Concentrations of Surface-Dust Metals in Native American Jewelry-Making Homes in Zuni Pueblo, New Mexico

MELISSA GONZALES
VALLABH SHAH
University of New Mexico School of Medicine
Department of Internal Medicine
Albuquerque, New Mexico
ARLENE BOBELU
Dialysis Clinic, Inc.
Albuquerque, New Mexico
CLIFFORD QUALLS
University of New Mexico School of Medicine
General Clinical Research Center
Statistics Laboratory
Albuquerque, New Mexico
KATHY NATACHU
JEANETTE BOBELU
EUNICE JAMON
DONICA NEHA
SUSAN PAINE
PHILIP ZAGER
University of New Mexico School of Medicine
Department of Internal Medicine
Albuquerque, New Mexico

ABSTRACT. This pilot study was conducted to identify the metals used by home-based Native American jewelry makers, to quantify the metals in dust samples taken from jewelers' homes, and to compare these concentrations with background levels from control homes in which jewelry was not made. Participants were recruited from Zuni Pueblo, New Mexico. Surface dust samples were collected from the work and living areas of 20 jewelers' homes, and from the living areas of 20 control homes. Silver, copper, tin, boron, nickel, zinc, lead, and cadmium were significantly higher in work areas than in living areas of jewelry-making homes ($p \leq 0.02$). Silver, copper, nickel, and antimony were significantly higher in living areas of jewelers' homes compared with control homes ($p \leq 0.04$). Ventilation measures did not effectively reduce metal concentrations in jewelers' homes; concentrations in nonwork areas remained elevated.

<Key words: jewelry making, metals, Native American, residential exposure, surface dust, Zuni>

SKILLED CRAFTS such as jewelry making are practiced in many Native American communities in the United States. Jewelry making is culturally and economically vital for the Zuni tribe, whose work is known for its intricate designs. Inefficient exposure controls in home-based workshops may result in contamination of the home with byproducts from the jewelry-making process. The extent of metal exposures among home-based jewelers is essentially unknown.

Jewelry making is a potential source of exposure to heavy metals such as lead and cadmium, which are nephrotoxic.[1,2] Among the Zuni, the prevalence of end-stage renal disease is 6 times higher than in other Native American tribes and 20 times higher than in European American populations.[3] The severity and prevalence of renal disease in this population exceeds that expected from known risk factors such as diabetes. To date, no surveys have been conducted to evaluate the extent of environmental exposures, such as those arising from making jewelry, that may contribute to renal disease in this population.

The objectives of this pilot study were (a) to inventory the materials, personal protective equipment, and ventilation measures used by Zuni jewelers in their homes; and (b) to determine whether surface concentrations of metals are higher in jewelry-making households than in households in which no jewelry is made. The effectiveness of ventilation controls for reducing work and living area surface metal concentrations in jewelry-making homes was also evaluated. This study was performed to fill a gap in the existing knowledge regarding the extent of exposure to heavy metals and other potentially hazardous materials among Zuni jewelry makers. The authors hope that the results will aid in the formulation of targeted exposure questions and the selection of monitoring techniques for use in future population studies.

Method

Subjects. Participants were recruited from a previously assembled cohort of 1,500 Zuni tribal members who lived on the Zuni reservation in western New Mexico.[3,4] On the basis of data collected previously from adult (≥18 yr of age) cohort members regarding jewelry making, these individuals were stratified into 2 groups by household. If any household member reported making jewelry, all members of that household were included in the jewelry-making group. Otherwise, family members were classified in the non-jewelry–making control group. Twenty subjects were recruited from each group, one subject per household. The study protocol and informed consent forms were approved by the University of New Mexico Human Research Review Committee, Indian Health Services Institutional Review Board, and the Zuni Tribal Council. Subjects were recruited, and informed consent was obtained, by trained bilingual interviewers who were fluent in both English and the Zuni language (Shiwi). Informed consent was obtained from each participant after the nature of the survey had been fully explained.

Exposure survey. We developed a survey instrument to inventory the chemicals, metals, stones, and other materials used to make jewelry. Questions were also asked about the type and frequency of use of personal protective equipment and ventilation while working. The survey was developed with collaboration from Zuni tribal members who were part of the University of New Mexico field staff for the current study. It was designed to be sensitive to the tribal culture and beliefs and written in lay terms that would be understandable to the study population. A standardized oral translation of the survey was used to interview subjects who preferred Shiwi. Material safety data sheets were obtained from manufacturers or suppliers for each product reported in the survey, and product content and health hazard and safety information was extracted and summarized in a report for the participants.

All 20 jewelers interviewed (5 men and 15 women; mean age ± standard deviation = 43.2 ± 10.7 yr; average time making jewelry ± standard deviation = 22.1 ± 10.9 yr) reported making jewelry inside their homes. Of the 20 non-jewelry–makers interviewed (6 men and 14 women; mean age ± standard deviation = 43.8 ± 12.9 yr), 2 reported living in homes where another member of the household made jewelry, but that other person was not a member of the initial study cohort. These 2 households were subsequently reclassified as jewelry-making homes in the surface metal analyses.

Surface dust samples. The surface dust samples were collected and handled in accordance with standardized protocols.[5,6] A template was placed over the wall and floor areas closest either to the workbench (for work samples) or the dining room table (for living-area samples). A diagonal area of the template was then wiped with Whatman 41 70-mm filter paper (Whatman, Inc., Florham Park, New Jersey). A total of 715 cm^2 surface area was wiped at each location. Twenty-six wipe samples were collected from work areas and 22 from living areas of the 20 jewelry-making homes. Twenty-three samples were collected from living areas of the 20 control homes. Eighteen percent of the samples collected were duplicates obtained by wiping the opposite diagonal of the same template area. All surface wipe samples were analyzed for silver, copper, tin, mercury, nickel, zinc, lead, antimony, cadmium, and boron (a metalloid) by a single analytical laboratory using inductively coupled plasma mass spectrometry and graphite furnace atomic absorption spectrometry.[7,8]

Statistical analysis. Because the distributions of metal concentrations in surface wipe samples were right-skewed, these data were natural log-transformed for parametric analyses. An overall analysis of variance (ANOVA) of the metal concentrations, considered as a profile, found highly significant differences between locations ($p < 0.001$). Therefore, paired *t* tests were used to evaluate the differences between individual metals found in the work and living areas of jewelers' homes. Similarly, 2-sample *t* tests for potentially unequal variances were used to evaluate the differences between individual metals found in living areas of jewelers' and nonjewelers' homes. Two-sample *t* tests were also used to evaluate the effectiveness of ventilation measures in reducing surface metals in jewelers' homes. Data analyses were performed with SAS version 8.2 software (SAS Institute, Inc., Cary, North Carolina).

Results

Survey results. All of the jewelers interviewed (n = 20) reported using sterling silver. Other individual metals and metal alloys such as nickel silver (n = 1), copper (n = 1), and scrap silver (n = 2) were less commonly used. Table 1 shows use of personal protective equipment among the jewelers. Seventy percent or more of participants reported never using safety glasses, dust masks or respirators, face shields, gloves, or protective clothing when they made jewelry. Similarly, ventilation was infrequently used to control exposures while working

Table 1.—Reported Use of Personal Protective Equipment and Protective Clothing by Zuni Jewelry Makers (*n* = 20)

	Protection used?	
Type of protection	Yes	No
Safety glasses	3	17
Safety glasses with side shield	1	19
Dust mask	4	16
Face shield	0	20
Gloves	4	16
Apron	6	14
Coveralls	2	18

Table 2.—Reported Use of Natural and Mechanical Ventilation by Zuni Jewelry Makers (*n* = 20) while Working

	Ventilation used?	
Type of ventilation	Yes	No
Open doors	10	10
Open windows	12	8
Exhaust fan alone	7	13
Exhaust fan with collection bag	7	13

(Table 2). Natural ventilation (i.e., doors and windows open to the outside) was more commonly used than mechanical ventilation (i.e., an exhaust fan alone or with a collection bag).

Metals in surface dust. Table 3 gives the geometric means and 95% confidence intervals of the silver, copper, tin, boron, mercury, nickel, zinc, lead, antimony, and cadmium concentrations detected in living and work area samples. Results of the *t*-test analyses are also presented. All the metals, except antimony and mercury, were significantly higher in work area samples ($p \leq 0.04$) compared with living areas in jewelry-making homes. The concentrations of silver, copper, nickel, mercury, and antimony were significantly higher in jewelry-making than in control homes ($p \leq 0.02$).

Results of *t*-tests indicated that the ventilation methods used by the jewelers significantly reduced the concentrations of only a few metals in jewelry work area samples, as compared with work area samples from jewelry-making homes in which ventilation was not used (e.g., mercury was lower in work areas where fans were used [$p = 0.03$]; boron was lower when exhaust fan/collection bag devices were used [$p = 0.04$]; and copper was lower when open-door ventilation was used [$p = 0.04$]) (data not shown). None of the ventilation methods significantly reduced metal concentrations on surfaces in living areas of jewelers' homes ($p \geq 0.06$).

Discussion

This pilot study quantified and compared the concentrations of metals in the homes of Zuni jewelers and nonjewelers. The concentrations of silver, copper, nickel, and antimony were significantly higher in the living areas of jewelers' homes, compared with control homes ($p \leq 0.04$, *t* test). Silver, copper, tin, boron, nickel, zinc, lead, and cadmium concentrations were significantly higher in work area samples, compared with living areas in jewelry-making homes ($p \leq 0.02$, paired *t* test). Silver and copper are the 2 main component metals in sterling silver alloy, which was used by all the jewelry makers. Silver concentrations were 2 orders of magnitude greater in samples collected from the living areas of jewelry-making homes, compared with the background levels detected in samples from the living areas of control homes. Copper concentrations were 6 times greater. Survey results showed that personal protective equipment was rarely used. Ventilation was used infrequently, and the methods used did not significantly reduce surface dust concentrations of most metals in either work or living areas of jewelers' homes. Our findings indicate that residual metals resulting from jewelry-making in the home pose a potential risk for chronic, low-level exposure to metals.

Information from the material safety data sheets for the products reported in the jewelry-making survey indicated that they contained silver, copper, tin, boron, nickel, zinc, lead, and cadmium. Sterling silver alloy is composed of 92% silver and 8% copper. Nickel silver contains copper, nickel, zinc, and trace amounts of lead. Brazing alloys contain cadmium, copper, silver, and zinc. Solders contain antimony, tin, zinc, and cadmium. Boron is the main constituent of flux and buffing compounds. Although mercury and mercury-containing products were not reported in the survey, mercury was included in the analysis because of its historical use in jewelry making and the significant health risks it poses, particularly to children.

Numerous silica-containing products and stones (e.g., turquoise) were also reported in the current survey. Silica exposure has been associated with impaired renal function and end-stage renal disease, even with little evidence of pulmonary silicosis.[9,10]

Metals from the jewelry-making process contributed in numerous ways to the surface dust deposits in homes. All of the jewelers used compressed-gas torches to heat-manipulate metals; in the process, metals were volatilized and subsequently condensed on nearby surfaces. Mechanical processes that use buffing, polishing, and grinding products—and accidental spills of products such as powdered boric acid flux—also contributed metals to house dust. The inefficient control of airborne metal fumes and dusts can lead to contamination of the work area and nearby rooms in the house. Living areas of the house can also be contaminated when certain jewelry-making tasks are conducted in areas of the

Table 3.—Results of *t*-Tests Comparing Metal Concentrations from Living Areas of Jewelry-Making and Non-Jewelry–Making Homes (*n* = 22 and 18 samples, respectively), and Paired *t*-Tests Comparing Metals in Living and Work Areas of Jewelry-Making Homes (*n* = 26 and 22 samples, respectively)

Metal	Method detection limit (μg/sample)	Sampling area*	$n^{\dagger}$	GM (μg/sample)	95% CI	$p^{\ddagger}$	$p^{\S}$
Silver	0.03	Living: nonjewelry	14	0.04	0.01−0.12		
		Living: jewelry	22	3.86	2.25−6.62	<0.001	
		Work: jewelry	22	10.35	5.36−20.02		0.001
Copper	0.02	Living: nonjewelry	18	0.37	0.24−0.59		
		Living: jewelry	22	2.13	1.36−3.33	<0.001	
		Work: jewelry	22	7.07	3.65−16.24		<0.001
Zinc	0.22	Living: nonjewelry	18	1.18	0.90−1.53		
		Living: jewelry	22	1.40	1.03−1.88	0.41	
		Work: jewelry	22	2.89	1.85−4.49		0.001
Boron	0.25	Living: nonjewelry	6	0.19	0.14−0.25		
		Living: jewelry	11	0.28	0.19−0.42	0.11	
		Work: jewelry	18	0.87	0.51−1.49		0.001
Nickel	0.047	Living: nonjewelry	18	0.10	0.07−0.13		
		Living: jewelry	22	0.17	0.12−0.23	0.02	
		Work: jewelry	22	0.33	0.19−0.55		0.005
Tin	0.35	Living: nonjewelry	16	0.20	0.15−0.26		
		Living: jewelry	21	0.17	0.16−0.19	0.37	
		Work: jewelry	22	0.28	0.21−0.38		0.006
Lead	0.0014	Living: nonjewelry	18	0.07	0.04−0.11		
		Living: jewelry	22	0.08	0.05−0.12	0.68	
		Work: jewelry	22	0.12	0.09−0.17		0.04
Antimony	0.0095	Living: nonjewelry	8	0.007	0.005−0.009		
		Living: jewelry	10	0.020	0.009−0.042	0.02	
		Work: jewelry	17	0.027	0.011−0.065		0.22
Cadmium	0.00325	Living: nonjewelry	7	0.004	0.002−0.007		
		Living: jewelry	11	0.003	0.002−0.005	0.61	
		Work: jewelry	15	0.007	0.014−0.004		0.004
Mercury	0.0008	Living: nonjewelry	4	0.0005	0.0004−0.0007		
		Living: jewelry	12	0.0009	0.0006−0.001	0.02	
		Work: jewelry	16	0.0014	0.0009−0.002		0.08

Notes: GM = geometric mean, and CI = confidence interval.
*A total of 715 cm^2 surface area was sampled in each location.
†Number of homes with samples exceeding the method detection limit for each metal.
‡Comparison of metals in living areas of jewelry vs. control homes. *t*-test. $p < 0.05$ was considered significant.
§Comparison of work vs. living areas of jewelry homes. Paired *t*-test. $p < 0.05$ was considered significant.

home other than the designated work area, as suggested by anecdotal evidence from the current study. We found that home work areas ranged from a separate room to a designated corner of the living area. Cross-contamination from one area of the home to another via clothes and shoes, as well as past jewelry making in the home, are also potential contributors to current levels of surface-dust metals measured in this study. These examples illustrate how metals used in the jewelry-making process can result in surface dust deposits in the home, particularly when efficient ventilation, protective clothing, and other exposure control methods are not routinely used.

Both mercury and lead cause neurological deficits, particularly in children.[11] Lead is also nephrotoxic.[1] Lead-based paint is the main source of lead in house dust.[12] The use of lead-based solders has declined as antimony-tin solders have been introduced to the jewelry-making market. In the current study, the lead levels in all the house dust samples (including the work area samples) were approximately 1/250 of the EPA standard of 40 μg/929 cm^2 surface area.[13] However, Yu et al.[14] reported that low-level environmental lead exposure was associated with accelerated deterioration of renal insufficiency in patients with initial chronic renal disease, no history of occupational lead exposure, and blood lead levels far below the normal range. Mercury concentrations in house dust, although very low, were significantly higher in surface dust samples collected in jewelry-making compared with control homes. Although no mercury products were reported in current use by the jewelers, the low levels of mercury may represent residual amounts remaining from the prior use of mercury-containing gilding and silvering amalgams.[15]

A limitation of this pilot study was that air samples of metals were not collected. Levels of airborne metals measured during jewelry making could better identify the specific source of individual metals, as well as provide information for development and implementation of exposure control measures. We also do not know whether the surface concentrations of metals in the control homes were true background levels, or whether previous jewelry making or other processes might have contributed to the metals currently detected in these homes. In addition, because many of the survey houses had combined living, dining, and kitchen areas, it was not possible to determine the full extent of potential exposures in areas where food is most often prepared and consumed, and ingestion is a likely route of exposure for jewelers and other members of their household. However, because young children crawl on the floor and frequently put their hands in their mouths,[16] they are at risk for ingesting any contaminants in house dust.

The implication for our findings is that all individuals who live in these jewelry-making households are at risk for higher exposure to metals because of home-based jewelry making. Little is known about the health hazards from long-term exposure to these metals. Because the home-based jewelry-making industry is a significant economic and cultural part of many Native American communities in the United States, future research should seek to identify the health effects of chronic exposure to low levels of metals such as those detected in this pilot study. Past research has focused primarily on the nephrotoxicity of individual heavy metals such as cadmium and lead,[2,14] which were found in combination with high concentrations of silver and copper in the current study. Future research may need to consider the combinations of metals found in homes in which jewelry is made.

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Requests for reprints should be sent to Melissa Gonzales, University of New Mexico School of Medicine, Department of Internal Medicine, Division of Epidemiology, MSC 10-5550, Albuquerque, NM 87131.

E-mail: mgonzales@salud.unm.edu

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