Research Article

Lead and Mercury Exposure and Related Health Problems in Metal Artisan Workplaces and High-Risk Household Contacts in Thimphu, Bhutan

Adeep Monger and Karma Wangdi

1Royal Centre for Disease Control, Department of Public Health, Ministry of Health, Thimphu, Bhutan
2Occupational Health and Chemical Safety Programme, Public Health Engineering Division, Department of Public Health, Ministry of Health, Thimphu, Bhutan

Correspondence should be addressed to Adeep Monger; adeepmonger11@gmail.com

Received 15 October 2019; Accepted 13 February 2020

Academic Editor: Atish Prakash

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Background. Metal artisans have been using lead and mercury in their settings for centuries. Exposure to these toxic heavy metals causes adverse health effects. We assessed the occupational exposure of metal artisans and their high-risk household contacts at Thimphu, Bhutan. Methods. A cross-sectional study in which 134 metal artisan center employees and 48 high-risk household contacts were tested for blood lead and mercury levels. Sociodemographic data, occupational exposure risk factors, and clinical syndrome related to lead and mercury exposure were further obtained and analyzed using EpiInfo 7.0. Results. The mean age of the metal artisan center employees was 36.02 ± 10.3. The prevalence of elevated blood lead and mercury level was 38.4% and 51.9%, respectively. Significantly higher prevalence of mercury level was observed among the artisans compared to nonartisans (66.97% vs. 16.0%). Among three centers, the goldsmith section of the Department of National Properties had the highest (94.1%). Profession as an artisan, mold designing, performing gold amalgamation, working for >8 hours a day, working for >5 years, and working at home were significant risk factors associated with elevated blood mercury level. Significant association was observed between elevated mercury level and complaints of burning or watery eyes (p = 0.001), anxiety, nervousness, irritability, severe shyness (p = 0.029), muscle aches (p = 0.019), and stomach cramps or pain (p = 0.009). Conclusion. The prevalence of elevated blood mercury level is concerning among the artisans. Advocacy, proper usage of personal protective equipment, awareness on chemical safety, and hazard associated with lead and mercury usage are needed to minimize the exposure.

1. Introduction

Mercury and lead are toxic heavy metals used worldwide causing a huge threat to human and environmental health [1, 2]. The Agency for Toxic Substances and Disease Registry (ATSDR) currently ranks lead and mercury as 2nd and 3rd on their substance priority list based upon the combination of their frequency of toxicity and potential for human exposure [3]. Lead and mercury exposure can occur through the respiratory, gastrointestinal system, and dermal contact [4]. Exposure has toxic effects in almost all organs in the human body as lead and mercury are neurotoxic and cardiotoxic in nature [5, 6]; it affects the gastrointestinal system and causes respiratory illness, hearing loss, and cancer [4, 7]. Lead and mercury exposure is accounted as the most prevalent occupational and environmental health problems globally [2]. Metal artisans are professionals specialized in building traditional ornamental arts and crafts monuments. Lead being highly malleable and ductile, and also due to its density, it is used by the artisans as a weight substitute and to imprint the sculptures into the metals. Mercury is mixed with gold to form an amalgam, which is then applied to metals and sublimed by fire to obtain a rich metallic glow and durable golden appearance. During the subsequent process of fire gold gilding, mercury vapors are released...
posing occupational and environmental health hazards. Metal artisans are at high risk when they are exposed to lead and mercury via various means such as lead-contaminated dust particles, imprinting and grinding of sculptures, mercury amalgamation process posing a significant risk to their health.

The high-risk household contacts of the artisans are also at the risk of developing lead and mercury toxicity through artisan’s contaminated cloths, practicing metal artisan work at home, and living close to the artisan center. Currently, there is a paucity of information on the occupational exposure to lead and Mercury among the artisans and their high-risk household contacts. We, therefore, conducted this study to assess the prevalence of elevated blood level of lead and mercury, associated risk factors, and clinical manifestations in Thimphu, Bhutan.

2. Materials and Methods

2.1. Study Design and Setting. A cross-sectional observational study was conducted among the employees of metal artisan centers and their high-risk household contacts in Thimphu. Thimphu is the capital city in the western region of Bhutan. Three main artisan centers in the study include Department of National properties (DNP goldsmith and bronze section), Dharma Arts and Crafts Centre (Dharma ACC), and Druk Bronze Casting Centre.

2.2. Data Collection and Testing. A standard investigator-administered questionnaire was used to document their sociodemographic characteristics, occupational exposure and safety, and presence of sign and symptoms of lead and mercury exposure. From each participant, 10 ml of venous blood samples were collected in metal-free, evacuated, prescreened, K2 EDTA vacutainer tubes (BD, Franklin Lakes NJ USA). Blood lead and Mercury levels were analyzed using Agilent 7700x inductively coupled plasma mass spectrometry (ICP-MS) as per the method by Ryszard et al. [8].

2.3. Data Processing and Analysis. The data were double-entered into Epi-Data Entry version 3.1 (Epi-Data Association, Odense, Denmark) and exported into EpiInfo 7 for analysis. The prevalence of elevated levels of Mercury and lead levels were expressed in the form of percentages. Univariable analysis was performed to examine the unadjusted association of variables with elevated levels of mercury and lead in blood and presented as odds ratio (95% CI). Unpaired two-tailed t-test was used to determine the potential differences between the means of selected study groups. A p value of <0.05 was considered to be significant.

2.4. Ethical Consideration. Ethical clearance was sought from Research Ethics Board of Health, Bhutan, and the study was conducted only after the approval. Informed consent was obtained from all the participants.

3. Results

3.1. Sociodemographic Characteristics. A total of 177 (134 metal artisan employees and 43 high-risk household contacts) were enrolled in the study. A majority of the study participants was from DNP comprising 58.10%, while Dharma ACC and Druk Bronze Casting Centre employees comprised 32.09% and 9.7%, respectively. The metal artisan employees’ age ranged from 17 to 70 years with the mean age of 36.02 ± 10.3 years, and most of the employees were at the age of 25–34 years. Of 134 employees, 109 were artisans and 25 were nonartisan employees comprising office secretariat, night watchmen, and storekeeper (Table 1).

3.2. Prevalence. Of the total 177 participants, 68 (38.40%) had elevated blood lead levels (>5 μg/dL interpreted as the abnormal level of lead in blood) and 92 (51.98%) had elevated blood mercury levels (>10 μg/L interpreted as the abnormal level of lead in blood), respectively. Although not much difference in the prevalence of elevated blood lead level was observed between the employees of metal artisan center and high-risk household contacts, there was a significant difference in the blood mercury level (Table 2). Stratifying the occupation of the employees with elevated toxic heavy metal profiles, metal artisans (66.97%) had significantly elevated blood mercury level compared to nonartisans (16.0). There was no notable difference in elevated blood lead level observed between artisans (45.87%) and nonartisans (40.0%). Figure 1 illustrates the findings.

Of the three centers, DNP goldsmith section (94.11%) metal artisan employees had the highest elevated blood mercury level followed by Dharma ACC (20.93%). Both DNP and Dharma ACC had high prevalence of elevated blood lead level among its employees: 50.00% and 41.86% compared to the Druk Bronze Casting Centre (Figure 2).

3.3. Risk Factors Associated with Lead and Mercury Exposure. Table 3 shows that working as a metal artisan, working for more than 8 hours in a day, practicing metal artisan work at individual’s home, chronically been exposed as a metal artisan for more than five years, mold designing, and performing amalgamation process were significant risk factors for elevated mercury level. The odds ratio of having an elevated blood mercury level was highest practicing a profession as metal artisan (OR 10.64) followed by performing amalgamation process (OR 5.66). There were no significant associated risk factors elucidated with elevation of blood lead level in this study (data not shown).

Chronic exposure to mercury is associated with elevation in blood mercury level significantly. Figure 3 shows that increase in number of years working as metal artisan increases the blood Mercury level in a dose- and time-dependent manner. The amalgamation process being the most significant risk factor was considered further for correlation of elevated mercury level with the proximity of the last amalgamation process. Figure 4 illustrates that those artisans who performed amalgamation process on a daily basis had 100% elevated blood mercury level with the mean blood
mercury level of 206.58 μg/dL compared to those artisans who are involved in amalgamation process but had interruption in between with increased time gap (days and weeks).

3.4. Clinical Signs and Symptoms Associated with Elevated Blood Mercury Level. Prominent symptoms among employees of metal artisan centers exposed to mercury included burning or watery eyes (58.4%), headaches (58.4%), anxiety, nervousness, irritability, severe shyness (51.9%), and muscle aches (47.3%). A significant association was found between elevated mercury level in the exposed metal artisans and complaints of burning or watery eyes ($p < 0.001$), anxiety, nervousness, irritability, severe shyness ($p = 0.029$), muscle aches ($p = 0.019$), and stomach cramps or pain ($p = 0.009$). Furthermore, above significant clinical manifestations were observed more as their blood mercury level increased in a dose-dependent manner as shown in Table 4.

4. Discussion

This study found extremely high blood level of mercury among the artisans, though elevated level of lead was slightly lesser. Metal artisans are exposed to lead and mercury and are at the risk of developing adverse health effects if proper interventions are not initiated.

The prevalence of lead and Mercury level was 44.77% and 57.46%, respectively. This prevalence reported is in

| Characteristics                                      | Participants $n$ (%) with Blood lead | Blood mercury |
|-------------------------------------------------------|--------------------------------------|---------------|
|                                                       | Normal $^1$                           | Elevated $^2$ | Normal $^3$ | Elevated $^4$ |
| Total (employees of artisan centers + high-risk household contacts) ($n = 177$) | 109 (61.5)                             | 68 (38.4)     | 85 (48.02) | 92 (51.98)     |
| Employees of artisan centers ($n = 134$)             | 74 (55.22)                             | 60 (44.77)    | 57 (42.54) | 77 (57.46)     |
| High risk household contacts ($n = 43$)              | 35 (81.3)                              | 8 (18.6)      | 28 (65.12) | 15 (34.88)     |

$^1$Blood lead <5 μg/dL, $^2$blood lead >5 μg/dL, $^3$blood mercury <10 μg/dL, and $^4$blood Mercury >10 μg/dL.

Figure 1: Prevalence of elevated blood lead and Mercury levels among two different occupational groups.

3.4. Clinical Signs and Symptoms Associated with Elevated Blood Mercury Level. Prominent symptoms among employees of metal artisan centers exposed to mercury included burning or watery eyes (58.4%), headaches (58.4%), anxiety, nervousness, irritability, severe shyness (51.9%), and muscle aches (47.3%). A significant association was found between elevated mercury level in the exposed metal artisans and complaints of burning or watery eyes ($p = 0.001$), anxiety, nervousness, irritability, severe shyness ($p = 0.029$), muscle aches ($p = 0.019$), and stomach cramps or pain ($p = 0.009$). Furthermore, above significant clinical manifestations were observed more as their blood mercury level increased in a dose-dependent manner as shown in Table 4.

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The prevalence of lead and Mercury level was 44.77% and 57.46%, respectively. This prevalence reported is in
comparative with rates ranging from 20.4% to 75.0% for lead [9–12] and 15.0% to 72% elsewhere [11, 13–15]. This possible reason for such variation could be attributed to different setting, cultural context, and environment. The prevalence of elevated blood levels differed significantly between 3 centers, and this is feasibly due to the working environment, number

**Table 3: Risk factors associated with elevated blood Mercury level.**

| Risk factors                        | Elevated Hg level* | OR     | 95% CI          | p value |
|-------------------------------------|--------------------|--------|-----------------|---------|
| Artisan                             | Yes                | 73     | 36              | 10.64   | 3.40–33.33 | 0.003   |
|                                     | No                 | 4      | 21              |         |           |         |
| Mold designing                      | Yes                | 35     | 9               | 3.3     | 1.39–7.83 | 0.005   |
|                                     | No                 | 40     | 34              |         |           |         |
| Amalgamation process                | Yes                | 45     | 9               | 5.66    | 2.37–13.49 | 0.001   |
|                                     | No                 | 30     | 34              |         |           |         |
| Work hour >8 hrs.                   | Yes                | 37     | 13              | 3.13    | 1.45–6.71 | 0.002   |
|                                     | No                 | 40     | 44              |         |           |         |
| Working at home                     | Yes                | 43     | 23              | 1.51    | 0.7–313.77 | 0.002   |
|                                     | No                 | 33     | 27              |         |           |         |
| Working as artisan for >5 years     | Yes                | 67     | 39              | 3.09    | 1.29–7.36 | 0.008   |
|                                     | No                 | 10     | 18              |         |           |         |

* >10 μg/L.

**Figure 2: Comparison of prevalence among three sites.**

**Figure 3: Correlation of elevated blood Mercury and duration of exposure.**

**Figure 4: Elevated Hg level due to proximity of last gold amalgamation.**
of workers at site, and also the amount of mercury and lead utilized daily. The goldsmith section of DNP uses the most mercury in a daily basis than the other two centers, thus utilized daily. The goldsmith section of DNP uses the most of workers at site, and also the amount of mercury and lead utilized daily. The goldsmith section of DNP uses the most mercury in a daily basis than the other two centers, thus utilized daily. The goldsmith section of DNP uses the most mercury and lead among the artisans.

Table 4: Percentage of participants who reported having clinical symptoms related to mercury exposure within the past 6 months of the study on blood mercury level among employees at artisan worksites in Thimphu Bhutan, 2018 (n = 131).

| Clinical symptoms | Participants reporting clinical symptoms occasionally or often by blood mercury level n (%) |
|-------------------|--------------------------------------------------|
|                   | All blood Hg levels (n = 131) | Blood Hg ≤ 10 (n = 55) | Blood Hg > 10 to ≤100 (n = 35) | Blood Hg > 100 (n = 41) | p value |
| Burning or watery eyes | 76 (58.46)² | 25 (46.30)² | 21 (60.00) | 30 (73.17) | 0.001 |
| Headaches | 76 (58.46)² | 27 (50.00)² | 21 (60.00) | 28 (68.29) | 0.081 |
| Anxiety, nervousness, irritability, severe shyness | 68 (51.91) | 25 (45.45) | 18 (51.43) | 25 (60.98) | 0.029 |
| Muscle aches | 62 (47.33) | 22 (40.00) | 15 (42.86) | 25 (60.98) | 0.019 |
| Stomach cramps or pain | 57 (43.51) | 20 (36.36) | 17 (48.57) | 20 (48.78) | 0.009 |
| Increased tiredness | 50 (38.17) | 13 (23.64) | 17 (48.57) | 20 (48.78) | 0.162 |
| Forgetfulness, lack of concentration | 54 (41.22) | 26 (47.27) | 11 (31.43) | 17 (41.46) | 0.602 |
| Metal taste in mouth | 27 (20.61) | 11 (20.00) | 6 (17.14) | 10 (24.39) | 0.725 |
| Decreased hearing | 28 (21.54)² | 12 (22.22)² | 7 (20.00) | 9 (21.95) | 0.928 |
| Clumsiness or tremors | 15 (11.45) | 5 (9.09) | 5 (14.29) | 5 (12.20) | 0.792 |
| Vomiting, diarrhea, or constipation | 23 (17.56) | 13 (23.64) | 6 (17.14) | 4 (9.76) | 0.211 |
| Difficult breathing, shortness of breath | 18 (13.74) | 10 (18.18) | 5 (14.29) | 3 (7.32) | 0.325 |
| Skin rash | 16 (12.21) | 7 (12.73) | 6 (17.14) | 3 (7.32) | 0.577 |
| Increase in salivation (drooling) | 12 (9.23)² | 6 (10.91) | 4 (11.43) | 2 (5.00)² | 0.649 |

¹ Self-reported by the participants, ² missing = 1, and ³ comparison between blood Hg ≤ 10 and > 100 μg/dL.

5. Conclusion

The blood levels of mercury and lead among the artisans are elevated. This could possibly be attributed to work environment, lack of awareness on work place safety, and harmful effects of Mercury and lead and on the need to use PPEs. Therefore, advocacy and awareness training programmes on chemical safety and hazard associated with handling of lead and mercury by metal artisans needs to be organized. Responsible administrators need to ensure
proper usage of PPEs to minimize the exposure. A monitoring programme and supervision is required to tract the activities of metal artisans so that environment is not contaminated via unscrupulous usage. Furthermore, to reduce the exposure to other high risk household contacts, such as vulnerable population and nearby residents, proper identification of safe designated areas for metal artisan practice and stringent rules for not practicing metal artisan work at home are crucial.

Data Availability

The data used to support the finding of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

The authors would like to acknowledge Khesar Gyalpo University of Medical Sciences, Bhutan, Toxicology Laboratory, Ramathibodi Hospital, Faculty of Medicine, Mahidol University of Medical Sciences, Thailand, and Gidakom Hospital for rendering the technical support.

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