction (RT-PCR), serology, and rapid test.

Figure 1 Flowchart of databases used in the study of mining workers in Brazil, March 2020 to April 2021

Data on the number of COVID-19 cases in each municipality where a unit was located were obtained from the GitHub repository. This is a public repository that provides data on cases of COVID-19 at the municipal level by using official data from the federative units reports[13].

Participants and mining units

Mining workers (n = 17,523) from five units of the mining company in Brazil were evaluated. Of the five mining units, three have iron ore as a business unit and two have nickel. Due to confidentiality matters, the mining units were denominated as IO1, IO2, IO3, N1, and N2. The mining workers were distributed by unit as follows: IO1, n = 9,381; IO2, n = 896; IO3, n = 515; N1, n = 4,525; N2, n = 2,206.

Note that the multinational mining company classifies IO3 as an iron ore business, and this classification was kept in this study; however, IO3 is a port unit responsible for operating a long pipeline, where part of the company's iron ore is transported within Brazil and subsequently exported. Despite not being an ore extraction unit like the other units and having many workers in the administrative sector, IO3 remained in our analysis due to its importance to the company and due to the number of workers in this location.

Study location

The mining units are in five municipalities, in three states of Brazil: Minas Gerais (MG), Goiás (GO), and Rio de Janeiro (RJ). In this study, the municipalities where the units are located received similar denominations (IO1, IO2, IO3, N1, and N2) as their respective units.

Supplementary Table S1 shows selected characteristics of the municipalities according to information provided by the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* – IBGE)[14]. According to the estimates, from the last Brazilian census, in 2010, the most populated municipalities were N2 (42,361 inhabitants) and IO3 (32,747 inhabitants), followed by IO1 (17,908 inhabitants), N1 (8,716 inhabitants), and IO2 (4,085 inhabitants). The estimated population for 2021 maintained this same ranking. Compared to the 2010 census, the number of inhabitants decreased in IO1 and IO2 and increased in IO3, N1, and N2 in 2021. Regarding the demographic density, IO3 had the highest value (71.96 inhabitants/km^2) whereas N2 had the lowest (4.30 inhabitants/km^2).

Supplementary Table S1 Description of the municipalities' characteristics

Municipality	*State*	*Population*		*Demographic density (2010)*
		Demographic census (2010)	*Estimated (2021)*	
IO1	MG	17,908 inhab.	17,438 inhab.	10.37 inhab./km^2
IO2	MG	4,085 inhab.	3,861 inhab.	31.37 inhab./km^2
IO3	RJ	32,747 inhab.	36,731 inhab.	71.96 inhab./km^2
N1	GO	8,716 inhab.	11,643 inhab.	7.97 inhab./km^2
N2	GO	42,361 inhab.	47,064 inhab.	4.30 inhab./km^2

GO: Goiás; inhab.: inhabitants; km^2: square kilometers; MG: Minas Gerais; RJ: Rio de Janeiro.

Variables

The variables evaluated in this study were clinical-epidemiological, sociodemographic, and occupational. The clinical-epidemiological variables were: tested for SARS-CoV-2 (no; yes); positive cases (no; yes); quarantine (no; yes), demonstrated by its frequency, minimum and maximum days, and median; and symptoms compatible with COVID-19 (no; yes).The tests used to detect SARS-CoV-2 among the mining workers were the reverse transcription-polymerase chain reaction (RT-PCR), the serology, and the rapid test. To better compare results from mining units and municipalities, all three tests were considered in our analysis since the municipalities used the three test types. In this study, only the first positive test was considered. The reasons for quarantine were being a positive case for COVID-19, symptomatology compatible with the disease, contact with a confirmed or suspected case,

municipal decree, travel, contact with a traveler or having participated in events. The symptoms recorded were chills, headache, nasal congestion, runny nose, diarrhea, difficulty breathing, sore throat, muscle aches, fever, cough, and loss of taste or smell.The sociodemographic variables included sex (male; female); age (in years) and age group (18-29; 30-39; 40-49; 50-59; 60-79 years); and state of residence. Occupational variables were the mining unit (IO1, IO2, IO3, N1, and N2); business unit (iron ore; nickel); employment contract (employee; outsourced); shift work (no; yes); and occupational risk (low risk; medium risk; high risk).

Outsourcing or subcontracting is a form of work organization where a company hires another company to perform certain services with its workers[15]. In this study, workers hired directly by the mining company are called employees.

Occupational risk is a classification adopted by the multinational mining company based on increased contact with other workers, according to the Occupational Safety and Health Administration (OSHA) criteria[16]. The three groups are high risk, encompassing workers with potential exposure to SARS-CoV-2, such as healthcare professionals in attendance; medium risk, considering workers such as security professionals, property security, cleaning, driver, cafeteria, civil firefighter, occupational health professionals, receptionist, and computer technician with a direct relationship with the community; and low-risk are all remaining workers.

Statistical analysis

A descriptive analysis compared the sociodemographic and occupational characteristics of mining workers tested for SARS-CoV-2, the positive cases, those placed in quarantine, and those with any symptoms compatible with COVID-19. Absolute and relative frequencies were defined for categorical variables and means and standard deviations (SD) for the quantitative variable age. Pearson's chi-square and Fisher's exact tests were also used for categorical variables.The cumulative incidence (i.e., the percentage of new positive RT-PCR, serology, or rapid tests), its respective 95% confidence interval (95% CI), and the 7-day moving average (MA) were calculated to compare the cases of COVID-19 at the multinational mining company's units versus the cases confirmed by their respective municipalities. The MA was calculated by summing the COVID-19 cases in the last seven days and then dividing the sum by seven. The results for both cumulative incidence and MA were compared by visual analysis.

Statistical analyses were conducted using Stata (version 16.0, College Station, Texas, USA) and R (version 4.0.4, R Foundation for Statistical Computing, Vienna, Austria; www.r-project.org) software. Data were analyzed from April to August 2021 and from February to March 2022.

Ethical issues

This study is part of an investigation called "*Observa-COVID*," conducted by researchers from the Federal University of Minas Gerais (UFMG) and the Federal University of Ouro Preto (UFOP) in 2020-2021 aiming to assess information about the COVID-19 and work, social, family, and community variables among miners. This study was carried out under the Declaration of Helsinki principles and was approved by the Research Ethics Committee at UFMG (CAAE: No. 36804720.9.0000.5149, approved in: October 6th, 2020) and by the governance and compliance committee of the multinational mining company.

Results

Clinical-epidemiological features

Figure 1 shows the number of tests and workers tested, records with the reason for quarantine, and symptoms compatible with COVID-19. A total of 14,573 workers were tested for COVID-19 and 77,747 tests (RT-PCR = 52,476; serology = 5,586; rapid test = 19,685) were performed during the study period. Among workers tested (n = 14,573), 3,287 (22.6%) were positive for SARS-CoV-2. The highest percentage of positive cases for SARS-CoV-2 was identified by RT-PCR (66.1%, n = 2,173), then by rapid test (20.7%, n = 680), and serology (13.2%, n = 434).

Regarding the quarantine, 9,171 records with a reason for quarantine were identified. A total of 6,205 workers were quarantined (**Figure 1**). Among this total, 66.2% of workers were quarantined one time, 24.0% two times, 6.9% three times, and 2.9% four times or more. The minimum and the maximum number of days in quarantine were 1 and 84, respectively. The median of days in quarantine was 9.

The number of records with symptoms was 3,104. Moreover, 1,121 workers had symptoms compatible with COVID-19 **(Figure 1)**. **Figure 2** shows the main symptoms compatible with COVID-19; cough (39.3%), headache (36.8%), muscle aches (34.4%), runny nose (33.4%), and sore throat (31.8%) were the most common ones.

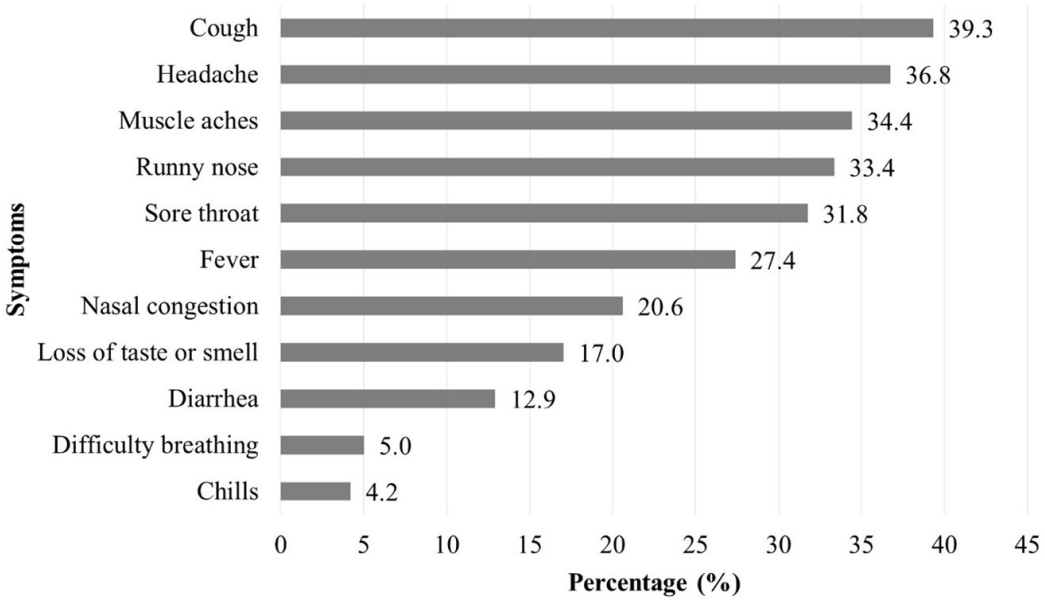


Figure 2 Percentage of symptoms among workers who reported any symptoms compatible with COVID-19 (n = 1,121) in a multinational mining company in Brazil, March 2020 to April 2021.

Sociodemographic characteristics

Table 1 shows that most workers were male (88.4%). Male and female workers tested for SARS-CoV-2 similarly. However, female workers presented higher proportions of positive cases, quarantine, and symptoms compatible with COVID-19 than male. A total of 38.4% of workers were 30-39 years old, with a mean age of 36.1 years. As age increased, the trends for tests, positive tests, quarantine, and symptoms decreased. More than half of the workers (54.1%) resided in the state of Minas Gerais. Workers residing in Goiás state were more likely to be tested. The workers living in Rio de Janeiro had more positive cases, were placed in quarantine more often, and presented more symptoms compatible with COVID-19.

Table 1 Description of total workers and workers tested, positive for COVID-19, quarantined, and with any symptom compatible with COVID-19 according to sociodemographic characteristics. Brazil (Minas Gerais, Goiás, and Rio de Janeiro), March 2020 to April 2021

Characteristic	*Total workers*	*Tested*		*Positive cases* [a]		*Quarantined*		*With any symptom compatible with COVID-19*	
	n (%)	*n (%)*	p-*value**	*n (%)*	p-*value**	*n (%)*	p-*value**	*n (%)*	p-*value**
Sex									
Male	15,044 (88.4)	12,851 (85.4)	0.500	2,859 (19.0)	0.010	5,331 (35.4)	< 0.001	942 (6.3)	< 0.001
Female	1,974 (11.6)	1,675 (84.8)		423 (21.4)		862 (43.7)		178 (9.0)	
Total	17,018 (100.0)	14,526 (85.4)		3,282 (19.3)		6,193 (36.4)		1,120 (6.6)	
Age group									
18-29 years	4,708 (27.8)	3,929 (83.4)	0.001	893 (19.0)	0.019	1,694 (36.0)	< 0.001	350 (7.4)	< 0.001**
30-39 years	6,508 (38.4)	5,467 (84.0)		1,281 (19.7)		2,499 (38.4)		474 (7.3)	
40-49 years	3,842 (22.7)	3,212 (83.6)		748 (19.5)		1,317 (34.3)		216 (5.6)	
50-59 years	1,586 (9.4)	1,288 (81.2)		294 (18.5)		499 (31.5)		63 (4.0)	
60-79 years	281 (1.7)	214 (76.2)		33 (11.7)		51 (18.2)		3 (1.1)	
Total	16,925 (100.0)	14,110 (83.4)		3,249 (19.2)		6,060 (35.8)		1,106 (6.5)	

(Continues)

Table 1 Continuation

Characteristic	Total workers		Tested		Positive cases[a]		Quarantined		With any symptom compatible with COVID-19	
	n (%)		n (%)	p-value*	n (%)	p-value*	n (%)	p-value*	n (%)	p-value*
Age (years)	Mean	SD[b]	Mean	SD[b]	Mean	SD[b]	Mean	SD[b]	Mean	SD[b]
	36.1	10.0	36.0	9.9	36.0	9.6	35.6	9.3	34.2	8.7
State of residence										
Minas Gerais	9,176 (54.1)		7,315 (79.7)	< 0.001	1,697 (18.5)	< 0.001	3,571 (38.9)	< 0.001	535 (5.8)	< 0.001
Goiás	5,496 (32.4)		5,110 (93.0)		1,107 (20.1)		1,909 (34.7)		466 (8.5)	
Rio de Janeiro	356 (2.1)		317 (89.0)		173 (48.6)		205 (57.6)		44 (12.4)	
Others	1,924 (11.4)		1,402 (72.9)		244 (12.7)		392 (20.4)		52 (2.7)	
Total	16,952 (100.0)		14,144 (83.4)		3,221 (19.0)		6,077 (35.8)		1,097 (6.5)	

[a]First positive test. [b]Standard deviation. *Chi-square test; **Fisher's exact test.

Occupational characteristics

Table 2 shows that mining units IO1 and N1 had the highest proportion of workers, 53.6% and 25.8%, respectively. Workers from mining unit N1 were tested more, and those from mining unit IO3 had more positive cases for SARS-CoV-2, were placed more in quarantine, and presented more symptoms compatible with COVID-19. Regarding the business unit, more than half of the total workers (61.6%) were from iron ore. Most workers from nickel were tested, and they were more likely to have symptoms compatible with COVID-19. Among quarantined workers, the highest proportions were observed for iron ore.

Table 2 Description of total workers and workers tested, positive for COVID-19, quarantined, and with any symptom compatible with COVID-19 according to occupational characteristics. Brazil (Minas Gerais, Goiás, and Rio de Janeiro), March 2020 to April 2021

Characteristic	Total workers	Tested		Positive cases[a]		Quarantine		With any symptom compatible with COVID-19	
	n (%)	n (%)	p-value*	n (%)	p-value*	n (%)	p-value*	n (%)	p-value*
Mining unit									
IO1	9,381 (53.6)	7,198 (76.7)	< 0.001	1,647 (17.6)	< 0.001	3,621 (38.6)	< 0.001	517 (5.5)	< 0.001
IO2	896 (5.1)	727 (81.1)		135 (15.1)		247 (27.6)		44 (4.9)	
IO3	515 (2.9)	455 (88.4)		249 (48.4)		291 (56.5)		65 (12.6)	
N1	4,525 (25.8)	4,222 (93.3)		888 (19.6)		1,610 (35.6)		396 (8.8)	
N2	2,206 (12.6)	1,971 (89.4)		368 (16.7)		436 (19.8)		99 (4.5)	
Total	17,523 (100.0)	14,573 (83.2)		3,287 (18.8)		6,205 (35.4)		1,121 (6.4)	
Business unit									
Iron ore	10,796 (61.6)	8,385 (77.7)	< 0.001	2,031 (18.8)	0.820	4,158 (38.5)	< 0.001	625 (5.8)	< 0.001
Nickel	6,727 (38.4)	6,188 (92.0)		1,256 (18.7)		2,047 (30.4)		496 (7.4)	
Total	17,523 (100.0)	14,573 (83.2)		3,287 (18.8)		6,205 (35.4)		1,121 (6.4)	

(Continues)

Table 2 Continuation

Characteristic	Total workers	Tested		Positive cases[a]		Quarantine		With any symptom compatible with COVID-19	
	n (%)	n (%)	p-value*	n (%)	p-value*	n (%)	p-value*	n (%)	p-value*
Employment contract									
Employee	3,458 (19.7)	3,183 (92.0)	< 0.001	1,033 (29.9)	< 0.001	2,181 (63.1)	< 0.001	461 (13.3)	< 0.001
Outsourced	14,065 (80.3)	11,390 (81.0)		2,254 (16.0)		4,024 (28.6)		660 (4.7)	
Total	17,523 (100.0)	14,573 (83.2)		3,287 (18.8)		6,205 (35.4)		1,121 (6.4)	
Shift work									
No	8,383 (71.4)	7,781 (92.8)	< 0.001	1,805 (21.5)	< 0.001	3,103 (37.0)	< 0.001	580 (6.9)	< 0.001
Yes	3,359 (28.6)	3,255 (96.9)		834 (24.8)		1,681 (50.0)		388 (11.6)	
Total	11,742 (100.0)	11,036 (94.0)		2,639 (22.5)		4,784 (40.7)		968 (8.2)	
Occupational risk[b]									
Low risk	16,825 (96.0)	13,940 (82.8)	< 0.001	3,098 (18.4)	< 0.001	5,834 (34.7)	< 0.001	1,038 (6.2)	< 0.001
Medium risk	651 (3.7)	590 (90.6)		169 (26.0)		341 (52.4)		78 (12.0)	
High risk	47 (0.3)	43 (91.5)		20 (42.6)		30 (63.8)		5 (10.6)	
Total	17,523 (100.0)	14,573 (83.2)		3,287 (18.8)		6,205 (35.4)		1,121 (6.4)	

[a]First test positive. [b]High risk: healthcare professionals in attendance; Medium risk: security professionals, property security, cleaning, driver, cafeteria, civil firefighter, occupational health professional, receptionist, and computer technician with direct relationship with the community; Low risk: all remaining professionals. *Chi-square test.

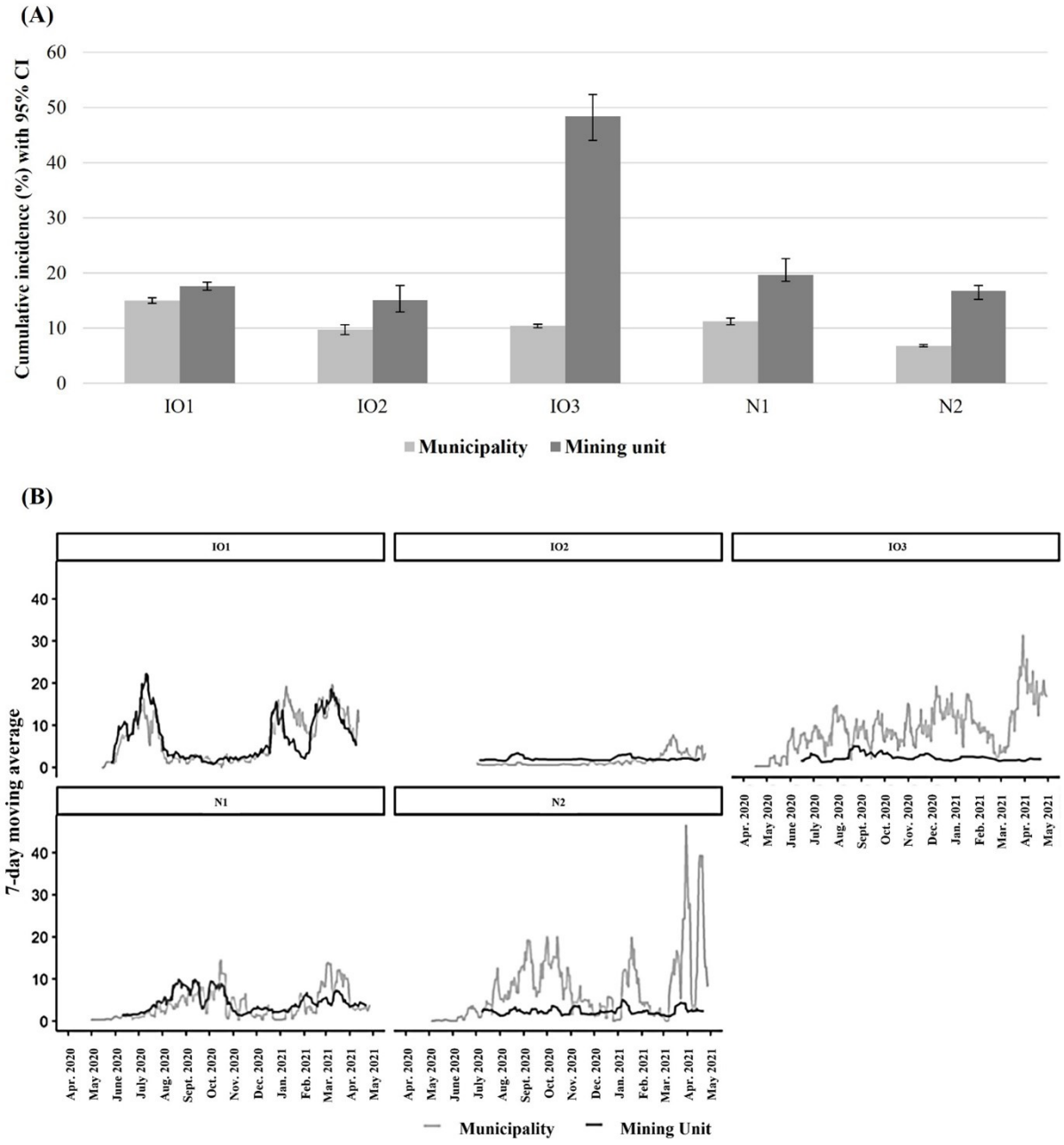
Additionally, 80.3% of the total workers were outsourced, and just over one-quarter of the workers were on shift schedules (28.6%). Compared to outsourced, employees were tested more, had more positive tests for SARS-CoV-2, were quarantined more, and showed more symptoms compatible with COVID-19. Analysis of the shift work showed a higher proportion of workers in shifts being tested, having positive cases, being quarantined, and showing symptoms compatible with COVID-19 (**Table 2**).

Another important piece of information concerns the occupational risk adopted by the multinational mining company: almost all workers were classified as low-risk (96.0%), followed by medium-risk (3.7%) and high-risk (0.3%). Workers at high risk had the highest proportions of testing, positive cases, and quarantine. However, those at medium risk presented more symptoms compatible with COVID-19 (**Table 2**).

Dynamic of COVID-19 cases in the mining units and their municipalities

Figure 3A shows the cumulative incidence of COVID-19 cases among workers by the municipality and mining unit. The cumulative incidence of all mining units was higher than that of their respective municipalities. By far, the mining unit IO3 had the highest cumulative incidence (48.4%, 95% CI: 44.0%;52.7%) compared with the other mining units (N1: 19.6%, 95% CI: 18.5%;20.8%; IO1: 17.6%, 95% CI: 16.8%;18.3%; N2: 16.7%, 95% CI: 15.2%;18.3%; IO2: 15.1%, 95% CI: 12.9%;17.6%). The municipalities presented the following cumulative incidences: IO1 15.0% (95% CI: 14.5%;15.5%), IO2 9.7% (95% CI: 8.8%;10.7%), IO3 10.4% (95% CI: 10.1%;10.7%), N1 11.2% (95% CI: 10.6%;11.7%), and N2 6.8% (95% CI: 6.6%;7.1%).

Figure 3B shows an overview of the comparison between the MA of COVID-19 cases among workers by municipality and mining unit. The curves of mining units and municipalities were similar in IO1 and N1 units. When cases peaked in the municipality, cases among workers increased. For the IO2 unit, the dynamics of the municipality and workers were similar in 2020. In 2021, municipalities showed peaks but IO2 workers did not. Finally, municipalities N2 and IO3 had more cases of COVID-19, and the curves of these municipalities and mining units presented a different distribution, that is, they did not reach the peak of COVID-19 cases at the same time.



95% CI: 95% Confidence interval.

Figure 3 (A) Cumulative incidence and (B) 7-day moving average of COVID-19 cases among workers by municipality and mining unit from a multinational mining company in Brazil, March 2020 to April 2021

Discussion

Among workers tested for SARS-CoV-2, about one-fifth had at least one positive test. About one out of three workers entered quarantine. The main symptoms reported were cough, headache, muscle aches, runny nose, and sore throat. Female workers, middle-aged adults, living in Rio de Janeiro state, employees from the IO3 mining unit working in shifts at high-risk positions were the profile with more outcomes related to COVID-19. The cumulative incidence in all five mining units was higher than in the municipalities where they were located. Three out of the five units showed peaks of COVID-19 with MA cases among their workers similar to their respective municipalities. Finally, two municipalities evaluated had a higher MA of COVID-19 cases than their respective mining units.

In general, results for some sociodemographic and occupational characteristics were consistent regardless of the condition evaluated (i.e., those tested for SARS-CoV-2, the positive cases, those placed in quarantine, and those with any symptoms compatible with COVID-19). For the variables such as sex, age, state of residence, and mining unit, for example, the categories more tested were not those which presented more positive results, quarantine, or symptoms. This underscores the importance of mass testing to identify workers at increased risk of infection. On the other hand, employees were more tested than the outsourced and had more COVID-19 outcomes (positive tests, quarantine, and symptoms), suggesting the need for more attention to this second group the workforce in companies, also relevant in terms of the COVID-19 impact, as already shown for workers in shifts.

The type of work activities and working conditions are potential SARS-CoV-2 exposure sources[17]. For example, healthcare workers in the services sector are highly exposed to the virus due to physical proximity with patients, co-workers, and their long working hours[18]. These last two characteristics are common in mining sectors when working from home is impossible, evidencing their exposition[5,19]. Research conducted between August and November 2020 with 295 Brazilian healthcare workers evidenced that 22.6% had at least one positive test for SARS-CoV-2[20]. This study found the same proportion.

Many mining workers entered quarantine, which could be explained by their high exposition to the virus[5,19] and preventive measures adopted by the mining company. Despite the high number of COVID-19 cases among the mining workers, these findings highlight the importance of administrative controls to mitigate the transmission of the virus inside extractive companies[21].

A sample of healthcare workers from Brazil reported the same five symptoms related to COVID-19 found in this study, and interestingly, three of these five symptoms—headache, muscle aches, and runny nose—were reported in workers diagnosed for COVID-19[20]. This draws attention to the importance of screening for symptoms in the work environment with a high risk of infection, along with other measures, such as testing, quarantine, isolation of suspected cases, and encouraging vaccination of workers[22].

The literature has shown that men are more susceptible to COVID-19 than women due to higher receptor expression for coronavirus, immunological factors resulting in reduced resistance to infections, and adoption of more risk behaviors, such as drinking and smoking[23]. However, this study showed that female workers had more outcomes related to COVID-19 than male. We hypothesized that this result is due to the difference in the type of occupations and employment contracts between the sexes. Possibly, SARS-CoV-2 testing and control is higher among workers hired by the company, mainly those in administrative activities, where women are more present. Another possible explanation could be that workers at high risk, healthcare professionals, are proportionately composed of more women and, consequently, are tested more. But additional work is needed to explain this finding since we could not categorize the type of occupation.

Middle-aged workers had more outcomes related to COVID-19. Social contact between young and middle-aged adults (23-44 years) predominates in workplaces[24]. Despite the easy transmission of SARS-CoV-2 among workers, managing the disease in this environment by adopting mitigation measures is easier when compared with public spaces and communities, for example[24]. In addition, the increased risk in this group due to occupational exposure may facilitate the risk within the community, reinforcing the importance of the company adopting protocols for COVID-19 since it is an essential activity[5].

As for the higher frequency of positive cases, quarantines, and symptoms compatible with COVID-19 among workers residing and working in Rio de Janeiro, this can be explained by the large circulation of people in this state due to its tourism vocation, port activity, small territory, and extensive highway, the last two allowing people to cross the state in few hours[25]. This finding may be explained by the high dispersion of people and their interaction in a small territory, consequently facilitating the spread of the SARS-CoV-2, which is highly transmissible[24,25]. Considering the working conditions, we hypothesize that both IO3's employees and outsourced workers underwent a higher number of tests compared to other mining units, since it was essential to ensure the transportation of necessary goods and resources during the pandemic. Consequently, IO3 workers were unable to work remotely, which increased the risk of contracting and spreading the virus[4].

Regarding employment contracts, employees were more likely to present more outcomes related to COVID-19. One possible explanation is the higher proportion of testing among these workers, consequently more positive results for SARS-CoV-2. Another possible explanation is the company focusing more on its employees when compared with outsourced workers. Additionally, more turnover among outsourced workers could result in a lower number of COVID-19 diagnoses. Workers who were sick or with symptoms may even have been removed without the mining company knowing, especially at

the peak of the pandemic. Outsourcing is common in mining industries and has been pointed out to help companies to overcome challenges brought by the pandemic[26]. Bearing in mind the importance of outsourced workers for mining, companies should also prioritize testing, screening, and preventive measures for these workers.

Working on a shift schedule has been associated with adverse health conditions. Although the relationship between shift work and SARS-CoV-2 infection is not well established, a possible explanation highlights the disruption in the circadian rhythms[27]. The workers analyzed and involved in shift work had percentages ranging from a third to a quarter of positive tests, quarantines, and symptoms compatible with COVID-19. Thus, follow-up studies are needed to clarify the possible relationship between this type of exposure and the epidemiological events of COVID-19.

According to the occupational risk criteria, workers classified as high-risk were more tested for SARS-CoV-2, had more positive results, and were more placed in quarantine. Although other groups of workers have an important role in the transmission of SARS-CoV-2[17], this result is expected since health frontline workers represent a category of workers with a great risk of contamination by this virus[7,18,20-22]. However, workers could be infected in situations other than their occupation, such as at home, in transport, or during leisure time[28]. The mass testing of all workers can prevent outbreaks like COVID-19 with the recognition and subsequent temporary leave of the sick worker, preventing contamination and the quarantine of many other workers[7].

During the pandemic, the individuals in this study range from miners to workers who can work from home, but this variable was not evaluated from the database of the mining company. Considering miners' work environment, a reason that explains this increased predisposition is a large amount of dust, toxic waste and gases, radioactivity, low oxygen concentration, high temperatures, and stress to which they are exposed, regardless of whether they are outdoors or indoors[10]. Circumstances like these can affect the workers' pulmonary function[12]. Moreover, the physical proximity at the workplace, lack of access to places for hand hygiene, or even the absence of this habit, and the transport conditions within the company and on the commute are other factors that can contribute to spreading the virus[18] between miners and other workers in the multinational mining company that cannot work from home.

The workplace improvement, adequate distance, places for handwashing with water and soap, alcohol gel availability, use of certified face masks, educational materials in a language understood by workers, symptom screening, and policies to discourage working while experiencing symptoms compatible with COVID-19 help to reduce the transmission of SARS-CoV-2 in environments like these[21,28]. Employers in industries such as mining must recognize how essential their workers are and provide the best care to ensure their health and safety[7].

Workers who can work from home in the face of a pandemic such as that of COVID-19 have the advantage of being able to practice social distancing and reducing contact with other people from work. Reduced social interactions result in less pressure on the health system[18]. Understanding occupational exposure to respiratory infections among workers, considering how many workers are exposed and their different professional categories, positions, and sectors, helps in prevention and control measures in the workplace. These prevention and control measures will be critical to reducing the transmission of infectious diseases both inside and outside the workplace[21].

Furthermore, the dynamics of cities are essential for understanding the health-disease process of their population[29]. The places where individuals live, interact, and carry out their activities have health implications[30]. Thus, the presence and mobility of workers impact the population from municipalities where mining companies are localized as well as interfere in the transmission of diseases such as COVID-19[8,9]. For example, in this study, all mining units presented cumulative incidence higher than that from the municipalities, possibly affecting the dynamic of virus transmission across the population.

Furthermore, the MA of cases of COVID-19 in three of the five municipalities where the mining companies are localized was like that of the mining companies. For the two municipalities with MAs higher than that of the mining companies, we hypothesized that this was due to other economic activities that also stand out in these municipalities, which are tourism, in N2, Goiás, and tourism, port activity, small territory, and extensive highway in IO3, Rio de Janeiro, as previously stated[25]. Another possible explanation is that, for some reason, the contamination among operating workers had a greater impact on the spread of the disease in these two municipalities. Additionally, the highest number of inhabitants and the smallest number of workers in municipalities N2 and IO3 can help to explain this finding.

This study has some limitations. First, some information about sociodemographic determinants and COVID-19 was not collected since it used secondary data. Data was collected by the company's

health service on a routine basis, without specific training aimed for research purposes. Second, a sensitivity analysis was not conducted to explore the difference between the sexes. However, the unexpected result for sex may be explained by the sample size; also, since women may represent the group tested more often in the company, it could create a selection bias, resulting in controversial and uninterpretable results. Third, the difficulty of grouping the answers for the type of occupation variable did not allow its use since the categories were many and some answers had incomplete information. Similarly, using the variable area of activity was difficult since the meaning of its answers was too unclear to group them. Fourth, these findings should be interpreted with caution since they do not reflect the risk. Finally, although RT-PCR is considered the gold standard for detecting SARS-CoV-2, tests such as serology and rapid testing were also used, particularly at the beginning of the pandemic, due to the tracking policy adopted by the company and the absence of tests in the market. However, a study carried out with this population using only RT-PCR tests to detect SARS-CoV-2 found a frequency of positive results similar to this study (24.6% versus 22.6%)[31].

This study also has strengths. Despite the COVID-19 pandemic lasting for two years and the advances made regarding its behavior, details about this disease remain poorly understood in some groups. This study advances, investigating more than 17,000 workers from a multinational mining company. Additionally, this research compares the COVID-19 cases between these workers and municipalities where the mining units are localized. These findings further emphasize the importance of policies, recommendations, and monitoring addressed to COVID-19 in the mining workplace to protect the health of workers and communities.

Conclusion

Approximately one-fifth of workers had at least one positive test for SARS-CoV-2. The study shows that overall, among workers of the multinational mining company, female, middle-aged adults, living in Rio de Janeiro state, employees from the IO3 mining unit working in shifts and at high-risk positions were the profile with more outcomes related to COVID-19. Additionally, the cumulative incidence of COVID-19 in all mining units was higher than that of their municipalities, and three of five municipalities had the same MA as their units. The understanding of clinical-epidemiological, sociodemographic, occupational characteristics and distribution of COVID-19 cases in the municipalities with mining can contribute to preventing the disease occurrence in the workplace and municipalities.

References

1. Sasaki N, Kuroda R, Tsuno K, Kawakami N. Workplace responses to COVID-19 associated with mental health and work performance of employees in Japan. J Occup Health. 2020;62(1):e12134.
2. Andrade MA, Castro CS, Batistão MV, Mininel VA, Occupational profile, psychosocial aspects and work ability of Brazilian workers during COVID-19 pandemic: IMPPAC cohort. Saf Health Work. 2021;13(1):104-11.
3. Neves JA, Machado ML, Oliveira LDA, Moreno YMF, Medeiros MAT, Vasconcelos FAG. Unemployment, poverty, and hunger in Brazil in covid-19 pandemic times. Rev Nutr. 2021;34:e200170.
4. The Lancet. The plight of essential workers during the COVID-19 pandemic. Lancet. 2020;395(10237):P1587.
5. Brasil. Ministério das Minas e Energia. Portaria nº 135/GM, de 25 de março de 2020. Define como essencial a disponibilização dos insumos minerais necessários à cadeia produtiva das atividades essenciais arroladas nos incisos do § 1º, do art. 3º, do Decreto nº 10.282, de 20 de março de 2020. Brasília, DF: Presidência da República, 2020 [cited 3 Dec. 2021]. Available from: http://www.planalto.gov.br/ccivil_03/Portaria/PRT/Portaria-135-20-MME.htm
6. Laing T. The economic impact of the coronavirus 2019 (COVID-2019): implications for the mining industry. Extr Ind Soc. 2020;7(2):580-2.
7. Gaitens J, Condon M, Fernandes E, McDiarmid M. COVID-19 and essential workers: a narrative review of health outcomes and moral injury. Int. J. Environ. Res. Public Health. 2021;18(4):1446.
8. Castillo G, Brereton D. The country and the city: mobility dynamics in mining regions. Extr Ind Soc. 2018;5(2):307-16.
9. Sharifi A, Khavarian-Garmsir AR. The COVID-19 pandemic: impacts on cities and major lessons for urban planning, design, and management. Sci Total Environ. 2020;749(20):142391.
10. Donoghue AM. Occupational health hazards in mining: an overview. Occup Med. 2004;54(5):283-9.
11. Naidoo RN, Jeebhay MF. COVID-19: a new burden of respiratory disease among South African miners?. Curr Opin Pulm Med. 2021;27(2),79-87.
12. Sood A, Pollard C, Le Suer K, Vlahovich K, Walker J. Caring for miners during the coronavirus

disease-2019 (COVID-19) pandemic. J Rural Health. 2020;37(1):165-8.

13. Cota W. 2020. Monitoring the number of COVID-19 cases and deaths in Brazil at municipal and federative units level. Scielo Preprints. 2020:362.
14. IBGE. IBGE Cidades [Internet]. Rio de Janeiro; 2021 [cited 2 Dec 2021]. Available from: https://cidades.ibge.gov.br/
15. Campos AG, organizador. Terceirização do trabalho no Brasil: novas e distintas perspectivas para o debate [Internet]. Brasília, DF: Ipea; 2018 [cited 2 Dec. 2022]. Available from: http://repositorio.ipea.gov.br/bitstream/11058/8258/1/Terceirização do trabalho no Brasil_novas e distintas perspectivas para o debate.pdf
16. United States Department of Labor. Occupational Safety and Health Administration. Harzard recognition [Internet]. Washington, DC; [2020] [cited 10 Mar. 2022]. Available from: https://www.osha.gov/coronavirus/hazards
17. Jackson Filho JM, Assunção AÁ, Algranti E, Garcia EG, Saito CA, Maeno M. A saúde do trabalhador e o enfrentamento da COVID-19. Rev Bras Saude Ocup. 2020;45:e14.
18. Barbieri T, Basso G, Scicchitano S. Italian workers at risk during the COVID-19 epidemic. Ital Econ J. 2021;8:175-95.
19. Wanderley LJ, Mansur MS, Milanez B, organizadores. Essencialidade forjada e danos da mineração na pandemia da COVID-19: os efeitos sobre trabalhadores, povos indígenas e municípios minerados no Brasil [Internet]. Brasília, DF: Comitê Nacional em Defesa dos Territórios Frente à Mineração; 2021 [cited 12 abr. 2022]. v. 1. Available from: http://emdefesadosterritorios.org/wp-content/uploads/2021/08/1_Publicacao_Mineracao_Covid_2021_.pdf
20. Villela EFM, Cunha IR, Fodjo JNS, Obimpeh M, Colebunders R, Van Hees S. Impact of COVID-19 on healthcare workers in Brazil between August and November 2020: a cross-sectional survey. Int J Environ Res. 2020;18(12):6511.
21. Baker MG, Peckham TK, Seixas NS. Estimating the burden of United States workers exposed to infection or disease: a key factor in containing risk of COVID-19 infection. PloS One. 2020;15(4):e0232452.
22. Carlsten C, Gulati M, Hines S, Rose C, Scott K, Tarlo SM, et al. COVID-19 as an occupational disease. Am J Ind Med. 2021;64(4):227-37.
23. Bwire GM. Coronavirus: why men are more vulnerable to COVID-19 than women?. SN Compr Clin Med. 2020;2(7):874-6.
24. Liu Y, Gu Z, Xia S, Shi B, Zhou XN, Shi Y, Liu J. What are the underlying transmission patterns of COVID-19 outbreak? An age-specific social contact characterization. EClinicalMedicine. 2020;22:100354.
25. Cavalcante JR, Cardoso-dos-Santos AC, Bremm JM, Lobo AP, Macário EM, Oliveira WKD, et al. COVID-19 no Brasil: evolução da epidemia até a semana epidemiológica 20 de 2020. Epidemiol Serv Saude. 2020;29(4):e2020376.
26. Austin-Egole IS, Iheriohanma E. Outsourcing as a leveraging strategy for organizational productivity in Covid-19 era. EJBM. 2021;13(6):133-9.
27. Lim RK, Wambier CG, Goren A. Are night shift workers at an increased risk for COVID-19?. Med Hypotheses. 2020;144:110147.
28. Dyal JW, Grant MP, Broadwater K, Bjork A, Waltenburg MA, Gibbins JD, et al. COVID-19 among workers in meat and poultry processing facilities - 19 states, April 2020. MMWR Morb Mortal Wkly Rep. 2020;69(18):557-61.
29. Caiaffa WT, Ferreira FR, Ferreira AD, Oliveira CDL, Camargos VP, Proietti FA. Saúde urbana: "a cidade é uma estranha senhora, que hoje sorri e amanhã te devora". Cien Saude Colet. 2008;13(6):1785-96.
30. Proietti FA, Caiaffa WT. What is urban health?. Cad Saude Pública. 2005;21(3):940-1.
31. Menezes Júnior LAA, Parajára MC, Silva JI, Friche AAL, Andrade ACS, Silva LS, et al. Is outsourced and shift work associated with increased risk of covid-19? Findings from a database of mining workers. On press.

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Authors' contributions

Parajára MC, Silva JI, Menezes-Júnior, LAA, Sales ADF, Friche AAL, Machado EL, Silva LS, Andrade ACS, Freitas SN, Caiaffa WT, and Meireles AL contributed to the design of the study, data collection, preparation, critical reviews of the manuscript, and approval of the final published version. Parajára MC, Silva JI, Andrade ACS, Freitas SN, Caiaffa WT, and Meireles AL contributed to the data analysis and interpretation. The authors assume full public responsibility for the work performed and content published.

Data availability

The datasets generated and analyzed in this study are unavailable due to confidentiality agreements.

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