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Assessment of Health Consequences of Steel Industry Welders' Occupational Exposure to Ultraviolet Radiation

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ABSTRACT

Background: Welding is among the most important frequently used processes in the industry with a wide range of applications from the food industry to aerospace and from precision tools to shipbuilding. The aim of this study was to assess the level of steel industry welders' exposure to ultraviolet (UV) radiation and to investigate the health impacts of these exposures.

Methods: In this case–control study, we measured the intensity of UV at the workers' wrist in Fars Steel Company through manufacture of different types of heavy metal structures, using UV-meter model 666230 made by Leybold Co., from Germany.

Results: The population under the study comprised 400 people including 200 welders as the exposed group and 200 nonwelders as the unexposed group. The results of the questionnaire were analyzed using SPSS software, version 19. The average, standard deviation, maximum and minimum of the UV at the welders' wrist were 0.362, 0.346, 1.27, and 0.01 μW/cm^2, respectively. There was a significantly ($P < 0.01$) higher incidence of cataracts, keratoconjunctivitis, dermatitis and erythema in welders than in their nonwelders.

Conclusions: This study showed that the time period of UV exposure in welders is higher than the permissible contact threshold level. Therefore, considering the outbreak of the eye and skin disorders in the welders, decreasing exposure time, reducing UV radiation level, and using personal protective equipment seem indispensable. As exposure to UV radiation can be linked to different types of skin cancer, skin aging, and cataract, welders should be advised to decrease their occupational exposures.

Keywords: Cataract, dermatitis, keratoconjunctivitis, melanoma and erythema, ultraviolet radiation, welding

INTRODUCTION

Welding is one of the important and regularly used processes in industry and its usage ranges from the food industry to aerospace and from precision tools to shipbuilding. The human's need for modern, light, firm, and steady connections in recent years, especially the recent 20 years, has developed this skill rapidly and the governments have invested vastly in this area. Specifically, humans' competition in nuclear sciences which must target only at peace is another cause of fast development of this skill.[1] Welding is among dangerous careers and the related workers are exposed to many risks. The detection and refusal of these threats play a significant role in their health and making their environment healthy. On one hand, welding is among occupational

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processes which are dangerous, laborious, and harmful. In welding operations, metal pieces get connected using heat or pressure or both. In other words, welding is the connection of metal pieces with the aid of welding wire and heat.[2] Electromagnetic radiations with the wavelength of 100–400 nm are the ultraviolet (UV) radiation. These radiations based on wavelength are divided into three ranges of A, B, and C, each with 315–400, 280–315, and 100–280 nm, respectively.[3] The UV radiation is produced by a high number of sources. The most important source of human exposure to UV radiation is obviously the sun. Although the most important source of exposure to electromagnetic radiation for everybody is the sun, welders' exposure to ultraviolet-C radiation is exclusively due to the welding procedures.

Several studies have shown the relationship between occupational and nonoccupational exposure especially that of UV in welding and the risk of health impacts including cataract, keratoconjunctivitis, dermatitis, melanoma, and erythema.[4] Cataract is the cause of 48% blindness in the world and 50–55% in African countries.[5] According to the examination of UV in welding by Megbele *et al.*, the occurrence of cataract and keratoconjunctivitis symptoms, such as eye strain, tearing, photophobia, blurred vision, and sensation of sand in the eye have been reported.[6] In another study by Davies *et al.*, the rate of cataract and keratoconjunctivitis in welders has been reported higher than the control group.[7] Some studies have also mentioned harmful impacts, such as dermatitis with symptoms such as itchiness and actinic keratosis.[8] In addition, Xu *et al.*, have reported that the welding UV had caused symptoms of itchiness, redness, and raised spots on the welder's skin and hands.[9] The wavelength accounting for the symptoms of dermatitis is usually placed at the spectrum of UV radiations between 290 and 400 nm.[10] Despite several studies on exposure with these radiations in recent decades, different results have been reported about skin melanoma. Tenkate has reported that the sun UV and the artificial sources of this radiation, such as arc welding, had caused skin melanoma.[4] However, Emmett *et al.*, in their study did not observe a significant difference in terms of melanoma symptoms between welders and the group control.[11] Although our findings are not completely in line with those of Emmett *et al.*, our findings about melanoma were the same as those obtained by Emmett *et al*. Erythema usually deteriorates due to exposure to the wavelength 290–320 nm which is associated with edema, redness, blister, peeling and flaking skin, feeling coldness, fever, and vomit.[12] Since 0.2–2% of workers in industrial countries are welders[13] and in regard to the evidence on the bad effects of welding UV radiations on people's physical health as well as the fast development of this technology in the world, the necessity of assessment and control of such harmful factors in posts of electrical arc welding is perceived more than ago. Over the past several years, our lab has performed extensive experiments on the health effects of exposure of animal models and humans to different sources of electromagnetic fields such as cellular phones,[14-22] mobile base stations,[23] mobile phone jammers,[24] laptop computers,[25] radars,[21] dentistry cavitrons,[26] and magnetic resonance imaging.[16,27] Therefore, this study was conducted aiming at assessment of the welders' amount of occupational exposure to UV radiation and the health impacts of such exposure.

METHODS

Study design and participants

In this cross-sectional study, the measurement of the radiations was done by the Das LUX-UV-IR-meter direct reading device model 666 230 LEYBOLD made in Germany. In this research, the intensity of UV radiations at the welders' wrist was measured. A total of 200 welders working in Fars Steel Factory who all did arc welding in some of the work hours, and also lacked background of diabetes, eye surgery, and any nonoccupational physical impairments related to the research, were selected using simple random method. In addition, 200 workers, who matched the test group in terms of gender, mean age, education, socioeconomic condition, and other significant factors but did not weld, were selected randomly as the nonexposed, or nonwelders group. All subjects voluntarily partook in the study after receiving oral information about the aims of the study. Furthermore, participants signed an informed consent form before commencement of the study.

Variables assessment

For both groups (exposed and nonexposed), information registration forms including demographic information and the assessment form of impacts caused by occupational exposure with an electrical arc in welding were filled out. The questionnaires used in this study were developed by consideration of the literature on the impacts of welding; its trustworthiness and validity were assessed and approved through test-retest, Cronbach's alpha calculation, and several critical experts.

Statistical analysis

After collecting the measurement results and completion of the questionnaires, statistical analyses were performed by the IBM SPSS Statistics for Windows, Version 19.0 software. The statistical test used for analyzing the results of the symptoms was Chi-square test, and for

comparing the features of the exposed and nonexposed groups, *t*- and Chi-square tests were applied.

RESULTS

The results are shown in Table 1; comparison of the demographic features of the groups under the study showed that there were no significant differences between them. The mean age, work duration, daily work hours in the exposed and nonexposed groups were 36.4 and 35.95, 11.54 and 10.48 years, 7.66 and 7.48 h, and the average of daily welding hours and welding duration in the welders were 3.39 h and 6.18 years, respectively.

As shown in Table 2, there was a significant difference between the exposed and nonexposed groups in terms of two symptoms, that is, visual decline and blurred vision with $P < 0.001$ whereas the other three symptoms, that is, study headache, diplopia, and photophobia holding $P > 0.05$, did not reveal a significant difference.

Table 1: Demographic characteristics of participants (*n*=400)

Demographic characteristics	Groups				*P*
	Nonwelders (*n*=200)		Welders (*n*=200)		
	Mean	SD	Mean	SD	
Age (years)	35.95	11.24	36.34	11.65	0.810
Occupational reputation (year)	10.48	8.47	11.54	8.42	0.376
Daily work (h)	7.48	1.08	7.66	0.93	0.211
Daily welding (h)	-	-	3.39	1.6	-
Welding duration (year)	-	-	6.18	4.38	-

SD=Standard deviation

Table 2: Distribution of cataract symptoms in participants (*n*=400)

Cataract symptoms	Groups				*P*
	Nonwelders (*n*=200)		Welders (*n*=200)		
	Number	Percentage	Number	Percentage	
Headaches during study					
Yes	6	3	14	7	0.331
No	194	97	186	93	
Visual decline					
Yes	8	4	38	19	<0.001
No	192	96	162	81	
Diplomia					
Yes	6	3	16	8	0.213
No	194	97	184	92	
Blurred vision					
Yes	8	4	58	29	<0.001
No	192	96	142	71	
Photophobia					
Yes	8	4	18	9	0.251
No	192	96	182	91	

Table 3 shows that, out of eight, seven symptoms including eye redness and hotness, tearing, photophobia, sensation of sand in the eyes, painful eye inflammation, eyelid inflammation, and eyelid and face inflammation showed a significant difference between the exposed and nonexposed groups with $P < 0.001$ and the only nonsignificant difference was related to eye burning with $P > 0.05$.

As shown in Table 4, four symptoms of the four under the study between the exposed and nonexposed groups, including skin redness and inflammation, peeling and flaking skin, actinic keratosis, and skin itching, showed to be significantly different with $P < 0.05$. According to Table 4, with regard to erythema symptoms, all the three items, including redness, burning, inflammation and thinning of the skin, showed a significant difference between the exposed and nonexposed groups with $P < 0.01$.

Table 5 reveals that four symptoms of skin melanoma including change in the shape, size, or color of previous moles, skin color and black skin nodule, did not show any significant difference.

The average, standard deviation, maximum and minimum UV radiation at 200 welders' wrists were 0.00362, 0.346, 1.27, and 0.001 μW/cm^2, respectively.

DISCUSSION

Comparison of cataract symptoms revealed that visual decline and blurred vision in the welder group is more common than the nonwelder. In recent years, much evidence has shown that emission of UV radiation may act as a dangerous factor in the formation of human cataract. The mechanism is still unknown, but it seems that it is the result of the protein accumulation by the act of free radicals at the lens level.[28] Ajayi Iyiade *et al.* in their study of welders has concluded that 11.6% of the people had cataract, 5.2% of whom suffered vision decline.[29] Alakija has reported that 2.3% of 400 welders in the city of Benin had cataract.[30] According to the study on electrical arc welders by Megbele *et al.*, cataract outbreak in welders is higher than the control group; statistics shows a significant difference.[6] The study by Xu *et al.*, showed 50.2% of the welders had the symptoms of blurred vision.[9] Comparing the symptoms of keratoconjunctivitis showed that eye redness and hotness, tearing, photophobia, sensation of sand in the eyes, painful eye inflammation, eyelid inflammation, and eyelid and face inflammation were more common in welders than the nonwelder. The UV radiation which is produced in welding is the cause of keratoconjunctivitis among welders.[31] In a research by Davies *et al.*, the amount of keratoconjunctivitis outbreak was much higher in welders than the nonwelders.[7] In a study by Megbele *et al.*, on electrical arc welding, severe eye pain, tearing, sensation

Table 3: Distribution of keratoconjunctivitis symptoms in participants ($n=400$)

Keratoconjunctivitis symptoms	Groups				*P*
	Nonwelders ($n=200$)		Welders ($n=200$)		
	Number	Percentage	Number	Percentage	
Eye redness					
Yes	44	22	128	64	<0.001
No	156	78	72	36	
Tearing					
Yes	36	18	150	75	<0.001
No	164	82	50	25	
Eye burning					
Yes	36	18	56	28	0.130
No	164	82	144	72	
Photophobia					
Yes	16	8	112	56	<0.001
No	184	92	88	44	
Sensation of sand in the eyes					
Yes	26	13	124	62	<0.001
No	174	87	76	38	
Painful eye inflammation					
Yes	20	10	124	62	<0.001
No	180	90	76	38	
Blepharitis (inflammation of eyelids)					
Yes	16	8	58	29	<0.001
No	184	92	142	71	
Erythema of eyelids and face skin					
Yes	22	11	62	31	<0.001
No	178	89	138	69	

of sand in the eyes, and photophobia as the symptoms of keratoconjunctivitis occurred more in the welders than nonwelders; the relationship between the figures was meaningful and also agrees with the current results. In the study by Xu *et al.*, 61.4% of the welders had the symptoms of tearing and photophobia. In addition, the symptoms of harm to eyes including painful eye neuron, sensation of sand in the eyes, and feeling eye burning were reported in welders with different reputation.[9] In the study by Alakija on welders, the symptoms of sensation of sand in the eyes and tearing were higher in the welder group with $P < 0.01$, but although eye redness and photophobia were more common among the welders, they were not meaningfully different;[30] this is not in the same line with the current study's results. The comparison of dermatitis symptoms shows that skin itching, skin redness increase together with inflammation, peeling and flaking skin, and actinic keratosis is more common in the welder group than the nonwelder. Dr. Lachapelle has suggested that such symptoms in people may originate from different causes. Chemicals, gases, vapours, dusts, and mists at workplace account for these symptoms.[32] Bruze *et al.*, have reported that the UV radiations cause dermatitis in welders.[8] In the study by Xu *et al.*, 39% and 34.9% of the welders had the symptoms of face and hand skin itching, respectively. In addition, the symptoms of redness and raised spots on the welders' face and hand skin were reported.[9] This conforms to the results of the current study on dermatitis. The comparisons of melanoma symptoms show that there is no meaningful difference between the welders group and the nonwelders in terms of melanoma symptoms. Howe *et al.* have reported that melanoma is a global health problem among the whites and the most important risk to it is exposure to UV.[33] The skin spots[34] and moles[35] increase the risk of melanoma. Tenkate has reported that the UV radiation from the sun and artificial sources such as welding arc causes skin melanoma.[4] Emmett *et al.*, in their study on welders, assistant welders, and nonwelders did not find a difference;[11] a result which does not match that of the current study. The comparison of erythema symptoms shows that redness, becoming burned, inflammation, or thinness of the skin are more common among the welders group. Erythema is a severely irritated skin response which is caused by the skin exposed to the UV radiation and is associated with redness, thinness, and edema.[36] Emmett *et al.* in their study on welders noticed the symptoms of erythema therein,[11] as in the current study. The welders' average exposure in this study was higher than the standard limit. A study by Harper *et al.*, was conducted on

Table 4: Distribution of dermatitis symptoms in participants (*n*=400)

Symptoms	Groups				*P*
	Nonwelders (*n*=200)		Welders (*n*=200)		
	Number	Percentage	Number	Percentage	
Dermatitis symptoms					
Skin itching					
Yes	52	26	84	42	<0.01
No	148	74	116	58	
Erythema with swelling					
Yes	26	13	78	39	<0.001
No	174	87	122	61	
Peeling and flaking skin					
Yes	8	4	40	20	<0.001
No	192	96	160	80	
Skin keratosis					
Yes	12	6	82	41	<0.001
No	188	94	118	59	
Erythema symptoms					
Skin redness					
Yes	48	24	84	42	<0.01
No	152	76	116	58	
Skin burning					
Yes	18	9	96	48	<0.001
No	182	91	104	52	
Skin swelling or thinness					
Yes	8	4	38	19	<0.001
No	192	96	162	81	

Table 5: Distribution of skin melanoma symptoms in participants (*n*=400)

Skin melanoma symptoms	Groups				*P*
	Nonwelders (*n*=200)		Welders (*n*=200)		
	Number	Percentage	Number	Percentage	
Skin darkness					
Yes	26	13	42	21	0.187
No	174	87	158	79	
Change in shape, size, or color of a previous mole					
Yes	6	3	14	7	0.331
No	194	97	186	93	
Graying skin					
Yes	6	3	10	5	0.721
No	194	97	190	95	
Black skin nodules					
Yes	8	4	18	9	0.251
No	192	96	182	91	

the welders in copper industry. They employed the Harper direct reading device for measurement of UV in welding and concluded that the amount of UV received by welders was less than the standard maximum, a result which does not conform to those of the present study. However, with the increase of the voltage, the amount rises to match the current study results.[37] The effective irradiance at the welders' wrist was in the range 0.01–1.27 W/m^2 (1–127 μW/cm^2) under the study conditions. The corresponding permissible exposure time per day by the ACGIH was only 0.1–10 s, whereas in this study the welders' daily average exposure to this ray was higher than the standard maximum; therefore, it may be expected that the welders in this industry would get harmed.

CONCLUSIONS

According to the findings of the present study, the time period of UV received by the welders was much higher than the maximum standard suggested by the ACGIH. Therefore, in regard to the outbreak of the eye and skin disorders among welders, decrease of exposure time, control of UV radiation, and usage of decent personal protection devices are indispensable. In addition, welders must attend the related training courses on the harms of UV to the eye and skin, and their eyes and skin must frequently be examined so as to avoid harms to these two body organs.

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