RBSO
Revista Brasileira de Saúde Ocupacional
ISSN: 2317-6369 (online)

Research article

Rafael Araujo Silva[a,b]
https://orcid.org/0000-0001-5913-6138

Lorena Espina Coelis[b]
https://orcid.org/0009-0004-4589-4463

Rafaella Santos Pereira[b]
https://orcid.org/0009-0004-7925-8182

Daniela Santos Angonesi[c]
https://orcid.org/0009-0000-8067-3720

[a] Universidade Federal de Alfenas, Faculdade Farmácia. Alfenas, MG, Brazil.
[b] Corpo de Bombeiros Militar de Minas Gerais. Belo Horizonte, MG, Brazil.
[c] Polícia Militar de Minas Gerais. Belo Horizonte, MG, Brazil.

Contact:
Rafael Araujo Silva
E-mail:
rafael.silva@sou.unifal-mg.edu.br

How to cite (Vancouver):
Silva RA, Coelis LE, Pereira RS, Angonesi DS. Occupational impact of COVID-19 on military firefighters: A cohort study of incidence, reinfection, and absenteeism. Rev Bras Saude Ocup [Internet]. 2025;50:e33. Available from: https://doi.org/10.1590/2317-6369/13724en2025v50e33

Occupational impact of COVID-19 on military firefighters: A cohort study of incidence, reinfection, and absenteeism

Impacto ocupacional da Covid-19 em bombeiros militares: um estudo de coorte sobre incidência, reinfecção e absenteísmo

Abstract

Introduction: As essential first responders, military firefighters faced a high occupational risk during the COVID-19 pandemic. **Objectives:** To analyse the incidence of and absenteeism due to SARS-CoV-2 infection among the entire cohort of military firefighters in Minas Gerais, Brazil, from March 2020 to March 2023. **Methods:** Retrospective population-based cohort study (5,786 active-duty military personnel) using administrative data from the Integrated Health Management System of the Military Fire Department of Minas Gerais. **Results:** A substantial disease burden was observed, with a cumulative incidence of 49.8% over the 3-year period. At the peak of the pandemic, the daily incidence rate among firefighters was approximately five times higher than that in the general population of Minas Gerais (Incidence Rate Ratio [IRR] ≈ 5.0). Absenteeism due to confirmed and suspected cases had a significant operational impact, accounting for 24,653 lost working days in the first year of the pandemic alone. **Conclusion:** Military firefighters experienced a disproportionately high impact from the pandemic, demonstrating their heightened occupational vulnerability. These findings underscore the urgent need to formally categorize firefighters as a high-risk group in public health policies and emergency preparedness plans to safeguard this vital workforce and ensure the operational capacity of community emergency services.

Keywords: COVID-19; Firefighters; Absenteeism; Occupational Health.

Resumo

Introdução: Como socorristas essenciais da linha de frente, os bombeiros militares enfrentaram alto risco ocupacional durante a pandemia de COVID-19. **Objetivos:** Analisar a incidência e o absenteísmo por infeção por SARS-CoV-2 na coorte completa de bombeiros militares de Minas Gerais, Brasil, entre março de 2020 e março de 2023. **Métodos:** Estudo de coorte retrospectivo de base populacional (5.786 militares na ativa), usou dados administrativos do Sistema Integrado de Gestão de Saúde do Corpo de Bombeiros Militar de Minas Gerais. **Resultados:** Observou-se uma carga elevada da doença, com uma incidência cumulativa de 49,8% ao longo do período de três anos. No pico da pandemia, a taxa de incidência diária entre os bombeiros foi aproximadamente cinco vezes superior à da população geral de Minas Gerais (Razão de Taxas de Incidência [RTI] ≈ 5,0). O absenteísmo por casos confirmados e suspeitos teve um impacto operacional significativo, correspondendo a 24.653 dias de trabalho perdidos apenas no primeiro ano da pandemia. **Conclusão:** Os bombeiros militares sofreram um impacto desproporcionalmente alto da pandemia, o que demonstra a sua elevada vulnerabilidade ocupacional. Estes achados reforçam a necessidade urgente de categorizar formalmente os bombeiros como um grupo de alto risco nas políticas de saúde pública e nos planos de preparação para emergências. A proteção destes trabalhadores é essencial para assegurar a resiliência e a capacidade operacional dos serviços de emergência em toda a comunidade no caso de futuras crises de saúde.

Palavras-chave: Covid-19; Bombeiros; Absenteísmo; Saúde do Trabalhador.

Introduction

The COVID-19 pandemic caused by the SARS-CoV-2 virus constituted one of the most important public health challenges of recent decades[1]. Declared a global pandemic by the World Health Organization (WHO) in March 2020, its status as a Public Health Emergency of International Concern (PHEIC) was maintained until May 2023[2]. The virus is characterized by high transmissibility via respiratory droplets and a wide clinical spectrum[2-4], ranging from asymptomatic infection to severe acute respiratory syndrome, with outcomes influenced by factors such as age and pre-existing comorbidities[5-8]. The global crisis necessitated immediate and coordinated responses from governments, fundamentally altering societal dynamics and placing immense strain on public health systems worldwide[9].

In response to the public health crisis, the continued operation of essential services placed frontline workers at a high and continuous occupational risk. Healthcare professionals were at the epicenter of this exposure, with global meta-analyses reporting a SARS-CoV-2 prevalence of approximately 11%, with nurses and physicians as the most affected categories[10]. This risk was compounded by systemic factors, including inadequate access to Personal Protective Equipment (PPE) and high rates of asymptomatic cases that facilitated silent transmission within healthcare settings[11]. In Brazil, the impact was particularly severe, with studies indicating an infection rate as high as 35.8% among physicians during the first year of the pandemic[12]. Beyond the physical contagion, the crisis exacted a severe toll on mental health, leading to high incidences of burnout, anxiety, and depression, underscoring the profound vulnerability of those directly involved in patient care[13].

Alongside healthcare personnel, firefighters constitute a unique and critical group of first responders. Their multifaceted responsibilities, which traditionally extend beyond fire suppression to include high-contact duties such as providing pre-hospital emergency care and conducting rescue operations, were intensified during the pandemic[14]. These routine activities involved potential exposure to individuals with confirmed or suspected COVID-19, and their roles were further broadened to include managing vaccination sites and distributing medical supplies. This expanded operational scope resulted in an exposure profile comparable to that of their healthcare counterparts, leading not only to a high risk of physical contamination but also to occupational stress and adverse mental health outcomes[15,16]. The substantial burden of infection on this group is documented in the literature; for instance, seroprevalence studies in the United States reported rates ranging from 2.5% to 9% among firefighters early in the pandemic[17-20], while a study in Sergipe, Brazil, found a prevalence of 38% during the first wave[21]. Despite this evidence of vulnerability, firefighters have received comparatively less focus in large-scale epidemiological research in Brazil, creating a critical gap in understanding the full impact of the pandemic on this essential workforce.

The present study is geographically focused on Minas Gerais, a state with over 21 million inhabitants that was substantially impacted by the pandemic, recording the second-highest number of cases of the disease in Brazil between 2020 and 2023[22]. The Minas Gerais Military Fire Department (*Corpo de Bombeiros Militar de Minas Gerais* [CBMMG]) is an important institution within the broader Latin American context that maintains a well-structured occupational health system, which provides a unique opportunity for a population-based cohort study. Therefore, this study aims to conduct a comprehensive epidemiological analysis of COVID-19 within the entire cohort of military firefighters in Minas Gerais over three years (March 2020 to March 2023). Specifically, we seek to: (1) determine the cumulative incidence, reinfection rates, and temporal trends of the disease; (2) quantify the impact of COVID-19 on absenteeism; and (3) provide data-driven findings to inform occupational health policies and preparedness strategies for future public health emergencies.

Methodology

Study design

This study was designed as a retrospective, population-based cohort analysis, examining the entire population of military firefighters of the CBMMG between March 2020 and March 2023. The study population included all personnel on active duty, encompassing both operational and administrative staff, irrespective of rank, gender, or function. The only exclusion criterion was personnel who were not on active duty (e.g., retired or on extended leave for reasons other than illness) during the study period. This approach ensures a comprehensive assessment of the pandemic's impact across the entire occupational group. The variables analysed included the diagnosis of COVID-19, time in the institution, demographic data on age and gender, geographical distribution, and days lost from work.

Structure of the Health System

The CBMMG operates as a state institution with constitutional responsibilities that include civil defense, social defense, and public security. Its health system is managed in collaboration among three organizations—namely, the CBMMG, the Minas Gerais Military Police (PMMG), and the Minas Gerais Military Personnel Pension Institute (IPSM)—to provide a comprehensive healthcare service tailored to the needs of its military personnel and their dependents. This health system functions through two primary modalities:

- Organic Network: This network consists of health units where healthcare professionals affiliated with the institution deliver medical assistance to firefighters and their families.
- Accredited Network: This modality involves partnerships with private healthcare providers—including hospitals, clinics, and laboratories—to ensure broader access to medical services.

Integrated Health Management System (SIGS)

The CBMMG's health database is supported by the SIGS, a digital platform that records all medical care provided within its network. The SIGS serves as a centralized database for documenting diagnoses and managing health-related absences. When a firefighter requires sick leave due to a medical condition, the following process is followed:

- A healthcare professional from the organic network evaluates the firefighter and records the diagnosis in SIGS.
- If the firefighter is treated within the accredited network, the diagnosis must be reviewed and approved by a professional from the organic network before being entered into SIGS.
- All instances of sick leave are mandatorily recorded in this system, ensuring accurate tracking of absenteeism.

Data Extraction

The primary data for this study were provided by the CBMMG Healthcare Advisory Office, which extracted the information from the SIGS database. This database is not publicly accessible and is restricted under the Brazilian General Data Protection Law (LGPD). Medical leave records for the entire study period were extracted and organized into an Excel® spreadsheet for analysis. The raw data included the following variables for each individual: name, registration number, position, city of assignment, length of service (in years), age, gender,

diagnosis according to the International Classification of Diseases, 10th Revision (ICD-10), and the start and end dates of the leave period.

Following an institutional protocol published in March 2020[23], cases were defined as follows:

- Confirmed Cases: Individuals with a positive laboratory test for SARS-CoV-2, recorded under the ICD-10 code U07.1.
- Suspected Cases: Individuals presenting with acute respiratory infection symptoms (ICD-10 codes J00–J22) without laboratory confirmation. These cases were considered for the absenteeism analysis but not for the incidence calculations of the confirmed disease.

For comparative analysis, data on the general population of Minas Gerais and Brazil were obtained from an open-access database developed by Cota[24], which aggregates official data confirmed by State Health Departments and obtained from the Ministry of Health's official platform. This repository provided daily updates on confirmed cases of the disease, ensuring transparency and accessibility for public health research.

Data processing

To ensure data accuracy, the SIGS database was preprocessed to consolidate multiple records corresponding to a single illness event. Each sick leave record was cross-referenced using unique identifiers (e.g., registration number) to identify instances where an individual received multiple consecutive licenses for the same continuous episode of illness, such as an initial leave followed by an extension due to clinical worsening or other complications. In such cases, these consecutive licenses were treated as a single event, and only the first license associated with the diagnosis was considered for the incidence counts to prevent overestimation.

Definition of Reinfection

For the purposes of this analysis, each reinfection was treated as a distinct epidemiological event. The operational definition for a new infection episode was a positive laboratory diagnosis for SARS-CoV-2 recorded at an interval of 90 days or more after the date of the primary infection[25]. This temporal criterion is a standard practice in surveillance studies and guidelines, adopted to mitigate the risk of misclassification due to the persistence of viral genetic material, which can lead to recurrent positive results even in the absence of a replicative virus.

Epidemiological and Absenteeism Calculations

The incidence rate of COVID-19 was calculated based on confirmed cases (ICD-10 U07.1) only. The rate per 1,000 firefighters was determined using the following formula:

$$Incidence\ rate = \frac{Number\ of\ cases}{Total\ population\ at\ risk} \times 1{,}000$$

To account for fluctuations in the workforce due to recruitment, retirements, and other factors, the mean population size over the three-year study period was used as a stable estimate for the "total population at risk."

To analyze absenteeism, the methodology proposed by Lima et al.[23] was applied. The percentage of working days lost was calculated by distinguishing the cause of sick leave: confirmed COVID-19 (U07.1), suspected COVID-19 (J00–J22), and other health conditions (all other ICD-10 codes). The calculation was performed as follows:

$$Percentage\ of\ days\ lost\ (\%) = \frac{Days\ lost\ due\ to\ health\ problems}{Days\ potentially\ worked} \times 100$$

The components of this calculation were defined as:

- Working days lost due to health problems: this metric quantifies the total number of workdays lost due to sick leave. It was calculated by summing all sick leave days recorded in the SIGS database for each specific health condition category.
- Days potentially worked: This represents the total number of workdays available for all active firefighters for each annual period of study. It was calculated separately for each one-year interval (e.g., March 2020 to February 2021) by multiplying the total number of days in that period by the number of active firefighters in that specific year.

Statistical Analysis

Data analysis was conducted using RStudio (packages: dplyr, ggplot2, tidyr, and lubridate). Descriptive statistics, including means, standard deviations (SD), and frequencies, were used to characterize the study population and outcomes. The chi-square test was employed to assess the associations between categorical variables, such as infection rates between genders, age groups, and cities. The analysis of temporal trends was descriptive, based on a visual inspection of the incidence curves over the study period. A p-value of < 0.05 was considered statistically significant.

Ethical aspects

This study was conducted according to the ethical standards for research involving human subjects. It received approval from the Minas Gerais Military Police Research Ethics Committee on December 15, 2023, under protocol number CAE: 76367523.7.0000.0283. The CBMMG Healthcare Advisory Office and the CBMMG General Command formally authorized access to the SIGS database. All data obtained were anonymized, and no individual data were disclosed.

Results

The study population consisted of 5,786 active-duty military firefighters, of whom 5,191 (89.7%) were male and 595 (10.3%) were female. The baseline demographic and epidemiological characteristics of the cohort during the study period (March 2020 to March 2023) are summarized in **Table 1**.

Table 1 Baseline Demographic and Epidemiological Characteristics of the Study Cohort (N = 5,786)

Characteristic	N (%)
Gender	
Male	5,191 (89.7)
Female	595 (10.3)
Age group (years)	
≤ 36	2,850 (49.25)
> 36	2,936 (50.75)
Geographic Distribution (Top 5 Cities)	
Belo Horizonte	2,495 (43.10)
Contagem	1,034 (17.9)
Uberlândia	480 (8.30)
Juiz de Fora	449 (7.80)
Uberaba	255 (4.40)
Infection Status	
Individuals with Confirmed COVID-19 (≥1)	2,879 (49.8)
Total Confirmed COVID-19 Episodes[1]	3,333
Individuals with Suspected COVID-19 (≥1)	3,238 (56.0)
Total Suspected COVID-19 Episodes[2]	4,064
Reinfection History (among confirmed individuals)	
Individuals with at least one reinfection [3]	453 (8.08)

[1] Total count of distinct infection events, including primary cases and subsequent reinfections. [2] Total count of distinct suspected illness events. [3] Number of individuals who had two or more confirmed infection events. The percentage was calculated based on the total number of firefighters (N = 5,786).

Over the 3-year study period, the impact of COVID-19 on the cohort was substantial. Nearly half of all firefighters (49.8%, n = 2,879) were affected by at least one confirmed infection, accounting for a total of 3,333 distinct infection episodes. Among those with a confirmed diagnosis (n= 2,879), 2,426 (84.3%) had a single infection, while 453 (15.7%) experienced at least one reinfection. Furthermore, more than a half of the corps (56.0%, n = 3,238) presented with at least one suspected case of COVID-19, corresponding to a total of 4,064 suspected illness episodes. Each of these confirmed and suspected episodes resulted in a period of sick leave, directly contributing to absenteeism within the corps.

Incidence Analysis

A comparative analysis of the cumulative incidence rates for confirmed COVID-19 across different subgroups is detailed in **Table 2**.

Table 2 Comparative Analysis of Cumulative Incidence Rates by Subgroup during the pandemic (March 2020 to 2023)

Characteristic	Individuals with a Confirmed Case (n)	Cumulative Incidence (per 1,000)[1]	Proportion (%)	p-value[2]
Gender				
Male	2,539	489.1	48.9	0.001
Female	340	571.4	57.1	
Age group (years)				
≤ 36	1,430	501.8	50.2	0.53
> 36	1,449	493.7	49.4	
Geographic Distribution (Top 5 Cities)				
Belo Horizonte	1,048	420.0	42.0	
Contagem	335	324.0	32.4	
Uberlândia	187	389.6	39.0	< 0.001
Juiz de Fora	159	354.1	35.4	
Uberaba	122	478.4	47.8	

[1]Cumulative incidence rate = (number of cases during the period/exposed population) x 1,000

[2] p-values were calculated using the chi-square test, which compares the proportion of infected individuals between subgroups.

A statistically significant difference was found in the proportion of infected individuals between genders ($p < 0.05$). For context, the cumulative incidence rate was higher among female firefighters (571.4 per 1,000) than among their male counterparts (489.1 per 1,000). The mean age of the affected firefighters was 36.41 ± 7.65 years, with a median age of 36. The age range was considerable, with the youngest being 19 and the oldest 58. In contrast to gender, the difference in infection proportions between the younger (≤ 36 years) and older (> 36 years) groups was not statistically significant ($p > 0.05$), as the incidence rates were similar (501.8 and 493.7 per 1,000, respectively). Finally, a statistically significant variation in infection proportions was also observed across the geographic distribution ($p < 0.001$). While the highest absolute number of cases was recorded in Belo Horizonte, the city of Uberaba presented the highest incidence rate (478.4 per 1,000), indicating a greater relative impact on firefighters stationed there.

Absenteeism Analysis

The impact of COVID-19 on workforce availability is detailed in **Table 3**, which presents the working days lost and the corresponding absenteeism rates by cause over the three years of the pandemic.

Table 3 Analysis of absenteeism during the COVID-19 pandemic regarding the percentage of working days lost due to confirmed/suspected cases of COVID-19 and other health diagnoses among military firefighters in Minas Gerais, Brazil

Period (Mar–Feb)	Cause of Absence	Working Days Lost (n)	Absenteeism Rate (%)
2020–2021	Confirmed COVID-19	9,148	0.48
	Suspected COVID-19	15,505	0.75
	Other Diseases	33,026	1.60
2021–2022	Confirmed COVID-19	12,103	0.57
	Suspected COVID-19	13,001	0.61
	Other Diseases	34,424	1.62
2022–2023	Confirmed COVID-19	4,974	0.23
	Suspected COVID-19	4,202	0.20
	Other Diseases	39,904	1.89

Notes: Period 1: March 2020–February 2021 (Population: 5,627; Days potentially worked: 2.06 x 10^6). Period 2: March 2021–February 2022 (Population: 5,804; Days potentially worked: 2.12 × 10^6). Period 3: March 2022–February 2023 (Population: 5,786; Days potentially worked: 2.11 x 10^6). "Other Diseases" category includes all sick leave records with ICD-10 codes not related to confirmed or suspected COVID-19.

In the early stages of the pandemic (March 2020 to February 2021), a total of 57,689 working days were lost to illness. Of this total, 42.7% (24,653 days) were directly attributed to confirmed and suspected cases of COVID-19, corresponding to a combined absenteeism rate of 1.20%. As shown in **Table 3**, the impact remained high in the second year, with a rate of 1.18%, before decreasing significantly in the third year to 0.43%. This decline is probably due to factors such as widespread vaccination and increased population immunity.

Temporal Trends and Comparative Incidence

The annual incidence of confirmed cases showed fluctuation. In the first year of the pandemic (March 2020–February 2021), the yearly incidence was 14.90% (n = 862). This increased to a peak of 27.11% (n = 1,569) in the second year, followed by a decline to 16.19% (n = 937) in the final year. The temporal evolution of the daily cases is illustrated in **Figure 1**, showing a mean of 5.68 (±7.62) confirmed cases per day, with a peak of 56 daily cases.

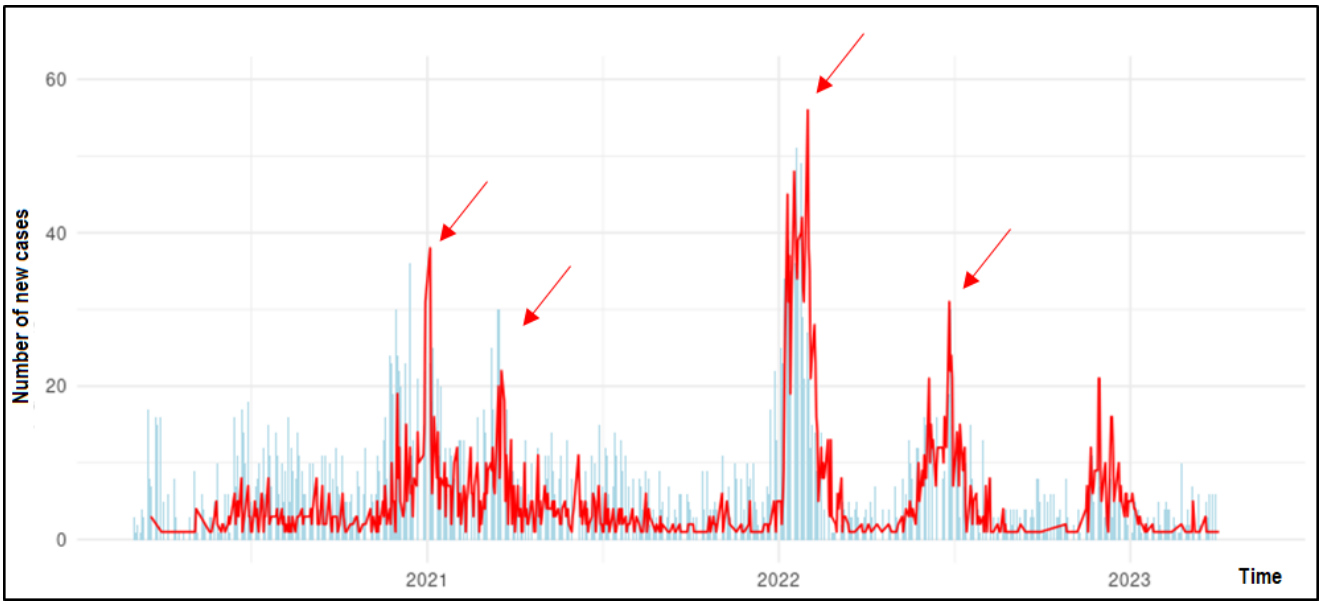

Figure 1 Daily incidence of suspected and confirmed COVID-19 cases in CBMMG firefighters
Legend: The blue bar graph represents cases initially classified as suspected based on CBMMG protocols, corresponding to acute respiratory infections (ICD-10 codes J00–J22). The red line graph depicts confirmed COVID-19 cases (ICD-10 U07.1) within the CBMMG. Red arrows indicate peaks in the observed cases.

As shown in **Figure 2**, the moving averages of incidence in the CBMMG followed a similar curve pattern to those of the general population in Minas Gerais and Brazil. However, the daily incidence rate among firefighters was consistently and markedly higher. At the peak of the Omicron wave in 2022, the incidence rate in the CBMMG reached 9.95 cases per 1,000 firefighters, a rate approximately five times higher than that observed in the general population of Minas Gerais (1.98 per 1,000) and Brazil (1.40 per 1,000).

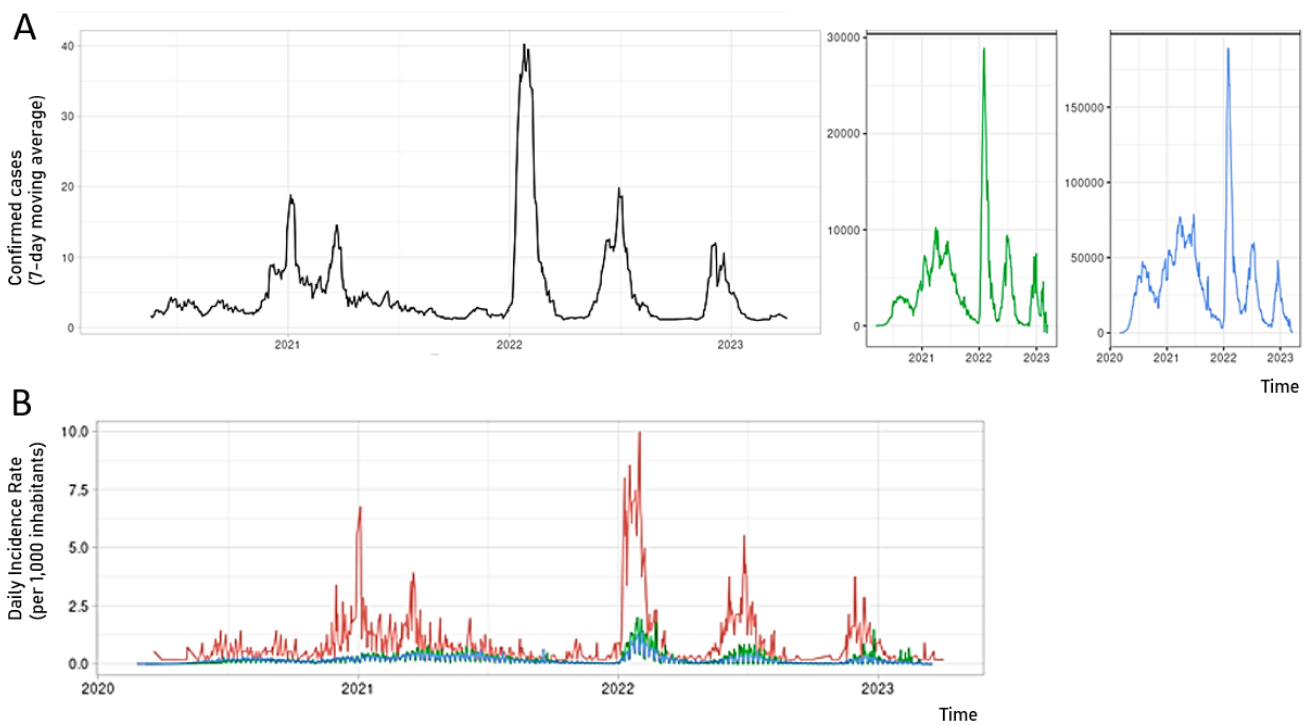

Figure 2 Temporal dynamics of confirmed COVID-19 cases: absolute numbers and incidence rates

Figure 2A shows the seven day moving average of absolute daily confirmed cases for the CBMMG (black), the state of Minas Gerais (green), and Brazil (blue). **Figure 2B** shows the daily incidence rate per 1,000 inhabitants for the CBMMG (red), Minas Gerais (green), and Brazil (blue), highlighting the disparity in risk.

Discussion

This study revealed the impact of the SARS-CoV-2 virus among military firefighters in the Brazilian state of Minas Gerais, with a cumulative incidence of 49.8% over three years. This suggests that almost half of the personnel were infected at least once. This rate is significantly higher than that of the general populations of Minas Gerais (20.01%) and Brazil (18.18%) over the same period[24], which reinforces the elevated occupational risk faced by this group. The disparity was particularly pronounced during peak transmission waves; at the height of the Omicron wave in 2022, for example, the daily incidence rate among firefighters was five times higher than that in the general population of Minas Gerais (Incidence Rate Ratio [IRR] = 5.03), providing quantitative evidence of their disproportionate risk.

For instance, studies conducted in the United States reported prevalence rates ranging from 2.5% to 9% among firefighters and paramedics in 2020[17–20]. However, these lower rates may reflect methodological differences (e.g., reliance on serological tests) and earlier pandemic phases. In contrast, Brazilian firefighters in Sergipe exhibited a prevalence of 38% during the first wave, aligning more closely with our findings[21].

A higher incidence of COVID-19 was observed among female firefighters compared to their male counterparts. However, this result should be interpreted with caution. The sample size was significantly different, with female firefighters comprising only 10.3% of the total fire department, which limits the statistical power and generalizability of this finding. Therefore, while the difference is noted, definitive conclusions about gender-based risk cannot be drawn from this cohort alone. This is particularly relevant given that it contrasts with general population trends, in which men often experience higher rates of severe outcomes and mortality[26].

Significant geographical variation in the incidence was also observed across the state. The highest absolute number of cases was recorded in Belo Horizonte, the state capital, which is expected given its larger population. When comparing the incidence rates that account for the population size, Uberaba and Belo Horizonte exhibited the highest risk. These variations likely reflect local differences in the community transmission intensity. However, it is essential to note that even cities with lower rates demonstrated a substantial infection burden, suggesting that firefighters faced a consistently high occupational risk due to the pervasive nature of the pandemic.

Another key finding of this study was the high rate of reinfection. As shown, 15.7% of the infected firefighters (n = 453) experienced at least one reinfection. Of those individuals, 401 had two confirmed infections, 49 had three, and 3 had four distinct episodes during the study period. This has significant operational implications, as repeated infections within the same individuals can deplete the workforce through absenteeism, increase the workload for the remaining personnel, and lead to greater occupational stress. Furthermore, this result illustrates the challenge posed by SARS-CoV-2 variants that can evade the immune system and cause repeated breakthrough infections despite prior immunity from infection or vaccination.

The high incidence observed in this study is consistent with the recognized occupational hazards of this profession. The firefighters' work environment, which is characterized by frequent close-contact interactions, high physical exertion, and potential exposure to airborne contaminants, contributes to a heightened risk of respiratory viral transmission. This risk increased during the pandemic as firefighters' duties expanded to include tasks such as transporting patients, managing vaccination sites, and performing emergency triage. These tasks increased their exposure frequency compared with the general population. This observation is consistent with the findings of Graham et al.[14], who identified occupational activities (e.g., close patient contact) and environmental factors as significant contributors to firefighters' vulnerability[14].

Concerning absenteeism, the pioneering study by Lima et al.[23] first demonstrated a significant increase in sick leave due to acute respiratory infections among these firefighters after the pandemic's onset[23]. Building

on this foundation, our study provides a comprehensive analysis of absenteeism over the entire three-year period. In the initial year (March 2020–February 2021), absenteeism due to confirmed and suspected COVID-19 cases accounted for approximately 1.20% of all absences, while other illnesses contributed to 1.60%. Notably, 42.73% of all lost working days during this period were directly attributed to COVID-19. This burden remained high in the subsequent year (1.19%) before decreasing by approximately threefold in the final period, likely due to increased population immunity and expanded vaccine availability. The absenteeism observed at CBMMG, particularly during peak periods, impacted the operational workforce. The high interdependence among firefighters means that even modest absenteeism can disrupt task distribution and increase workload.

From an epidemiological perspective, reduced workforce numbers in emergency services may compromise response efficiency and amplify public health risks. Studies have shown that the combination of operational demands and continuous exposure to high-risk environments increases the likelihood of developing physical and mental health conditions. The pandemic exacerbated these stressors, leading to psychological distress, sleep disorders, and musculoskeletal pain[27].

The combination of intense operational demands and continuous exposure to high-risk environments increases the susceptibility to adverse mental health outcomes. The pandemic intensified these stressors, contributing to psychological distress, sleep disorders, and burnout. Therefore, these findings emphasize the necessity for emergency response organizations to implement robust institutional support programs and mental health monitoring policies, particularly during and after prolonged public health crises. For instance, the CBMMG's existing Occupational Health Program (*Programa de Saúde Ocupacional* – PSO), which mandates biannual psychological consultations for the early screening of profession-related mental health conditions, serves as a foundational model.

A temporal analysis of cases within the CBMMG provides essential knowledge about the evolution of the pandemic. The initial phase of the study was characterized by a higher prevalence of suspected cases compared with confirmed cases, likely due to broader screening protocols and limited access to confirmatory testing. However, this trend reversed in 2022, with confirmed cases consistently exceeding suspected cases, indicating improved diagnostic capacity and increased viral transmission. Additionally, a clear temporal correlation was observed between the confirmed case peaks and the emergence of the new SARS-CoV-2 variant. Incidence peaks within the CBMMG corresponded to major pandemic waves in Brazil, including those driven by the P.1 (Gamma) variant in 2021 and, most notably, the Omicron variant in early 2022[28]. This alignment suggests that the infection dynamics within the corps were directly mirrored, yet amplified, by community transmission.

This amplification is clearly evidenced when comparing the corps to the general population. The moving averages of the daily cases show that the temporal pattern of the pandemic was similar across all three groups (CBMMG, Minas Gerais, and Brazil). However, after normalizing the population size, the daily incidence rate revealed a pronounced discrepancy. The consistently elevated rate among firefighters accentuates the distinct occupational hazards they faced. At the peak in 2022, the incidence rate in the CBMMG (9.95 per 1,000) was approximately five times higher than that in Minas Gerais (1.98 per 1,000) and Brazil (1.40 per 1,000), a finding that strongly emphasizes the heightened vulnerability of this professional group.

This study has several strengths, including its population-based design, which analyzed a large, well-defined occupational cohort over a three-year longitudinal period. The use of comprehensive administrative data from the SIGS enabled a detailed analysis of infection trends and absenteeism. However, some limitations must be acknowledged.

First, the reliance on secondary data from an administrative database may introduce biases related to data completeness and the potential for underreporting, particularly of asymptomatic or mild cases that did not result in sick leave. Second, our case classification was based on the ICD-10 codes rather than a detailed review of the clinical charts. While institutional protocols were in place, this could lead to some degree of misclassification, especially for suspected cases defined by respiratory symptoms. Third, this study did not assess clinical outcomes, such as disease severity, hospitalization rates, or long-term sequelae such as post-COVID-19 conditions, as this

information was not available in the dataset. Fourth, while comparisons with the general population serve as a valuable benchmark, the absence of a formal control group limits the ability to draw definitive causal inferences regarding occupational exposure. Finally, our analysis of temporal trends was descriptive; advanced time-series modeling was not performed, which could be a direction for future research to explore the drivers of incidence peaks more deeply. Despite these limitations, this study provides critical evidence on the disproportionate impact of the COVID-19 pandemic on military firefighters.

Conclusion

This study's main contribution is the quantitative demonstration that military firefighters in Minas Gerais bore a disproportionate burden of the COVID-19 pandemic. With nearly half of the corps infected (49.8%) and an incidence rate that peaked at five times that of the general population (IRR ≈ 5.0), the occupational risk was substantial.

This high rate of infection translated directly into significant absenteeism, which has profound public health implications. The depletion of this essential workforce compromises the capacity to respond not only to pandemic-related demands but also to all other emergencies. Therefore, investing in the health and protection of firefighters is a direct investment in public safety and community resilience. These findings should inform future public health policies to ensure that first responders are adequately protected, thus safeguarding the emergency services available to the entire population. Future research should focus on the long-term occupational effects of the pandemic on this cohort, such as post-COVID-19 conditions and the sustained impact on mental health.

References

1. Centers for Disease Control and Prevention. COVID-19 and Your Health. 2025 [cited Jul 21 2025]. Available from: https://www.cdc.gov/covid/index.html
2. World Health Organization. Coronavirus disease (COVID-19). Geneva: World Health Organization; 2025 [cited Jul 21 2025]. Available from: https://www.who.int/news-room/fact-sheets/detail/coronavirus-disease-(covid-19)
3. Li Q, Guan X, Wu P, Wang X, Zhou L, Tong Y, et al. Early transmission dynamics in Wuhan, China, of novel coronavirus–infected pneumonia. N Engl J Med. 2020 Jan;382(13):1199-207. https://doi.org/10.1056/NEJMoa2001316
4. Zhu J, Ji P, Pang J, Zhong Z, Li H, He C, et al. Clinical characteristics of 3062 COVID-19 patients: a meta-analysis. J Med Virol. 2020 Oct;92(10):1902-14. https://doi.org/10.1002/jmv.25884
5. Bhaskar S, Sinha A, Banach M, Mittoo S, Weissert R, Kass JS, et al. Cytokine storm in COVID-19: immunopathological mechanisms, clinical considerations, and therapeutic approaches: Front Immunol. 2020 Jul;11:1648. https://doi.org/10.3389/fimmu.2020.01648
6. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. Lancet. 2020 Feb;395(10223):497-506. https://doi.org/10.1016/S0140-6736(20)30183-5
7. Lai CC, Shih TP, Ko WC, Tang HJ, Hsueh PR. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and coronavirus disease-2019 (COVID-19): the epidemic and the challenges. Int J Antimicrob Agents. 2020 Mar;55(3):105924. https://doi.org/10.1016/j.ijantimicag.2020.105924
8. Petrilli CM, Jones SA, Yang J, Rajagopalan H, O'Donnell L, Chernyak Y, et al. Factors associated with hospital admission and critical illness among 5279 people with coronavirus disease 2019 in New York City: prospective cohort study. BMJ. 2020 May;369:m1966. https://doi.org/10.1136/bmj.m1966
9. Anderson RM, Heesterbeek H, Klinkenberg D, Hollingsworth TD. How will country-based mitigation measures influence the course of the COVID-19 epidemic? Lancet. 2020 Mar;395(10228):931-4. https://doi.org/10.1016/S0140-6736(20)30567-5
10. Gómez-Ochoa SA, Franco OH, Rojas LZ, Raguindin PF, Roa-Díaz ZM, Wyssmann BM, et al. COVID-19 in health-care workers: a living systematic review and meta-analysis of prevalence, risk factors, clinical characteristics, and outcomes. Am J Epidemiol. 2021 Jan;190(1):161-75. https://doi.org/10.1093/aje/kwaa191
11. Nguyen LH, Drew DA, Graham MS, Joshi AD, Guo CG, Ma W, et al. Risk of COVID-19 among front-line health-care workers and the general community: a prospective cohort study. Lancet Public Health. 2020 Sep;5(9):e475-83. https://doi.org/10.1016/S2468-2667(20)30164-X

12. Russo G, Cassenote A, Oliveira BLCA, Scheffer M. Demographic and professional risk factors of SARS-CoV-2 infections among physicians in low- and middle-income settings: findings from a representative survey in two Brazilian states. PLOS Glob Public Health. 2022 Oct;2(10):e0000656. https://doi.org/10.1371/journal.pgph.0000656

13. McNeill M. Extraordinary impacts on the healthcare workforce. Dela J Public Health. 2022 Dec;8(5):164-7. https://doi.org/10.32481/djph.2022.12.038

14. Graham EL, Khaja S, Caban-Martinez AJ, Smith DL. Firefighters and COVID-19: an occupational health perspective. J Occup Environ Med. 2021 Jun;63(8):e556-63. https://doi.org/10.1097/JOM.0000000000002297

15. Carvalho DW. A natureza jurídica da pandemia da Covid-19 como um desastre biológico. 2020 [cited Jan 29 2024]. Available from: https://www.conjur.com.br/2020-abr-21/direito-pos-graduacao-natureza-juridica-pandemia-covid-19-desastre-biologico/

16. Freitas VS. A saúde dos bombeiros militares no combate a COVID-19 no Brasil. PubSaúde. 22 out 2020 [cited Jan 29 2024]. Available from: https://pubsaude.com.br/revista/a-saude-dos-bombeiros-militares-no-combate-a-covid-19-no-brasil/

17. Caban-Martinez AJ, Schaefer-Solle N, Santiago K, Louzado-Feliciano P, Brotons A, Gonzalez M, et al. Epidemiology of SARS-CoV-2 antibodies among firefighters/paramedics of a US fire department: a cross-sectional study. Occup Environ Med. 2020 Dec;77(12):857-61. https://doi.org/10.1136/oemed-2020-106676

18. Mulligan K, Berg AH, Eckstein M, Hori A, Rodriguez A, Sobhani K, et al. SARS-CoV-2 seroprevalence among firefighters in Los Angeles, California. Occup Environ Med. 2022 May;79(5):315-8. https://doi.org/10.1136/oemed-2021-107805

19. Newberry JA, Gautreau M, Staats K, Carrillo E, Mulkerin W, Yang S, et al. SARS-CoV-2 IgG seropositivity and acute asymptomatic infection rate among firefighter first responders in an early outbreak county in California. Prehosp Emerg Care. 2022 Jan-Feb;126(1):6-12. https://doi.org/10.1080/10903127.2021.1912227

20. Vieira V, Tang IW, Bartell S, Zahn M, Fedoruk MJ. SARS-CoV-2 antibody seroprevalence among firefighters in Orange County, California. Occup Environ Med. 2021;78(11):789-92. https://doi.org/10.1136/oemed-2021-107461

21. Borges LP, Nascimento LC, Heimfarth L, Souza DRV, Martins AF, Rezende Neto JM, et al. Estimated SARS-CoV-2 infection and seroprevalence in firefighters from a Northeastern Brazilian state: a cross-sectional study. Int J Environ Res Public Health. 2021 Ago;18(15):8148. https://doi.org/10.3390/ijerph18158148

22. Ministério da Saúde (BR). Painel Coronavírus. Brasília, DF: Ministério da Saúde; 2025 [cited Jul 21 2025]. Coronavírus Brasil. Available from: https://covid.saude.gov.br/

23. Lima EP, Vasconcelos AG, Corrêa LRT, Batista AG. Frontline losses: absenteeism among firefighters during the fight against the COVID-19 pandemic. Rev Bras Saude Ocup. 2020;45:e27. https://doi.org/10.1590/2317-6369000016420

24. Cota W. Monitoring the number of COVID-19 cases and deaths in Brazil at municipal and federative units level. SciELO Preprints; 2020 [cited Jan 30 2024]. Available from: https://preprints.scielo.org/index.php/scielo/preprint/view/362

25. Ma X, Wang Z, Chen Y, Li Z. The symptoms and interval of Omicron SARS-CoV-2 reinfection among healthcare workers in a hospital of Southern China: a cross-sectional study. BMC Infect Dis. 2024 Mar;24(1):354. https://doi.org/10.1186/s12879-024-09221-3

26. Jin JM, Bai P, He W, Wu F, Liu XF, Han DM, et al. Gender differences in patients with COVID-19: focus on severity and mortality. Front Public Health. 2020 Apr;8:152. https://doi.org/10.3389/fpubh.2020.00152

27. Guimarães LAM, Junior JM, Oliveira FF. Saúde mental na Segurança Pública frente à pandemia: uma revisão narrativa. Rev Bras Cienc Policiais. 2023 maio;14(12):365-89. https://doi.org/10.31412/rbcp.v14i12.1025

28. Gomes BBM, Ferreira NN, Garibaldi PMM, Dias CFSL, Silva LN, Almeida MAALS, et al. Impact of SARS-CoV-2 variants on COVID-19 symptomatology and severity during five waves. Heliyon. 2024 Nov;10(22):e40113. https://doi.org/10.1016/j.heliyon.2024.e40113

Information about academic work: Work derived from the Monograph "Military firefighter health management in the face of biological disasters: an analysis of the COVID-19 pandemic", presented in 2024 within the Postgraduate *Lato Sensu* Program – Specialization in Strategic Health Management at the Federal Institute of Minas Gerais (Sul de Minas) by Rafael Araújo Silva, Lorena Espina Coelis, Rafaella Santos Pereira, and Daniela Santos Angonesi Mendes.

Acknowledgments: This study is derived from the final research project of the Postgraduate Program in Strategic Health Management. The authors sincerely thank the Minas Gerais Military Police (PMMG) and the Federal Institute of Southern Minas Gerais for providing the program and authorizing the scientific dissemination of part of the findings.

Authors' Contributions: Silva RA, Coelis LE, Pereira RS, Angonesi DS contributed to the design of the study; the collection, analysis and interpretation of data; and the drafting and critical revision of the manuscript. All authors approved the final version and take full responsibility for the work done and the content published.

Data availability: The dataset supporting the findings of this study is available from the Minas Gerais Military Fire Department (CBMMG) upon reasonable request. These data are not publicly available due to institutional restrictions as they contain information pertaining to a state organization.

Funding: The authors declare that the study was not funded.

Competing interests: The authors declare that there are no competing interests.

Presentation at a scientific event: The authors declare that the study has not been presented at a scientific event.

Received: July 25, 2024
Revised: August 14, 2025
Approved: August 25, 2025

Responsible editors:
Carlos Machado de Freitas
Eduardo Algranti