How long-term metal and lead exposure among foundry workers affect COVID-19 infection outcomes in Jordan

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Abstract

Foundry workers face a number of occupational health hazards, which may lead to an increased risk of respiratory disease, cancer, and anxiety level and are associated with endocrine, hematologic, renal, and neurological problems in humans. This study aims to evaluated thyroid functions, glutathione level, and the risk of infection with SARS-CoV-2 after vaccinated (two doses of the BNT162b2 mRNA COVID-19 vaccine) foundry workers in Jordan. We examined the efficacy BNT162b2 vaccine by calculating the rate of mortality and the degree of severity from mild to severe respiratory infections in 105 adult males foundry workers occupationally exposed to metals and Pb who had been received two doses, 21 days apart, of the BNT162b2 vaccine. Seventy-five male subjects not exposed to the Pb and who received two shots of the BNT162b2 vaccine (Pfizer–BioNTech) served as the control group. In foundry workers who were infected with COVID-19, the mortality rate (0%) was similar as in the control group (0%), and increased transmission of infection with SARS-CoV-2; the non-hospitalized infections increased nearly 3.4-times and hospitalized infections increased 4.29-times among people exposed to lead and metal contamination compared to the healthy persons control group. Also, among the foundry workers, the blood lead, FT3, and FT4 levels were significantly higher \((p < 0.0001)\) and the levels of glutathione and TSH were significantly decreased \((p < 0.0001)\) compared with the control group. In conclusion, long-term exposure to Pb is associated with a risk of infection with COVID-19 despite the 2 doses of the BNT162b2 vaccine (Pfizer–BioNTech). Also, exposure to Pb is associated with hyperthyroidism and a reduction in glutathione.

Keywords COVID-19 · Foundry workers · Lead exposure · Pollution · Thyroid hormones · Oxidative stress

Introduction

New and unexplored topics relatively continue to emerge in environmental and sustainability, such as the factors that determine the spread of the 2019 novel coronavirus disease (COVID-19), which produces severe respiratory disease and causes global many people died. Multiple studies have shown that there may be a relationship between an unsustainable environment with severe air pollution and the spread of COVID-19 (Coccia 2020, 2021a, 2021b). In particular, people living in areas with high levels of air pollution are at high risk of developing respiratory diseases, as the mixing of particulate matter with infectious pathogens such as SARS-CoV-2 can negatively affect (Coccia 2020; He et al. 2020). In fact, scientists point out that high levels of air pollution increase the viral infectivity and morbidity and mortality of the COVID-19 (Gupta et al. 2021). Scholars assert that air pollution can be one of the factors that determines the spread of COVID-19 in society. In addition, climatic, environmental, demographic, and geographic factors also affect (Bashir et al. 2020; Coccia 2021b). Several studies have found that the disease spreads more in densely populated urban areas, possibly due to higher rates of social contact between infected and uninfected individuals (Khavarian-Garmsir et al. 2021).

A foundry is a factory that produces metal castings. This involves melting and liquefaction of metals to form molten metal, which is then poured into a mold, with impurities removed from the mold by cooling, and the metal ultimately becomes solid (Ribeiro and Filho 2006). Foundry workers during these operations are exposed to many hazardous
substances. These included particulate matter and metals, polycyclic aromatic hydrocarbons (PAH), high heat, silica, and machinery, and even exposure to lead through inhalation or ingestion (Palda 2003). Exposure to these metals leads to an imbalance between oxidants and antioxidants and might mediate the formation of a state of oxidative stress, as the levels of the lipid peroxidation marker malondialdehyde (MDA) increase and the activity of the enzyme glutathione (GSH) decreases (Liu et al. 2009).

Long-term exposure to air pollution has been hypothesized to worsen COVID-19 outcomes because the pollution may be suppressing the early immune responses to infection (Conticini et al. 2020; Hu et al. 2021). Many studies have shown the relation between long-term exposure to air pollution and COVID-19 mortality (Cole et al. 2020; Liang et al. 2020). Furthermore, most studies on cumulative deaths were before the vaccination process and in the early stages of the epidemic (Cole et al. 2020; Liang et al. 2020; Travaglio et al. 2021). A major question that arises is how long exposure to metal pollution, especially lead, can affect the diffusion of COVID-19 in foundry workers vaccinated with two dose of COVID-19 vaccine. Therefore, this study aimed to investigate the effect of long exposure to metal pollution, especially lead, on the mortality, infection rate, and the risk of infection with SARS-CoV-2 after taking the second dose of Pfizer–BioNTech vaccine; in addition, we studied the effects of long exposure to metal pollution on thyroid functions and glutathione level.

### Materials and methods

This study was conducted from July 2021 to January 2022. The study population consisted of 180 men who received two doses of the BNT162b2 messenger RNA vaccine within July 2021 (Pfizer–BioNTech) who did not undergo thyroid surgery or receive any form of thyroid treatment.

These participants were classified into two main groups. Group 1: Including 105 (men) foundry workers \((n = 105)\) with a mean age of 38.7 ± 7.06 years who worked in non-ferrous metal foundry for 18 ± 6.3 years in Amman, Jordan. Group 2: Including healthy men \((n = 75)\) with a mean age of 39.4 ± 5.04 years who did not live in areas close to factories in Amman, Jordan, and not worked in non-ferrous metal foundry as control group (Table 1).

The health records for 7 months after vaccination for all the population study were used to evaluate the following outcome measures for COVID-19: infection rates (symptomatic), hospitalization rates, and mortality rates. Simple descriptive statistics were used to calculate the percentage of patients with symptomatic infection, requiring hospitalization, or dying as a result of COVID-19.

### Biochemical analysis

#### Lead in the blood

An inductively coupled plasma mass spectrometer Agilent ICP-MS (7700 series, Agilent Technologies, Tokyo, Japan) was used to determine lead levels in blood samples (Nakata et al. 2021). Analytical quality control was performed using the certified reference material of Seronorm™ Trace Elements Whole Blood L-2 (Sero, Billingstad, Norway).

#### Thyroid blood test

Samples were centrifuged at 3000 rpm for 10 min after at least half an hour. Then, the serum was used for analysis. The measurements of TSH, FT3, and FT4 were conducted by electrochemical luminescence (ECLIA) on Cobas 8000 (Roche Diagnostics, Germany).

#### Glutathione blood test

GSH was measured following the method described by Beutler et al. (1963) using a kit from Biodiagnostic Co., Egypt. The procedure was described in the insert of the kit.
Statistical analysis

Data analyses were performed using Graph Pad Prism and SPSS programs. Based on normality distribution, variable levels were expressed as mean ± SD. Qualitative data was expressed as absolute numbers. For differences assessments, ANOVA, chi-squared ($\chi^2$), or Kruskal–Wallis tests were appropriately used followed by LSD as post hoc test. $P < 0.05$ is significant.

Results

Relative to the control group with a mean age of 39.4 ± 5.04 years (healthy peoples were not exposed to metals pollution and lead), foundry workers ($n = 105$) with a mean age of 38.7 ± 7.06 years who worked in non-ferrous metal foundry plant for 18 ± 6.3 years, especially lead, had significantly increased in blood level of lead (15.9 ± 1.65 vs. 10.7 ± 1.12 µg/dL; $p < 0.0001$), FT3 (3.7 ± 1.73 vs. 2.2 ± 0.75 pg/mL; $p < 0.0001$), and FT4 (1.91 ± 0.49 vs. 1.43 ± 0.49 ng/dL; $p < 0.0001$), and a significant decreased in TSH (1.72 ± 0.41 vs. 2.5 ± 0.92 mIU/L; $p < 0.0001$) and GSH (20.85 ± 4.95 vs. 29.01 ± 4.1 mg/dL; $p < 0.0001$) (Fig. 1).

In this study, we monitored both groups (foundry workers and the control population) for COVID-19 infections for 7 months. We show an increase in deaths (0 vs. 0%), non-hospitalized infections (22.85 vs. 6.66%), and hospitalized infections (5.71 vs. 1.33%) respectively (Table 2).

Discussion

Heavy metal fumes are released into the air of non-ferrous alloy foundries during the manufacturing operations, and foundry workers are exposed to them (Peixe et al. 2014). Therefore, blood is used to screen and monitor Pb exposure assessment (Barbosa et al. 2005).

Our study focuses on the percentage of mortality, hospitalization, and non-hospitalization among foundry workers who were infected with SARS-CoV-2 after taking the second dose of BNT162b2 messenger RNA vaccine (Pfizer–BioNTech); the mortality rate was similar (0%) for both foundry workers and control group (0%). Non-hospitalized infections were increased nearly 3.4-times, and hospitalized infections increased 4.29-times foundry workers compared with control group. Exposure to pollutants can lead to immune suppression, which leads to an increase in infections (Woodby et al. 2021). This leads to a worse

| Table 2 | All subjects received the two doses from the BNT162b2 messenger RNA vaccine (Pfizer–BioNTech). The percentage (%) of foundry workers and controls who died were not admitted to the hospital and who entered the hospital were recorded during the 6 months after receiving the two doses from the BNT162b2 messenger RNA vaccine (Pfizer–BioNTech) |
| Foundry workers ($n = 105$) | Control ($n = 75$) |
| --- | --- |
| Death | Infected, non-hospitalization | Infected, hospitalization | Death | Infected, non-hospitalization | Infected, hospitalization |
| 0 (0%) | 24 (22.85%) | 6 (5.71%) | 0 (0%) | 5 (6.66%) | 1 (1.33%) |

![Fig. 1](image-url) The effect of exposure to metal pollution for foundry workers on the level of BLL, GSH, TSH, FT3, and FT4 compared to healthy people who were not exposed to metals pollution.

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production of oxygen species, and causes a state of oxidative stress (Ercal et al. 2001). In this study, we observed a significant decrease in the level of GSH in the blood during exposure to Pb and metal contamination at work.

There was no significant difference for FT4 between groups, while there was a strong relationship ($p < 0.001$) between FT3 levels and lead exposure (Yılmaz et al. 2012). There was a non-significant decrease in TSH with a strong significance to an increase in FT4 that was observed in workers exposed to Pb (Dursun and Tutus 1999). One study reports a drastic decrease in thyroid function tests in Pb-exposed workers (Wu et al. 2011). Another occupational study showed that Pb-exposed workers had a significant increase in thyroid function tests and decrease in TSH (Fahim et al. 2020). Our study found a significant decrease in TSH and a significant increase in TF3 and FT4 in Pb-exposed workers.

**Conclusions**

This study finds that long-term exposure to metal pollution and lead in non-ferrous metal foundry may have supported increase both the transmission and risk with COVID-19 infection despite vaccination with the 2 doses of BNT162b2 messenger RNA vaccine (Pfizer-BioNTech). Also, exposure to the pollution is associated with hyperthyroidism and a reduction in glutathione.

**Author contribution** MJS conceived and designed the study, conducted the study, collected and organized the data, analyzed the data, interpreted the results, and wrote the initial and final drafts of the article. All authors read and approved the final manuscript.

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**Data availability** The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Declarations**

**Ethics approval** The study protocol conformed to the ethical guidelines of the 1975 Helsinki Declaration. Also, the Ethical Committee approval was obtained from Ethical Committee of Middle East University-Jordan.

**Consent to participate** Fully informed written consent was prospectively obtained from the study participant can be requested at any time.

**Consent for publication** All authors express their consent to publish.

**Competing interests** The authors declare no competing interests.
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