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Is outsourced and shift work associated with an increased risk of COVID-19? Findings from a study about mining workers

O trabalho terceirizado e por turnos está associado ao aumento do risco de COVID-19? Descobertas de um estudo com trabalhadores da mineração

Abstract

Objectives: to investigate the sociodemographic and occupational risk factors associated with COVID-19 infection in mining workers. *Methods:* a retrospective cohort study, using secondary workers' health data from a multinational mining company, from March 2020 to April 2021. A COVID-19 case was defined based on a SARS-CoV-2 positive result in a polymerase chain reaction (PCR) test. Risk ratios (RRs) for positive testing were estimated using Poisson's regression model. *Results:* of 10,484 workers, 2,578 (24.6%) had at least one positive result for COVID-19. Each worker underwent an average of 4.0 (standard deviation: 3.6) tests, totaling 41,962 PCR tests. Most of the evaluated workers were male (88.3%), aged from 30 to 39 years (38.7%), outsourced (74.1%) and non-shift workers (70.5%). Our multivariate model showed that outsourced (RR: 1.39; 95% confidence interval [95%CI]: 1.27;1.51) and shift workers (RR: 1.10; 95%CI: 1.01;1.20) had a higher risk of SARS-CoV-2 infection than their counterparts. *Conclusions:* outsourced and shift workers have a higher risk of COVID-19 infection than their counterparts. Therefore, it is necessary to provide continuous monitoring with regular and adequate testing for mitigation and prevention of COVID-19 in these occupational groups.

Keywords: SARS-CoV-2; employment; shift work schedule; outsourced services; mining; occupational health; cohort studies.

Resumo

Objetivos: *investigar os fatores de risco sociodemográficos e ocupacionais associados à infeção por COVID-19 em trabalhadores da mineração.* Métodos: *estudo de coorte retrospectivo com dados secundários dos trabalhadores de uma empresa multinacional de mineração, de março de 2020 a abril de 2021. Casos de COVID-19 foram definidos por meio do resultado do teste reação em cadeia da polimerase (PCR) positivo para SARS-CoV-2. Riscos relativos (RR) para testes positivos foram obtidos por regressão de Poisson.* Resultados: *dos 10.484 trabalhadores testados, 2.578 (24,6%) tiveram pelo menos um resultado positivo. Foi realizada uma média de 4,0 (desvio-padrão: 3,6) testes para cada trabalhador, totalizando 41.962 testes. A maioria dos trabalhadores eram do sexo masculino (88,3%), com idade entre 30 e 39 anos (38,7%), terceirizados (74,1%) e que não trabalhavam em turnos (70,5%). No modelo múltiplo, os trabalhadores terceirizados (RR: 1,39; intervalo de confiança de 95% [IC95%]: 1,27;1,51) e trabalhadores por turnos (RR: 1,10; IC95%: 1,01;1,20) apresentavam maior risco de infecção quando comparados com seus homólogos.* Conclusões: *os trabalhadores terceirizados e por turnos exibiram maior risco de infecção pelo SARS-CoV-2 quando comparados com seus homólogos. Portanto, é necessário fornecer monitoramento contínuo com oferta regular e adequada de testes para mitigação e prevenção da COVID-19 nestes grupos ocupacionais.*

Palavras-Chave: *SARS-CoV-2; emprego; jornada de trabalho em turnos; serviços terceirizados; mineração; saúde do trabalhador; estudos de coortes.*

Introduction

In January 2020, the World Health Organization (WHO) declared the disease caused by the SARS-CoV-2 virus, COVID-19, a global public health emergency.

During the pandemic, the workdays further exposed workers to COVID-19, especially professional categories that were unable to be performed isolated or remotely[1]. Mining workers are unable to work completely remotely, which may have increased their exposure to SARS-CoV-2 virus by bringing them closer to infected members of the public, especially since carriers can be infectious without or before showing significant symptoms[2]. Moreover, such risk may be increased from working next to asymptomatic or even sick infected colleagues (presenteeism) who still report to work. Therefore, the occupational environment constitutes a potential contributor to the spread of the disease[3]. Considering this workplace reality, mask use, social distancing, environment ventilation, and infection surveillance became even more necessary measures to minimize transmission[3].

Mining is one of the main economic activities around the world. As it was considered an essential activity during the pandemic, it continued even during the lockdowns. Furthermore, an evaluation of official data from the state health department of Minas Gerais, Brazil, found that COVID-19 infections were higher in territories that had mining companies than non-mining territories[4].

The primary means of transmission and containment measures of COVID-19 have been studied for the general population. Still, little information is available for the occupational setting as determinants are not well established nor are work conditions entirely under control[5]. This is relevant since work schedules and contract types are factors that may influence the risk of COVID-19 infection. Shift work (especially at night) has been associated with increased vulnerability to infectious diseases due to circadian rhythm disruption, sleep deprivation, and impaired immune function[6]. Furthermore, outsourced or subcontracted workers may have less access to protective equipment, testing, vaccination, and sick leave than directly employed workers[7], while facing more job insecurity and pressure to work even when symptomatic or exposed to the virus.

Therefore, we tested three hypotheses related to the risk of COVID-19 infection in an occupational setting. First, we expected outsourced individuals working in shifts to have a higher risk for COVID-19. Second, we hypothesized that sex is a confounding factor in the relation between shift work and COVID-19 infection due to the disparity between male and female mining shift workers. Third, we predicted that the combined effect of shift work and outsourcing would increase the risk for COVID-19. To test these hypotheses, we have the following objectives: (1) to identify what sociodemographic and occupational factors are associated with COVID-19 infection; (2) to investigate whether sex is a confounder in the association between shift work and COVID-19; and (3) to analyze a possible interaction between shift work and employment contract on COVID-19 infection. Understanding sociodemographic and occupational characteristics may support prevention and control measures of infectious disease transmission in the workplace.

Methods

Study design and population

This is a retrospective cohort study with workers from a multinational mining company in Brazil. The database was made available by the company and contained sociodemographic, occupational, and COVID-19 data. COVID-19 tests and results were required and monitored by the company's corporate health team and then registered in the database.

Workers from five units in three geographic locations of Brazil were evaluated: two in Minas Gerais State, two in Goiás State, and one in Rio de Janeiro State. Of the five mining units, three have iron ore and two nickel ore as their business unit. The occupational positions of these workers are diverse and include management positions such as administrative and process analysts and assistants, apprentices, administrative assistants, and others. The production area included general services assistants, boilermakers, weeders, electricians, foremen, engineers, furnace workers, machine operators, bricklayers, janitors, welders, mechanics, and others. The health area included doctors, nurses, and nursing technicians. Other areas include cleaning professionals, restaurant and laboratory staff, security personnel, drivers, and others. The sample population included 17,523 workers from all sectors of the company. Of the total sample population, 1,081 (6.2%) workers had no sociodemographic data, 4,900 (28.0%) had no occupational data, and 1,058 (6.0%) had no COVID-19 polymerase chain reaction (PCR) test data. Therefore, 10,484 workers were included in this study (**Figure 1**).
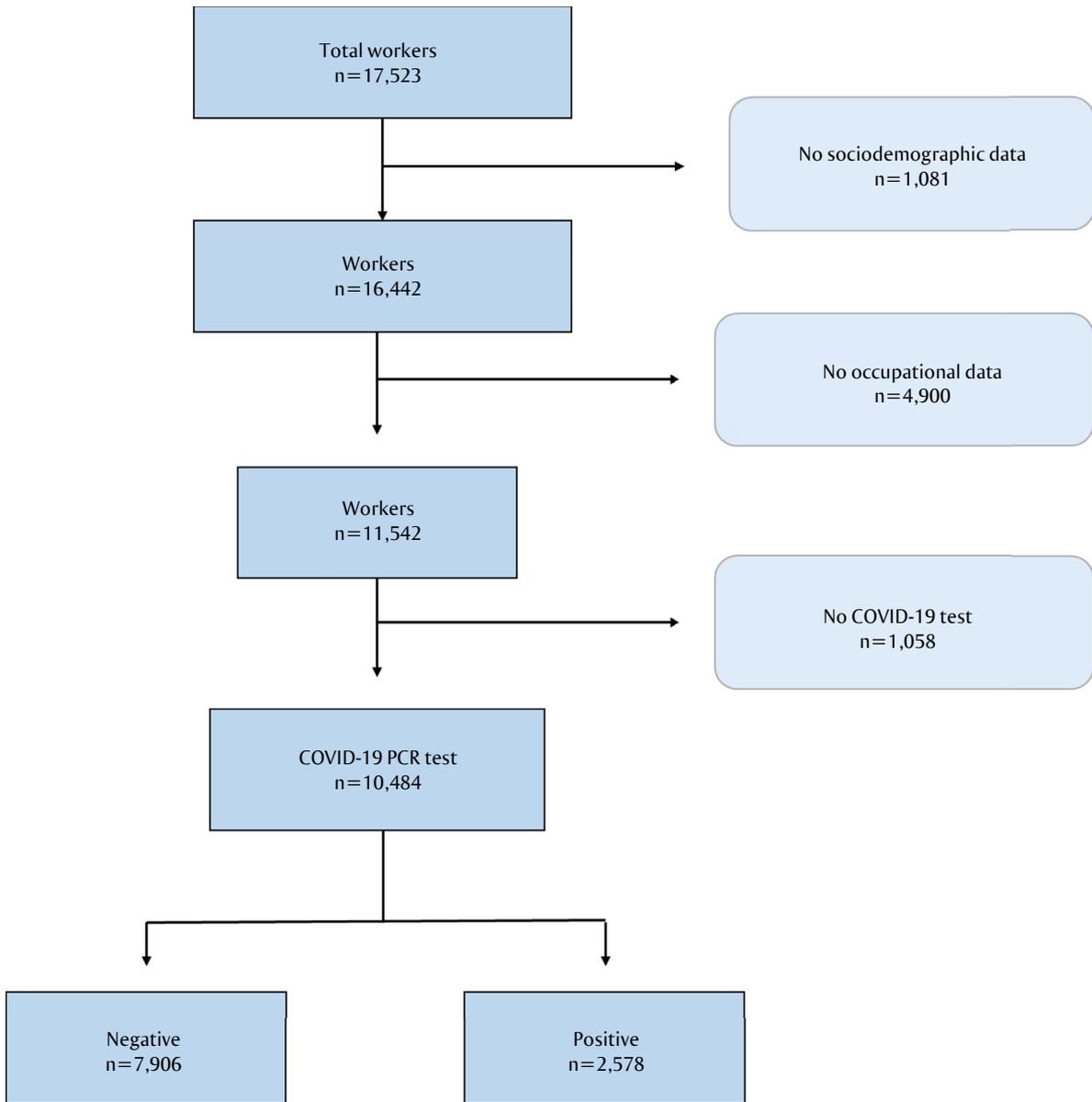
Figure 1 Flowchart of study participants.

Outcome

The primary outcome for this study was a first positive test result for COVID-19 infection in the evaluated individuals. The criteria used to perform the test was symptomatology compatible with COVID-19 (chills, headaches, nasal congestion, runny noses, diarrhea, difficulty breathing, sore throats, muscle aches, fever, cough, and loss of taste or smell), contact with a confirmed or suspected case or a traveler, and having participated in events. Moreover, the workers were tested on a weekly, biweekly, or monthly basis depending on their occupation. Cases of COVID-19 were defined using a positive PCR test for SARS-CoV-2 with nasopharyngeal swabs. All workers evaluated in this study were tested for COVID-19, comprising a total of 41,962 PCR tests from March 2020 to April 2021.

Exposures

The evaluated exposures were stratified into sociodemographic and occupational data. The sociodemographic variables included sex (male and female) and age (18-29, 30-39, 40-49,

50-59, and 60-79 years). Of the occupational variables, company affiliation (employee and outsourced workers), type of shift work (shift and non-shift worker), and occupational risk (high, medium, and low risk) were evaluated.

Outsourced or subcontractor workers were defined as those hired by a company that provides services or contract workers, under exclusive subordination, for a main company.

The participants were categorized as non-shift workers if they worked administrative day shifts from 7 am to 4 pm from Monday to Friday. Alternating shift workers were categorized as those with the following types of schedules: three days on followed by three days off (three days from 7am to 7pm with three days off) and four days on followed by four days off (two days from 7am to 7pm, two days from 7pm to 7am, and four days off).

Occupational risk group criteria for COVID-19 were based on the USA Occupational Safety and Health Administration (OSHA)[8]. Healthcare providers were classified in the high-risk group. Security professionals, property security, cleaners, drivers, cafeteria workers, firefighters, occupational healthcare providers, receptionists, and other professionals who directly assist other workers or people were included in the medium-risk group, and the remaining workers in the low-risk group[8].

Statistical analysis

To compare participants' baseline sociodemographic and occupational characteristics with PCR tests, the Student t-test or one-way ANOVA were conducted. To investigate whether sociodemographic and occupational factors were associated with the risk of COVID-19 infection, multivariate Poisson's regression with robust variance was performed. Sex, age, occupational risk, shift work, and outsourcing were included as explanatory variables and geographic location and the number of tests for COVID-19, as covariates in our model to control for their effect on the outcome of interest. These variables were selected based on the scientific literature and biological plausibility. For example, we know that sex can influence susceptibility to COVID-19 infection[9], age can be related to disease severity[10], occupational risk can influence exposure to the virus[1], shift work can affect the immune system[11], outsourcing is associated with working and health conditions[10], and that the number of tests for COVID-19 can influence the detection of infection[12]. These variables are considered confounding factors because they can affect both the exposure and the outcome of interest. For example, if we fail to control for sex in our model, we may obtain a biased estimate of the relative risk between outsourced and non-outsourced workers for COVID-19 infection in the case of differences in the proportion of men and women between two groups. Thus, we can obtain the adjusted risk ratios (RRs) for each level of the exposure variables (e.g., shift work) compared to a reference level (no shift work), keeping the values of the other explanatory variables constant in our model (sex, age, occupational risk, outsourcing, location, and the number of tests).

RRs and 95% confidence intervals (95%CI) were reported and robust standard errors to ensure accurate estimation of 95%CIs and p-values were used.

Mantel-Haenszel analysis was performed to verify whether sex constituted a possible confounding variable between the association of COVID-19 infection risk and alternating shifts.

Moreover, stratification was performed to verify a possible effect modification on COVID-19 infection considering the interaction between shift work and employment contract.

A p-value of 0.05 was adopted as a significance threshold for multivariable regression. All statistical analyses were performed on Stata IC 15.0 (Stata Statistical Software, College Station, TX, USA).

Ethics

This study belongs to 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 to assess information about COVID-19 and work, social, family, and community variables among miners. This study was conducted according to the guidelines in the Declaration of Helsinki. All procedures were approved by the Research Ethics Committee of the Federal University of Minas Gerais (CAAE: 36804720.9.0000.5149) in October 6, 2020 and by the compliance governance committee of the company in which the study was conducted. Exemption from informed consent forms was obtained as the data used in this study were secondary and anonymized.

Results

Sociodemographic and occupational characteristics

The study population consisted 17,523 workers, of which 1,081 had no sociodemographic data (6.1%),

4,900 had no occupational data (28.0%), and 1,058 had failed to perform a COVID-19 PCR test (6.0%). Therefore, our study sample comprised 10,484 workers, with at least 24.6% of positive results for COVID-19 (Figure 1). Most participants were male (88.3%), aged 30 to 39 years (38.7%), outsourced (74.1%), classified in the low-risk group for COVID-19 infection (95.0%), and non-shift workers (70.5%) (**Table 1**).

Table 1 Sociodemographic and occupational characteristics, stratified by COVID-19 test results for mining workers (n=10,484)

Characteristic	Total n (%)	Prevalence of COVID-19 n (%)	COVID-19 tests (n=41,962) mean (SD)	p-value*
Total, n (%)	10,484 (100.0)	2,578 (24.6)	4.0 (3.6)	-
Sociodemographic				
Sex				
Male	7,906 (88.3)	2,240 (24.2)	3.9 (3.5)	**< 0.001**[e]
Female	2,578 (11.7)	338 (27.5)	5.2 (4.6)	
Age (years)				
18-29	2,953 (28.2)	715 (24.2)	3.7 (3.4)	
30-39	4,062 (38.7)	992 (24.4)	4.2 (3.7)	
40-49	2,381 (22.7)	611 (25.7)	4.2 (3.7)	**< 0.001**[f]
50-59	945 (9.0)	235 (24.9)	4.0 (3.8)	
60-79	143 (1.4)	25 (17.5)	3.0 (3.1)	
Occupational				
Employment contract				
Employee	7,773 (25.9)	1,693 (21.8)	3.6 (3.5)	**< 0.001**[e]
Outsourced	2,711 (74.1)	885 (32.6)	5.2 (3.8)	
Shift work				
No	7,388 (70.5)	1,757 (23.8)	4.1 (3.8)	0.329[e]
Yes	3,096 (29.5)	821 (26.5)	4.0 (3.2)	
Occupational risk[1]				
Low	9,964 (95.0)	2,413 (24.2)	3.9 (3.5)	
Medium	479 (4.6)	145 (30.3)	6.0 (5.1)	**< 0.001**[f]
High	41 (0.4)	20 (48.8)	11.0 (6.7)	

Data are shown as absolute (n) and relative (%) numbers, or mean ± SD.
SD: Standard deviation
*Statistical tests to compare the mean of COVID-19 PCR tests according to sociodemographic and occupational variables.
[e]Student T-test for two categories.
[f]One-way Anova for three or more categories.
[1]Occupational risk: High risk: assistance healthcare providers; Medium risk: security professionals, property security staff, cleaners, drivers, cafeteria workers, firefighters, occupational healthcare providers, receptionists, and other professionals who directly cared for other workers or people; Low risk: other employees.

Characteristics of testing for COVID-19

A total of 41,962 PCR COVID-19 tests were performed. The workers most tested for COVID-19 included women (mean: 5.2; SD 4.6), aged 30 to 49 years (mean: 4.2; SD 3.7), who were outsourced (mean: 5.2; SD 3.8), and showed medium (mean: 6.0; SD 5.1) and high occupational risk (mean: 11.0; SD 6.7) (**Table 1**).

Risk factors for COVID-19 infection

Table 2 shows the variables associated with COVID-19 infection in our multivariate model, adjusted by sociodemographic and occupational variables and number of tests for COVID-19. We observed that outsourced workers (RR: 1.39; 95%CI: 1.27-1.51), work in shifts (RR: 1.10; 95%CI: 1.01-1.20), and medium occupational risk (RR: 1.26; 95%CI: 1.06-1.50) remained significant risk factors for COVID-19 infections (**Table 2**). Further analyses evaluated whether sex could configure a confounding variable in the association between COVID-19 infections and shift work. Our crude and pooled-adjusted Mantel-Haenszel analysis showed a percentage difference below 2%, lower than the suggested cutoff of 10 to 20% for a confounding variable.

Table 2 Multivariate analysis of sociodemographic and occupational risk factors for positive COVID-19 results for mining workers (n=10,484)

Characteristic	Crude analysis			Adjusted analysis		
	RR	95%CI	p^e	RR	95%CI	p^f
Sociodemographical						
Sex						
Male	1.00			1.00		
Female	1.13	1.01;1.27	**0.031**	1.07	0.95-1.20	0.241
Age (Years)						
18-29	1.00			1.00		
30-39	1.01	0.92;1.11	0.861	0.94	0.85-1.03	0.215
40-49	1.06	0.95;1.18	0.291	0.99	0.88-1.10	0.890
50-59	1.03	0.88;1.19	0.723	1.00	0.85-1.15	0.991
60-79	0.72	0.48;1.07	0.109	0.77	0.52-1.14	0.212
Occupational						
Employment contract						
Employee	1.00			1.00		
Outsourced	1.49	1.38;1.62	**< 0.001**	1.39	1.27-1.51	**< 0.001**
Shift work						
No	1.00			1.00		
Yes	1.11	1.03;1.21	**0.010**	1.10	1.01-1.20	**0.027**
Occupational risk[1]						
Low	1.00			1.00		
Medium	1.25	1.06;1.48	**0.009**	1.26	1.06-1.50	**0.009**
High	2.01	1.30;3.13	**0.002**	1.40	0.89-2.21	0.143

RR: Risk ratio; 95%CI: 95% of confidence interval.

*Multivariate Poisson regression with robust standard errors analyzed the relation between COVID-19 incidence and several variables, including sex, age, employment status, shift work, and occupational risk. The model also incorporated the geographic location of participants (the states of Minas Gerais, Goiás, and Rio de Janeiro) and the number of PCR tests conducted during the study period as covariates.

[1] Occupational risk classification as defined by the company: High risk: assistance healthcare providers; Medium risk: security professionals, property security, cleaners, drivers, cafeteria workers, firefighters, occupational healthcare providers, receptionists, and other professionals who directly cared for other workers or people; Low risk: other employees.

[e] p-value from Poisson's Regression with standard errors of the univariate analysis.

[f] p-value from Poisson's Regression with standard errors of the multivariate analysis.

Furthermore, our risk modification analysis for COVID-19 infection assumed the presence of combined changes in occupational variables (**Figure 2**). By fixing shift work in our analysis, we observed that the variables had a gradient of probability for COVID-19 infections. Outsourced workers employed in shifts had a higher risk of infection with COVID-19 than outsourced non-shift workers (RR: 1.51; 95%CI: 1.35;1.70, versus RR: 1.12; 95%CI: 0.99;1.26, respectively).
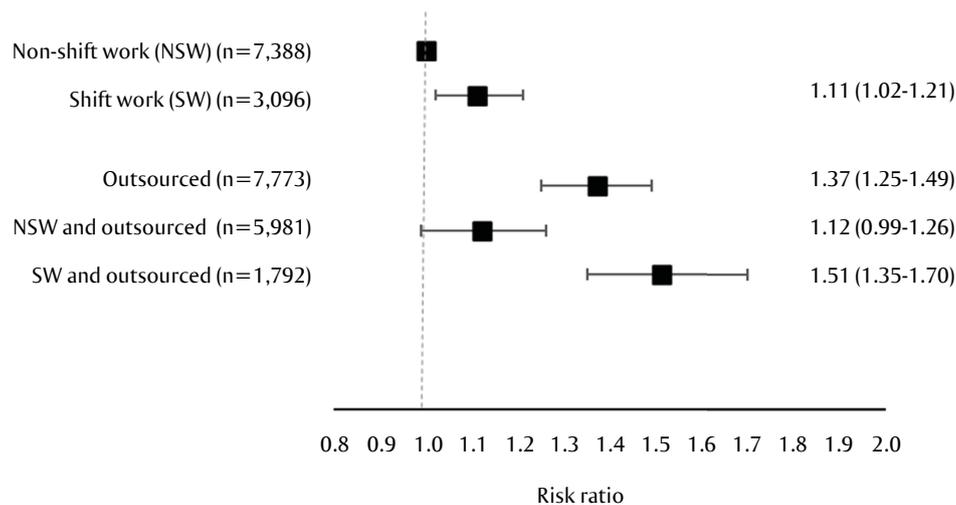

Figure 2 Risk ratio of the association of occupational parameters and COVID-19 positive results for mining workers considering the interaction between shift work and outsourcing (n=10,484)

Discussion

This retrospective cohort study investigated data from workers tested for COVID-19 by PCR at a multinational mining company. Our findings suggest that outsourced and shift workers are at a higher risk of COVID-19 infection and that sex and age fail to constitute risk factors. Furthermore, we found that combining shift work with outsourced showed a dose-response gradient in risk for COVID-19 infection.

Most studies investigating the risk of COVID-19 in essential workers evaluated healthcare workers, who have a much higher risk of becoming infected than other occupations[13]. Essential workers employed outside the healthcare sector generally include low-paid workers whose jobs require close interaction with the public, proximity to their co-workers or both, which puts them at greater risk of infection[14]. Additionally, short and long-term exposure to mining can cause respiratory health problems ranging from acute to chronic. Thus, mining workers configure a group at higher risks of respiratory diseases due to their activity in addition to the risk of exposure to SARS-CoV-2[15].

The higher risk for COVID-19 in workers may stem from these workers having frequent or sustained close contact with other people in areas with community transmission[8]. A review study by the European Center for Disease Prevention that examined whether outbreaks in occupational settings in the European Economic Area and the United Kingdom were associated with occupational groups reported that factors potentially related to a higher risk of SARS-CoV-2 infection may include worker contacts in closed environments, such as in elevators and shared bathrooms[16]. Moreover, workers in the mining industry are often subjected to crowding in their work routine, such as living quarters, shift changes, and on company-provided transportation, which can range from five to 46 passengers in cars and buses, respectively, on trips that can last up to two hours. Besides cafeterias, the self-service model offers a great risk of food contamination from saliva drops and everyday serving utensils; all of which can be a major source of contamination and should be avoided[17]. Furthermore, it is possible that transmission occurred indirectly by contaminated objects in changing rooms or increased contact in changing rooms[18].

We observed no differences in the sociodemographic variables of sex and age, unlike the general population, for which studies indicate that men and individuals aged over 50 years old

have a higher risk of contracting COVID-19[19]. As expected, these results may be partly explained by the characteristic of the evaluated worker population (who were mostly men) and the predominant age group referred to adult subjects, with almost 90% of the individuals aged from 18 to 49 years.

Other socioeconomic variables, such as income and education, were unavailable due to their inexistence in the database, precluding us from analyzing these aspects in association with the finding that outsourced workers were at the highest risk of COVID-19. However, recent data from the UK Office for National Statistics reported high mortality rates from COVID-19 in individuals in low-skilled occupations[20]. This is partly due to low-skilled workers being affected by socioeconomic disadvantages associated with worse health outcomes and higher overall mortality rates[21]. Furthermore, several studies show that outsourced workers have a large discrepancy in wages than contracted employees[22]. In the petrochemical industry, for example, outsourced workers earn on average 52% less than company employees' wages, varying according to different jobs from 27% to 87%[22,23]. Moreover, outsourced workers usually receive no company profit shares, have lower overtime pay, some receive no transportation, childcare, or educational benefits, and obtain lower food stamps and health care-related benefits than company employees[22]. Outsourcing is a common form of contract in the mining industry. Thus, in our research, to be enrolled as an outsourcing mining worker can be considered a proxy related to the income and education in this occupational population[22].

In addition to outsourced workers' socioeconomic discrepancies, negative health outcomes are also expected[22], which go beyond Brazil and the mining sector[22,24]. Quinlan and Bohle's systematic review of 25 studies showed that 92% of the evaluated research found worse occupational health and safety outcomes in outsourced workers[24].

Clarke et al. postulated some hypotheses for such worsened health results, relating them to the job insecurity associated with outsourced workers and its consequences (regularity of jobs, periods of unemployment, the time and energy spent searching for jobs, and the social support resources that are available to workers). The first is the economic pressure outsourced workers often experience, resulting in greater work intensity and interfering with their health and safety. The second factor is disorganization, shown by poor training and supervision, inadequate communication between workers in multi-employer workplaces, reduced ability to collectively express concerns, and the performance of tasks in poorly designed work environments with inadequate staffing and safety protocols. The third factor is poorer regulatory protection for these workers as outsourcing weakens existing regulatory regimes and places additional logistical demands on already overstretched means of work[25].

Another important risk factor our study found was that shift workers were at higher risk of COVID-19 infections. When combined with other occupational risk factors, such as being outsourced or occupational risks, and assessed by occupational category, the risk of becoming infected was higher than those factors alone. Other studies support these findings[20,21]. Shift workers in a non-healthcare setting had a 1.81 (95%CI: 1.04;3.18) higher odds for COVID-19 infection than their counterparts[7]. Furthermore, shift work was associated with a higher likelihood of in-hospital COVID-19 positivity (Odds Ratio [OR]: 2.49; 95%CI: 1.67;3.7) than participants outside shift work[7].

Some biological factors in shift workers predispose them to a higher risk of COVID-19. Shift workers are subjected to changes in their circadian cycle, resulting in insufficient sleep syndrome (defined as a decreased quantity or impaired quality of sleep[26]). The American Heart Association has recognized sleep deprivation as a cardiovascular risk factor, which is associated with central obesity, high fasting blood glucose, hypertension, metabolic syndrome, sleep disorders, and immunological changes[27]. These factors have been well established as risk factors for the unfavorable evolution of COVID-19[28]. Another critical factor to be considered is that insufficient sleep syndrome impairs immunity, making its carriers more susceptible to viral infections such as the common flu[29]. Shift workers are at higher risk of common infections with colds and gastroenteritis[29]. It is believed that sleep can influence the immune system via the hypothalamus-pituitary-adrenal axis and the sympathetic nervous system. A night of sleep deprivation activates the hypothalamus-pituitary-adrenal axis, raising plasma cortisol. The latter reduces the expression of several genes that encode pro-inflammatory cytokines. It is also known that glial neurons and immune cells share common intercellular signals[29]. Furthermore, Lim and Goren have postulated a further hypothesis, in which the disruption of circadian rhythms due to

shift work could suppress melatonin and change immune activity, putting night shift workers at greater risk of infection[30]. Moreover, fatigue related to shift work can also result in difficulty maintaining protective measures.

In addition to physiological mechanisms, a potential explanation may be that shift work, as outsourcing, is a marker of lower socioeconomic status, which is associated with increased vulnerability to COVID-19 infection. Although income or education characteristics were no assessed, it is important to consider that this type of workday is more common in lower-income workers[31]. Therefore, the effect of shift work on COVID-19 infection could also stem from socioeconomic disparities in the workday.

The demand for 24-hour services has amplified shift work in several occupational categories[11,32-34]. Approximately 15 to 28% of U.S. and European workers are employed in some shift schedule[11,33]. Few data are available for Brazil, but it is estimated that this work format comprises about 15% of the Brazilian workforce[34]. Based on these data, the hypothesis that shift workers are more susceptible to SARS-CoV-2 infection and more likely to acquire the more severe forms of the disease is plausible and should be considered by public health measures.

Besides the risk of infection with SARS-CoV-2, it is also necessary to assess which groups of individuals are more vulnerable to severe cases of the disease. Mining workers may not initially be classified as at risk for severe forms of COVID-19 because they are young and supposedly healthy individuals[35]. However, specific characteristics of this population draw attention as many workers have comorbidities associated with the severe form of COVID-19 and their continued activities during the pandemic. Miners are at risk of developing diseases such as cancer and pneumoconiosis due to their exposure to airborne breathable dust, which predispose them to other respiratory diseases[36]. These factors contribute to workers being at an increased risk of COVID-19 infection, a situation that continues to worsen. A study with 1,478 shift workers evaluated risk factors of COVID-19 (hyperglycemia, altered blood pressure, dyslipidemia, hypovitaminosis D, obesity, pre-existing cardiovascular diseases, and smoking). It showed that 91% of workers had at least one risk factor for severe COVID-19[17]. Moreover, according to a study with 235,685 participants by UK Biobank, the probability of severe COVID-19 in shift workers (OR: 2.06; 95%CI: 1.72-2.47)

was near that of healthcare providers (OR: 2.32; 95%CI:1.33-4.05), who show the highest risk[37].

Furthermore, shift workers experience changes in their circadian cycle, resulting in insufficient sleep syndrome (defined as a decreased quantity or impaired quality of sleep[37]). This chronic sleep deprivation has several impacts, including chronic fatigue[39], a feeling of tension or exhaustion induced by stress. It decreases performance and contributes to "human errors" and work accidents[40]. During the COVID-19 pandemic, the fatigue related to shift work could also result in difficulty maintaining protective measures, contributing to infection for COVID-19.

The study has limitations. Participants' socioeconomic characteristics, such as income, education, and skin color, were not assessed. These features are significant to evaluate the social aspects of these workers and their association with COVID-19. However, as described previously, only some socioeconomic markers of these workers were presented, such as outsourcing and shift work. Another important limitation was the allocation of workers by occupational risk. It was pre-established by the mining company, based on the United States OSHA's "Risk of Worker Exposure to COVID-19" material[8]. This categorization resulted in few workers being in the high and medium occupational risk categories and the vast majority of mining workers were considered low risk. It may lead to inaccuracies related to variations in risk across sectors and production positions. Furthermore, information on the detailed occupations and sectors of employees and outsourced workers, which could support our results on outsourcing and COVID-19 infection, must be included. Despite this incompleteness related to this variable, it reflects the company's reality since this variable, based on occupation, was used as one of the criteria for testing and monitoring workers' health during the COVID-19 pandemic. Therefore, the results are relevant to workers' health but should be interpreted cautiously. Thus, we highlight the importance of good-quality data to define high-risk groups of COVID-19 infection and create policies and protocols to protect the most vulnerable workers.

Secondary data use in scientific research can bring benefits such as time and resource economies. However, it also implies some challenges and limitations that researchers must consider. One of the main problems is the validity of secondary data, which may fail to correspond to the objectives and hypotheses of current research

and have the original collectors' unintentional or intentional biases. Another problem is the updating of secondary data, which may be outdated, especially if collection was conducted a long time ago or over a long period of time. Finally, a problem stems from the availability of secondary data, which may be scarce or nonexistent for certain topics or contexts of interest. Despite these problems, secondary data also have relevance and importance for scientific research. A positive aspect is the large size of secondary databases, which can cover many individuals or cases, enabling a more extensive and representative analysis of the studied phenomenon. Another positive aspect is the importance of secondary data on workers' occupational health since data on health in this population is scarce. Furthermore, using secondary data from big companies is also important to show their fragility and the need to improve the quality of their collection. These data can provide evidence on risk and protective factors related to exposure and infection by COVID-19 and other health outcomes, improving health, safety, and well-being conditions in the work environment.

Furthermore, a high ratio of incomplete data may have introduced a selection bias, which may have overestimated or underestimated the prevalence of COVID-19 infections. However, we found no differential loss on sociodemographic data (sex and age). Despite this, the large sample size ensures some representativeness. Another possible limitation refers to the evaluation period; underreporting at the beginning of the pandemic may relate to the limit of testing of individuals since PCR tests were scarcely available. Furthermore, this study only analyzed the first positive result for COVID-19, ignoring reinfection and the reasons for more than one positive test by a person. Another limitation is the risk of community infection from social interactions, which this research was unable to evaluate.

Despite the limitations, this study has several important strengths. First, by using a retrospective cohort study, it could compare infection risk across a range of occupational characteristics. Furthermore, its large sample size (> 10,000 individuals) enabled us with empirical evidence from the pandemic and allowed us to investigate the extent to which occupational factors may explain the observed outcomes. The evaluation of SARS-CoV-2 infection by PCR was also a highlight of this study since it is considered the gold standard test for virus detection. Moreover, this is the first study to assess how the pandemic impacted outsourced workers. This study was performed in the absence of a vaccine, enabling it to evaluate the natural history of COVID-19. A new study should be conducted post-vaccination.

To our knowledge, this is the first study to establish a link between outsourced and shift work in a non-healthcare settings and COVID-19. Further evidence from other studies is needed to validate our findings. Thus, it may be useful to revisit the criteria for defining high-risk groups and to develop and implement appropriate policies and protocols to protect these most vulnerable workers. Therefore, we emphasize the need of analyzing organizational aspects of the activity that hinders social distancing and inappropriate use of personal protective equipment; including investigating other organizational policies toward reducing risk factors, such as supervision of safety protocols, increased cleaning schedules, reduction in the number of workers on shifts, provision of personal protective equipment for workers (suitable and sufficient), and direction to COVID-19 vaccination programs.

Conclusion

Sociodemographic characteristics failed to configure risk factors for COVID-19 infection in workers from a multinational mining company. Among occupational factors, outsourced and shift workers have a higher risk of COVID-19 infection. These findings contribute to knowledge of the determinants and especially to the work conditions in occupational settings, urging the reconsideration of occupational infection prevention and control strategies based on workplace hazard by using appropriate combinations of safe work practices, considering these occupational categories as high risk, and increasing testing frequency and coverage to mitigate and prevent COVID-19.

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Conflict of interest statement

The authors declare no conflicts of interest.

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Authors' contributions:

Menezes Júnior LAA, Parajára MC, Silva JI, Friche AAL, Andrade ACS, Silva LS, Machado EL, Freitas SN, Caiaffa WT and Meireles AL contributed to the study conception and draft. Menezes Júnior LAA, Freitas SN, Andrade ACS, Caiaffa WT and Meireles AL contributed to data analysis and interpretation. All authors approved the final version of this study for publication and take public responsibility for the work done and content published.

Data availability:

The datasets generated and/or analyzed as part of this study are publicly unavailable due to confidentiality agreements. However, they are available upon reasonable request to the corresponding author.