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Co-Exposure Effects of Lead and Noise on the Level of Malondialdehyde (MDA) among Printing Industry Workers (Case Study)

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Abstract

Background: Printing industry workers face hazards from noise and lead exposure. This study investigates the combined effects of lead and noise on malondialdehyde (MDA) levels in these workers, as previous research has focused on isolated effects. This study aimed at assessing the impact of simultaneous lead and noise exposure on the health of people working in the printing industry.
Materials and Methods: Using TENMARS ELECTRONICS sound-meter following ISO9612:2009, malondialdehyde (MDA) levels were measured using Buege and Aust spectrophotometer Model CE1010 CECIL series 1000. Blood lead analysis followed NIOSH8003 method. Data were statistically analyzed using SPSS 20.0 with Pearson and ANOVA tests. The Kolmogorov-Smirnov test was employed to check the normality of the data.
Results: The study found that the die-cut unit had significantly higher daily noise exposure (mean ± standard deviation = 87.71 ± 1.469 dB) compared to other units. Additionally, the printing unit had significantly higher lead concentration (mean ± standard deviation = 0.1431 ± 0.02 ppb) and malondialdehyde (MDA) concentration (mean ± standard deviation = 0.9963 ± 0.238 mmol/lit) compared to other units.
Conclusion: The study found a strong link between blood lead levels and malondialdehyde (MDA) concentration in printing industry workers. However, no significant correlation was found between MDA levels and noise exposure or the combined exposure to noise and lead. These findings emphasize the need to address lead exposure in the printing industry to protect workers' health and prevent elevated MDA levels.

Keywords: Lead, Noise, Malondialdehyde, Printing

Introduction

Noise represents a significant occupational health risk across various industries, including the printing industry [1]. The World Health Organization (WHO) has estimated that over 12% of the global population is exposed to detrimental levels of noise, defined as exceeding 85 decibels (dBA), in their workplace environments [2, 3]. Prolonged exposure to chronic noise stress can serve as a triggering factor for several health conditions, including mental disorders, sleep disorders, cardiovascular diseases, and hypertension [4].

In addition to organic solvents, mineral oils, resins, and paper dust, lead stands as a prominent occupational hazard within the printing industry [5]. This heavy metal is extensively utilized as an essential material in various printing processes [6]. Organic and inorganic pigments, including lead sulphate, lead chromate, and lead oxide, are commonly employed in the production of different colors. Lead can enter the body through multiple routes such as water and air, leading to adverse effects [7]. These include disruption of the bone marrow hematopoietic system and development of anemia [8], as well as damage to the nervous system [9] and cardiovascular system [10]. The presence of lead can interfere with normal cellular functioning by disrupting cell signaling processes, interactions, and functions [11]. Thus, lead contamination represents a significant occupational risk factor in workplace environments. Given the significance of the health risks faced by workers in the printing industry, who are simultaneously exposed to high levels of noise and hazardous amounts of lead, it becomes crucial to identify the health implications arising from the combined exposure to these two sources. However, the health effects resulting from the combined impact of noise and lead exposure have remained understudied [12-14].

One study conducted on male rats provided evidence that exposure to both lead and noise for a duration of one month led to a significant increase in malondialdehyde (MDA) levels and a decline in overall antioxidant capacity levels [15]. Another research highlighted the potential ototoxic effects of lead exposure, including alterations in electrophysiology [16]. Further, a case study involving workers in the printing industry discovered that co-exposure to lead and noise resulted in elevated MDA levels. These studies collectively emphasize the detrimental effects of lead and noise exposure on health and underscore the need for further research to elucidate the mechanisms of oxidative stress induced by these environmental stressors [17].

Numerous studies have established a direct relationship between noise-induced hearing loss and levels of oxidative stress [18, 19]. Additionally, research has demonstrated that exposure to lead induces oxidative stress in the human body [20]. Oxidative stress refers to an imbalance between antioxidants and the production of reactive oxygen species (ROS) [21]. Excessive production of ROS, triggered by occupational stressors such as noise exposure, can result in heightened lipid peroxidation (LOP), oxidation of proteins and nucleic acids, and DNA damage [22]. Exposure to noise has been found to enhance the generation of free radicals. With growing exposure levels, there is a corresponding rise in the levels of malondialdehyde (MDA), catalase (Cat), and total antioxidant capacity (TAC) enzymes [23-25]. MDA, a highly toxic byproduct of lipid peroxidation, hinders the activity of antioxidants in the body [26, 27]. A study conducted in a printing press in Mexico City examined the potential simultaneous effects of lead and noise exposure on MDA levels among workers. It found that MDA levels increased with higher levels of noise exposure and blood lead concentration [28]. Consequently, MDA is utilized as a biomarker for assessing oxidative stress in the body [29].

Indeed, the existing research on the effects of lead and noise exposure on MDA levels within the printing industry is limited. The underlying mechanisms of oxidative stress induced by these stressors and their cumulative impacts on MDA levels remain challenging to fully comprehend. Further research is necessary to develop a comprehensive understanding of the effects of lead and noise exposure on MDA levels and overall health. Based on the aforementioned gaps in knowledge, the objective of this study is to examine the concurrent effects of lead and noise on MDA levels among workers in the printing industry. By examining these associations, the study aims to contribute to the existing scientific literature and provide insights into the potential health risks faced by printing industry workers.

Materials and Methods

Work Environment and Samples: This case study was conducted in 2019 and involved a total of 80 male workers employed in a printing industry located in the western region of Tehran province, Iran. The study excluded workers in service and office units, such as the kitchen and security departments, as these units were not exposed to noise. However, manufacturing units, including the die-cut, glue, and boxing units, were exposed to noise levels exceeding 85 dBA. Further, workers in the printing unit were exposed not only to noise but also to lead fumes. Throughout their working hours, all participants in this study were exposed to lead particulate matter. Individuals who had worked for less than one year in the printing establishment were excluded from the research. In accordance with ethical considerations and to minimize any potential adverse effects, blood sampling was conducted as part of the workers' routine annual testing. During the workers' routine annual blood testing, they were approached and provided with a consent form, which outlined the details of the study and their voluntary participation. The study was conducted in adherence to ethical guidelines and was approved by the Iran University of Medical Sciences under the ethics code IR.IUMS.REC.1397.828. This code ensures that the study was carried out in accordance with the ethical standards and regulations set forth by the institution. Obtaining informed consent from the participants is an essential aspect of conducting ethical research.

MDA concentration in the plasma: The concentration of malondialdehyde (MDA) in the plasma was determined using the method described by Buege and Aust [30]. Firstly, a TCA-TBA-HCL solution was prepared, which consisted of 15% thiobarbituric acid (w/v), 15% trichloroacetic acid (w/v) at a concentration of 0.375%, and 0.25 N hydrochloric acid. Next, 1 ml of each plasma sample was mixed with 2 ml of the TCA-TBA-HCL solution. The samples were then subjected to boiling in a laboratory water bath for 15 minutes. After removing the tubes from the water bath, they were rapidly cooled using cold water and centrifuged for 10 minutes. The supernatant was carefully separated, with its absorbance measured at a wavelength of 535 nm using a Model CE 1010 CECIL series 1000 spectrophotometer. The absorbance values were compared with blank samples that contained all the components except red blood cells (RBCs). Finally, the concentration of MDA was calculated using its extinction coefficient of 105 * 1.56 M^-1cm^-1 and reported in mmol/lit.

Lead concentration in the whole blood: The concentration of lead in whole blood was analyzed following the NIOSH 8003 method. Blood samples were collected in 6 ml tubes containing EDTA K2 (Ethylenediaminetetraacetic acid K2) and stored at 4 °C for 3 days. To prepare the specimens, 2 ml of whole blood sample was mixed with 0.8 ml of ammonium pyrrolidinedithiocarbamate-Triton X100 (APDC-TX) surfactant solution. The APDC-TX surfactant solution was prepared using ammonium pyrrolidinedithiocarbamate (CAS No: 5108-96-3) and Triton X100 (CAS No: 9002-93-1) obtained from TITRACHEM. Subsequently, 2 ml of aqueous saturated methyl isobutyl ketone (MIBK) (CAS No: 108-10-1) obtained from Merk was added to the centrifuge tubes. The tubes were then centrifuged for 10 minutes at 2000 rpm using a centrifuge machine (model D-7200 manufactured by Hettich company, Germany). Finally, all the specimens were analyzed using an atomic absorption spectrometer model GF 5000 manufactured by GBC company, equipped with a graphite furnace manufactured in Australia [31].

Measurement of noise exposure in the work environment: To achieve an equivalent sound pressure level (Leq) in each unit separately, a sound level meter was used for noise measurement. The measurement was conducted in accordance with the ISO 9612:2009 standard method, which takes into account the participants' tasks and their daily noise exposure level. The assessment of noise in each unit was carried out following interviews with the participants, during which their routine tasks on a regular work shift and the total time spent on each task were recorded. A sound level meter from TENMARS ELECTRONICS CO., LTD, specifically the TM 103 Series manufactured in Taiwan, was utilized for the measurements. The Leq was recorded for each task over a duration of 15 minutes [32]. The uncertainty of the noise exposure level measurement was calculated using the ISO standard for job-based measurement (ε). The equation applied for calculating the daily personal noise exposure level (LEp,d) is as follows:

Formula 1.

$$L_{Ep,d} = 10 \times \log \frac{1}{8}\left(t_1 \times 10^{\frac{L_1}{10}} + t_2 \times 10^{\frac{L_2}{10}} + \cdots\right)$$

The data were analyzed using SPSS 20.0 software. Pearson correlation and ANOVA tests were employed to analyze the data. The Kolmogorov-Smirnov test was used to check the normality of the data. Continuous quantitative data (blood lead level and blood malondialdehyde level) followed a normal distribution (p=0.083 and p=0.200 respectively). The results were reported as mean ± standard deviation (M±SD). The significance level for correlation analysis was set at $p < 0.01$, indicating that correlations with p-values below this threshold were considered statistically significant.

Results

The study included a total of 80 male participants. The age range of the participants was between 24 and 56 years, with a mean age of 34.20 ± 7.09. The majority of the participants fell into the age group of 30-40 years, comprising 62.5% of the sample. Regarding educational background, the highest proportion of workers (N = 52, 65%) had completed high school. In terms of work experience, 72.5% of the workers (N = 58) had less than 10 years of experience. Additionally, 60.8% (N=48) of the participants reported working for 8 to 15 hours per day. Among the workers, the majority had a body mass index (BMI) greater than 25 kg/m2, with 52 individuals (65.8%) falling into this category. The mean systolic blood pressure was 115.37 ± 6.35, while the mean diastolic blood pressure was 65.68 ± 8.52.

The analysis revealed that there was no significant linear correlation between age and blood lead levels in the samples (P = 0.736; rs = -0.038). Similarly, no significant linear correlation was found between systolic blood pressure and blood lead levels (P = 0.738; rs = 0.038), as well as between diastolic blood pressure and blood lead levels (P = 0.463; rs = 0.083). Furthermore, no significant positive correlation was observed between body mass index (BMI) and blood lead levels (P = 0.529; rs = 0.071). These results indicate that there was no significant relationship between age, blood pressure, BMI, and blood lead levels in the samples analyzed.

The one-way ANOVA test revealed a significant difference in the mean concentration of MDA among various work units (P < 0.001), indicating that the MDA concentration varied across different work units. Additionally, the Pearson test indicated a significant positive relationship between blood lead concentration and MDA concentration (P = 0.622; rp< 0.001). This suggests that higher blood lead concentrations were associated with elevated MDA concentrations. However, no significant relationship was found between daily noise exposure (LEp,d) and blood lead concentration (P = 0.703), indicating that daily noise exposure did not have a significant impact on blood lead levels. Similarly, there was no significant relationship between daily noise exposure (LEp,d) and MDA concentration (P = 0.857) either, suggesting that daily noise exposure did not significantly affect MDA levels. These findings are summarized in Table 1.

Table 1. Correlation and relationship between MDA concentration, blood lead levels, and daily noise exposure

		MDA concentration	Blood lead level	Daily noise exposure
MDA concentration	Pearson correlation	1	0.622**	0.020
	sig. (2-tailed)		0.000	0.857
	N	80	80	80
Blood lead level	Pearson correlation	0.622**	1	0.043
	sig. (2-tailed)	0.000		0.703
	N	80	80	80
Daily noise exposure	Pearson correlation	0.020	0.043	1
	sig. (2-tailed)	0.857	0.703	
	N	80	80	80

**. Correlation is significant at the 0.01 level (2-tailed)

According to the results, the daily noise exposure in the die-cut unit was significantly higher compared to the other units, with an average of 87.71 ± 1.469 dB. The overall average daily noise exposure across all units was 84.632 ± 9.55 dB.

Regarding lead concentration, the printing unit had a significantly higher mean concentration compared to the other units, with a value of 0.1431 ± 0.02 ppb (Table 2). The overall mean concentration of lead across all units was 0.0847 ± 0.049 ppb.

Table 2 reports the mean concentration of MDA in different units of the printing house. The results indicate that the MDA concentration in the printing unit was significantly higher compared to the other units, with an average of 0.9963 ± 0.238 mmol/lit. The overall mean concentration of MDA across all units was 0.499 ± 0.376 mmol/lit.

Table 2. Mean blood serum MDA concentration, daily noise exposure ($L_{Ep,d}$), and lead concentration in different units of the printing house

Units	Number of workers (N)	Mean MDA (mmol/lit)±SD	Mean $L_{E,pd}$ (dBA) ± SD	Mean lead (ppb) ±SD
Administrative	7	0.2716±0.1679	84.7±1.68	0.0595±0.0338
Printing	22	0.9963±0.2380	84.94±3.34	0.1431±0.0208
Diecut	10	0.1723±0.1202	87.71±1.46	0.0692±0.0521
Cutting	2	0.1370±0.0028	85.10±1.13	0.0419±0.0057
Boxing	3	0.1893±0.1480	85.16±1.15	0.0806±0.0525
Gluing	18	0.5411±0.1649	85.83±1.90	0.0665±0.0377
Services	2	0.2290±0.0113	85.05±2.33	0.0545±0.0212
Storeroom	5	0.1738±0.1077	86.36±0.85	0.0547±0.178
Kitchen	2	0.1015±0.0530	84.80±1.97	0.0517±0.067
Security	5	0.3522±0.1076	86.09±2.89	0.0441±0.0247
Repair and maintenance	4	0.1412±0.1064	64.75±4.22	0.0722±0.0466
Total	80	0.4998±0.3762	84.63±9.55	0.0847±0.0490

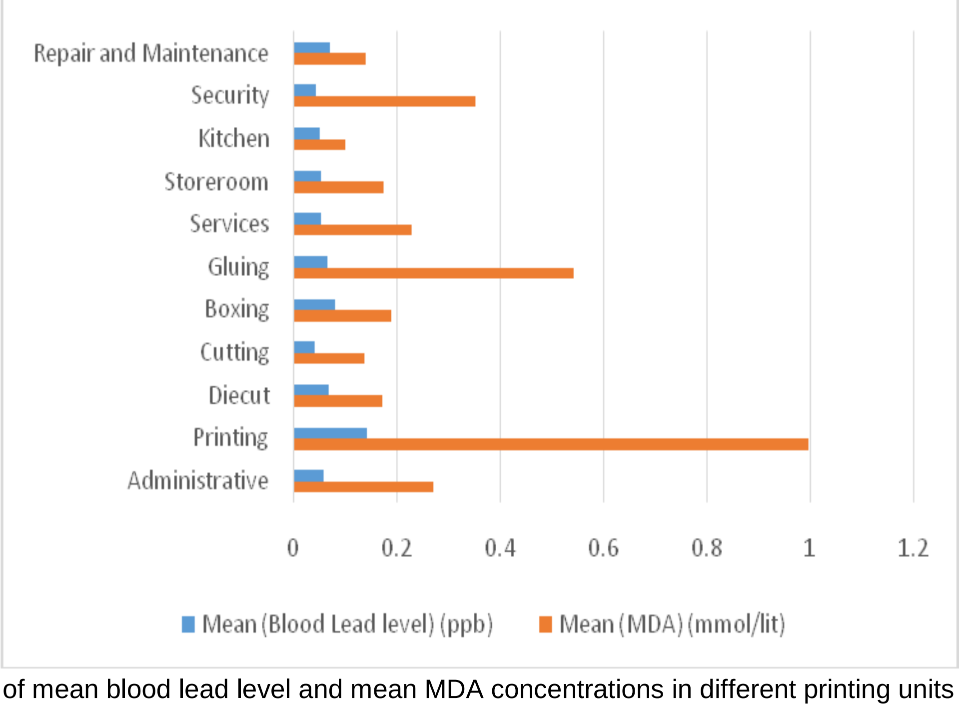

Fig. 1. Comparison of mean blood lead level and mean MDA concentrations in different printing units

Discussion

Employees working in printing houses are exposed to a range of risks and potential hazards associated with their job location and assigned tasks. These hazards encompass exposure to chemicals during the handling of raw materials containers, printing inks, and other chemical preparation processes. Additionally, they frequently come into contact with detergents, cleaners, as well as engage in repair and maintenance activities involving printing machines. Moreover, the proximity to printing machines, which generate high levels of noise, poses significant risks. Thus, a study was conducted to examine the combined impact of lead and noise exposure on the levels of MDA among printing house workers and machine operators.

A significant relationship was observed between the average blood lead concentration and the mean MDA concentration among the workers. Additionally, the study revealed a correlation between the concentration of MDA in the blood serum and the specific working units of the subjects. Notably, the highest concentration of MDA was detected among participants working in the printing unit, potentially attributable to the presence of lead-based chemicals within this unit. Further, the average concentration of blood lead among employees in the printing unit exceeded that of other units, likely due to the utilization of printing inks (see Figure 1). It is important to note that none of the other units employ ink in their processes.

In a study conducted by Bashir Al-Vbaidy et al., a group of 30 workers from a battery plant factory in Iraq, who were exposed to lead, were compared to an unexposed control group comprised of 11 individuals. The researchers found that the lead levels in the exposed employees were 360% higher compared to the control group. Their study clearly demonstrated that lead exposure can induce oxidative stress, as evidenced by elevated levels of MDA in the plasma and erythrocytes of the exposed workers [33]. Therefore, the findings of Bashir Al-Vbaidy and colleagues' research align with the current investigation, supporting the correlation between lead concentration and MDA concentration.

In a separate study conducted by Peraica et al., an investigation was carried out on workers from a battery-producing company who were exposed to lead. The findings of their study indicated a significant rise in MDA levels in the plasma samples of lead-exposed workers compared to the control group (1.895 ± 0.133 mmol/L, $P < 0.05$) [34]. Hence, the research conducted by Peraica et al. aligns with the present study in terms of the association between lead concentration and MDA concentration.

Previous studies conducted by Masroury et al. [12], Kaygusuz et al. [18], and Yildirim [13] have reported an increase in MDA concentration in response to noise exposure. However, this aspect of our findings has not been in accordance with the previous research. Additionally, our results indicated that the work unit played a role in determining the daily noise exposure, with employees in the die-cut unit experiencing the highest levels of noise. Surprisingly, no significant relationship was found between daily noise exposure and MDA concentration in the serum. This suggests that the noise present in this particular printing house may not have an impact on the concentration of MDA in the blood serum.

The current study had several limitations that should be acknowledged. Firstly, the sample size utilized in this study was small. Thus, it is advisable to expand the scope of blood lead monitoring and oxidative stress testing to larger printing facilities with larger sample sizes in order to gain a more comprehensive understanding of the extensive effects of occupational risk factors. Additionally, it is recommended to conduct concurrent studies to explore the association between lead levels in the respiratory air and blood within the printing industry. The presence of lead in the blood can be attributed to various factors, including potential exposure from a second job. Furthermore, given the existence of various units with distinct levels of exposure to different noise and chemical factors, including lead, it is crucial to conduct cohort studies that examine the simultaneous exposure to multiple risk factors.

Conclusion

Overall, there was a significant positive association between the mean concentration of MDA in printing workers and blood lead concentration. However, no correlation was observed between noise exposure, co-exposure to noise and lead, and MDA concentration. These results contrast with previous research findings, highlighting the need for further extensive investigations involving a larger number of printing house workers. It is also recommended to conduct additional studies to explore the impact of lead concentration in the respiratory air on oxidative stress among individuals working in the printing industry. Such research endeavors will contribute to a better understanding of the occupational risk factors associated with these workplaces.

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