Original

Occupational Exposure to Nickel in the Ceramic Workers: Biological Monitoring and Respiratory Outcomes

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Abstract

Background: Nickel (Ni) compounds such as nickel oxide are used as pigments in ceramic industries. The toxicity of nickel can occur in the glaze preparation processes. This study aimed to ascertain whether exposure to Ni dust is associated with pulmonary response. **Methods:** This cross-sectional study was performed on 49 ceramic workers (exposed group) occupationally exposed to nickel dust, as well as 55 unexposed employees (referent group). Information about smoking habits, overtime work, length of employment, skin dermatitis, job title, use of respiratory protection equipment, ventilation system, age, and BMI index were collected through questionnaires. The parameters of pulmonary function were measured. Urine samples were taken from 49 workers at both pre- and post-shift (98 samples). The referent group was examined only once (55 samples). To determine the nickel, the samples were pre-concentrated by Solid Phase Extraction (SPE) and analyzed using inductively coupled plasma-atomic emission spectroscopy (ICP-AES). **Results:** Urinary Ni value in the exposed workers was significantly higher than that in the referent group. All pulmonary function parameters in the exposed group were significantly lower than those of the referent group ($P<0.001$). Those using respiratory protection equipment also exhibited a significantly lower urinary Ni concentration than those not using respiratory protection equipment. **Conclusion:** These findings indicate that exposure to Ni in the ceramic industry is higher than the recommended biological exposure index and is associated with a significant decrement in the pulmonary function parameters.

Keywords: Ceramic workers; Nickel; Spirometry; Urine; Biological monitoring

Introduction

Occupational exposure to Ni may occur from inhaled particulates in mining, milling, smelting, and refinishing industries.[1] Nickel is used in various metal alloys, including stainless steel, batteries, electroplating, catalysts, pigments, and ceramics.[2] Ceramic glazes are a significant source of nickel exposure for the workers. A ceramic glaze comprises clay, kaolin, talc, feldspar, dolomite, zircon, zinc oxide, and lithium carbonate. Glaze in the form of an aqueous suspension of raw materials can be applied to the ceramic body before firing it by brushing, sponging, dripping, or spraying. Glazes prevent cracks, distortions, and other clay surface defects and add mechanical strength to the body. A decoration is critical to the generation of beauty on a wide variety of ceramic ware. For instance, nickel oxides and carbonates produce

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green, blue, or red colors.[3, 4] Human exposure to pigment occurs through a combination of inhalation and skin exposure during weighing, manufacturing, and handling processes. Many studies confirm the association between exposure to nickel dust and increased risk of skin allergies [5-7], and lung cancer in nickel exposed workers.[8-11]

Some studies have shown an increased prevalence of respiratory symptoms and decreased lung functional capacity following occupational exposure to nickel. [12, 13] Up to now, the health consequences of exposure to nickel compounds were not studied among workers of the ceramic industries in Iran. Therefore, the aims of this cross-sectional study were to determine the urinary nickel concentration in the workers compared to the referent group and to compare the parameters of pulmonary function between the exposed and referent groups.

Methods

This study was performed in the ceramic industry. The workers were selected from 39 tile workers and 16 pottery workers with past history and current exposure to ceramic dust. Fifty-five office workers were also chosen in the same workplaces without exposure to nickel as the referent group. All participants in both groups were men and non-smokers. Subjects with a history of exposure to other pulmonotoxic agents, and respiratory illnesses were excluded from the study. The interviewer obtained information recorded on questionnaires about smoking habits, overtime work, length of employment, skin dermatitis, job title, use of respiratory protection equipment, ventilation system, age, and BMI. To determine nickel at the pre- and post workers' work shift (98 samples), Urine samples were collected. The referent group was examined only once (55 samples). Ten ml of urine samples were collected in polyethylene tubes. A solid-phase extraction method developed in a previous study of the authors followed by Inductively coupled plasma-atomic emission spectroscopy (ICP-AES) was used for the analysis of samples.[14]

parameters of pulmonary function (PFT) were measured with a vitalograph spirometer (model 2120). The tests were performed in a standing position, as suggested by the American Thoracic Society (ATS) guidelines. The measured parameters included forced vital capacity (FVC), forced expiratory volume in one second (FEV1), forced expiratory flow (FEF) 25-75, and FEV1/FVC ratios. Statistical analysis was performed using the SPSS version 21 software. The means of quantitative variables were compared using Student's t-test. A paired t-test was used to compare the changes between before and after shift values. Analysis of covariance (ANCOVA) was used to study the variable's effect on after shift measurement after controlling for the before the shift.

Results

The demographic data and the results of the spirometry tests are presented in Table 1.

The average age in the exposed group was 30.98, and for the referent group was 32.53 years. There were no significant differences in demographic data between groups. Pulmonary function test parameters were lower in the exposed group than in the comparison group Table 1. Analysis of the ventilatory function showed significant decrements in all parameters between the two studied groups (P<0.001)Table 1. Urinary nickel concentrations ranged from 0.01 µg/l to 144 µg/l with a mean of 37.61 µg/l at the end of the work shift and 0.01 µg/l to 53 µg/l with a mean of 12.97 µg/l at the start of the work shift. The observed difference was statistically significant (P<0.001) Table 2. There was a significant difference in the mean concentration of nickel between post-shift samples of workers and the referent group (P=0.008)Table 2.

Workers who worked in the evening shift had higher urine nickel than those who worked in the morning shift (41.35µg/l versus 33.40 µg/l) Table 3.

Analysis of covariance showed that after adjusting for pre-shift nickel, the effect of the shift variable was not significant Table 4. Higher urinary nickel concentrations were also found in workers with skin

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dermatitis (44.23µg/l versus 35.22 µg/l). Analysis of covariance showed that the effect of skin dermatitis was not significant Table 4. Workers without respiratory protection equipment and local exhaust ventilation while mixing or handling of glazes had higher levels of nickel than workers with protection (57.50 µg/l versus 26.06 µg/l and 44.56 µg/l versus 21.87 µg/l, respectively). Analysis of covariance showed that only using respiratory protection equipment on the after shift nickel was significant Table 4. The urinary nickel levels of pottery workers were slightly higher than tile workers (38.70 µg/l versus 37.22 µg/l). Analysis of covariance showed that the effect of job title on after shift nickel was not significant Table 4. There was a higher urinary nickel level in the group over work history 61 months than in the group under work history of 61 months (49.87 µg/l versus 22.07 µg/l). Analysis of covariance showed that the effect of overtime work and work history on after shift nickel was not significant Table 4.

Table 1. Demographic characteristics of the studied groups

Variables	Exposed group		Referent group		*P*-value
	Mean	S.D	Mean	S.D	
Age (Year)	30.98	4.89	32.53	6.15	0.14
BMI	25.39	3.28	25.13	3.89	074
Overtime work (hour)	10.15	4.19	9.45	2.37	0.39
Length of employment (month)	51.43	3.32	53.24	5.98	0.27
FVC (liter)	3.99	0.59	4.68	0.52	<0.001
FEV1 (liter)	3.12	0.65	3.95	0.69	<0.001
FEV1/FVC (percent)	81.05	8.23	89.78	4.97	<0.001
FEF 25-75(liter)	3.41	0.78	4.38	0.75	<0.001

Table2. Comparison of means of urinary nickel between pre- and post-shift samples of workers and referent groups

Samples	Mean(SD)	t	*P*-value
Pre-Shift Samples of workers Referent	12.97(15.28) 12.14(14.65)	0.96	0.34
Post-shift samples of workers Referent	37.61(41.90) 12.14(14.65)	2.75	0.008
Pre-Shift samples Post-Shift samples	12.97(15.28) 37.61(41.90)	-3.95	<0.001

Table 3. Comparison of urinary Ni concentration in the pre- and post-shift of the workers by independent variables

Factor		N	Pre-Shift Mean(S.D)	Post-Shift Mean(S.D)
Shift	morning	24	13.50(15.8)	33.40(43.33)
	evening	25	12.48(15.09)	41.35(41.09)
Skin dermatitis	NO	36	11.86(15.5)	35.22(42.72)
	Yes	13	16.08(14.8)	44.23(40.46)
Use of respiratory protection equipment	No	19	14.37(15.56)	57.50(51.27)
	Yes	30	12.10(15.3)	26.06(30.75)
Ventilation system	Non- Standard	36	12.78(15.11)	44.56(46.74)
	Standard	13	13.54(16.37)	21.87(22.12)
Job title	Pottery Glazer	15	14.27(18)	38.70(49.95)
	Tile Glazer	34	12.41(14.19)	37.22(39.40)
Length of employment (month)	≤24	29	12.86(15.78)	22.07(22.47)
	60-25	11	14.35(16.37)	39.30(40.40)
	≥61	9	11.27(13.57)	49.87(54.15)
Overtime work (hour)	No	29	14.69(16.47)	32.10(38.16)
	1-20	11	10.27(14.6)	58.81(54.27)
	21-60	9	10.78(12.66)	29.44(30.92)

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Table 4. Results of analysis of covariance for after shift urinary nickel by independent factors controlled for before shift nickel

Variables	F	*P*-value
Shift	0.33	0.57
Skin dermatitis	0.09	9.76
Use of respiratory protection equipment	8.50	0.006
Job title	0.07	0.80
Ventilation system	3.20	0.08
Work history (month)	1.90	0.16
Overtime work (hour)	1.94	0.16

Discussion

The concentration of urinary nickel in the workers (37.61 µg/l) was 3.1 times greater than that in the referent group and 12.54 times greater than the biological exposure indices recommended by the occupational and environmental health center of Iran (3 µg/l).[15] In agreement with our findings, Tandon et al. reported a high level of nickel in the urine of electroplaters and pigment industry workers compared to the control group.[16] Our study shows that high nickel levels in workers can cause skin dermatitis. In agreement with our results, Fathi et al. (2013) showed skin dermatitis among decorators in the ceramics industry.[17] In our study, exposure to nickel decreased by using standard general ventilation systems and respiratory protection equipment. To reduce workers' exposure to lead, chromiun, and nickel dusts, engineering controls including ventilation systems, and the use of personal protective equipment was recommended by Mousavian et al. (2017).[18] The higher urinary nickel level was found for pottery glazers, probably due to the use of more nickel in the raw material structure and differences in work processes. High values of urinary nickel were also observed in workers with prolonged exposures. The FVC, FEV1, FEV1/FVC, and FEF values for exposed workers were significantly lower than those of the referent group.

Our results show that the ceramic industry's activity is associated with a decline in lung function, but we cannot say this result is only related to nickel. Indeed, in the ceramic industry in addition to exposure to coloring agents such as nickel, exposures to silica may also be associated with decreased parameters of lung function. Previous studies in the ceramic industry have been performed on the effect of silica in the ceramic industry and have shown a significant association between inhalation of silica dust and decreased parameters of lung function. Zarei et al. (2018)[19] and Rasoul et al. (2017)[20] reported that exposure to silica reduces lung functional capacity. Exposure to nickel could occur in the general population when they use glazed ceramics to prepare food. Li et al. (2020) reported that acid foods are more likely to release heavy metals from the ceramic foodware.[21] Calbo et al. (2004) recommended using Mg and Zn and low content of Cr to reduce black pigments' toxicity containing chrome/iron/nickel.[22]

Conclusions

To decrease exposure to nickel, pre-employment examination and previous exposure of workers should be available, and workers with a history of asthma and allergies should have less exposure to nickel dust.

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Conflict of interest statement

The authors declare that there is no conflict of interest.

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