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Prevalence of color vision deficiency among arc welders

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KEYWORDS
Color vision deficiency;
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Abstract
Purpose: This study was performed to investigate whether occupationally related color vision deficiency can occur from welding.
Methods: A total of 50 male welders, who had been working as welders for at least 4 years, were randomly selected as case group, and 50 age matched non-welder men, who lived in the same area, were regarded as control group. Color vision was assessed using the Lanthony desatured panel D-15 test. The test was performed under the daylight fluorescent lamp with a spectral distribution of energy with a color temperature of 6500 K and a color rendering index of 94 that provided 1000 lx on the work plane. The test was carried out monocularly and no time limit was imposed. All data analysis were performed using SPSS, version 22.
Results: The prevalence of dyschromatopsia among welders was 15% which was statistically higher than that of nonwelder group (2%) ($p = 0.001$). Among welders with dyschromatopsia, color vision deficiency in 72.7% of cases was monocular. There was positive relationship between the employment length and color vision loss ($p = 0.04$). Similarly, a significant correlation was found between the prevalence of color vision deficiency and average working hours of welding a day ($p = 0.025$).
Conclusions: Chronic exposure to welding light may cause color vision deficiency. The damage depends on the exposure duration and the length of their employment as welders.

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PALABRAS CLAVE
Deficiencia de la visión del color;
Test D-15 de Lanthony;
Exposición a la luz ultravioleta;
Luz de soldadura

Prevalencia de la deficiencia de la visión del color entre los soldadores con arco eléctrico

Resumen

Objetivo: Este estudio se realizó para investigar si se puede producir una deficiencia de la visión del color relacionada con la profesión de soldador.

Métodos: Se seleccionó como grupo del caso a un total de 50 soldadores que habían ejercido la profesión durante un mínimo de cuatro años, y se les comparó con 50 varones no soldadores que vivían en la misma zona, como grupo de control. Se evaluó la visión del color utilizando el test Lanthony D-15 desaturado. La prueba se llevó a cabo bajo la lámpara fluorescente de luz de día, con una distribución energética espectral con temperatura cromática de 6.500 K y un índice de representación de 94 que aportaba 1000 lux en el plano de trabajo. La prueba se realizó de forma monocular, no imponiéndose ningún límite de tiempo. Los análisis de los datos se realizaron utilizando el software SPSS, versión 22.

Resultados: La prevalencia de la discromatopsia entre los soldadores fue del 15%, lo cual fue estadísticamente superior al grupo de no soldadores (2%) ($p = 0{,}001$). Entre los soldadores con discromatopsia, la deficiencia de la visión del color en el 72,7% de los casos fue monocular. Se produjo una relación positiva entre la duración del empleo y la pérdida de la visión del color ($p = 0{,}04$). De forma similar, hallamos una correlación entre la prevalencia de la deficiencia de la visión del color y la media de horas laborales de una jornada de soldadura ($p = 0{,}025$).

Conclusiones: La exposición crónica a la luz de la soldadura puede causar una deficiencia de la visión del color. El daño depende de la duración de la exposición, y del tiempo en la profesión como soldadores.

Introduction

Welding, a widely used industrial process, is one of the most intense artificial sources of invisible and visible optical radiation. Welding emits a wide spectrum of radiations ranging between 200 nm and 1400 nm. These radiations include ultraviolet rays (200–400 nm), Visible light (400–700 nm) and infra-red rays (700–1400 nm).[1] UV light is usually divided into 3 bands, including UVA (320–400 nm), UVB (290–320 nm) and UVC (100–290 nm).[2] Ultraviolet radiation can cause phototoxic retinal injury especially in children and young adults, because crystalline lens UVB retinal protection is deficient in these groups. In other word, there are UVB windows in the crystalline lens of children and adults under 30 years of age.[3–6] In addition, visible light and near infra-red penetrate to the retina and may cause thermal or photochemical damage, which may be permanent and sight threatening, according to the intensity and duration of exposure.[7] Retinal damage induced by arc welding is referred to as phototoxic maculopathy.[8]

Short wavelength light has two phototoxic effects. One is burnescence of the ocular lens from exposure to UVB, which reduce the amount of short wavelength light arriving at the retina.[9] The other is direct selective damage to the short wavelength sensitive cones caused by UV and visible light.[10] Both of these phototoxic effects can produce clinical blue yellow color vision defects.[9,10]

On the other hand, according to AFSCME (2004), various gasses are emitted during welding and can cause ocular disorders.[11] Report of health effects from manganese in welding fume exposure have been relatively recent.[12] Although there is a large body of literature on the association between occupational manganese exposure and ill health,[13] vision was assessed in only two studies, and both found loss of color vision and changes in near visual contrast sensitivity.[14,15]

Occupation-related color vision deficiency usually cause blue-yellow color discrimination loss or, less frequently, a combination of blue-yellow and red-green loss.[16] The eyes may be unequally involved, and the course is variable depending on exposure and other factors.[16,17] Occupational color vision loss is usually sub-clinical, and workers are unaware of any deficit. It can be assessed using sensitive tests, such as the Farnsworth-Munsell 100 Hue (FM-100) or the Lanthony D-15 desaturated panel (D-15 d).[18]

In the recent years, many studies have been carried out on the impairment of color vision. However, there are few studies that have specifically investigated the effect of arc welding on color discrimination.[14,15,19,20] This study was performed to investigate whether occupationally related color vision deficiency can occur from welding and if so, is there any relationship between exposure duration and color vision defects? The issue that is not evaluated in previous studies.

Methods

A total of 50 male welders, who had been working as welders for at least 4 years, with a mean (±SD) age of 29.3 (±6.36) were considered for inclusion in this study. Subjects were selected with simple random sampling method from the list of welders who lived in the welding park of Zahedan city. To compare the results with those of a normal population, 50 age matched healthy non-welder men, with a mean (±SD) age of 28.06 (±6.13) were randomly recruited from the staff of an eye hospital, where we conducted our examinations. All the selected subjects accepted to participate in our study. Written consent was obtained from all participants after they had been fully informed of the nature of the study according to the code of ethics in the declaration of Helsinki protocol. The welders were asked about the length of their employment as welder, the average working hours of welding a day, use of protective glasses during welding and alcohol consumption. Each patient underwent a complete ophthalmologic examination, refractive errors were optimally corrected for the test distance and best corrected visual acuity was determined monocularly using the Snellen chart, according the standard protocol. The exclusion criteria were as follows: (1) those with the history of congenital color vision deficiency were excluded (it should be noted that our cases in both group passed vision screening tests including color vision test whenever they start their work in hospital or as a welder, so it is expected to be aware of their problem), (2) glaucoma, retinal/optic nerve disease, significant cataract, diabetes and any other ocular or systemic disease which may lead to color vision deficiency, (3) patients taking concomitant medication know to affect color perception. The monocular best corrected visual acuity of all participants was 6/9 or better.

Color vision was assessed with the color arrangement test-namely, the Lanthony desatured panel D-15 test. The test is conducted at 50 cm and composed of a single set of 15 caps with desatured colors. It is used in studies on group of exposed workers as it is sensitive enough for the early detection of mild acquired dyschromatopsia and it is much less time consuming than FM-100. Furthermore, it is simple and well accepted by workers. Fifteen panel caps, numbered on the back, were placed in front of the subject in random order. The subject was required to place the caps in an oblong box, in order of chromatic similarity, starting from the fixed reference cap. To be accurate, the test must be conducted under standard daylight source illuminant C. This can be accomplished by a Macbeth lamp. However, over the years, it has become so expensive and the MacBeth Division of the Kollmorgan Corporation discontinued the manufacture of it due to lack of demand.[21,22] However, obtaining a source that mimic illuminant C is difficult because of cost consideration and lack of availability. According to color vision standards, the illuminant for color vision testing should have a CCT between 5500 K and 7500 K.[23,24] So we used a daylight fluorescent lamps with a color temperature of 6500 K, a color rendering index of 94 and a balanced spectral distribution that provided 1000 lx on the work plane. The test was carried out monocularly and no time limit was imposed. Subjects were allowed to review their arrangement and to make changes.[25] Participants with a prescription for eyeglasses wore their own nontinted glasses during the test.

The order of the caps is plotted on the scoring sheet on a diagram that shows correct cap positions extending in a circle from the reference cap. Color vision loss was classified within types of acquired dyschromatopsia based on Verriest's classification: type I, a loss in red-green range; type II, a combined loss in the blue-yellow and red-green ranges; and type III, a loss in the blue-yellow range. A person was classified in to one of the categories, if this person misplaced the caps by at least two caps. One cap inversion was classified as normal.[26]

Data were analyzed in SPSS.22 software (SPSS for Windows, SPSS Inc., Chicago, IL, USA). A statistical significant difference was considered if p-value < 0.05. Kolmogorov–Smirnoff test for normality indicated that the distribution of age, length of employment and average working hours were not normal and therefore non-parametric tests were used for statistical analysis.

Results

In this cross sectional study, 100 eyes of 50 welders were investigated as a case group. The mean (±SD) age of welders was 29.3 (±6.36) years. The control group included 100 eyes of 50 subjects with a mean (±SD) age of 28.06 (±6.13) years. There was no statistically significant difference for age between two groups (p = 0.305).

The mean (±SD) duration of exposure of welders to welding light was 10.58 (±5.76) years and the average working hours of welding a day was 8.10 (±1.18) h. Almost all the welders use eye protection during welding. As to alcohol consumption, none of our subjects consume alcohol during their life.

The prevalence of dyschromatopsia among welders was 15% (95% CI, 8.91%, 23.85%), which was statistically higher than that of nonwelder group (2%) ((95% CI, 0.35%, 7.74%), p = 0.001). Among welders with dyschromatopsia, color vision deficiency in 72.7% (95% CI, 39.32%, 92.67%) of cases was monocular. Table 1 shows the prevalence of different type of color vision impairment among two groups. According to the table, the impairment of color vision discrimination in welders tends to be of the blue-yellow type, although some cases of red-green impairment have also been found.

Table 2 represents the Spearman correlation between qualitative color vision impairment and characteristics of welders. According to the table, there was no statistically significant correlation between age of welders and prevalence of color vision deficiency (p = 0.426), while we found a positive relationship between the employment length and color vision loss (p = 0.04). Similarly, a significant correlation was found between the prevalence of color vision deficiency and average working hours of welding a day (p = 0.025). These issues were not evaluated since yet.

Discussion

In the last years an increasing number of studies have investigated color dyschromatopsia in workers exposed to several solvents, metals and other industrial chemicals.[18] Only few data are available on the effect of occupational exposure to arc welding on color perception.[14,15,19,20] This study was done to assess the effect of exposure to welding light on color perception of welders in Zahedan, Iran. The result of this study shows that the prevalence of acquired dyschromatopsia was statistically significantly higher in welders than in non-welders.

Table 1 Prevalence of different type of color vision impairment among two groups.

Type of color vision deficiency	Welders *n* (%) 95% CI			Nonwelders *n* (%) 95% CI		
	OD	OS	Both eyes	OD	OS	Both eyes
Type I (R-G)	3 (6%) (1.56%, 17.54%)	1 (2%) (0.1%, 12.01%)	4 (4%) (1.29%, 10.51%)	1 (2%) (0.1%, 12.01%)	1 (2%) (0.1%, 12.01%)	2 (2%) (0.35%, 7.74%)
Type II (R-G & Y-B)	1 (2%) (0.1%, 12.01%)	–	1 (1%) (0.05%, 6.24%)	–	–	–
Type III (Y-B)	6 (12%) (4.97%, 25%)	4 (8%) (2.59%, 20.11%)	10 (10%) (5.16%, 18.04%)	–	–	–
Normal color vision	40 (80%) (65.86%, 89.5%)	45 (90%) (77.41%, 96.26%)	85 (85%) (76.15%, 91.09%)	49 (98%) (87.99%, 99.9%)	49 (98%) (87.99%, 99.9%)	98 (98%) (92.26%, 99.65%)
Total number of subjects	50	50	100	50	50	100

Table 2 Relationship between color vision impairment and characteristics of welders.

	Dyschromatopsia	
	p-value	Spearman *R*
Age	0.426	0.080
Length of employment (year)	0.040	0.205
Average working hours	0.025	0.224

According to previous studies, occupation related color vision deficiency, like other acquired dyschromatopsia, usually cause an impairment in blue-yellow color discrimination or, less frequently, a combination of blue-yellow and red-green loss, while congenital dyschromatopsia more frequently result in R-G deficits.[16,18] In our study too, the impairment of color vision deficiency in welders tend to be of the blue-yellow type, although some cases of red-green impairment has also been found.

In addition, in acquired dyschromatopsia the deficiency can be unequal or monocular, and can have a variable course, depending on various factors, including exposure.[16–18] Our result demonstrate that color vision deficiency in 72.7% of defected welders was monocular, which was similar to previous studies.

Since the mid-1960s, we have known that even moderate intensities of light can damage the retinas of rats. Photic damage to the retina after long term exposure has been reported in pigeons, rats, mice, rabbits, piglets, monkeys and even human.[1] The extent of damage produced by acute exposure to ultraviolet radiation has been investigated in multiple studies. Not only does the damage depend on the exposure duration but also on the spectrum of the ultraviolet radiation applied.[27] In our study we found a significant positive relationship between average working hours of welders and the length of their employment as welders with the prevalence of color vision deficiency.

Light damage to the retina seems to be multi-factorial and several different mechanisms may be involved.[28] Welding produce UV, visible and infrared radiation at damaging levels. These radiations and their secondary effects are responsible for the ocular hazards that are seen clinically.[6] There is a shift in the site of damage from photoreceptors outer segment at short wavelengths to the pigment epithelium at longer (>470 nm) wavelength, suggesting that there are at least two mechanisms responsible for photo damage.[29]

Incipient retinal light damage can cause subclinical retinal symptoms. The situation in which colors appear somehow desatured and faded, black seems to be slightly grayish, white appears somehow dirty when being compared with the image of normal eye. No fundus change might be detectable in this early preclinical stage.[28]

It should be considered that there are several methods of assessment of light damage including psychophysical (reduction in visual field, color vision defects), electroretinographic (reduction in rod function), physiological, morphological and biochemical.[28] For instance, Shahriari et al. reported pathological effect of UV light on the retina using electroretinography. They report an obvious decrease in voltage amplitude of photopic ERG and conclude that the cone cells are the site of pathological effect.[30]

To assess dyschromatopsia, Bowler et al.[13] and Mergler et al.[14] administered the Lanthony D-15 desatured panel and observed that color vision in exposed welders was significantly impaired in both eyes.[14,20] Gupta and Spingh evaluate color vision deficiency among 520 welders and report that approximately 75% of welders had color vision deficiency due to exposure to radiant energy,[19] which was consistent with our results.

Our study has some limitations, we cannot distinguish the effect of damaging light from the effect of exposure to poisonous fumes with the available data. However, our results showed that chronic exposure to welding may cause color vision deficiency. The damage depends on the exposure duration and the length of their employment as welders. Besides, it is reported that optical radiation exposure is responsible for welders' increased risk of retinal phototoxicity[6] and subsequently color vision deficiency. Therefore, the use of effective protective glasses should be advocated as an industrial hygiene measure of this occupational group. Welders should be adequately informed about the danger of welding too close to the eyes and of looking round the side of the visors, even for a very short period. In our study, although almost all of our subjects tell that they wear their protective glasses during welding, the higher prevalence of color vision deficiency among welders in comparison to non-welders show that they do not use their protective glasses properly and may be strike the arc before lowering their protective glasses.

Conflicts of interest

The authors have no financial interests or relationships to disclose.

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