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Alteration of saliva and serum concentrations of manganese, copper, zinc, cadmium and lead among career welders

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Abstract

Human saliva offers a unique noninvasive approach for populational study. Purposes of this study were to investigate the feasibility of using saliva manganese (Mn) concentration as a biomarker of Mn exposure among career welders and to study the variations of Mn, copper (Cu), zinc (Zn), cadmium (Cd), and lead (Pb) in saliva as affected by the welding profession. Forty-nine male welders, of whom 28 were in the low exposed group and 21 in the high exposed group, were recruited. Control subjects were 33 military soldiers without metal exposure. Ambient Mn levels in breathing zones were 0.01, 0.24 and 2.21 mg/m^3 for control, low, and high exposed groups, respectively. Saliva samples were collected to quantify metals by inductive coupled plasma mass spectrometer (ICP-MS). Saliva concentrations of Mn and Cu were significantly higher in welders than in controls ($p < 0.01$); the variation in saliva levels appeared likely to be associated with airborne Mn levels among study populations. Saliva levels of Zn were significantly lower in welders than in controls ($p < 0.05$), while Cd and Pb levels in saliva were unchanged. Significant associations were observed between saliva and serum for Mn ($r = 0.575$, $p < 0.05$) and Cu ($r = 0.50$, $p < 0.05$). Moreover, saliva Mn concentrations were higher among welders with 5–10 years of employment than those with less than 5 years of employment. Linear regression analysis revealed a significant correlation between saliva Mn and Cu and between saliva Mn and Zn. Taken together, these data suggest that Mn concentrations in saliva appear reflective of welders' exposure to airborne Mn and their years of welding experience. respectively. Elevated Mn levels among welders may alter the homeostasis of Cu and Zn.

Keywords: Saliva; Welders; Manganese; Copper; Zinc; Cadmium

1. Introduction

The relationship between manganese (Mn) exposure and Parkinsonism has long been established (Mena et al., 1967; Barbeau et al., 1976; Tanner, 1989; Wang et al., 1989). In severe cases, the patients exhibit extrapyramidal disorders, such as imbalance in walking or on arising and tremor (Inoue and Makita, 1996; Jiang et al., 2006). Noticeably, the symptoms of Mn intoxication, once established, usually become progressive and irreversible, reflecting to some extent the permanent damage of neurologic structures. Thus, the early diagnosis is crucial for prevention of Mn intoxication in occupational and environmental settings.

Previous studies from this laboratory has determined trace metal concentrations, such as Mn, iron (Fe), zinc (Zn), copper (Cu) and lead (Pb), in serum or the whole blood samples of welders (Li et al., 2004). Serum levels of Mn and Fe are significantly higher among welders

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than control subjects; however, the increase in serum levels of Mn is not associated with welder's employment age. A later study from this group further suggests that serum concentrations of ferritin and transferrin among welders are increased in comparison to controls (Lu et al., 2005). A more recent study from this group has attempted to compare Mn levels in red blood cells (MnRBC) to Mn levels in plasma (MnP) or the whole blood (MnB) among Mn-exposed smelting workers (Jiang et al., 2007). The MnRBC of both exposed workers and controls are significantly higher than the values of MnB or MnP. Interestingly, the pallidal index values (PI) of magnetic resonance imaging (MRI) signals among Mn-exposed workers are significantly associated with MnRBC. While these studies provide the useful information on Mn exposure-related changes of biological parameters, the levels of Mn in saliva as well as the factors that may affect saliva Mn concentrations have never been explored.

Human saliva is produced by salivary glands including parotid, submandibular, and sublingual glands. The daily secretion of saliva ranges between 800 mL and 1500 mL, which contains mainly water (98%), electrolytes, mucus, antibacterial constituents, and various enzymes (Guyton and Hall, 1996; Reznick et al., 2006). In general, the composition of saliva reflects those of typical extracellular fluids; yet the active transport and secretion mechanisms in salivary production processes render the saliva distinctive in its ionic composition. For example, saliva contains much higher quantities of potassium and bicarbonate ions and much less sodium and chloride ions than plasma. Thus, saliva does not simply a replica of serum, but rather it has its own chemical and biochemical properties allowing it for potential uses in clinical diagnosis.

Because of the ready access and noninvasive sampling nature, the saliva serves as an ideal biological matrix alternative to blood samples for large-scale risk assessment in general population. However, the quantitative analysis of metal concentrations in saliva, including Mn, among Mn-exposed welders has not been performed.

This study was designed to test the hypothesis that the concentrations of metal ions in saliva may change as the function of Mn exposure among welders. Specifically, this study was aimed at determining (1) the study sites where Mn exposure could be analyzed in a dose-related fashion, (2) changes in saliva metal concentrations, i.e., Mn, copper (Cu), zinc (Zn), cadmium (Cd), and lead (Pb), in Mn-exposed welders in comparison to non-exposed control subjects, (3) the correlation between the prevalence of the altered saliva metal concentrations and the external Mn exposure indices, and (4) the variations of saliva metal concentrations as the function of metals in serum.

2. Subjects and methods

2.1. Factory and production processes

Two factories were chosen for this study for their intensive, day-to-day indoor welding application. Factory A is located in the northeast of Beijing metropolitan region and manufactures the steel fames for building constructions. The welding workshop has the area 120 m × 60 m, with the height of 12 m. There are windows and fans located near the roof. Factory B is located in Taian, Shandong Province, and mainly constructs oil transportation cylinder tanks. The tank has the diameter of 3 m with the length of 5.5 m. There are two openings on the top of the tank with the diameter of 1 m. The openings were open when the welding was in progress. During the production process, the welders in Factory B work both inside and outside of the cylinder tanks, while welders in Factory A primarily work indoor in the workshop but not inside of a confined space. The electric arc weld has been a primary technique in the welding practice in both factories. The J506, J4303 and J502 are the major welding rods employed and the daily consumption is 5–10 kg/person/day. Both factories are not adjacent to any other metal industries.

Table 1
Summary of demographic data among welders and control subjects

	Control	Welders		
		Factory A	Factory B	Combine
Number of cases	33	28	21	49
Mean age (yr) (95% CI)	29.1 ± 6.8 (18–34)	29.0 ± 9.1 (18–53)	31.7 ± 9.1 (26–45)	30.6 ± 9.8
Years in welding employment (95% CI)	0	4.7 ± 2.4 (0.4–19)	10.3 ± 4.4 (5.8–17)	8.1 ± 3.6*
Initial working age (yr) (95% CI)	21.0 ± 2.9 (18.9–23.2)	21.4 ± 2.5 (18.3–24.5)	22.2 ± 3.9 (19.9–24.6)	22.0 ± 3.5
Smoking (%)	45.5	40.0	46.2	44.4
Alcohol (%)	36.4	40.0	30.1	33.3
Airborne MnO_2 (mg/m^3) (95% CI)	0.01 (0–0.03)	0.24 ± 0.07* (0.01–1.0)	2.21 ± 1.17**,# (0.02–11.1)	0.60**

Data represent mean ± S.D.: *$p < 0.05$, **$p < 0.01$ compared with the control workers; #$p < 0.01$ compared with workers in Factory A.