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Occupational Exposure to Heavy Metals in Two Occupational Settings in Jordan

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Abstract: Some occupations involve the exposure of workers to heavy metals. Two occupations were selected dental technicians and welding technicians. The objectives of the present studies are: to study the prevalence of selected heavy metal among workers in Jordan and to correlate the toxicity of selected heavy metals with occupational diseases. Study methodology included constructing a questionnaire to collect data from study participants and measuring heavy metals using atomic absorption spectroscopy. The questionnaire was constructed through reviewing various related studies and validated through pretesting of 20 participants to check for clarity and consistency of answers. Study participants included 50 dental technicians and 51 welders. Participants in control groups were selected from non-exposed workers in each setting. Study findings: among dental technicians, two heavy metals were measured, chromium and cobalt. the mean concentration of chromium is 46.18±58.2 μg dL^{-1} which is significantly (p = 0.003) higher than the mean concentration of control group (17.84±43.45 μg dL^{-1}). The mean concentration of cobalt is 2.23±6.53 μg dL^{-1} which is significantly (p = 0.01) higher than the control group (0.20±0.38 μg dL^{-1}). The mean concentration of chromium among welders is 25.05±14.60 μg dL^{-1} and this is significantly (p = 0.000) higher than the mean concentration of control (15.87±14.52 μg dL^{-1}). About 50% of jewelry technicians reported being affected by diseases which mainly included allergy. Epilepsy (5.88%) and diabetes (13.7%) were reported among welders but not dental technicians. Sensitivity and asthma were more prevalent among welders compared with dental technicians. There is an occupational exposure to heavy metals which have to be periodically checked for technical workers in such occupations not to develop future occupational diseases.

Key words: Heavy metals, occupational exposure, occupational disease, dental technicians, welders

INTRODUCTION

Various effects due to exposure to cadmium have been reported to involve many organs and systems. Acute adverse effects due to overexposure to cadmium have been reported. Currently in most occupational settings, chronic effects are of greater concern. It has been shown that the main symptom is respiratory distress due to chemical pneumonitis and edema. High exposure level of cadmium (40-50 mg m^{-3} for 1 h) was shown to cause death (Hathaway *et al*., 1991). The current cadmium tolerable intake standard established by the Joint Expert Committee on Food Additives (JECFA) of WHO is 25 μg kg^{-1} of body weight per month (mg kg^{-1} bw/mo). Average cadmium intakes are about 5 mg kg^{-1} bw/mo.

Chronic occupational exposure to cadmium is likely to be associated with an increased occurrence of lung cancer, kidney damage and chronic obstructive lung disease (WHO, 1992). It is believed that the kidney is the organ most sensitive to the toxic effects of cadmium and kidney damage due to cadmium exposure occurs when cadmium accumulates in the kidneys. This damage is progressive over time and is irreversible reaction. Chronic lung injury also develops in workers in relation to the period and level of exposure. But the effects on the lung occur quite slowly. The exposure level at which these effects occur is unknown Anyhow, the define level of exposure linked with lung damage is thought to be above that which causes kidney damage NIOSH (1992). According to the National Institute for Occupational Safety and Health (NIOSH), cadmium is considered to be a potential human carcinogen NIOSH (1984). Both of lung and prostate cancers have been of concern. Although, the evidence linking overexposure to cadmium with lung cancer is strong, the evidence linking cadmium exposure with prostate cancer is weaker (Thun *et al*., 1991).

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In humans, inhalation of copper fume has been shown to induce irritation of the upper respiratory tract, metallic or sweet taste and discoloration of the skin and hair. Copper fume exposure is associated with metal fume fever, an acute 24-48 h illness characterized by influenza-like symptoms including fever, chills, sweating, weakness, headaches, muscle aches and dryness of mouth and throat (ACGIH, 1999).

Kronenberger *et al.* (1981) conducted a clinical study of dental laboratory technicians from Germany, the sample included 250 dental technicians and 70 volunteers. They found that half of participants complained of respiratory symptoms; pneumoconiosis was noted on 27 chest radiographs. They also found that 21 had a fiber optic bronchoscopy and interstitial fibrosis was noted in 12 biopsies; the lesions were topographically located near dust deposits.

Several reasons are beyond the utilization of cobalt and chrome in non-precious dental alloys. These reasons include availability and being inexpensive compared to conventional gold alloys. Furthermore such alloys exhibit an inferior corrosion resistance (Reclaru *et al.*, 2004).

Chromium exhibits several biological roles. Trivalent chromium is included as a nutritional constituent for a large group of organisms (Hogan, 2010). In addition, trace amounts of trivalent chromium affect sugar and lipid metabolism in human. Moreover, its deficiency is assumed to lead to a chromium deficiency (Mertz, 1993). Other chromium states as hexavalent chromium is proved to be very toxic and mutagenic when inhaled. Moreover, other states have not been recognized as a carcinogen when in solution, even though it may cause allergic contact dermatitis (Tox FAQs, 2001).

It has been recommended to lower daily chromium intake in the United States from 50-200 μg for an adult to 35 μg (adult male) and to 25 μg (adult female) (Vincent, 2004).

Cobalt is one of the essential elements in the body. It is required to form cobalamin, vitamin B12. Its deficiency causes anemia (Haloi *et al.*, 2010). Vitamin B12 is essential for thymidine synthesis and ultimately, DNA biosynthesis and the transcription process itself Yukinori (Kusaka *et al.*, 2001). Irrespective of the fact that cobalt is an essential element in little quantities, it has been estimated that soluble cobalt salts are toxic and the LD50 is in a range between 150 and 500 mg kg^{-1} (Barceloux, 1999). Cobalt has been associated with contact dermatitis and is known as carcinogenic (Basketter *et al.*, 2010). It has also been reported to cause beer-drinker's cardiomyopathy after the addition of cobalt to beer to stabilize the beer's foam (Barceloux, 1999).

Welding is considered the principal industrial process used for joining metals. It has been shown that 0.2-2% of the total workforce is engaged in welding in industrialized countries. Furthermore, welding workers are exposed to fumes and gases which may be hazardous to their health (Stern, 1981). Welders usually used mild steel in welding process but welding of stainless steel and high performance alloyed steel is also widely practiced. It is probably that a large number of welders use the most common welding Methods, Manual metal Arc (MMA) and Metal Active or inactive Gas (MAG or MIG) are exposed to welding fumes at concentrations far exceeding the threshold limit values proposed by the National Institute of Security and Health (Stern *et al.*, 1986).

It has been shown that welding may have deleterious effects on the male reproductive system. By two case-control studies of infertile couples, it was found an increased risk of reduced semen quality (Rachootin and Olsen, 1983; Mortensen, 1988). Other studies showed associations between paternal exposure to welding and delayed conception and reduced fertility (Bonde, 1990). Other effects due to a long-term exposure of welders to welding fumes include various diseases of a respiratory system (Sinczuk-Walczak *et al.*, 2001). The airways are the main route by means of which dusts enter a human body.

Pneumoconiosis may affect welders as early as after several years of work and is considerably more common in case of welders working in small or badly ventilated rooms rather than in case of those who work outdoors. Asthma and bronchitis incidenence rates are increased among welders. Other illnesses may occur simultaneously as diseases of nervous, cardiovascular or digestive systems (Matusiak and Wycislik, 2009). Other reports showed that several cases of acute poisoning resulting from heavy exposure to one or more welding fume or gas were documented.

It has been reported that core and filler metals are usually made of alloy similar in chemical composition to the materials being welded. The most commonly used material is mild steel. Special steels usually have chromium, nickel, molybdenum, aluminum, cobalt, vanadium or tungsten. Chromium is the main constituent in stainless steel electrodes, up to 26% while nickel (21%) while manganese content is about 14%. In high chromium hard facing electrodes, the chromium content may contain up to 30% chromium, present as chromium metal and chromium carbides.

Study hypothesis: We hypothesized that there is an occupational exposure to heavy metals due to the involvement of heavy metals within processing of items related to dental technician's process and welding process. We also hypothesized that occupational diseases may be related to occupational exposure to heavy metals.

Study objectives: The present study was conducted to achieve the following objectives:

- To explore occupational exposure of welders at Irbid industrial city and dental technicians working at Jordan University of Science and Technology to selected heavy metals
- To explore the prevalence of occupational diseases among participants at mentioned occupational settings

MATERIALS AND METHODS

Study questionnaire: Study questionnaire was constructed through reviewing related studies in literature. It included two main parts: demographic part and occupational part. Questionnaire was pretested by distributing it to 20 participants to check for clarity, the time required for its filling and changes required in questions. The final form of questionnaire was established and ready to be distributed.

Study design: A cross sectional study was designed to collect data from all participants at the same time frame.

Study setting: The present study was conducted in the following places: Dental laboratories in Dental Teaching Centre-Irbid, dental laboratories at Faculty of Dentistry at Jordan University of Science and Technology and several private dental laboratories in Irbid city. workers in welding in Irbid Industrial City were also recruited to participate in this study.

Private dental laboratories were listed and selected using stratified random technique so that four sites in which laboratories are distributed were determined and from each two laboratories were selected.

Control group was selected from non-exposed workers in each setting. For dental technicians, medical technologist were selected as a control group and for welders, control group included mechanical workers.

Study sample: The present study included 50 dental technicians and 51 welders.

Data collection: Relevant data and urine samples were collected from both study and control groups after signing informed consent. The consent form was approved by the institutional review board at Jordan University of Science and Technology. Various settings were visited and informed about research in terms of objectives, volunteer participation and research methodology.

Sample analysis of heavy metals: The concentrations of heavy metals under study were analyzed by Atomic Absorption Spectrophotometer (AAS) which allow for the measurement of a wide range of concentrations of metals in biological samples.

Statistical analysis: Collected data were analyzed by Chi-Square test, frequency, percentage and t-test using statistical package for the social sciences SPSS (Version 16, SPSS, an IBM Company, Chicago, USA). $p = 0.05$ was considered statistically significant.

RESULTS AND DISCUSSION

Using of protective tools during working by welding and dental technicians: As shown in Table 1, the use of hearing tools was reported by about 8% of welders and 32% dental technicians. Protective coat was reported to be used about 45% of welders and by 68% of dental technicians. Wearing gloves was reported by about 53% of welders and 56% of dental technicians. Protective glasses were more used by welders (about 80%) compared by dental technicians (50%). Protective shoes were mainly used by welders (about 59%) compared by dental technicians (2%). Head cap was also more used by welders (about 73%) compared by dental technicians (about 11%). Welding glasses were more used by welders (about 86%) compared by dental technicians (28%). The use of face mask was reported to be about 45% by welders and 42% by dental technicians.

Work related risk factors among welding and dental technicians: As shown in Table 2, about 78% of welders reported the exposure to gases and 64% of dental technicians reported the same exposure. Exposure to metal gases was reported by about 92% of welders and 66% of dental technicians. Exposure to thermal variations cold/heat was reported by about 78% of welders and 60% of dental technicians. Living closed to factory was higher among welders (about 59%) than dental technician (4%). Smoking was reported by about 27% of welders and 24% of dental technicians.

Diseases experienced by welders and dental technicians: As shown in Table 3, various diseases were reported by welders and dental technicians. Epilepsy was reported by about 6% of welders, diabetes was also reported by about 14% of welders. About 53% of welders reported having sensitivity while 28% of dental technicians reported having sensitivity. Asthma was more prevalent among welders (about 43%) than dental technicians (2%).

The concentration of heavy metals among welders and dental technicians: As shown in Table 4, two heavy meals were measured Chromium and Cobalt. The

mean concentration of Chromium among welder is 25.05±14.60 μg dL^{-1} and this is significantly (p = 0.000) higher than the mean concentration of control (15.87±14.52 μg dL^{-1}). Among dental technicians, the mean concentration of Chromium is 46.18± 58.2 μg dL^{-1} which is significantly (p = 0.003) higher than the mean concentration of control group (17.84±43.45 μg dL^{-1}). Cobalt was measured for dental technicians and its mean concentration is 2.23± 6.53 μg dL^{-1} which is significantly (p = 0.01) higher than the control group (0.20±0.38 μg dL^{-1}).

The present study was conducted to explore the impact of occupational exposure to some heavy metals in Jordan. Two occupations with potential exposure to heavy metals were chosen and included dental technicians and welders.

Regarding dental technicians, the data of the present study showed that concentrations of Co and Cr clearly reflect recent exposure; this due to the fact that concentrations may fluctuate with emotional changes, the time of day, sample taken or foods eaten prior taking the sample (Laker, 1982; Gerstenberger *et al*., 1997; Chowdhury *et al*., 2000). The data showed significant exposure among dental technicians compared with control (p = 0.02). Actually, based on this finding, it can be concluded that working conditions lead to over exposure of dental technicians to the gases. Similarly, this is applied for other work risks factors including metal gases, noise contamination and cold/heat stress conditions. In all cases, dental technicians have higher exposure to adverse occupational conditions compared with control group (p<0.05 in all cases). Taken together, the previous conditions reflect various sources for direct contact with heavy metals during work.

The data in the present study showed that the mean concentration of chromium for dental technicians was higher than that of control group. Similarly, the mean level of cobalt for dental technicians was higher than that for control group. Such findings are due to the nature of the work and to the environment of laboratory. Dental technicians expose to heavy metal through inhalation and

Table 1: The use of protective tools during working (welding and dental technicians)

	Welders		Dental technicians	
Variables	Frequency (N)	Percentage	Frequency (N)	Percentage
Hearing tools				
Yes	4	7.84	16	32.00
No	47	92.19	34	68.00
Protective coat				
Yes	23	45.10	34	68.00
No	28	54.90	16	32.00
Gloves				
Yes	27	52.90	28	56.00
NO	24	47.10	22	44.00
Glasses				
Yes	41	80.40	25	50.00
No	10	19.60	25	50.00
Shoes (protective)				
Yes	30	58.82	1	2.00
No	21	41.18	49	98.00
Head cap				
Yes	19	10.00	10	11.47
No	32	37.30	40	88.53
Welding glass				
Yes	44	86.30	14	28.00
No	7	13.70	36	72.00
Face mask				
Yes	23	45.10	21	42.00
No	28	54.90	29	58.00

Table 2: Work Related Risk Factors (welding and dental technicians)

	Welders		Dental technicians	
Variables	Frequency (N)	Percentage	Frequency (N)	Percentage
Gases				
Yes	40	78.40	32	64
No	11	21.60	18	36
Metal gases				
Yes	47	92.20	33	66
No	4	7.80	17	34
Cold/heat				
Yes	40	78.43	30	60
No	11	21.57	20	40
Living closed to factory				
Yes	30	58.82	2	4
No	21	41.18	48	96
Smokings				
Yes	14	27.46	12	24
No	37	72.54	38	76

Table 3: Diseases experienced by welders and dental technicians

	Welders		Dental technicians	
Variables	Frequency (N)	Percentage	Frequency (N)	Percentage
Epilepsy				
Yes	3	5.88	0	0
No	48	94.12	50	100
Diabetes				
Yes	7	13.70	0	0
No	44	39.30	50	100
Sensitivity				
Yes	27	52.94	14	28
No	24	47.06	36	72
Asthma				
Yes	22	43.10	1	2
No	29	56.90	49	98

Table 4: The concentration of heavy metals among welders and dental technicians

	Welder			Dental technicians		
Heavy metal (μg dL^{-1})	Study	Control	p-value	Study	Control	Study
Chromium	25.05±14.60	15.87±14.52	0.000	46.18±58.2	17.84±43.45	0.003
Cobalt				2.23±6.53	0.20±0.380	0.010

skin absorption when making dental prosthesis such as crown, bridge and metallic removable partial denture framework; in addition, the environment of dental laboratory may have airborne contamination from dust and metals. The result of this study are in line with the findings by Afridi *et al.* (2006) which indicate a correlation of heavy metals in biological samples (blood, urine and hair) with respect to the duration of exposure time among workers of steel mill.

Our data regarding welding technicians showed that the mean chromium level was 15.87 μg dL^{-1} with SD+14.52 and 25.05 μg dL^{-1} with SD+14.60 μg dL^{-1} for control group and welders, respectively. The results showed a significant correlation between exposure level between welder group and control group ($p = 0.000$). The findings of the present study are in line with other studies in which it was reported that welders are exposed to Chromium and subjected to adverse health effects. On this trend of research, several researchers Pritchard *et al.* (2001), Waalkes *et al.* (2000) and Carlisle *et al.* (2000) reported that Cr VI exposure leads to various cellular interferences such as cell cycle arrest, neoplastic transformation or apoptosis induction depending on cell type, concentration of the metal and time of exposure.

CONCLUSION

The results of the present study showed that Chromium level is correlated significantly with sensitivity ($p = 0.03$). These findings agree with other reported results in literature in which it was shown that effects due to a long-term exposure of welders to welding fumes include various diseases of a respiratory system (Bonde, 1990).

A significant correlation between chromium level and smoking ($p = 0.015$) was shown. These findings agree with other results in which it was recommended that ongoing workplace measures to reduce exposure to metal fumes and promote smoking cessation should be reinforced (Wong *et al.*, 2010).

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