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Original article

Factors Influencing the Use of Control Measures to Reduce Occupational Exposure to Welding Fume in Australia: A Qualitative Study

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ABSTRACT

Background: Exposure to welding fume is associated with adverse effects on worker health. The use of various control measures can reduce levels of exposure and the resulting health effects. However, little is known about the factors that may influence workers' use of control measures in the workplace and their perceived intervention needs. This study aimed to investigate workers' and other stakeholders' views on ways to improve the use of welding fume control measures in Australian workplaces.

Methods: We conducted a series of online focus group discussions and individual interviews with participants who have some occupational involvement in welding, whether as workers, employers or industry representatives, union representatives, or regulators. A semi-structured question guide was used, and all discussions and interviews were recorded and transcribed for analysis.

Results: Five focus group discussions and five individual interviews were conducted with a total of 21 participants. Three major themes emerged. The first addressed the current awareness of welding fume harms and concern about exposure; the second focussed on the current use of control measures, and barriers and facilitators to their use; and the last centred around intervention needs and the contents of a potential effective intervention.

Conclusion: Improving the use of control measures to prevent exposure to welding fume requires knowledge around the barriers and facilitators of control, use, and the intervention needs of stakeholders. This study has provided such knowledge, which will facilitate the design and implementation of an intervention to reduce welding fume exposure and ultimately protect the health of workers.

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1. Introduction

Welding is a common work activity, with estimates suggesting that more than 10 million workers worldwide weld as a part of their job [1]. Exposure to welding fume has been associated with a variety of adverse health effects [2–4], including lung cancer and non-malignant respiratory disease [5,6].

Welding fume exposure can be reduced through the use of control measures, including ventilation, on-tool extraction, and respiratory protection [3,5]. However, little is known about the

prevalence of use of these control measures, with most studies focussing on the use of ventilation or respiratory protection alone [5]. A Swedish study found that 90% of welders reported working in a workplace that used general mechanical ventilation, whereas only 40% reported using powered air-purifying respirators (PAPRs) [7]. In Australia, a survey conducted in 2020 found that 32% of welders reported using no respiratory protection at all [8]. Similarly, a more recent survey of Australian welders found that half of those surveyed reported using neither ventilation nor an air-supplied helmet, and 2% used no protective equipment of any kind [9].

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In order to improve protection, it is important to know what factors influence the use of control measures among welders and employers. Understanding the barriers and facilitators to the use of control measures allows more informed approaches designed to increase their use. We aimed to obtain detailed information about the extent of use of various welding fume control measures and the factors influencing this use, in order to better understand how control measure use could be improved. In particular, we aimed to explore the following:

- a) workers' and employers' awareness and understanding of the harms associated with exposure to welding fume;
- b) which control measures are currently being used in Australian workplaces;
- c) the barriers and facilitators that workers and employers face in using different welding fume control measures; and
- d) views around a potential intervention to increase the use of control measures.

The information obtained from this study will be used to inform the design and implementation of an intervention to improve the use of control measures to reduce exposure to welding fume.

2. Materials and methods

2.1. Design

This study used a qualitative research design. Focus group discussions were used to gather an in-depth understanding of the use of currently available control measures, barriers and facilitators to the use of these control measures, and workers' awareness of the harms of exposure to welding fume [10]. Where participants were unable or unwilling to attend scheduled focus group discussions, individual interviews were conducted following the same question schedule.

2.2. Participants and recruitment

Participants were recruited from one of three groups: (a) workers who undertake welding as part of their job; (b) employers, company representatives, and/or industry representatives in the welding industry; and (c) union representatives or regulators involved in the welding industry. All had some occupational involvement in welding.

Participants were recruited through their connection with union and industry groups involved in the study. Representatives from these groups were provided with an email and social media invitation containing information about the study. This information was either sent to members of their mailing lists or posted to the social media accounts (including Facebook, LinkedIn, and Instagram) of the organisation. Individuals interested in participating were requested to email an expression of interest to the study team, who then arranged a convenient time for the conduct of each focus group or interview.

Individuals were eligible to participate if they were adult residents of Australia and were involved in welding as a part of their employment. There were no exclusions as to age, gender, or cultural background, although participants were required to speak a sufficient level of English to participate without translation. Participant recruitment continued until data saturation was reached; that is, until no new themes or issues arose in the focus groups or interviews [11].

This study was approved by the University of Sydney Human Research Ethics Committee (approval 2022/279).

2.3. Data collection

Data were collected via online focus group discussions and individual interviews using videoconferencing platforms (Zoom and Microsoft Teams). All discussions and interviews took place between August and November 2022.

A semi-structured question guide was used to allow flexibility in the discussion and to provide opportunities to probe for further information where necessary (Table 1). Each focus group discussion and interview began with a brief overview of the research area and the aims of the discussion. The questions began generally with a discussion of participants' welding experience and knowledge and awareness of welding fume harms. Participants were then asked about ways to control welding fume exposure and the factors that might make them (or others) more or less likely to use particular control measures. Finally, participants were asked to identify and comment on possible elements of an intervention aiming to improve the use of control measures.

Each focus group discussion involved between two and five participants, plus a facilitator and a note taker who were members of the study team. The membership of individual focus groups was limited to people with similar or complementary roles within the welding industry to ensure that all group members were able to speak openly. Each discussion took between 45 and 90 minutes to complete. Individual interviews used the same question schedule as the focus group discussions and took between 20 minutes and one hour to complete.

2.4. Data analysis

The data from all focus groups and interviews were combined for analysis, although a distinction was made between group membership in reporting. Analysis focussed on the identification of key themes and patterns emerging from the data to address the research aims. Deductive and inductive codes, reflecting the questions asked and the concepts arising during the discussions, respectively, were used to build these themes. Key excerpts from the discussions were used to illustrate themes, with pseudonyms assigned to all participants according to the group they represented (W = worker; I = industry; U = union or regulator).

2.5. Rigour

Each focus group and interview was audio and video recorded using the videoconferencing platform. Automatically generated transcripts provided by the platform were checked and corrected where required by a member of the study team. Two members of the study team familiarised themselves with the data to obtain an overall impression before beginning the coding process. Codes were then discussed with the study team as a whole and refined

Table 1
Focus group discussion guide

| |
|---|
| How serious do you think the threat to health from welding fume is? |
| Tell me about ways you have seen welders protect themselves from the potential harms of welding fume. |
| Do you think that workers in general are protected from the harms of welding fume exposure? How so/not? |
| What might make you or others more likely to use a control measure such as on-tool extraction or a respirator? |
| What might make you or others less likely to use one of these control measures? |
| Have you had any problems using these sorts of control measures? |
| Can you think of any ways that we might be able to help workers to understand the hazards of welding fume and increase their use of control measures? |

and grouped as appropriate. Member checking was also used to confirm the validity and reliability of study findings [12]. This involved asking members of later focus group discussions for their interpretation of and opinion on topics discussed during previous discussions.

3. Results

3.1. Participant demographics and characteristics

Five focus group discussions and five interviews were conducted with a total of 21 participants. Participants comprised nine welders and boilermakers, seven company and industry representatives, four union representatives, and one regulator. All participants were male. Participants reported a range of experience with welding, spanning from an apprentice boilermaker to people with more than 40 years of experience in the industry. The majority of company and union representatives also had personal welding experience.

Three major themes emerged from the data. The first focussed on workers' and employers' awareness of and concern around welding fume harms; the second addressed the current use of control measures, and the barriers and facilitators to this use; and the third centred around a potential intervention to increase the use of welding fume control measures. Each of these themes is described below.

3.2. Theme one: awareness of harms

3.2.1. Awareness of welding fume harms

There was general agreement that the level of awareness of welding fume harms had increased in recent years. However, it was widely acknowledged that there were still many people in the industry who lacked awareness of the harms of exposure and, in particular, were unaware of the International Agency for Research on Cancer (IARC) reclassification of welding fume as carcinogenic.

While some noted that younger workers were more likely to be aware of the hazards of welding fume exposure: *"probably younger guys that are more attuned to ... what's going around in the media and so on, and are probably more health conscious, are certainly more likely to be aware"* (I2, FG4), others thought that young workers were not receiving enough information in this regard: *"a lot of young apprentices are not being taught anything or not being informed about this at all"* (W7, I3). Awareness was also thought to be low among workers who had trained overseas:

"Some of the labour we get from overseas, whilst being ... reasonably well skilled, I don't think ... they get the exposure, the information, a lot of people here get. You know, whether that's by fair means or foul, whether that's just coincidental, but they don't seem to have an understanding of the health and safety culture and ... what the need is to mitigate the fume exposure" (U4, FG1)

Employers' awareness of the hazards of welding fume exposure was also an issue; although some noted that while they might be aware of the dangers of welding fume exposure, some businesses and business owners may not recognise or accept that it is their responsibility to minimise the harms: *"maybe it's not that people don't understand, it's maybe that there's not enough understanding by employers that they have the responsibility to make that sort of stuff happen"* (I3, FG4). Awareness was also seen to be hampered by a focus on other hazards, including silica and asbestos.

3.2.2. Concern around welding fume exposure

The level of concern around welding fume harms was also thought to vary among workers and businesses. Concern was

generally thought to be linked to the level of awareness, although not all of those who were aware of the harms were thought to be concerned: *"everyone's aware of what they're exposed to, and it's just a way of life for some guys, and it pays well, so they're not going to stop"* (W9, FG5).

There was a general consensus that older workers did not see welding fume exposure as a threat to their health as they had been exposed for their entire careers with little or no apparent serious health effects. Some noted that this lack of concern could have adverse effects on younger workers, who might model their behaviours. Related to this, those who had seen the adverse health effects of welding fume, whether personally or to others around them, were more likely to be concerned.

Concern around welding fume exposure and the related harms was not always seen to translate into action. Participants noted that workers might be afraid to speak up about welding fume exposure for fear of losing their job or other opportunities, for example. In addition, it was thought that there was a wider work culture issue at play and that workers' voices may not be strong enough to counteract this culture:

"Sometimes, even the best education that we can provide them doesn't fall on deaf ears, but it doesn't get implemented because it clashes with an existing culture ... and we do have to change industry's culture to the current acceptance of the way that workers have been exposed to welding fumes" (U1, FG4)

3.3. Theme two: current use of control measures

3.3.1. Adequacy of current control measures

Many thought that, in general, the current control of welding fume in workplaces was poor, although there was agreement that this varied across workplaces and that it had become better controlled in recent years. Ventilation, in particular, was found to be very poorly used, with many reporting that ventilation was *"non-existent"* (W5, FG3), even in new purpose-built workshops. Many also considered overhead fans and open doors to be sufficient ventilation:

"But in our workshop, it's pretty good ... we have the big fan, overhead fan, and the doors are normally open. We have four doors that go around the shop, and they're normally open." (W1, I5)

Further, even where control measures such as PAPRs and ventilation were used, they were not always adequate or used effectively:

"Getting welders to be able to properly fit respirators because so many bearded ones that flatly refuse to remove their beards. And so how do you deal with people that have got that kind of mindset? You know, it makes it very difficult to try and use appropriate PPE" (I2, FG4)

"Things like an exhaust duct, exhaust fans, and snorkels are fantastic for moving smoke, but they move it from one area and dump it in another" (W2, FG5)

3.3.2. Barriers to the use of control measures

The major barrier to the use of control measures was seen to be the cost. The size of the business was also mentioned as a barrier to implementing controls, whether due to cost or other considerations, with control seen to be poorer in smaller businesses and, by extension, better in larger businesses. The attitude of employers and business owners could also be a barrier to the use of control measures:

"I think you've got an employer that is a barrier in a lot of work-places. It's trying to convince them that it's a necessary control ... I think it does come down to an employer being on board to start with" (U3, FG2)

Age was also mentioned as an influence on whether controls were used, with younger workers seen as much more likely to use PAPRs than older workers. Some mentioned that PAPR units were bulky, uncomfortable, or heavy and that they were not suited to all body shapes. Similar comments were made around the use of on-tool extraction, with the extraction units being heavy and hard to use, as well as limited with regard to some welding processes.

3.3.3. Facilitators to the use of control measures

Despite these barriers, some noted that in some workplaces, there was little reluctance to use control measures such as PAPRs among workers. In some cases, this was likely linked to their concerns about the health effects of welding fume exposure. For others, their willingness to use PAPRs and other respiratory protection was due to their comfort, particularly in warmer climates: *"our guys love PAPR because it's like air conditioning on your head" (I4, FG2)*.

There was a general consensus that the provision of control measures, particularly PAPRs, increased their use: *"if they're there, they'll use them" (W2, FG5)*, and some noted that PAPRs and other protective measures should be provided in the same way as other safety equipment, such as earplugs and safety glasses.

3.4. Theme three: intervention needs

3.4.1. General considerations

There was a general agreement that any intervention to increase the awareness of welding fume harms and the use of control measures would need to present a clear, consistent, and straightforward message that was tailored to the target audience:

"The information that's out there at the moment for welders to interpret and to navigate through and for employers, it can be very difficult ... So I think the information that's out there could be a lot more straightforward and a lot simpler, and that would lead to better education within the industry" (I1, FG4)

Participants discussed the need for any intervention to be multi-faceted, including the need for the targets of such an intervention to be widespread, with some noting that education and awareness needed to be improved across the entire spectrum. However, others argued that any intervention needed to start at the top, targeting employers, as they were the ones in control and with the legislative requirement to provide a safe workplace. One participant summed this up as *"safe workplace versus safe worker" (U5, FG1)*.

Other targets for an intervention were also mentioned, including the families of workers and other workers onsite who may be exposed to welding fume despite not actually welding themselves:

"I think a campaign should also look at targeting people that work with welders because a lot of times they're left out of the equation ... So, there probably needs to be a little bit of concentrated effort there to make people that work in those areas aware that just because you're not welding, it doesn't mean that you're not actually breathing in the fumes and exposing yourself to the risk" (U4, FG1)

3.5. Contents of a potential intervention

When commenting on the specific contents of a potential intervention, many participants mentioned the need for visual aids such as pictures of filters from PAPR and ventilation units taken

before and after welding to show the potential harms of welding fume. The use of video exposure monitoring, where monitoring results are presented alongside video footage of the welder working to show where exposures were occurring, was also mentioned as potentially helpful:

"So as soon as you can start to make it more visual for them rather than you just sort of saying 'here's the number, that's your exposure level', I think ... that would be a big shift." (I3, FG4)

Providing the results of exposure monitoring was also thought to be useful in increasing awareness and the use of control measures, and some stated that providing clear guidance on what controls to use in certain situations could be helpful:

"If we gave them clear guidance and said ... 'if you find yourself in this situation, do this. If you find yourself in this situation, do this. If you find yourself in a different situation ... which we don't have an answer for, you need someone to come in.'" (I1, FG4)

3.5.1. Method of delivery of intervention

Participants agreed that social media could be an important avenue for the delivery of an intervention, with one noting *"if you want to reach people, you go on social media" (U2, I1)*. Social media was seen to be an effective way of reaching multiple audiences, including young people and professional audiences. The use of an overarching industry body to disseminate intervention materials was also mentioned.

Some mentioned the use of a practical session demonstrating welding and the use of controls, while others thought that presenting intervention materials at toolbox or workplace safety meetings would be useful. However, one participant thought that welders were already aware of the issues that could be presented at a toolbox talk and that presenting information in this way would either be ignored or could work to ostracise welders:

"Welders know, you know, and all you're doing is just scaring the [trade assistants], and everybody else is going to just pick up their phone and start looking, 'it's got nothing to do with me' ... We'll have ... somebody else use it as an excuse to stop us from working, and we end up being the bad guys" (W2, FG5)

Other methods of delivery included posters in the workplace as well as stickers on welding rods and other consumables, although some mentioned that these stickers may not be effective as they may not be seen by the welder.

The incorporation of intervention materials into training and education was also mentioned. Participants felt that educating young workers as they came into the industry was an important way to raise awareness and concern around welding fume.

4. Discussion

This study aimed to obtain detailed information about the use of welding fume control measures and the factors influencing this use, in order to inform an intervention to increase the use of control measures. Overall, there was a general agreement that while awareness of welding fume harms had increased in recent years, many people involved in welding still lacked awareness and, in particular, were not aware of the IARC reclassification of welding fume as carcinogenic. This is consistent with results from a 2020 survey of welders in Australia and New Zealand which found that 37% of respondents were not aware of the IARC evaluation [8]. The level of concern around welding fume harms was also seen to vary, and participants noted that while workers may be aware of the

harms, not all workers were concerned about those harms. Further, awareness and concern were not always seen to translate into action, with some noting that workers may be afraid to speak up about welding fume exposure for fear of losing their jobs or other opportunities. Similarly, a study in Nepal found that although 90% of welders were aware of the effects of welding fume exposure, only 47% used some form of control measure [13].

Some participants in the current study also thought there was a wider work culture issue at play and that business owners and employers may not recognise or accept their responsibility to minimise the harms of welding fume exposure. This points to the need for an intervention to reiterate the duty and responsibility of employers and business owners to understand the risks and protect their workers from harm.

There was an overall feeling that the current control of welding fume, although varying across workplaces, was insufficient and that ventilation, in particular, was very poorly used. This is in line with a previous Australian survey which found that half of those surveyed used neither ventilation nor an air-supplied helmet while welding [9]. Many felt that the major barrier to the use of control measures was the cost, consistent with a survey of welders which found that 61% of respondents thought that the cost was stopping their workplace from introducing better safety measures [8]. There was a general consensus that the provision of control measures by employers increased their use, and some participants noted that these control measures should be provided in the same way as other safety equipment. This again points to employers and business owners being an important target for intervention.

With regard to an intervention, participants felt that any potential intervention should provide a clear and straightforward message and be multifaceted, both in terms of the strategies applied and the target audience. Consistent with the insights provided earlier, many also mentioned the need for a wider cultural change, with employers and their legislative requirement to provide a safe workplace, as well as the legislation itself, seen to be important targets for intervention. Participants also provided insights into the potential components of such an intervention, including the use of visual aids and videos. This is supported by previous reviews which have found that visual aids can be highly effective tools to change attitudes and reduce risky health behaviours [14,15]. Social media was mentioned as an effective intervention tool, with a recent review of the literature also concluding that social media may be a useful means of communicating occupational health and safety messages [16].

This study has provided a number of important insights into the use of control measures to reduce exposure to welding fume in Australia and the potential usefulness of an intervention to increase control use. However, it should be noted that the extent to which the results of this study are generalisable to the wider welding industry in Australia (and internationally) is uncertain. We recruited participants using convenience sampling and self-selection, a non-probability approach to recruitment that is common in exploratory qualitative research [17]. This sampling method may mean that the views expressed in our focus groups and interviews are not necessarily representative of the views of the wider population. In addition, the nature of this study meant that those who did not speak a sufficient level of English to participate in a discussion without translation could not be included. This may limit the generalisability of our findings to workers from non-English speaking backgrounds. However, recent Census data indicate that most workers employed in the welding trade are literate in English and were born in Australia [18], and therefore the impact of excluding those who could not speak English is not likely to be substantial.

The online nature of this study provided the opportunity to include participants from a variety of backgrounds across Australia,

which may have increased the transferability of our findings. The use of focus group discussions allowed us to gain a deeper understanding of the views and experiences of participants than may have been gained through other data collection methods, and it allowed us to probe for further understanding where required [19]. Where participants were not comfortable or available to participate in a group setting, we provided the opportunity for individual interviews to allow those participants to share their thoughts and experiences. The central themes uncovered were similar across both methods, enhancing the credibility of our findings.

In sum, the results of this study have provided some important insights and suggestions as to how to best increase the awareness of welding fume harms and the use of control measures among those employed in the welding industry in Australia. Gaining a comprehensive understanding of the barriers and facilitators to the use of control measures allows more informed approaches aimed at increasing their use. The findings of this study will be used to inform the development and implementation of an intervention to be disseminated throughout Australian workplaces. This will aim to ultimately improve the health of welders in Australia.

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Data statement

Anonymised datasets generated and analysed during this study are available from the corresponding author on reasonable request.

Conflicts of interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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