Original Article

Occupational Exposure to Artificial Ultraviolet Radiation from Welding in Australia

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Abstract

Background: Artificial ultraviolet radiation (UVR) is produced during welding and can cause damage to both the eyes (ocular) and the skin (dermal). We aimed to investigate the protection used by welders to reduce their exposure to ocular and dermal UVR. **Methods:** We conducted a cross-sectional online survey in Australia that asked welders about their welding tasks and the control measures they used to protect against UVR exposure. **Results:** There were 634 respondents, of whom 411 undertook welding themselves, 36 supervised other welders, and 130 both supervised and welded. Dermal UVR exposure occurred in 7.8% of welders and 14.4% of supervisors, whereas ocular UVR exposure occurred in 16.8% of welders and 33.1% of supervisors. The use of personal control measures was much lower among supervisors than welders; however, the presence of warning signs or barriers was reported more often by supervisors. **Conclusions:** Despite the well-known acute and chronic effects of exposure to UVR from welding, there are still many welders and supervisors who do not use adequate protection.

Keywords: *Cross-sectional survey, dermal exposure, ocular exposure, personal protective equipment*

Introduction

Welding is the process of joining metals by melting the metal with high heat.[1] Welding produces very high levels of artificial ultraviolet radiation (UVR) to the welder as well as to non-welding workers in the welding area.[2] The highest levels of UVR have generally been found for gas metal arc welding, with excessive exposure found to occur with only a few minutes of welding.[3]

Potential sites of exposure are the eyes (ocular exposure) and the skin (dermal exposure). Ocular exposure to welding UVR can cause acute effects such as photokeratitis (known colloquially as "welder's flash"), which manifests as a very painful sunburn to the eye.[3] In addition, ocular UVR from welding can cause ocular melanoma,[4] and the types of UVR emitted during welding are known to cause non-melanoma skin cancer.[5]

Control measures include the use of auto-darkening helmets or goggles to reduce exposure to the eyes and workwear that covers the skin.[2] In addition, as others working in the vicinity of welders are likely to be exposed to UVR, there is a need to separate other workers from the welding area as much as possible, most commonly by using physical barriers and distance.[6] However, little is known about whether welders and supervisors use these control measures in real-life situations.

We, therefore, investigated the nature and circumstances of exposure to UVR and the use of protective and control measures by Australian welders and supervisors.

Methods

This was a cross-sectional online survey of Australian welding workers. Full methods have been reported previously.[7] Individuals were eligible to participate if they were aged 18 years and above and did some welding as part of their occupation. Respondents were recruited during mid-2022 through email and social media via their connection with one or more organizations involved in the welding industry. Sample size calculations were performed with a confidence level (CI) of 95% and margin of error of 4%. Assuming a prevalence of exposure of 37.5% (based on our past research),[8] we aimed to recruit a minimum of 563 respondents.

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Respondents completed an online Qualtrics survey that collected demographic and job-related data. They were asked whether they supervised welders and/or welded themselves, and for each role they were asked whether they usually wore clothing that completely covered the skin, welding goggles, a welding helmet with goggles, and/or a welding shield. Answers were imported into the web application OccIDEAS[9] and used to provide a qualitative assessment of each worker's level of dermal and ocular exposure to UVR. We defined a low level of exposure as "present but not likely to require further control measures," high as "control measures are likely to be needed," and "medium" as a level between these two values.

All statistical analyses were conducted using Stata v16.1. We calculated the overall prevalence of exposure to dermal and ocular UVR and 95% CI separately for welders and supervisors. We then investigated the associations between demographic and job variables and dermal and ocular UVR exposure (separately for welders and supervisors) using Chi-squared tests and multivariate modified Poisson's regression analyses. The regression model was first estimated with all variables entered, and non-significant variables were removed consecutively with the model re-estimated each time to obtain the best model fit.

This study was approved by the [University of Sydney redacted for review] Human Research Ethics Committee (2021/946).

Results

A total of 634 respondents completed the survey. Of these, 411 only undertook welding themselves, 36 only supervised other welders, 130 both supervised and welded, and 57 did not undertake any welding or supervision tasks (this included those who worked as occupational health and safety professionals and those who worked around welders but did not undertake welding themselves; these individuals were excluded from further analysis). Dermal UVR exposure occurred in 7.8% of welders and 14.4% of supervisors, whereas ocular UVR exposure occurred in 16.8% of welders (mostly high exposure) and 33.1% of supervisors (mostly medium exposure) [Table 1].

Welders in the mining industry were less likely to be exposed to dermal UVR than those in other industries [Supplementary Table 1]. Those in micro workplaces (less than five workers), who spent less than 5 h per week welding, and who did not hold a formal welding qualification were more likely to be exposed to dermal UVR than the relevant comparison groups. Regression analysis showed that those in micro workplaces were more likely to be exposed to dermal UVR than those in large workplaces (adjusted prevalence ratio [aPR] = 1.14, 95% CI: 1.04–1.25), whereas those welding for 20 to 40 h per week were less likely to be exposed than those welding for less than 5 h per week (aPR = 0.89, 95% CI: 0.84–0.95) [Supplementary Table 2].

Table 1: Exposure to ultraviolet radiation in welders (*n*=541) and welding supervisors (*n*=166) to the skin (dermal UVR) and to the eyes (ocular UVR), by level of exposure

Exposure level	Welders		Welding supervisors	
	n	% (95% CI)	*n*	% (95% CI)
Dermal UVR exposure				
None	499	92.2 (90.0-94.5)	142	85.6 (80.2-90.9)
Medium	8	1.5 (0.5-2.5)	14	8.4 (4.2-12.7)
High	34	6.3 (4.2-8.3)	10	6.0 (2.4-9.7)
Ocular UVR exposure				
None	450	83.2 (80.0-86.3)	111	66.9 (59.7-74.1)
Medium	26	4.8 (3.0-6.6)	46	27.7 (20.9-34.6)
High	65	12.0 (9.3-14.8)	9	5.4 (2.0-8.9)

For supervisors, dermal UVR exposure did not differ by demographic or job-related factors [Supplementary Table 1]. Regression analysis showed that supervisors in the mining industry (aPR = 0.84, 95% CI: 0.77–0.91) and those welding for 20–40 h per week (aPR = 0.84, 95% CI: 0.73–0.97) were less likely than those in the manufacturing industry and those welding less than 5 h per week, respectively, to be exposed to dermal UVR [Supplementary Table 2].

For ocular UVR exposure, welders who had welded for more than 10 years were more likely to be exposed and supervisors in micro workplaces were less likely to be exposed [Supplementary Table 3]. In the Poisson regression analyses, welders aged 35–54 years (aPR = 0.91, 95% CI: 0.84–0.98) and 55 years and older (aPR = 0.90, 95% CI: 0.82–0.99) were less likely than younger workers to be exposed to ocular UVR [Supplementary Table 4]. Welders with more than 10 years of experience were more likely to be exposed than those with less experience (aPR = 1.17, 95% CI: 1.08–1.27). Among supervisors, those in micro workplaces were less likely to be exposed to ocular UVR than those in large workplaces (aPR = 0.82, 95% CI: 0.68–0.98).

The use of personal protective equipment was lower among supervisors than welders, with clothing that covered the skin being worn by 93.7% of welders and 85.4% of supervisors and eye protection being worn by 88.0% of welders and 67.6% of supervisors [Table 2]. The higher-level controls of barriers and signs separating welding areas were reported by 59.7% of welders and 68.7% of supervisors. The majority (83.0%) of respondents reported that other workers were present in the welding area.

Discussion

A recent survey found that only 20% of welders felt they were protected from exposure to welding fumes at work.[10] It is encouraging to observe that dermal and UVR exposure

Table 2: Prevalence of use of control measures when welding

	Welders *n* (%)	Welding supervisors *n* (%)
Clothing that completely covered skin		
Yes	507 (93.7)	129 (85.4)
No	33 (6.1)	22 (14.6)
Don't know	1 (0.2)	-
Goggles, welding helmet with goggles, or welding shield		
Yes	476 (88.0)	102 (67.6)
No	59 (10.9)	49 (32.4)
Don't know	6 (1.1)	-
Use of warning or safety signs and barriers to separate the welding area from other parts of the worksite		
Yes	323 (59.7)	114 (68.7)
No	211 (39.0)	50 (30.1)
Don't know	7 (1.3)	2 (1.2)

is much less common, with 8% of welders exposed to dermal UVR and 17% exposed to ocular UVR.

Ocular UVR from welding has been shown to cause melanoma of the eyes.[4] Our study showed that exposure to ocular UVR was less common among those with fewer years of welding experience, suggesting that changes in the training system may be improving the safety culture. Although the majority of welders (88%) reported using welding goggles or shields to protect against ocular exposure, a smaller proportion (67%) of supervisors reported the use of these protections. The lack of use of eye protection is particularly surprising as the consequences of ocular UVR exposure include welder's flash. This extremely painful condition usually occurs shortly after exposure and tends to reinforce the need for eye protection.[11] It has also been shown that high levels of ocular UVR exposure occur even within helmets,[12] which emphasizes the importance of protection.

It is also known that the types of UVR produced during welding cause skin cancer.[5] Flame-resistant shirts, along with aprons and gloves, are required to be worn while welding, and such special welding workwear is likely to provide adequate skin protection for welders themselves. However, UVR from welding arcs contains a higher proportion of shorter wavelengths than light from the sun, so supervisors and other workers in the area may not have adequate skin protection if wearing only ordinary workwear designed for solar exposure.[13] The ambient UVR levels in factories may exceed the maximum permissible exposure by more than five times,[2] so it is concerning that nearly one in six supervisors did not even wear clothing that covered their arms.

Most respondents (83%) reported that other workers were present in the welding area. This highlights the importance of engineering and workplace design control measures to decrease UVR exposure for all workers, as non-welders are unlikely to wear eye protection or, as observed in our results, even wear protective skin covers when supervising welders. The separation of the welding area from other work areas by the use of distance and barriers (partitions or curtains) is an important control measure for the protection of non-welders.[6] These are far from being universal; however, with 60% of welders and 69% of supervisors reporting the presence of safety signs and/or barriers in the current study.

The use of an online survey was the most effective way to make our survey available to as many workers as possible. However, the use of this approach means that there is a potential response bias. Although the exact representativeness of the respondents is not certain, the respondents did cover a wide range of types of welding workplaces and had varied experience in welding. Given the lack of available information on welding safety in relation to UVR, the use of this method seems a reasonable approach despite its potential limitations.

Conclusion

The results of this study show that there are still many supervisors, and even some welders, who are not protecting their eyes and skin from UVR during welding. This is surprising and suggests that occupational health and safety professionals need to emphasize these basic protections to employers and workers.

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Conflicts of interest

LF is the Director of the company OccIDEAS Pty Ltd.

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Supplementary Table 1: Number and proportion of total welders (*n*=541) and welding supervisors (*n*=166) who were exposed to ultraviolet radiation to the skin (dermal UVR) by demographic and job characteristics

Demographic characteristic	Welders			Welding supervisors		
	N exposed	% exposed (95% CI)	*P*	*N* exposed	% exposed (95% CI)	*P*
Age group			0.357			0.629
18-34	14	8.1 (4.0-12.2)		6	12.5 (3.1-21.9)	
35-54	14	6.1 (3.0-9.1)		13	17.3 (8.7-26.0)	
55+	14	10.1 (5.1-15.2)		5	11.6 (2.0-21.3)	
Industry of employment			0.022			0.127
Manufacturing	24	8.7 (5.4-12.0)		17	20.2 (11.6-28.9)	
Mining	2	1.9 (0.0-4.6)		1	3.6 (0.0-10.5)	
Construction	6	6.6 (1.5-11.7)		4	13.3 (10.8-25.6)	
Other	10	14.3 (6.1-22.5)		2	8.3 (0.0-19.5)	
Size of workplace			0.002			0.156
Micro (< 5)	12	18.2 (8.9-27.5)		6	30.0 (9.8-50.2)	
Small (5-19)	13	9.4 (4.5-14.2)		5	10.2 (1.7-18.7)	
Medium (20-200)	11	4.8 (2.0-7.6)		11	15.3 (6.9-23.7)	
Large (>200)	5	5.0 (7.2-9.3)		2	8.7 (0.0-20.3)	
Years of welding experience			0.614			0.807
10 years or less	12	8.8 (4.0-13.5)		9	13.6 (5.3-22.0)	
More than 10 years	30	7.4 (4.9-10.0)		15	15.0 (7.9-22.1)	
Formal welding qualification/s			0.001			0.181
Yes	30	6.3 (4.1-8.5)		22	13.7 (8.4-19.1)	
No	12	17.9 (8.7-27.1)		2	33.3 (0.0-71.3)	
Hours spent welding in typical week[a]			0.017			
Less than 5 hours	16	14.0 (7.6-20.4)				
5-20 hours	13	8.4 (4.0-12.8)				
20-40 hours	4	2.8 (0.1-5.5)				
More than 40 hours	2	4.3 (0.0-10.0)				
Highly variable hours week to week	7	8.6 (2.5-14.8)				

[a]Not asked of supervisors

Supplementary Table 2: Adjusted prevalence ratios and 95% CIs for association between demographic and occupational factors and exposure to artificial UVR to the skin (dermal) for welders and supervisors

Demographic characteristic	Welders		Supervisors	
	aPR[a]	95% CI	aPR[b]	95% CI
Size of workplace				
Large (more than 200)	1.00			
Medium (20-200)	1.01	0.96-1.06		
Small (5-19)	1.06	0.99-1.13		
Micro (fewer than 5)	1.14	1.04-1.25		
Hours spent welding in typical week				
Less than 5 h per week	1.00		1.00	
5-20 h per week	0.94	0.88-1.01	0.91	0.79-1.06
20-40 h per week	0.89	0.84-0.95	0.84	0.73-0.97
More than 40 h per week	0.92	0.85-1.00	1.02	0.78-1.32
Highly variable h per week	0.95	0.88-1.02	0.96	0.80-1.15
Industry of employment				
Manufacturing			1.00	
Mining			0.84	0.77-0.91
Construction			0.96	0.82-1.12
Other			0.90	0.78-1.03

[a]Adjusted for size of workplace and hours spent welding in typical working week. [b]Adjusted for hours spent welding in typical working week and industry of employment

Supplementary Table 3: Number and proportion of total welders (*n*=541) and welding supervisors (*n*=166) who were exposed to ultraviolet radiation to the eyes (ocular UVR) by demographic and job characteristics

Demographic characteristic	Welders			Welding supervisors		
	N exposed	% exposed (95% CI)	*P*	*N* exposed	% exposed (95% CI)	*P*
Age group			0.964			0.290
18-34	30	17.4 (11.8-23.1)		12	25.0 (12.7-37.3)	
35-54	38	16.5 (11.7-21.2)		29	38.7 (27.6-49.8)	
55+	23	16.7 (10.4-22.9)		14	32.6 (18.4-46.7)	
Industry of employment			0.742			0.301
Manufacturing	49	17.8 (13.2-22.3)		33	39.3 (28.8-49.8)	
Mining	19	18.3 (10.8-25.7)		9	32.1 (14.7-49.6)	
Construction	14	15.4 (8.0-22.8)		8	26.7 (10.7-42.6)	
Other	9	12.9 (5.0-20.7)		5	20.8 (4.5-37.2)	
Size of workplace			0.642			0.037
Micro (<5)	10	15.2 (6.5-23.8)		2	10.0 (0.0-23.2)	
Small (5-19)	20	14.4 (8.5-20.2)		14	28.6 (15.8-41.3)	
Medium (20-200)	44	19.3 (14.2-24.4)		31	43.1 (31.5-54.6)	
Large (>200)	17	17.0 (9.6-24.4)		8	34.8 (15.2-54.4)	
Years of welding experience			0.008			0.703
10 years or less	13	9.5 (4.6-14.4)		23	34.8 (23.3-46.4)	
More than 10 years	78	19.3 (15.4-23.2)		32	32.0 (22.8-41.2)	
Formal welding qualification/s			0.658			0.079
Yes	81	17.1 (13.7-20.5)		55	34.4 (27.0-41.8)	
No	10	14.9 (6.4-23.5)		0	0.0	
Hours spent welding in typical week[a]			0.273			
Less than 5 hours	21	18.4 (11.3-25.6)				
5-20 hours	31	20.0 (13.7-26.3)				
20-40 hours	16	11.3 (6.1-16.5)				
More than 40 hours	10	21.3 (9.5-33.0)				
Highly variable hours week to week	13	16.0 (8.0-24.1)				

[a]Not asked of supervisors

Supplementary Table 4: Adjusted prevalence ratios and 95% CIs for association between demographic and occupational factors and exposure to artificial UVR to the eyes (ocular) for welders and supervisors

Demographic characteristic	Welders		Supervisors	
	aPR[a]	95% CI	aPR	95% CI
Age				
18-34	1.00			
35-54	0.91	0.84-0.98		
55+	0.90	0.82-0.99		
Years of welding experience				
10 years or less	1.00			
More than 10 years	1.17	1.08-1.27		
Size of workplace				
Large (more than 200)			1.00	
Medium (20-200)			1.06	0.90-1.25
Small (5-19)			0.95	0.80-1.14
Micro (fewer than 5)			0.82	0.68-0.98

[a]Adjusted for age and years of welding experience