Occupational safety measures and morbidity among welders in Vellore, Southern India

Vijay Alexander¹, Kulandaipalayam Natarajan C Sindhu¹ ,
Pradeep Zechariah¹, Abigail Veravolu Resu¹ , Suryanarayan Rajendran Nair¹,
Deepthi Kattula², Venkata Raghava Mohan¹ , Reginald George Alex T³

¹Department of Community Health, Christian Medical College, Vellore, India, ²Division of GI Sciences, Christian Medical College, Vellore, India, ³Department of General Medicine, Christian Medical College, Vellore, India

Background: Welders in the unorganized occupational sector in the economically developing world are exposed to respiratory, skin, eye, ear, and neurological problems exacerbated by non-usage of personal protective equipment (PPE).

Objective: To study the frequency of health problems and the usage of PPE among welders in unorganized welding units in Vellore, India.

Methods: A cross-sectional survey was conducted among 150 welders to determine the frequency of skin, ear, eye, and respiratory morbidity and the usage of PPE. A group of 150 non-welders were chosen for comparison.

Results: Significant differences in the frequency of skin burns, redness, hyper pigmentation, itching, eye injuries, and sensorineural deafness were observed among the welders and non-welders ($P < 0.001$). Hypertension was noted in 12.6% of the welders as compared to 0.7% among the non-welders. None of the welders used appropriate PPE. For welders, low educational attainment was associated with an increased risk of eye injury ($P < 0.05$, OR = 0.29). There was also a significant difference between sensorineural deafness and a welder having less than 10 years of welding work experience ($P < 0.001$, OR = 18.18) which could probably be accounted for by the healthy worker effect.

Conclusion: Welders in this sample experienced a significant skin, eye, and ear morbidity accentuated by the non-usage of PPE. All worked without formal training and were unaware of the safe working guidelines that exist, but are not implemented for the welders in India.

Keywords: Welders, Respiratory morbidity, Skin problems, Ocular injury, Sensorineural hearing loss, Personal protective equipment

Introduction

Welding is a metal joining process involving local fusion or melting of a flux-coated electrode through heat input. A common source of heat for the welding process involves an electric arc struck between a flux-coated electrode and the metallic joint, known as metal arc welding.^{1–3} Gas arc welding is another method in which the welding gas, either active or inert, protects the molten metal from oxidation.⁴

In 2003, it was estimated that over a million workers between 20 and 40 years old worldwide, were employed in the welding industry.^{5,6} Welders and those working in the vicinity, are exposed to toxic emissions recognized as health hazards. For example, welding fumes containing manganese particles have shown to result in serious neurotoxic effects.⁷ Welding emissions differ based on type of metals used in the process. For example, Nickel chromium bare wire and strip electrode welding emit

dinitrogen tetroxide, nitric oxide, nitrogen dioxide, ozone, phosgene, and phosphine which can result in local effects like skin and eye problems, as well as systemic effects like COPD, chronic bronchitis, and emphysema.^{8,9} The inhalation of the welding fumes also expose welders to increased risk of pneumonic infections as well as lung cancer.^{10,11} Inhalational changes as a result of welding fume exposure were extensively studied in the chest radiographs of welders that highlighted the negative impact of welding fumes on lung health.¹² A study from India reported higher respiratory impairment in smoking welders than non-smoking welders, indicating the synergistic effect of smoking along with inhaled gases on the lung function among welders.^{13,14} Welders also are at risk for developing skin conditions, such as hyper pigmentation with an increased frequency as observed among the welders in a study at rural Delhi, India.¹⁵ Welding-related trauma includes acute eye injuries, especially those caused by foreign bodies in the form of minute metal chips, brief loss of vision, welding arc or flash burns, and trauma to the hands.^{15–17} A study from India found that the usage of personal protective equipment by

Correspondence to: Reginald George T Alex, Department of General Medicine, Christian Medical College, Vellore 632004, India. Email: dralex98@cmcvellore.ac.in

welders offered 67% protection against respiratory, skin, and eye morbidities.¹⁸ Therefore, enforcing the usage of PPE among welders is important.¹⁴ Although the government of India has standard regulations for the use of PPE by welders, compliance to the usage has been poor in the unorganized welding sector of India as seen in studies from the other developing countries like Nigeria and Tanzania that have highlighted the sub-optimal usage of PPE which was 34.2–50%, respectively.^{16,19,20} In Nigeria, an intervention to educate welders about PPE use found a significant increase in the use of PPE.²¹ Hence education among welders on the importance of use of PPE can play a pivotal role in reducing injuries.

In India, many studies in the past have primarily focused on health issues of welders employed at organized sectors, with minimal attention to those employed in the unorganized welding sectors.^{18,22} With increasing unorganized welding units in urban India, and with little data available on welders, it is important to understand the different spectra of health problems among them in order to provide information to plan appropriate interventions and to increase awareness of potential health hazards. Hence, the aim of the study was to determine the frequency of health problems, occupational hazards, and use of PPE among welders in the unorganized sector in Vellore, India.

Materials and methods

A sample size of 150 welders and 150 non-welders was calculated using the prevalence of COPD from previous studies on welders.^{23,24} The 150 welders were surveyed from 47 local welding units, located within a 20 mile radius of Vellore city. Vellore city is in the state of Tamil Nadu, Southern India. Also 150 workers not involved in welding or welding-related work, were selected from the same geographic location as the unexposed group. This unexposed group included roadside vendors and shopkeepers between the ages of 18 and 60 years. The unexposed group was unlikely to be exposed to the fumes, sparks, or inhalational toxic gases from welding. The inclusion criteria for welders included being a male aged between 18 and 60 years and currently working at an unorganized welding unit for at least the last one year in the aforementioned geographic location. Exclusion criteria included having a physical deformity, as the working pattern and duration of work of these individuals is likely to vary. The unorganized welding industry was defined as a road-side welding unit not a part of the organized industrial sector or an independent working unit (e.g. factory). Welders working at organized welding industries or firms were excluded because their working environment is equipped with mechanized ventilation and supplied with PPE by the authorities. Exclusion criteria included having a physical deformity, as the working pattern and duration of work of these individuals is likely to vary. A snowball sampling technique was used since the unorganized welding units in Vellore are not formal employers and their locations

and employees are not tracked by the government. Due to the unavailability of an exhaustive list of all the welders and their workplaces, this snowball sampling guided the interviewer to different welding units and was repeated until the desired sample size was achieved.

Informed consent was obtained after explaining the study in the local language (Tamil). The interviewer administered a piloted-structured questionnaire which included questions on sociodemographic details, job description, personal history, welding exposure, morbidity, and PPE usage. Following the interview, information sheets and health education was provided to participants, highlighting the various health hazards associated with welding and the importance and type of PPE usage. The study was approved by the Institutional Review Board and Ethics Committee of the Christian Medical College and Hospital in Vellore.

Symptoms related to the eyes, ears, skin, and respiratory system were collected and previous year occupation injuries were documented by recall. Placido's disk and Snellen's chart were used to examine the corneal surface and visual acuity, respectively.^{25,26} Peak expiratory flow rates (PEFR) were measured using a hand-held peak flow meter calibrated by the Department of Physiology, Christian Medical College and Hospital, Vellore, India. Three readings were observed for each individual and the average of the three readings was computed. Tuning fork (256 Hz) was used to perform the Rinne's, Weber's and the Absolute Bone Conduction (ABC) tests to elicit conductive and sensorineural deafness.

Data were entered using EpiData Data Entry (Data Management, Odense Denmark, EpiData Association, 2000–2008) and analyzed using SPSS statistics 20 (Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp). The socioeconomic status assessment was performed using the modified Kuppusamy scale, a scale used in the urban communities of India that incorporates education, head of household occupation, and household income.²⁷ Descriptive statistics were computed as mean and standard deviation for continuous variables. Discrete variables were expressed as proportions. The associations of various symptoms and injuries experienced in the last year between the welders and non-welders were assessed with chi-square (χ^2) and the Fisher's exact tests and the magnitude of association was assessed using simple logistic regression and expressed as odds ratios (OR) with 95% confidence intervals (CI).

Results

A total of 150 welders and 150 non-welders participated in the study. The mean age of welders and non-welders was 36.4 years (SD = 13.2 years) and 37.3 years (SD = 11.1 years), respectively. With respect to education, 46.7% welders and 55.3% of non-welders had completed middle school (8 years of schooling in India). Baseline characteristics are shown in Table 1. There was no significant

Table 1 Baseline characteristics of welders and non-welders in Vellore, India

Baseline characteristic	Groups	Welders (n = 150)	Non-welders (n = 150)
Age (yrs)	18–25	31 (20.7%)	12 (8%)
	26–35	59 (39.3%)	72 (48%)
	36–45	25 (16.7%)	42 (28%)
	46–60	26 (17.3%)	16 (10.7%)
	>60	9 (6%)	8 (5.3%)
Educational attainment	Illiterate	2 (1.3%)	5 (3.3%)
	Primary school certificate	51 (34.0%)	32 (21.3%)
	Middle school certificate	70 (46.7%)	83 (55.3%)
	High school certificate	24 (16%)	23 (15.3%)
	Post high school diploma	2 (1.3%)	4 (2.7%)
	Graduate	1 (0.7%)	3 (2%)
Socioeconomic status	Middle/lower middle	2 (1.3%)	9 (6%)
	Lower/upper lower	148 (98.7%)	141 (94%)
Marital status	Married	110 (73.3%)	134 (89.3%)
	Unmarried	40 (26.7%)	16 (10.7%)
Smoking status	Yes	34 (22.7%)	25 (16.7%)
Alcohol use	Yes	39 (26%)	28 (18.7%)

difference in the education and socioeconomic status between the welders and the non-welders ($P > 0.05$). As per the modified Kuppasamy scale, 98.7% of the welders and 94% of the non-welders belonged to the upper segment of low socioeconomic status (a strata of the Kuppasamy scale defined as those with eight years of schooling, semi-skilled job, and a household monthly income of \$50–\$75).²⁷

The occupational profile of the welders is shown in Table 2. Approximately, 23% of the welders smoked compared to 16.7% of the non-welders, although this difference was not significant. Among smokers, 76.5% of the welders and 56% of the non-welders smoked beedis, a locally made cigarette of tobacco flakes in a rolled *tendu* (*Diospyros melanoxylon*) leaf. Alcohol consumption was reported by 26% of the welders (average of 355 ml per week) and 18.7% (28) of the non-welders (average of 438 ml per week), another non-significant difference.

Morbidity profile showed 21.3% of the welders and 6% of the non-welders suffered from at least one morbidity such as hypertension or diabetes. Hypertension was documented among 19 (12.6%) welders and 1 (0.7%) non-welder. Diabetes was documented equally among the welders and non-welders (1.3%). A history of asthma was noted in two (1.3%) welders and three (2%) non-welders. Both hypertension and diabetes were noted in six (4%) welders and three (2%) non-welders. The presence of hypertension between welders and non-welders was significantly different ($\chi^2 = 10.940$, $P < 0.05$). A significantly higher frequency of skin burns (83.3%), hyper pigmentation (12.7%), and itching (8%) was observed among welders compared to non-welders. A significantly increased frequency of eye injuries (91.3%), foreign body (metallic chips) injury (88%), photophobia (47.3%), foreign body

Table 2 Occupational profile of welders in the unorganized sector in Vellore, India

Baseline characteristic	Groups	Welders (n = 150)
Age started welding	<15 years	31 (20.7%)
	15–18 years	62 (41.3%)
	>18 years	57 (38%)
Reason for welding	Interest in welding	138 (92%)
	Forced to weld	1 (0.7%)
	Inherited as a family business	4 (2.7%)
Welding experience	No alternative options	7 (4.7%)
	<10 years	51 (34%)
	10–20 years	49 (32.7%)
Certified training in welding	>20 years	50 (33.3%)
	Yes	1 (0.7%)
How did you learn welding?	No	149 (99.3%)
	Observing co-workers/seniors	150 (100%)
Welding type	Metal arc welding	139 (92.7%)
	Gas metal arc welding	11 (7.4%)
Metal type	Stainless steel	144 (96%)
	Aluminum/Brass	6 (4%)
Hours worked per day	<4 h	24 (16%)
	4–8 h	122 (81.3%)
	>8 h	4 (2.7%)

sensation (29.3%), frequent watering of the eyes (26%), reduced vision (10%), and congestion (8%) was observed among the welders compared to non-welders. There was also increased frequency of intense pain of the eyes and sudden loss of vision among the welders when compared to the non-welders, although the difference was not statistically significant. The mean number of eye injuries (spark injuries) and foreign body (metallic chips) injuries a welder experienced was 4.09 per welder/year ($SD = 2.7$) and 2.85 per welder/year ($SD = 1.9$), respectively. Also 2% of the welders reported reduced hearing compared to the non-welders, however this difference was not statistically significant. (Table 3) At least one ophthalmic consultation in the last one year was reported by 119 (96%) welders and 5 (4%) non-welders ($P < 0.001$, $OR = 111.323$, $CI = 41.982 - 295.189$). Among the 119 welders who underwent an ophthalmic consultation, 118 welders said the reason for the consult was a sustained eye injury during welding with only one person reporting the consult for a reduced vision. There was a significant difference in the frequency of cataract and reduced visual acuity assessed by clinical examination and Snellen's chart, respectively, among the welders (11.3%) compared to non-welders (3.3%). Also 2% of the welders reported reduced hearing when compared to non-welders, however this difference was not statistically significant (Table 3). There was also a statistically significant difference in the frequency of sensorineural hearing loss among the welders (29.3%) compared to non-welders (0.7%) indicated by a positive ABC test (Table 4). Welders experienced significantly more frequent body aches compared to the non-welders. Symptoms related to metal fume fever was significantly different with respect to musculoskeletal aches, joint pains, and

Table 3 Skin, eye, and ear symptoms among welders and non-welders in the previous 12 months in Vellore, India

System	Symptom	Welder (n=150)	Non-welder (n=150)	P-value (Fisher's exact)
Skin	Burns	125 (83.3%)	0 (0%)	<0.001
	Redness	6 (4%)	0 (0%)	0.030
	Hyperpigmentation	19 (12.7%)	0 (0%)	<0.001
Eye	Itching	12 (8%)	0 (0%)	<0.001
	Any eye injury	137 (91.3%)	0 (0%)	<0.001
	Foreign body injury	132 (88%)	0 (0%)	<0.001
	Frequent watering	39 (26%)	0 (0%)	<0.001
	Congestion	12 (8%)	0 (0%)	<0.001
	Intense pain	5 (3.3%)	0 (0%)	0.060
	Photophobia	71 (47.3%)	0 (0%)	<0.001
	Foreign body sensation	44 (29.3%)	0 (0%)	<0.001
	Sudden loss of vision	2 (1.3%)	0 (0%)	0.498
	Reduced vision currently	15 (10%)	5 (3.3%)	0.035
	Brief periods of hearing loss	0 (0%)	0 (0%)	–
Ear	Hearing loss	3 (2%)	0 (0%)	0.247

malaise between the welders and non-welders with welders experiencing these symptoms in a higher proportion (Table 5). The mean PEFR for the welders and non-welders was 357.3 L/min (SD = 82.43) and 381.44 L/min (SD = 68.39), respectively (T -test value = 3.995, $P < 0.05$).

Almost all the welders (98.7%) worked in open spaces whereas, with less than 2% working in garages. At least one occupation accident was reported by 144 (96%) of the welders in the previous 12 months. Among these accidents, 139 (95.9%) injuries were related to the eye, five (3.4%) were burn injuries, and one (0.7%) was a crush injury of the hand. Only 8 (5.3%) welders had formal training on safe welding techniques.

It was noted that 126 (84%) welders used crude hand shields, 92 (61.3%) used safety glasses but of the non-auto darkening type, and only 1 welder (0.7%) reported wearing a fire proof apron. None of the welders used recommended hand shields, safety helmets, auto-darkening glasses, fire resistant caps, fire proof clothing, or ear plugs. All 150 welders worked bare handed. A cotton vest was the only clothing worn during welding by 133 (88.6%) welders. Only 6 (4%) welders kept their pockets free from match boxes, papers, and/or pocket notebooks which have the potential to catch fire during welding. To protect themselves from the inhalation of the fumes emitted, 97 (64.7%) welders tied an ordinary cotton towel to their face during work, 28 (18.7%) used a cloth mask,

Table 4 Examination of the corneal surface, corneal reflex, cataract and visual acuity, and the ear for conductive and sensorineural deafness among welders and non-welders in Vellore, India

	Welder (n=150)	Non-welder (n=150)	P-value (Fisher's exact)	OR (CI)
<i>Eye examination</i>				
Irregular corneal surface (Placido's disk)	3 (2%)	0 (0%)	0.247	0.98 (0.96–1.01)
Abnormal corneal reflex	0 (0%)	0 (0%)	–	–
Cataract	17 (11.3%)	5 (3.3%)	0.013	3.71 (1.33–10.33)
Reduced visual acuity (Snellen's chart)	32 (21.3%)	11 (7.3%)	<0.001	3.43 (1.66–7.09)
<i>Ear examination</i>				
Rinne's test abnormal	0 (0%)	2 (1.3%)	0.498	–
Weber's test (Lateralized towards the affected ear)	0 (0%)	2 (1.3%)	0.498	–
Absolute bone conduction test positive	44 (29.3%)	1 (0.7%)	<0.001	61.85 (8.39–455.9)

Table 5 Non-specific symptoms and symptoms of metal fume fever among welders and non-welders in Vellore, India

Non-specific symptoms	Welder (n=150)	Non-welder (n=150)	P-value (Fisher's exact)	OR (CI)
Frequent body aches	33 (22%)	0 (0%)	<0.001	1.01 (0.31–29.6)
Sudden loss of consciousness	2 (1.3%)	0 (0%)	0.498	–
Flu-like illness	2 (1.3%)	0 (0%)	0.498	–
Wheezing	3 (2%)	1 (0.7%)	3.041	–
Chest tightness	2 (1.3%)	0 (0%)	0.498	–
<i>Symptoms of metal fume fever</i>				
Fever episodes	0 (0%)	0 (0%)	–	–
Chills	0 (0%)	0 (0%)	–	–
Shivering	2 (1.3%)	0 (0%)	0.498	–
Musculoskeletal aches	127 (84.7%)	4 (2.7%)	<0.001	201.54 (67.89–598.30)
Joint pains	24 (16%)	0 (0%)	<0.001	–
Malaise	115 (76.7%)	10 (6.7%)	<0.001	46.0 (21.84–96.88)
Nausea	5 (3.3%)	0 (0%)	0.060	–
Vomiting	0 (0%)	0 (0%)	–	–

Table 6 Factors associated with morbidities in unorganized sector welders in Vellore, India

Morbidity	Variable	P-value	OR (95% CI)
Eye injury (n = 137, 91.3%)	Welding duration of >6 h/day	0.071	0.33 (0.09–1.10)
	No formal welding training	0.085	0.29 (0.07–1.19)
	Welding experience <10 years	0.059	3.21 (0.96–10.75)
	Education < high school	<0.05	0.29 (0.09–0.98)
Sensorineural deafness (n = 44, 29.3%)	Welding >6 h/day	0.099	0.42 (0.15–1.18)
	No formal welding training	0.079	3.10 (0.88–10.96)
	Welding experience <10 years	<0.001	18.18 (4.15–79.25)
	Education < high school	0.727	0.83 (0.29–2.33)
Skin burns (n = 125, 83.3%)	Welding >6 h/day	0.127	0.48 (0.19–1.23)
	No formal welding training	0.333	0.57 (0.18–1.78)
	Welding experience <10 years	0.637	1.24 (0.50–3.06)
	Education < high school	0.125	0.47 (0.18–1.24)

and one (0.7%) used a disposable mask. The concept of standard respirators was unanimously unknown among the welders. Only one welder worked at a welding unit where a fire extinguisher was installed. On questioning the other 149 welders, the reason for not requesting the installation of a fire extinguisher at their workplace, 146 (97.3%) welders responded that they never felt the need and 4 (2.7%) said that their supervisor could not afford one. When questioned on their immediate action in the event of a fire in their work place, 94.7% of the welders said they would douse the fire with the sand available nearby, 4.7% would use water, and 1 (0.7%) would use a fire extinguisher. All the 150 welders expressed that they were satisfied with their job and working conditions and expressed no need to incorporate changes in their work environment.

Multivariate logistic regression revealed a significant association between a welder having less than 10th grade and increased risk for eye injuries. Also a significant association was observed between sensorineural deafness and a welder having less than ten years of welding experience (Table 6).

Discussion

Previous studies have identified the health hazards experienced by welders, but these studies are pre-dominantly from the organized welding sector. There are few studies from the unorganized welding sector, especially from economically developing countries where welders work in under-equipped conditions and with no PPE. This is the first study to be conducted among welders in the unorganized welding sector of Southern India. The mean age of the welders in our study was 36.42 years (SD = 13.18 years) with a similar mean age observed in a study by Sabitu et al.¹⁶ and Budhathoki et al.²⁸ Among the welders, 98.7% belonged to the lower segment of socioeconomic status and 80.7% of them had only 8 years of schooling, which could possibly explain their placement in the local welding units with a poor working environment, taking into consideration the high unemployment factor for the less educated in an economically developing country such as India. Though 92% of the welders cited an interest in welding, the pragmatic reason for their chosen profession

is likely that they had no other choice and are probably reluctant to acknowledge their poor socioeconomic status and low education as reasons for their profession. In our study, 41.3% of welders starting working between the ages of 16–18 years, similar to the study done in rural Delhi by Chauhan et al.¹⁵ The majority (99.3%) of the welders in our study had no prior certified training in welding, similar to the observations from organized sectors of India and Nepal.^{6,13,22,28} This indicates a non-existent regulatory control of workers in the welding industry, both in the unorganized and organized sectors, in contrast to the other developing countries like Nigeria where welders receive training in the form an apprenticeship or a formal industrial training.¹⁶ This difference likely contributes to the spectra of morbidities encountered reported by welders in our study.

A significant difference was observed in the mean PEFr between the welders and non-welders. This is in agreement with the findings from studies by Szram J. et al. and Haluza et al. that have shown a positive correlation between smoking and deterioration of lung function among welders.^{14,29} Smoking was observed among 22.7% of the welders. However, their probable synergistic effect on the respiratory morbidity could not be quantified. No significant respiratory morbidity was observed in the welders in our study. This was probably due to the fact that 98.7% of the welders worked in open spaces exposing them to a lower concentration of fumes. This finding was in contrast to a study done in an India shipbuilding industry where welders showed an increased respiratory morbidity because of their poorly ventilated, closed working environment.¹⁹ Hypertension was significantly higher among the welders compared to the non-welders. However, this association does not necessarily indicate a sufficient causation given the small sample size and the multifactorial etiology that underlies hypertension. Metal arc welding (92.7%) was the primary type of welding performed by welders in our study since it is cheap, portable, and is versatile in welding various metals. Metal arc welding with open electric arc produces sparks in dangerous proportions, explaining the significantly high frequency of skin burns, redness, hyper pigmentation, and itching of the skin. Also a high frequency of eye injuries and sensorineural deafness was

observed among the welders in our study which was higher than the frequency reported in the study from coastal South India.²² The increased frequency in our study could be attributed to the fact that the study was conducted in the unorganized welding units in contrast to the Kumar SG et al. study which included welders in organized welding industries where working conditions are better (including PPE availability).²² Our study also showed a significantly higher frequency of cataract and reduced visual acuity, likely attributed to the emission ultraviolet radiation in arc welding. Musculoskeletal aches and joint pains were high among the welders since the majority of the welders worked for four to eight hours per day under hot and dry climate conditions (maximum 43.5 °C). This highlights the need for organized work breaks. The mean eye injuries observed was 4.09/person/year (SD = 2.7) with 96% of the welders having had at least an ophthalmic consult in the last one year, the majority citing the reasons for their consult being an eye injury sustained while welding. These findings highlight the need for the enforcement of mandatory PPE usage during welding, regardless formal, or informal workplace.

The use of PPE was inadequate among the welders. None of the welders used recommended PPE nor appropriate clothing and worked bare-handed in contrast to finding by Bhumika et al. and Kumar SG et al. This was because the industrial welders had access to PPE unlike the welders in our study who could not afford PPE and it was not provided by their employers.^{19,22} None of the welders worked in an environment equipped for a fire emergency and did not know the appropriate actions to be taken in the event of fire. There is a need for fire safety education and drills for welders. Every welder in this study expressed satisfaction in the working conditions, likely due to the interview being conducted in the presence of the employer or supervisor of the welding unit. This was a major limitation of the study. A higher level of education and more experience in welding was associated with the decrease of morbidities among the welders. However, increased welding experience having a protective effect may be explained by the healthy worker effect, where the healthy welders continued to work and those with health issues switched to other jobs. The healthy worker effect in our study could not be quantified as no records were maintained pertaining to the recruitment and retirement of welders. Hence, setting up criteria with respect to educational qualifications during recruitment, mandatory courses on training in welding, at least an apprenticeship and the implementation of a PPE awareness program are recommended as part of a pragmatic approach to reduce morbidity. Licensing and approval of the welding units under the government scanner would also likely contribute to the improvement in the working conditions of the welders over the long term.

The study has several limitations. Since there is no formal governing body that tracks welders in unorganized sector of Vellore district, systematic sampling was not feasible and time constraints reduced the sample size.

Conclusion

Welders in unorganized welding units in Southern India experience a high frequency of skin, eye, and ear morbidity with almost no access to PPE. Welders work without any formal training and as a result they were oblivious to safe working practices to protect their health. Welding standards exist in India but the employers of the unorganized welding units decline to adhere to the national standards. The unorganized welding sector must be brought under the scrutiny of the occupational health and safety department and the industrial governing bodies should maintain the minimum basic standard for the welfare of welders. This calls in for robust efforts by the concerned authorities to enforce qualification criterion and pre-placement training programs for welders, a certain challenge in a developing country such as India. At the very least, mandatory short-term training courses in welding and the implementation of a PPE awareness program are needed.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Kulandaipalayam Natarajan C Sindhu <http://orcid.org/0000-0002-0767-8602>

Abigail Veravolu Resu <http://orcid.org/0000-0002-5286-5642>

Venkata Raghava Mohan <http://orcid.org/0000-0001-5787-7223>

Reginald George Alex T <http://orcid.org/0000-0002-0767-8602>

References

- 1 Metal-arc welding: TheFreeDictionary.com. [cited 2015 Jun 27]. Available from: <http://www.thefreedictionary.com/metal-arc+welding>
- 2 AP-42, CH 12.19: Electric Arc Welding - c12s19.pdf. [cited 2015 Jun 27]. Available from: <http://www.epa.gov/ttnchie1/ap42/ch12/final/c12s19.pdf>
- 3 Arc Welding Fundamentals. Lincoln Electric. lincolnelectric. [cited 2015 Jun 27]. Available from: <http://www.lincolnelectric.com/en-us/support/process-and-theory/Pages/arc-welding-detail.aspx>
- 4 Isaxona C, Dierschke K, Pagelsa J, Löndahl J, Gudmundsson A, Hagerman I, et al. A novel system for source characterization and controlled human exposure to nanoparticle aggregates generated during gas – metal arc welding. *Aerosol Sci Technol* [Internet]. [cited 2015 Dec 8];47(1). Available from: <http://www.tandfonline.com/doi/full/10.1080/02786826.2012.724733>
- 5 Antonini JM, Lewis AB, Roberts JR, Whaley DA. Pulmonary effects of welding fumes: review of worker and experimental animal studies. *Am J Ind Med*. 2003 Apr;43(4):350–60.
- 6 Kumar SG, Dharanipriya A. Prevalence and pattern of occupational injuries at workplace among welders in coastal South India. *Indian J Occup Environ Med*. 2014 Dec;18(3):135–9.
- 7 Hedmer M, Karlsson J-E, Andersson U, Jacobsson H, Nielsen J, Tinnerberg H. Exposure to respirable dust and manganese and prevalence of airways symptoms, among Swedish mild steel welders

- in the manufacturing industry. *Int Arch Occup Environ Health*. 2014 Aug;87(6):623–34.
- 8 Koh D-H, Kim J-I, Kim K-H, Yoo S-W, Korea Welders Cohort Group. Welding fume exposure and chronic obstructive pulmonary disease in welders. *Occup Med Oxford Engl*. 2015 Jan;65(1):72–7.
- 9 Sandvik [Internet]. SS Bare Wire Strip, Rod Electrode SDS R13 2014 - ss-bare-wire-strip-rod-electrode-sds-r13-2014.pdf [cited 2015 Dec 8]. Available from: <http://smt.sandvik.com/globalassets/global/materials-center/welding-safety-information-sheets/stainless-steel-bare-wire-strip-rod/ss-bare-wire-strip-rod-electrode-sds-r13-2014.pdf>
- 10 Kendzia B, Behrens T, Jockel K-H, Siemiatycki J, Kromhout H, Vermeulen R, et al. Welding and lung cancer in a pooled analysis of case-control studies. *Am J Epidemiol*. 2013 Nov 15;178(10):1513–25.
- 11 Palmer KT, Cosgrove MP. Vaccinating welders against pneumonia. *Occup Med Oxford Engl*. 2012 Jul;62(5):325–30.
- 12 Wittczak T, Dudek W, Walusiak-Skorupa J, Świerczyńska-Machura D, Cader W, Kowalczyk M, et al. Metal-induced asthma and chest X-ray changes in welders. *Int J Occup Med Environ Health*. 2012 Jun;25(3):242–50.
- 13 Rastogi SK, Gupta BN, Husain T, Mathur N, Srivastava S. Spirometric abnormalities among welders. *Environ Res*. 1991 Oct;56(1):15–24.
- 14 Szram J, Schofield SJ, Cosgrove MP, Cullinan P. Welding, longitudinal lung function decline and chronic respiratory symptoms: a systematic review of cohort studies. *Eur Respir J*. 2013 Nov;42(5):1186–93.
- 15 Chauhan A, Anand T, Kishore J, Danielsen TE, Ingle GK. Occupational hazard exposure and general health profile of welders in rural Delhi. *Indian J Occup Environ Med*. 2014;18(1):21–6.
- 16 Sabitu K, Iliyasu Z, Dauda MM. Awareness of occupational hazards and utilization of safety measures among welders in Kaduna metropolis, Northern Nigeria. *Ann Afr Med*. 2009 Mar;8(1):46–51.
- 17 Tenkate TD. Optical radiation hazards of welding arcs. *Rev Environ Health*. 1998 Sep;13(3):131–46.
- 18 Bhumika N, Prabhu GV, Ferreira AM, Kulkarni MK, Vaz FS, Singh Z. Respiratory morbidity among welders in the ship building industry. Goa Indian J Occup Environ Med. 2012 May;16(2):63–5.
- 19 Indian standards (BIS) ON WELDING [Internet]. Available from: http://www.iwindia.com/pdf/BIS_Standards_on_Welding.pdf
- 20 Rongo LMB, Barten F, Msamanga GI, Heederik D, Dolmans WMV. Occupational exposure and health problems in unorganized industry workers in Dar es Salaam, Tanzania: a situation analysis. *Occup Med Oxford Engl*. 2004 Jan;54(1):42–6.
- 21 Adewoye KR, Awoyemi AO, Babatunde OA, Atoyebi OA, Salami SK, Issa FY. Effect of health education intervention on the awareness and use of personal protective equipments among unorganized welding units electric arc welders in Ilorin, Nigeria. *Indian J Occup Environ Med*. 2014 Jan;18(1):3–8.
- 22 Kumar SG, Dharanipriya A, Kar SS. Awareness of occupational injuries and utilization of safety measures among welders in coastal South India. *Int J Occup Environ Med*. 2013 Oct;4(4):172–7.
- 23 Baur X, Bakehe P, Vellguth H. Bronchial asthma and COPD due to irritants in the workplace – an evidence-based approach. *J Occup Med Toxicol Lond Engl*. 2012 Sep 26;7:19.
- 24 Bhome AB. COPD in India: iceberg or volcano? *J Thorac Dis*. 2012 Jun 1;4(3):298–309.
- 25 Kanellopoulos AJ, Asimellis G. Comparison of Placido disc and Scheimpflug image-derived topography-guided excimer laser surface normalization combined with higher fluence CXL: the Athens Protocol, in progressive keratoconus. *Clin Ophthalmol Auckl NZ*. 2013;7:1385–96.
- 26 Phung L, Gregori NZ, Ortiz A, Shi W, Schiffman JC. Reproducibility and comparison of visual acuity obtained with sight book mobile application to near card and Snellen chart. *Retina Phila Pa*. 2016 May;36:1009–20.
- 27 Kuppuswamy.pdf. [cited 2015 Jun 1]. Available from: <http://www.ijrdh.com/files/2%20kuppuswamy.pdf>
- 28 Budhathoki SS, Singh SB, Sagtani RA, Niraula SR, Pokharel PK. Awareness of occupational hazards and use of safety measures among welders: a cross-sectional study from eastern Nepal. *BMJ Open*. 2014;4(6):e004646.
- 29 Haluza D, Moshhammer H, Hochgatterer K. Dust is in the air. Part II: effects of occupational exposure to welding fumes on lung function in a 9-year study. *Lung*. 2014 Feb;192(1):111–7.