Occupational exposure environment, risk factors, and hazard awareness of metal sculptors and artist welders in the U.S.

Professor Serap Erdal1 PhD and Dr. Laurel Berman1 PhD

1Division of Environmental and Occupational Health Sciences, School of Public Health, University of Illinois.

Correspondence: Serap Erdal, Division of Environmental and Occupational Health, Sciences, School of Public Health, University of Illinois, 2121 West Taylor Street, Chicago, IL 60612, USA. Telephone: 312-996-5875. E-mail: erdal@uic.edu

Abstract

Although there have been significant efforts to understand the exposure conditions of industrial welders, artists who weld to create art objects have been overlooked in the past. In order to better understand work environment and occupational health and safety practices of artist welders/metal sculptors, we administered a questionnaire to two sample populations of artists. These populations came from a database of metal sculptors across the U.S., and from attendees of a regional sculptors’ workshop in the Southeastern U.S. A total of 93 national and 23 regional artists completed the questionnaire, with response rates of 81.6% and 79.5%, respectively. The questionnaire sought data on demographics; exposure attributes (type of welding process, base metals, electrodes/wires used); risk factors (exposure time, frequency and duration of welding); work environment (location of workspace, use and type of ventilation in the workspace); and exposure control measures employed (type of personal protective equipment used) and awareness about health hazards associated with welding fume exposures. The most commonly employed welding process and base metal were Metal Inert Gas welding and mild steel, respectively. Although the artists’ workplaces varied, welding in studios, garages, shops, and outdoors was common. Respiratory protection was not consistently used, and was primarily limited to non-welding activities, such as cutting, grinding, and coating application. Our data for exposure time, exposure frequency, ventilation use and type, and PPE use and type indicate that a segment of the artist welder population may potentially be a high-risk population due to longer work hours and a lack of proper ventilation and exposure control measures. It is essential to target this artist population in order to provide occupational health and safety training programmes specifically tailored to their employment needs, to reduce their health risks and to increase health hazard awareness related to their work practices.

Key words: arts, environmental health, exposure, hazard awareness, metals, occupational, sculptor, risk, welders, welding.

Introduction

According to the American Welding Society (AWS), a welding process is “a materials joining process which produces coalescence of materials by heating them to suitable temperatures with or without the application of pressure or by the application of pressure alone and with or without the use of filler material.” There are many different welding processes employed for joining metals such as mild steel (MS), stainless steel (SS), aluminum (Al), and others. However, the Shielded Metal Arc Welding (SMAW) and Metal Inert Gas (MIG) welding using hand-held electrodes and continuous wire, respectively, as the filler metal are the two most commonly employed processes. The concentration and rate of generation of welding fumes depend on welding process employed, and are a function of a number of welding process-specific (e.g., base metal; type, composition and dimension of electrode/wire; type of shielding gas; presence or absence of flux; geometry of joint; welding current and voltage), work environment-related (e.g., volume of space in which welding is performed; efficiency of fume removal by ventilation), and welder-specific (e.g., position, head-angle, technique and skill level of welder) parameters. While amount of fume generated during welding is primarily governed by the welding process employed, base metal and wire/electrode type used often dictates the chemical composition of welding fume. In welding, since vaporized metal, mainly, from consumable electrode/wire fed into the weld, is oxidized by oxygen in air, major components of welding fume are oxides of metals, which pose varying health hazards depending on their toxicity. The most common metal constituents of welding fume and associated health endpoints are: chromium (VI) and nickel/cancer, iron/siderosis, manganese/neurotoxicity, fluorides and cadmium/lung injury, zinc, copper, and cadmium/metal fume fever. In addition to toxic metals, welders are exposed to gaseous pollutants (e.g., carbon monoxide, ozone, and nitrogen oxides) produced during welding. While nitrogen oxides and ozone have adverse effects on respiratory system (e.g., pulmonary irritation, edema, decreased lung function), carbon monoxide exposure decreases oxygen transfer by blood to tissues by forming carboxyhemoglobin and results in symptoms of headache, fatigue, nausea, dizziness in low levels and...
unconsciousness and death at higher levels. In addition, UV radiation exposure and physical hazards are also of concern. Therefore, adverse health effects of welding are associated with various chemical, physical, and radiation hazards. Although mechanisms of toxicity associated with exposure to complex chemical mixture of welding fumes are not completely understood, exposure to welding fumes has been associated with respiratory effects (rhinitis, asthma, chronic bronchitis, emphysema, pulmonary edema, pneumonia, and pulmonary fibrosis), cancer, metal fume fever, effects on the renal system, nervous system, reproductive system, and skin and eye effects (Antonini, 2003; Moulin, 1997; Beach et al., 1996; Bellido-Milla, et al., 1995; Liss, 1996; Wang et al. 1994; Sferlazza and Beckett, 1991). The International Agency for Research on Cancer (IARC) has classified welding fumes as possible human carcinogens (OSHA, 2000).

In order to protect welders from these harmful exposures, the U.S. Occupational Safety and Health Administration (OSHA) requires use of eye and face protection (e.g., welding helmets, face shields), hand protection (e.g., leather gloves), and protective clothing (e.g., leggings) by welders. However, respiratory protection is required only if engineering controls (local or general ventilation systems) are not feasible in the work environment (OSHA 2003).

About 452,000 U.S. workers were employed as welders, cutters, solderers, and brazers in 2002 (BLS, 2004). Census data suggests that more than 800,000 U.S. workers are involved in welding or allied processes full time, while more than one million perform welding intermittently (Zimmer and Biswas, 2001). It is not clear whether artist welders are included in these estimates. According to the U.S. Department of Labor Bureau of Labor Statistics (2004), artists held about 149,000 jobs in 2002. However, this figure includes many different job categories in arts, including sculptors.

Since the 1970s, there has been significant effort to understand exposure conditions and actual exposures of industrial welders. However, artist welders, which include metal sculptors or individuals who weld to create art objects as a hobby or profession, have been overlooked as an occupational subpopulation of interest in this effort. This is evidenced by a scarcity of peer-reviewed scientific publications focusing on exposures and/or health effects observed in this welder subpopulation. The majority of studies published to date are qualitative in nature and focus on health hazards in the arts as a general topic. Our study is the first attempt that we know of with a specific focus on the exposure conditions (e.g., materials used), risk factors (e.g., exposure duration, exposure frequency), exposure control measures (e.g., ventilation type, use of personal protection), and health hazard awareness of U.S. artist welders.

Although scarce, the goal of the existing arts-welding literature is to inform and educate artists about the health effects of welding. As early as 1968, Siedlecki (1968) documented the hazards associated with welding of metal sculpture, including metal fume fever, lung damage, skin and eye burns, gases, radiant energy, electric shock, fire, and eye hazards. McCunney et al. (1987) cautioned that painters and sculptors could experiment with new and untried materials, with unknown potential hazards. Hart (1987) discussed the diverse assortment of health and safety hazards artists and craftspeople might encounter in their jobs, stressing the need for welding safety precautions in the artist studio. Harrison (1989) compared the artist or craft hobbyist to a small, poorly organized company, which would not know the specific health hazards posed by the materials the artists used, and thus would not take appropriate safety measures. Gupta et al. (1991) also postulated that some artists were unknowingly exposing themselves to a wide variety of hazardous materials and chemicals, with the increased risk of exposing their spouses and children if they worked at home. McCann (1992) maintained that few epidemiological studies have specifically examined artists and asserted that, from a public health point of view, there were four main aspects to occupational hazards in the arts: chemicals that are too toxic; inadequate labeling of products; lack of training in schools; and mis-diagnosis of occupational illnesses. Weiss and Lesser (1997) examined metalworking arts in terms of the unique hazards and exposures associated with foundry work, metal fabrication, blacksmithing, and finishing. The authors stated that self-employed artists and their workplaces were not protected by governmental agencies. They advocated for an understanding of problems unique to the metalworking artist's environment, and called for more awareness of potential hazards and a more effective approach to preventive education and management.

These studies demonstrate that the occupational environment of artist welders is poorly understood. In addition, the majority of this subpopulation of welders is self-employed and thus not protected by the regulations enforced by the U.S. OSHA. This is a significant departure from welders who work in manufacturing or industrial environments. Some artist welders may work long hours in poorly ventilated workspaces, in the absence of medical surveillance programmes or effective exposure control practices. Therefore, a segment of the artist welder community can potentially be classified as a high-risk population. However, to develop such a hypothesis, we first must know the work environment, exposure conditions, exposure behavior, health awareness, and exposure control practices of artists. This descriptive study attempts to develop this knowledge base via examination of data obtained through administration of a questionnaire to two distinct sample populations of artist welders in the U.S. In addition, the study aims to develop essential knowledge of exposure parameters (i.e., risk factors) such as exposure time, frequency, and duration to allow future estimation of average daily dose, thus, occupational health risk associated with exposure to total welding fume or fume constituents by welders.
Materials and Methods

We revised a questionnaire that was successfully administered to industrial welders in an earlier study (Vinson, 2005). The revised questionnaire consisted of twenty-six questions, which sought data on the following: 1) demographic information; 2) exposure attributes (e.g., type of welding process, welding base metal, electrode/wire used); 3) risk factors (i.e., exposure time, frequency and duration of welding), 4) work environment (location of workspace, use and type of ventilation); and 5) exposure control measures employed (e.g., type of personal protective equipment (PPE) used); and 6) awareness about health hazards associated with welding fume exposures.

The questionnaire was administered to two separate artist welder sample populations. The first population came from a database of artist welders across the U.S. We created a national database by compiling contact information for individual artists and arts agencies, organizations, or galleries via web-based searches. When completed, the database contained 173 listings. We personally contacted each entry in the database through e-mails, letters, faxes, or telephone calls to finalize the sample population, and to explain the purpose of the study and the content of the questionnaire. Subsequently, we modified the database to remove duplicates and/or incorrect entries (e.g., artists who were sculptors but did not weld; artists who hired other welders to work on their creations; artists whose work involved only casting or grinding). After modification, 114 individual artist welders comprised the national database and were personally contacted at least three separate times. The questionnaire was administered primarily via telephone. This first study sample population is identified as “Group 1 – National Respondents.” We should note that the national database was not constructed through random sampling of U.S. artist welders as it consisted of those well known enough to be listed in websites or those who were members of arts organizations or art galleries. This sample population primarily includes artists whose sculptures are exhibited in public spaces across the U.S.

The second sample population originated from forty-four attendees of a two-day workshop on welding safety and hazards for sculptors from the tri-state area of North Carolina, South Carolina, and Virginia, in October 2004. Thirty-five regional respondents were pre-selected by their attendance in the workshop. The time allocated for the administration of the questionnaire to the regional artists was limited.

Thus, questions regarding awareness of health hazards were not included in the questionnaire for this group. We should note that since Group 2 artist welders were attendees of a safety workshop they may be more aware of health hazards and risk associated with welding fume exposures than others; thus their responses to the survey questions may not be typical.

We statistically analyzed the questionnaire data for these two sample populations of artist welders using descriptive measures to extract information specific to each of the six separate sections of the questionnaire. The underlying statistical distributions for risk factors were obtained using ProUCL Version 3.00.02, developed by the U.S. Environmental Protection Agency (EPA) (2004) and Crystal Ball Version 7.1, developed by Decision Engineering (2005).

Results

A total of 93 artists in Group 1 and 35 artists in Group 2 completed the questionnaire, with 23 non-novice Group 2 questionnaire responses included in the analysis. The response rate of Group 1 was 81.6% (i.e., 93 of the 114 artists). The combined response rate for Group 2 respondents (i.e., experienced and novice artist welders) was 79.5% (i.e., 35 of the 44 artists). A separate response rate for regional experienced and novice artist welders could not be calculated because we had no information on the nine non-responding attendees in terms of their professional experience.

1. Demographic and Sample Population Data: Table 1.0 provides summary demographic data for the two artist welder sample populations. The majority of respondents in Group 1 and Group 2 were males (74% and 83%, respectively). The age ranges for Group 1 and Group 2 were also similar, ranging from 17 to 76. About 56% of the artists in Group 1 were over age 50. Group 2 artists were younger, with about 61% in the 20-50 years of age range and only 13% over age 50. The mean ages of Groups 1 and 2 were 50 and 33, respectively. In terms of welding experience in numbers of years welded, Group 1 had larger variability (SD: 15.07) than Group 2 (SD: 8.88), with means of about 23 and 9 years, respectively. In Group 1, male artists were older and had longer professional experience as welders than female artists (mean age: 52 vs. 44; mean number of years welded: 26 vs. 14).

2. Welding Process/Base Metal/Wire-Electrode Type Employed: Figure 1.0 presents the five main types of welding processes employed by the artists throughout their professional lifetimes, which were: SMAW, MIG welding, Tungsten Inert Gas (TIG) welding, Oxy-Acetylene welding (OAW), and Plasma Arc Welding (PAW). The SMAW, MIG, and OAW processes were used by the majority of the artists in Group 1 and Group 2 (68% to 86%). TIG welding was employed by about half of the respondents in both groups (i.e., 56% of Group 1 and 50% of Group 2). Although a small percentage of Group 2 respondents employed PAW, about half of the...
Group 1 respondents used it routinely. About 50% of Group 1 and 82% of Group 2 artists reported that they most often used MIG welding for their sculptures.

In terms of average numbers of years using a given process throughout the professional lifetime, Group 1 respondents used SMAW and OAW processes about 20 years. The average numbers of years of MIG, TIG, and PAW usage by Group 1 was 13.4, 10.9, and 10.4 years, respectively. There was not a dominant process employed by the Group 2 artists, with average numbers of years spent ranging from 8 years for the SMAW to 4 years for the PAW process.

Figure 2.0 presents the base metals used by the sample populations of artists throughout their professional lifetimes. Bronze, MS, SS, Al, and copper (Cu) were the most commonly used base metals by Groups 1 and 2, with less use of galvanized zinc (Zn) (not shown in Figure 2.0) and brass. The older and more experienced Group 1 artists were also more seasoned in the use of various base metals in their sculptures. The percentage of artists who used MS, SS, bronze, Cu, Al, and brass was 96%, 59%, 45%, 38%, 33%, and 20%, respectively. Titanium, silver, gold, cast iron, and scrap metal use was infrequently reported by Group 1. MS (96%) was also the base metal of choice of Group 2, followed by Al (39%), galvanized Zn (17%), Cu and brass (13%), and SS and bronze (9%). Among the Group 1 artists who welded on MS, half used it 75% of the time or greater and used other base metals much less frequently, with the exception of a few artists who exclusively worked with Cu, Al, or bronze. Among the Group 2 artists who welded on MS, 82% used it 75% of the time or greater.

In terms of types of welding wires and rods used over the professional lifetime, the response rate to this question was 86% and 70% for Group 1 and 2, respectively. This lower response rate may indicate a lack of detailed knowledge about the welding operation in general or the use of many different types of electrodes/wires precluding a full documentation. The primary electrode types used were E6011, E6013, and E7018 for MS and 308-16 for SS. Individual artists reported using many other types of electrodes for welding MS including E1681, E6010, E6014, E7011, E7013, E7014, and E7024. MIG-MS wire was used by the majority of artists employing the MIG process (94% of Group 1 and 75% of Group 2). MIG-SS and MIG-Silicon-Bronze wires were used by 59% and 46% of Group 1 and 23% and 6% of Group 2 artists who welded on SS and bronze, respectively. In general, tungsten electrodes are used for TIG welding, and OAW does not employ any electrodes or wires.

5. Exposure Time, Frequency and Duration: The artists were asked the numbers of hours per day they have welded on average and at maximum during a typical workweek, average and maximum number of days they weld per week, and average and maximum number of weeks they weld per year. We estimated number of welding days per year by multiplying number of days per week and number of weeks per year responses. The significance of exposure parameters (i.e., risk factors) of time (ET-h/d), frequency (EF-d/y) and duration (ED-y) is their use in the estimation of average daily dose received by exposed individuals, as shown in the equation below:

\[ ADD = \frac{C \times IR \times ET \times EF \times ED}{BW \times AT} \]

Here, \( ADD = \) Average Daily Dose (mg/kg-day), \( C = \) Exposure concentration in air (mg/m³), \( IR = \) Inhalation rate (m³/hr), \( ET = \) Exposure time (hr/day), \( EF = \) Exposure frequency (days/year), \( ED = \) Exposure duration (years), \( BW = \) Body weight (kg), \( AT = \) Averaging time (days) (=ED (years) x 365 d/year).

This equation estimates the average daily dose (ADD) received via the inhalation route as the primary exposure pathway of concern for welders. The ADD can be estimated deterministically or probabilistically. In deterministic analysis, the ADD corresponding to Central Tendency Exposure (CTE) and Reasonable Maximum Exposure (RME) exposure conditions are commonly estimated. The CTE-ADD provides an estimate of the dose under average exposure conditions. The RME-ADD provides an estimate of the dose under a plausible but worst case exposure scenario. Therefore,

### Table 1.0: Demographic and Sample Population Information for Artist Welders

<table>
<thead>
<tr>
<th>Artist Welder</th>
<th>Response Rate (%)</th>
<th>Number of Males (M)</th>
<th>Number of Females (F)</th>
<th>Age Mean (Range)</th>
<th>Welding Experience Mean (Range) (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>81.6 (95/114)</td>
<td>69</td>
<td>24</td>
<td>F: 44.1 (28-65)</td>
<td>F: 13.7 (2.5-33)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M: 52.2 (22-76)</td>
<td>M: 25.6 (5-60)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M+F: 50.1 (22-76)</td>
<td>M+F: 22.6 (2.5-60)</td>
</tr>
<tr>
<td>Group 2¹</td>
<td>79.5 (35/44)</td>
<td>19</td>
<td>4</td>
<td>F: 40.0 (26-49)</td>
<td>F: 13.8 (3-25)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M: 31.8 (17-70)</td>
<td>M: 7.7 (2-36)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M+F: 33.2 (17-70)</td>
<td>M+F: 8.7 (2-36)</td>
</tr>
</tbody>
</table>

¹The response rate for Group 2 includes novice (n=12) and experienced metal sculptors (n=23). The demographic information for Group 2 is provided for experienced metal sculptors (n=23) only.
Figure 1.0: Welding processes used by artist welder sample populations throughout their profession

SMAW: Shielded Metal Arc Welding; OAW: Oxy-Acetylene Welding; MIG: Metal Inert Gas Welding; TIG: Tungsten Inert Gas Welding; PAW: Plasma Arc Welding

Figure 2.0: Types of base metals used by artist welder sample populations in creating their art objects and sculptures

MS: Mild Steel; SS: Stainless Steel; Cu: Copper; Al: Aluminum
while the mean or 50th percentile is the measure used in the estimation of CTE-ADD, 90th or 95th percentile values (or maximum with a small sample size) are used in the estimation of RME-ADD. Table 2.0 provides these descriptive statistical measures (mean, median, standard deviation (SD), 90th and 95th percentile) for ET, EF, and ED for Group 1 and Group 2.

The probabilistic estimation of ADD commonly employs stochastic (e.g., Monte-Carlo) sampling techniques and a distribution of ADD can be obtained through a Monte-Carlo simulation involving random sampling from underlying distributions of input parameters used in the calculation of ADD. Although default statistical distributions for adult male and female body weight along with inhalation rate for occupational populations can be obtained from the U.S. EPA’s Exposure Factors Handbook (1997), such information for exposure time, frequency, and duration has not been reported to date for various occupational populations who do not follow the regular 40-h workweek. Table 3.0 provides the parameters of statistical distributions proposed for ET, EF, and ED for artist welders. We developed this information only for Group 1 because this group had the largest sample size and the highest response rate. The majority of exposure parameters of interest could be approximated by a normal distribution. The exception was the data for average EF and ED, for which, a better overall fit was obtained using a Beta distribution, although a normal distribution provided an equally good fit for data above the median. Since we are more concerned about accurate estimation of ADD and health risk for highly exposed individuals, the use of a normal distribution for these risk factors would be satisfactory.

As shown in Table 2.0, Group 1 and 2 artists welded about half of a typical 8-h workday on average. However, the number of hours welded on longest workdays in a typical workweek for both groups was comparable to an 8-h workday of industrial welders. Figures 3.0 and 4.0 show the cumulative frequency distribution of and normal distribution fit to the ET data for Group 1 artists welding on days reflecting their average and full workloads in a typical workweek, respectively. About 41% of Group 1 and 37% of Group 2 artists reported welding over 8 hours per day when working at full capacity during a regular workweek. The artists were also asked about the maximum number of hours they welded on a given day to finish a commissioned piece or a project. A significant fraction of artists (31% in Group 1 and 41% in Group 2) reported welding 10 hours or longer on those days with an approaching deadline. The majority of the artists did not specify the percent of time they welded longer than 10 hours; therefore it is not possible to ascertain the frequency of occurrence of these high

Table 2.0: Descriptive statistical measures for exposure time (ET), exposure frequency (EF), and exposure duration (ED) for artist welder sample populations

<table>
<thead>
<tr>
<th>Descriptive Statistics</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>90th</th>
<th>95th</th>
</tr>
</thead>
<tbody>
<tr>
<td>ET (h/d – typical work week)</td>
<td>Group 1</td>
<td>3.9</td>
<td>3.0</td>
<td>2.66</td>
<td>7.3</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>4.5</td>
<td>3.5</td>
<td>2.70</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>Group 1</td>
<td>7.5</td>
<td>8.0</td>
<td>3.82</td>
<td>12.4</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>9.1</td>
<td>8.0</td>
<td>5.25</td>
<td>15.9</td>
</tr>
<tr>
<td>EF (d/y) Ave</td>
<td>Group 1</td>
<td>140.0</td>
<td>140.0</td>
<td>104.8</td>
<td>266.9</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>63.4</td>
<td>38</td>
<td>75.68</td>
<td>176.5</td>
</tr>
<tr>
<td>EF (d/y Max)</td>
<td>Group 1</td>
<td>231.3</td>
<td>252.0</td>
<td>115.30</td>
<td>291.7</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>174.6</td>
<td>200.0</td>
<td>111.20</td>
<td>281.0</td>
</tr>
<tr>
<td>ED (y)</td>
<td>Group 1</td>
<td>22.6</td>
<td>22.5</td>
<td>15.07</td>
<td>39.3</td>
</tr>
<tr>
<td></td>
<td>Group 2</td>
<td>9.6</td>
<td>5.0</td>
<td>9.42</td>
<td>21.7</td>
</tr>
</tbody>
</table>

Table 3.0: Underlying statistical distributions for exposure time (ET), exposure frequency (EF) and exposure duration (ED) for Group 1 – National Respondents

<table>
<thead>
<tr>
<th>Exposure Parameter</th>
<th>Statistical Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>ET-average day-typical week (h/d)</td>
<td>Normal (Mean = 3.87, SD = 2.66)</td>
</tr>
<tr>
<td>ET-longest day-typical week (h/d)</td>
<td>Normal (Mean = 7.49, SD = 3.82)</td>
</tr>
<tr>
<td>EF-average (d/y)</td>
<td>Normal (Mean = 140.00, SD = 101.48); or Beta (Min=1, Max=364, α=1.1354, β = 1.74099)</td>
</tr>
<tr>
<td>EF-maximum (d/y)</td>
<td>Normal (Mean = 231.33, SD = 115.30)</td>
</tr>
<tr>
<td>ED (y)</td>
<td>Normal (Mean = 22.56, SD = 13.07); or Beta (Min=2, Max=60, α=1.3077, β = 2.55638)</td>
</tr>
</tbody>
</table>
maximum numbers of hours welded on a given day. Although there was not a statistically significant difference in the mean average (p = 0.322) and maximum (p = 0.176) number of hours welded on a given day between the two groups, the weekly and annual work habits of the two groups were statistically significantly different (p < 0.05). On average, while Group 1 welded 3.5 days per week and 36 weeks per year Group 2 welded 2.5 days per week and 23 weeks per year. Group 1 artists indicated that, at maximum, they welded for 5.5 days per week and 40 weeks per year. In contrast, Group 2 artists welded 4 days per week and 39 weeks per year, at maximum. Thus, exposure frequency in days welded per year, was about 20% higher for Group 1 than Group 2 under both average and maximum work conditions.

The exposure duration information indicating total number of years artists have been welding at the time of questionnaire administration showed that Group 1, in addition to welding more days in a given year, have been welding for a longer period as compared to Group 2 artists on average (22.6 y-Group 1 vs. 8.7 y-Group 2).

4. Workspace and Ventilation Use and Type: Figure 5.0 displays workspaces of artists. The majority of Group 1 artists work in studios (51%) with a smaller fraction welding outdoors (17%) and in garages (17%). In contrast, the majority of Group 2 artists weld in welding shops (52%), studios (26%), and outdoors (22%). A few artists also reported welding in basements, in colleges/universities, in large industrial workspaces such as a warehouse, and in building lobbies (e.g., for sculpture installation).

The majority of artists in both groups indicated that their workspaces were ventilated (98% in Group 1 and 87% in Group 2), although the ventilation methods used varied significantly. The workspaces of the majority of Group 1 artists were naturally-ventilated, relying on open doors (54%) and open windows (25%). About 30% of Group 1 had an exhaust fan in their workspace and only 7.5% had fume extractors and/or ducted stations. The use of engineering-based ventilation systems was more prevalent among Group 2, with 27% reporting use of fume extractors and/or ducted stations. The use of floor and overhead fans was also reported by 32% and 13% of Group 1, and 45% and 17% of Group 2, artists respectively, in combination with natural ventilation methods. In addition, reliance on window fans and central or forced air systems was a ventilation method of a few Group 1 and 2 artists. The artists were asked whether ventilation was on all the time while they welded. About 56% of Group 1 and 82% of Group 2 responded that ventilation was used throughout the workday.

5. Personal Protective Equipment and Health Hazard Awareness: The artists were asked whether they regularly used PPE (e.g., welding helmet, gloves, safety glasses, goggles, respiratory protection, hearing protection, protective clothing, and work-boots) to protect themselves from exposure to welding fumes. A high percentage of both sample populations (98% for Group 1; 96% for Group 2) reported the use of one or another type of PPE. Welding helmets (95%-Group 1; 78%-Group 2) and gloves (91%-Group 1; 78%-Group 2) were routinely used while welding. Some artists who exclusively worked with the OAW process only used
OAW goggles. Safety glasses were used by one third of each sample population, which is most likely due to the fact that safety glasses are often not commonly used under a welding helmet but provide a layer of protection from slag fragments when removing the helmet to chip along the weld. There was a striking difference in the use of respiratory protection between Group 1 and Group 2, with 66% of Group 1 and 26% of Group 2 reporting the use of respiratory protection. However, 60% of users of respiratory protection in Group 1 reported wearing respiratory protection while cutting, grinding, painting, applying coatings, sandblasting, and welding only certain materials (bronze, galvanized Zn, iron rods and/or unknown materials). Hearing protection and protective clothing such as coveralls, jackets, and leather aprons was used by 57% of Group 1 artists, with half of the artists using ear plugs and muffs only while grinding. In Group 2, protective clothing was used by 43% of artists and 39% used hearing protection, with two-thirds using ear plugs or muffs in general and the remainder while grinding or as needed.

As mentioned previously, the questions related to health hazard awareness were only administered to Group 1 artists due to time limitation for the questionnaire administration during the Tri-State Sculptors Workshop in October 2004. Group 1 artists were asked whether they were concerned about their exposure to welding fumes, and the reasons behind any expressed concerns. About 64.5% indicated that they were concerned about their exposure while the remainder was not concerned. The primary reasons voiced for lack of concern were taking protective measures (39%), having proper and adequate ventilation in the workspace (21%), and infrequent welding (18%). Other reasons were receiving a medical screening for metal concentrations; having had asthma as a child but no exasperation of symptoms with welding; welding outdoors; running/jogging with no respiratory problems; being naïve; and assuming that welding fume exposure is not important. The artists’ perceptions about the level of education of the artist-welder community about controlling their exposure to welding fumes and reasons for lack of education were acquired in the questionnaire. While 47% of Group 1 artists indicated that artists were educated about controlling their exposure, an equal percentage (47%) indicated that the artist community was not educated. Improper education and a lack of safety training (61%), being ignorant, and having machismo (36%), along with a lack of health hazard awareness (20%) and the cost associated with respiratory protection and ventilation equipment (14%) were reported as the main reasons for not being educated about controlling the artist-welder community’s exposure to welding fumes by the subset of respondents who indicated that artists were not educated. Individual artists also reported that most artists were not technical and thus did not understand health and safety regulations and Material Safety Data Sheets (MSDS). Artists were asked to identify the best methods for communicating risks associated with welding fume exposures to artists. The methods recommended were publications prepared for artists and metal sculptors (46%); training in welding, arts, and vocational schools, community colleges and universities (37%); publications from welding equipment and material suppliers (e.g., MSDSs, and
Discussion

The welding process and base metal/consumables employed, the type of workspace where welding is performed, along with ventilation characteristics of the space, and the type and percent time of PPE usage are the key parameters defining an artist welder's exposure environment and conditions. Group 1 and Group 2 artists had a similar pattern in terms of usage of welding processes since they began welding, with SMAW, MIG, and OAW being the most commonly employed processes, followed by TIG and PAW. Although fume generation depends on process and thermal conditions, workspace and subject-related attributes, the amount of fume generated from OAW is generally lower than that from arc welding. In general, SMAW and PAW produce high amounts of fume, MIG produces moderate fume, and TIG produces low fume levels.

MS was the base metal most used by both sample populations although other base metals (e.g., SS, Al, Cu, bronze, galvanized Zn) were also used in higher percentages by the more experienced Group 1 artists. MS consists mostly of iron (Fe) (95%) and less than 0.29% carbon (C), 0.85-1.2% manganese (Mn), 0.04% phosphorus (P), 0.4% silicon (Si), and 0.05% sulfur (S) (NIOSH, 1988). On the other hand, SS contains less than 0.08% C, 20% chromium (Cr), 15% nickel (Ni), 3% Mn, 0.75% Si, 0.04% P, 0.03% Si, and Fe constitutes the remainder of the mass. For SMAW, the electrodes used for MS (e.g., E6013) and SS (e.g., 308-16) commonly contain Fe, Mn, calcium (Ca), potassium (K), Si, fluoride (F), and titanium (Ti), with additional Cr and Ni in the case of SS electrodes. For MIG welding, the MS/SS wires both contain Fe and Mn, but SS wire also includes Ni (WHO, 1990). Thus, toxic metal exposures and associated adverse health effects are a concern for artist welders, in addition to fine and ultrafine particulate exposures. Although Cr is mainly in the trivalent form in welding fume, a small fraction of carcinogenic hexavalent Cr can also be found in fumes generated by most arc welding processes utilizing SS. Therefore, cancer risks are particularly of concern for those artists who work with SS containing Cr and Ni. Artist welders are also exposed to gaseous pollutants (e.g., carbon monoxide, ozone, and nitrogen oxides) produced during welding. In addition, many artists weld on coated or painted metal, resulting in additional exposures to organic compounds such as BTEX (benzene, toluene, ethyl benzene and xylenes), phenols, 1,4-dioxane, formaldehyde, acetaldehyde, acrolein, and potentially polynuclear aromatic hydrocarbons, dioxins, and lead (WHO, 1990). Thus, the chemical exposures of artist welders can be very complex.

Many artists welded in the basements and garages of their residences. Thus, exposures of their family members or children to toxic metals, particulates and
other chemicals may occur. In warmer climates or summer months, some artists welded outside. The use of oscillating floor fans for workspace ventilation was common. About half of the artists had some type of engineering control in their workspaces and the other half relied on natural ventilation based on air dispersion. It was not clear if the ventilation used was adequate for removing welding fumes from the workspace to levels below regulatory limits. The majority of the artists also indicated that they used at least one type of PPE to control their exposures although it was clear that they were confused about what constituted PPE, because some of the respondents indicated that they did not use any PPE but they proceeded to list one or more PPE tools as items they routinely use. Although welding helmets and gloves were uniformly used by artists in both groups, the use of respiratory and hearing protection was largely process-dependent and not that prevalent. Respiratory protection was often limited to non-welding activities. The lack of respiratory protection is particularly of concern for those artists who do not have proper ventilation in their workspaces.

We developed statistical distributions for ET (h/d), EF (d/y) (under normal and heavy work conditions), and ED (y) as exposure parameters and/or risk factors unique to artist welders. This information along with measurements of exposure in the breathing-zone of artists can be used to estimate ADD of total welding fume and fume constituents deterministically and probabilistically, which can then be used in future epidemiological and/or health risk assessment investigations. Personal exposure concentrations have been reported in the literature for welders employing specific process/material combinations. However, exposure concentrations significantly vary depending on many process-, material-, and welder-specific parameters. Thus, we recommend that personal exposure of sculptors be measured in future studies, prior to application of ET, EF, and ED information presented here. The ADD estimates can be integrated with information on toxicity of chemicals found in welding fumes to estimate occupational health risks posed by welding fume exposures for this unique population. We should caution that ET, EF, and ED information related to time scale of exposure for artist welders should not be used for industrial welders since the majority work 8-h shifts throughout the year except for vacation periods.

Although the more experienced Group 1 artists welded about the same number of hours per day as Group 2 artists, they welded significantly more days per year on average. An important finding, which supports the hypothesis that a segment of the artist welder population can be classified as a high-risk population, is that 53% of Group 1 and 63% of Group 2 artists reported welding 8 or longer hours per day when they worked at full capacity. The evidence for supporting this hypothesis gains strength when ET information is combined with EF data. Group 1 artists reported that they welded 140 days per year on average and 231 days per year at maximum. In contrast, Group 2 artists reported that they welded only 65 days per year on average and 175 welding days per year at maximum. Although artists do not appear to weld every workday, some artists may work more than 8 hours per day for more than five days a week throughout 60% of the year, as evidenced by 30% of Group 1 artists. This unregulated work practice of artists can result in significantly higher total annual exposures than industrial welders, although many industrial welders weld in the presence of other welders in a manufacturing environment and thus their total exposures are affected by the fumes generated by neighboring welders. Although some of the artists work in welding shops (12%-Group 1; 52%-Group 2) used by other artist welders or welders in general, some work alone in their studios, isolating their exposures.

About 35.5% of Group 1 artists were not concerned about their exposure to welding fumes, while the remaining was concerned. Some of the reasons for a lack of concern revealed the lack of fundamental knowledge about welding fume exposures and associated health effects by some artists. The artists were split in their perception about whether artist communities receive adequate and proper education about controlling welding fume exposures in their workspaces. The majority was cognizant of a lack of occupational health and safety training tailored for artist welders and a resultant lack of health hazard awareness. The artists’ own responses to health hazard awareness questions revealed that artists do not receive adequate health and safety training commonly afforded to industrial welders, and may unknowingly put themselves at higher risk by not employing, or improperly employing exposure reduction and control measures.

Although the data extracted from this study provides a glimpse into exposure behavior of artist welders, the results should be interpreted with caution due to small size, recall bias, and inability to validate the questionnaire responses. Future studies focusing on specific artist welder populations in a specific region or community could build on the findings presented in this manuscript, but should generate independent data for variables examined in this study. There is a need for additional studies focusing on this subpopulation of welders, because our results indicate that work practices and health hazard awareness of artist welders can result in high-risk behavior from health effects perspectives and identification of high-risk populations and prevention of health risks is the charge of occupational health community. Additionally, more data need to be generated to test the validity of our findings.

Conclusions

- Although artist welders work a variety of hours, in a variety of work spaces using a variety of ventilation methods, with various base metals and

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welding electrode/rod/wire combinations, some clear patterns emerged and important conclusions were drawn about some of the critical parameters (e.g., welding process employed, base metals used, exposure time, exposure frequency, exposure duration, ventilation use and type, PPE use and type) determining welding fume exposure of artists.

Conversely, industrial welders typically work 40-hour workweeks and use prescribed processes and materials to meet product specifications. In addition, many industrial welders weld in workplaces equipped with engineering control practices, proper medical screening, and occupational health and safety training. The surveyed artist welder population, although small in size as compared to industrial welders, is situated outside of this realm of opportunities.

Our data for exposure time, exposure frequency, ventilation use and type, and PPE use and type indicate that a segment of the artist welder population may potentially be a high-risk population due to longer work hours and a lack of proper ventilation and exposure control measures.

It is essential to reach the artist welder community with occupational health and safety training programmes specifically tailored to their needs, in order to reduce their health risks and to increase health hazard awareness related to their work practices.

Occupational health and safety training must also be an integral part of arts and welding education in schools.

The health care personnel treating artists should acquire information about exposure/work conditions and materials used.

The development of safer materials and user-friendly MSDS information by the industry should also be a priority.

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