Ultraviolet Exposure and Photokeratitis Complaints among Informal Welding Workers in Depok, West Java, Indonesia

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Abstract

One of the photokeratitis risk factors is acute reversible radiation of ultraviolet (UV) rays, which injure the cornea's epithelial tissue. Informal welding workers are susceptible populations to UV rays exposure. This study aimed to confirm the influence of UV radiation exposure on photokeratitis complaints in welding workers in Cimanggis, Depok, West Java. A cross-sectional study was conducted from February to June 2019 and used to select 100 welding workers purposively. A semi-structured questionnaire was used to determine photokeratitis complaints, age, education level, eye protection, safety knowledge, and work period; the UV radiation measured by A UV meter. Data were analyzed using a logistic regression test. This study found the proportion of photokeratitis to be 84.0%, with 76.0% of UV radiation exceeding the Threshold Limit Values (TLV). The logistic regression test showed a significant effect of UV radiation on photokeratitis after controlling confounding variables (education level, eye protection, safety knowledge, and welding distance) (p-value = 0.006; AdjOR = 7.236; 95% CI: 1.74–30.07). It can be concluded that UV radiation, more than TLV, constitutes the primary risk factor for photokeratitis complaints. Risks for photokeratitis were influenced by low education level, poor eye protection, limited safety knowledge, and welding distance ≤ 45 cm.

Keywords: photokeratitis, radiation, ultraviolet, welding, worker

Introduction

Photokeratitis is an eye disease or acute effect of ultraviolet (UV) radiation, which causes inflammation in the cornea.¹ It is often called UV keratitis.² Photokeratitis is a condition of the cornea's epithelial tissue injured by acute reversible radiation, including UV light radiation.¹

The condition is marked by eye pain, a sensation of foreign objects in the eyes, discomfort when exposed to light (photophobia), watery eyes, and persistently twitching eyes. These symptoms can last for 6 to 12 hours and tend to disappear within 48 hours. Exposure to continuous light radiation can cause visual paralysis or vision loss, even blindness.¹⁻³ Radiation derives from the sun as well as beam hazards and scattered radiation-producing machines and instruments. Non-sun sources such as welding, paint and ink curing techniques, tanning and LED lights, and the germicidal process of sterilization commonly found in hospitals and laboratories.^{1,3}

Based on the U.S Bureau of Labor Statistics data, occupational eye injuries accounted for 27,450 (61.8%) cases in 2008. Eye injuries caused by welding sparks con-

stituted 1,390 (5.1%) cases, which later reported as photokeratitis.³ The annual incidence of occupational eye injury in Hong Kong was estimated at 8,000 or 125 cases per 100,000.⁴ Workplace injury rates comprised 9.1% of Indonesia's bodily injuries, based on that country's 2018 Basic Health Research, or *Riset Kesehatan Dasar*.⁵ The incidence of occupational accidents impacting the eye is not yet recorded in Indonesia. *Riset Kesehatan Dasar* in 2013 listed occupational eye injuries caused by sharp objects, blunt tools, and machines, falling objects, poisoning, radiation, burns, etc. In that year, eye injuries in Indonesia were reported to represent only 0.6% of total injuries among farmers, fishermen, and laborers. In West Java Province, the proportion of eye injuries is 0.7%.⁶

Photokeratitis is generally associated with UV radiation from manufacturing, construction, trade, production, installation, maintenance, and hospital and laboratory services.³ One of the jobs posing the highest risk of exposure to UV light is welding. Welding is a process for connecting metal pieces into the desired shape. The welding trade is needed for both small- and large-scale con-

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struction.⁷ The welding process produces UV waves that can be absorbed by the eye's cornea, lens, and retina.⁸

Welding workers in the informal sector are vulnerable populations exposed to UV radiation. The lack of Occupational Health and Safety (OHS) oversight in the informal sector is due to the low level of guidance and programs for preventing occupational diseases and accidents.^{8,9} The current study focuses on the magnitude of radiation UV effects with photokeratitis complaints. The prevalence and risk of photokeratitis in Depok among informal welding workers have never been reported. This study aimed to determine UV radiation's effect on photokeratitis complaints in informal welding in Cimanggis Subdistrict, Depok, West Java, in 2019.

Method

A cross-sectional study was performed in 36 informal welding sector workshops in Cimanggis Subdistrict, Depok, West Java, Indonesia, in May-June 2019. A total of 100 informal welding workers were selected. Subjects were included if they were willing to work as welding workers for at least three months, were aged 17 years or more, and participated in the welding workshops. The main independent variable was UV radiation and photokeratitis.

This study carried out preliminary studies in the welding workshop in Cimanggis Subdistrict, Depok, West Java, in February 2019 in seven informal welding workshops with 20 welders. Through interviews with the welders, it was reported that 17 respondents were currently suffering eye complaints, and three others had had no eye complaints for the past three months. Symptoms were typically felt in red, sore, or "sandy" eyes and the feeling of a foreign object in the eye. They were felt after work and especially at night, so that participating workers had sleeping difficulty. These signs and symptoms are the characteristic of photokeratitis disease.¹

Ultraviolet (UV) radiation was measured by UV meters of each subject. Ultraviolet radiation Threshold Limit Value (TLV) was based on the Regulation of Ministry of Labor Republic Indonesia No. 5 of 2019 concerning of Occupational Safety and Health in Occupational Environment. Ultraviolet exposure was divided using TLV (0.0001 mW/cm²). A semi-structured questionnaire was used to collect data about photokeratitis complaints, age, education level, eye protection, safety knowledge, and work period. Photokeratitis was determined based on an eight-point questionnaire on subject complaints about their eyes. Did they feel painful, red, blurry, gritty, sensitive to bright light, tearing, or twitching? Did their eyelids feel swollen? Welding distance was measured using a tube measure/meter. Eye protection was assessed through a questionnaire and confirmed through direct observation. Safety knowledge was identified through

four questions: knowledge of occupational hazards, such as health and safety, protective equipment, and dangerous equipment; availability of PPE (Personal Protective Equipment); training; and the frequency of PPE use. Those questions were tested using statements such as, "There are always hazards with each occupation", "There is no hazardous exposure to eyes during the welding process", "UV radiation could impact the eyes' health condition", and "OHS should be involved in the prevention of disease and occupational injury". The age cut-off was 35 years because that is the age at which visual impairment often begins. High school and above were included as higher education. Cut-off points for working periods and welding distance were seven years and 45cm, respectively.

Statistical software was used to analyze each variable's distribution frequency and proportion, especially for photokeratitis and UV exposure. This study used $\alpha = 0.05$, power 80%, odds ratio (OR), and 95% confidence intervals (CIs). A backward logistic regression was used to obtain a fit model of UV exposure effect on photokeratitis complaints. Confounders were identified by 10% differences between crude OR and adjusted OR. The study fulfilled the Health Research Ethics Commission's code of ethics, the Veteran National Development University of Jakarta with Number B/1899/5/2019/KEPK, stipulated on May 10, 2019.

Results

The proportion of photokeratitis among informal welding workers was high (84%). Most informal welders were exposed to UV light radiation higher than the TLV (76%). The high proportion of UV light radiation exposure can lead to photokeratitis.

Table 1. Distribution of Photokeratitis Complaints and Ultraviolet Exposure among Welding Workers in Cimanggis Subdistrict, Depok, West Java, Indonesia

Variable	Category	Total (n = 100)	
		n	%
Photokeratitis	Yes	84	84
	No	16	16.0
Ultraviolet light radiation	> Threshold limit value	76	76.0
	≤ Threshold limit value	24	24.0

Table 2. Distribution of Photokeratitis Complaints

Photokeratitis Complaints	Frequency (n = 100)	Percentage (%)
Painful eyes	84	18.1
Red eyes	74	15.9
Blurred vision	39	8.4
Gritty feeling	78	16.8
Sensitivity to bright light	57	12.3
Swelling eyelids	46	9.9
Tearing eyes	66	14.2
Twitching eyes	20	4.3

Table 3. Crude Relationship between Variables and Photokeratitis Complaints among Welding Workers in Cimanggis Subdistrict, Depok, West Java, Indonesia

Variable	Category	Photokeratitis Complaints		Total	p-value	Crude OR (95% CI)
		Yes	No			
Ultraviolet light radiation	> Threshold limit value	69 (90.8%)	7 (9.2%)	76 (100%)	0.003*	5.914 (1.9–18.3)
	≤ Threshold limit value	15 (62.5%)	9 (37.5%)	24 (100%)		
Age	> 35 years	36 (80.0%)	9 (20.0%)	45 (100%)	0.476	0.583 (0.1–1.7)
	≤ 35 years	48 (87.3%)	7 (12.7%)	55 (100%)		
Education level	Low	56 (87.5%)	8 (12.5%)	64 (100%)	0.323	2.000 (0.6–5.8)
	High	28 (77.8%)	8 (22.2%)	36 (100%)		
Eye protection	No	48 (92.3%)	4 (7.7%)	52 (100%)	0.037*	4.000 (1.1–13.4)
	Yes	36 (75.0%)	12 (25.0%)	48 (100%)		
Safety knowledge	Bad	52 (91.2%)	5 (8.8%)	57 (100%)	0.046*	3.575 (1.1–11.2)
	Good	32 (74.4%)	11 (25.6%)	43 (100%)		
Working period	≤ 7 years	45 (88.2%)	6 (11.8%)	51 (100%)	0.365	1.923 (0.6–5.7)
	> 7 years	39 (79.6%)	10 (20.4%)	49 (100%)		
Welding distances	≤ 45 cm	48 (88.9%)	6 (11.1%)	54 (100%)	0.242	2.222 (0.7–6.6)
	> 45 cm	36 (78.3%)	10 (21.7%)	46 (100%)		

Notes: *significant in $\alpha = 0.05$; OR = Odds Ratio; CI = Confidence Interval

Table 4 Adjusted Effect of Ultraviolet Radiation Exposure and Photokeratitis Complaints

Variables	Coefficient (β)	Z-Score (Wald)	SE	p-value	AdjOR (95% CI)*
Ultraviolet radiation > TLV	1.979	7.415	0.727	0.006	7.236 (1.74–30.07)
Low level of education	1.134	2.466	0.722	0.116	3.108 (0.75–12.79)
Poor eye protection	1.100	2.678	0.672	0.102	3.004 (0.80–11.21)
Limited OHS knowledge	1.490	4.945	0.670	0.026	4.436 (1.19–16.48)
Welding distance ≤ 45 cm	0.481	0.473	0.700	0.492	1.618 (0.41–6.37)

Notes: *Multivariate logistic regression analysis adjusted for education level, eye protection use, OHS knowledge, and welding distance; SE = Standard Error; AdjOR = Adjusted Odds Ratio; TLV = Threshold Limit Value; OHS = Occupational Health and Safety

Table 2 shows the proportion of each photokeratitis complaint. The majority of informal welding workers' complaints were variations of painful, gritty, red eyes, tearing, and sensitivity to bright light. The least complaint was twitching eyes.

Table 3 shows a little difference between the strata of workers' ages, education levels, eye protection, safety knowledge, working periods, and welding distances. Data on the age proportion of workers in this study were normal, and more than half of the subjects were aged ≤ 35 years (55.0%). Approximately 76 respondents who worked with UV radiation exceeded the TLV, while 69 subjects (90.8%) experienced photokeratitis complaints. Working periods and welding distances had distributions so diffuse and broad that the distribution fell outside the Kolmogorov Smirnov test's normal range. Thus, the working period was classified through a normality test and took a median value of years, while the welding distance was given a median value of 45 cm. The subjects majority had worked in the welding sector for ≤ 7 years and welded at a distance of ≤ 45 cm. More than half of the subjects had graduated from high school. The chi-square test obtained p-values of 0.003 (OR = 5.914; 95% CI = 1.9–18.3), which indicated a relationship between

UV radiation and photokeratitis complaints in welders. A chi-square test found a significant relationship between eye protection variables and safety knowledge to photokeratitis (p-value < 0.05), while other variables had p-values > 0.05. That said, there was no relationship between the ages, levels of education, working periods, and welding distances with complaints of photokeratitis in Cimanggis Subdistrict welders.

After a logistic regression test, a significant effect of UV radiation during welding was the strong association with photokeratitis complaints, with adjustment by education level, eye protection, safety knowledge, and welding distance. This strong association was probably overestimated, and chance or systematic error was existed. Those could be seen through the wide confidence interval range. From the result, it was estimated that subjects who exceed TLV of UV radiation were 7.236 times likelier to suffer photokeratitis complaints than those exposed to UV radiation below the TLV.

Discussion

This study found that the number of welders in Cimanggis Subdistrict, Depok, West Java, who had experienced photokeratitis-type complaints, was relatively

high. Many respondents had experienced eye complaints like pain, burning sensation, and the feeling that a foreign object or "sand" was within. This complaint was often felt at night after welding at work that day. Those high proportions were likely due to working welders' schedules in Cimanggis Subdistrict, which average 8-hour days and 7-day workweeks. The workers are often exposed to UV radiation every day.

The wavelength, high duration, and frequency are factors of UV radiation exposure that can impact the severity of corneal reactions and disorders.⁹ According to previous study, UV radiation exposure over 30 minutes puts the subject at risk of photokeratitis.¹⁰ UV radiation exposure to the cornea will irritate the superficial corneal epithelium and inhibit the mitotic process. This irritation leads to an inflammatory response. The swelling will increase corneal thickness, resulting in changes to the corneal bias strength and visual obscurity. Recovery will occur approximately 72 hours after exposure.¹¹ According to other research, symptoms can last for 6–12 hours and then disappear within 48 hours. However, high-intensity radiation exposure will cause visual paralysis or vision loss, even blindness.¹ UV radiation cumulative exposure can lead to corneal epithelium damage.¹¹

The percentage of subjects exposed to UV radiation exceeding the TLV was high. The majority of welding workers in Cimanggis Subdistrict used the electric arc welding method; 16.0% used argon (TIG). This type of electric welding carries considerable risk to respondents' health because it produces a fire containing UV and radiation in gas form. UV radiation measurement was usually done from 9:00 am–2:00 pm, at which time UV light can be especially intense.¹² All welding activity was located outdoors, which also carries UV keratitis potential from increased sunlight exposure.² A bright sky, when data is collected, can increase UV radiation intensity because the sun is a natural source of UV rays.¹ Other influencing factors are seasons, the hemisphere, clouds, fog, and climate.¹²

The percentage of welders in the Cimanggis Subdistrict who experienced photokeratitis complaints after exposure to UV radiation exceeding the TLV was high, and a relationship was found between UV radiation and photokeratitis complaints. This finding was supported by previous study conducted on PT PAL Indonesia Surabaya welding workers where the incidence of photokeratitis with UV radiation $> 0.0001 \text{ mW/cm}^2$ was 43.48%.¹³ Our proportional finding was higher, probably due to this study conducted within informal welding workers.

The logistic regression test obtained a significant relationship between UV radiation and photokeratitis complaints after controlling for confounding variables. Crude

OR was 5.914, whereas adjusted OR for UV radiation relationship with photokeratitis complaints after controlled confounding variables (level of education, eye protection, safety knowledge, and welding distance) was 7.236. There was a difference between POR before and after controlling confounding variables. Hence, this study found that UV radiation during welding was a primary risk factor of photokeratitis complaints. This finding coincides with a previous study,¹⁴ that found that photokeratitis risk factors include an intensity of exposure to high UV radiation carried a 5.55-fold magnitude risk. Age greater than 41 years carried 7.09 times the risk, workers who rarely consumed vitamin A bore 12.82 times the risk, those who did not use PPE had 29.41 times the risk, and an exposure of more than 8 hours carried 4.87 times the risk.¹⁴

The most dominant risk factor besides UV radiation was an improper use of PPE.¹⁴ More research in welders in North Samarinda reported that photo keratoconjunctivitis/PKC was strongly related to the duration of exposure to UV radiation.¹⁵ UV radiation produced from welding arcs will create a high radiation spectrum that can have a significant impact on the worker's eyes. Furthermore, welding exposure can also impact those incidentally around the welding process.⁹

Eye disorders due to UV radiation exposure can be caused by a lack of prevention or eye protection. The emergence of eye disorders in these respondents is due to radiation intensity, distance from the welding arc, the angle at which radiation enters the eye, the type of eye protection used, or the failure to use eye protection at all.¹ The subject's knowledge and education supported the use of eye protection in respondents. Workers with strong knowledge demonstrated increased awareness and safety practices at work.¹⁶

Education strengthens a person's experience and skills to increase awareness of the importance of body health.¹⁷ Previous studies have found that workers with good academic and practical education tend to have no eye health problems.¹⁸ A high level of education can influence respondents to use eye PPE when welding. Educated welders also know the dangers of UV radiation in welding and how using protection can prevent eye disease, photokeratitis. The use of PPE is one of the proper steps for respondents in preventing and reducing health hazards.¹⁶ Education enhances safety knowledge, and that knowledge will influence the mindset and actions taken by workers in their work.^{16,19} So, to avoid photokeratitis, welders need safety training to improve their knowledge of occupational hazards and UV radiation prevention.¹⁶ Safety knowledge, attitudes, and practices can be related to the use of PPE. Training or intervention in safety knowledge can improve respondents/welder's safety status and use of PPE.¹⁹ Health promotion regard-

ing the prevention of UV-related diseases should include information about the eyes, the dangers of UV rays, and the benefits of eye protection. This promotion can increase prevention, awareness, and selection behavior in optimal eye protection measures.^{12,20,21}

Eye or face protectors can help respondents protect their eyes against UV radiation. Arc lightning or welding light can be avoided through eye protection,⁹ because UV radiation exposure without eye protection can cause eye complaints. The use of inadequate eye protection can cause the incidence of photokeratitis.² Eye protection can effectively reduce the symptoms of UV keratitis.²² The use of eye protection or other types of spectacles can protect the eyes against UV radiation exposure.^{1,23,24} Using spectacles can reduce UV radiation doses absorbed by the eye by 10%–25%, compared to someone who does not use eye protection.¹ Our subjects answered the questionnaire regarding the type of spectacles at 95.0% rate, but observations used eye protection only 48.0% of the time.

Welding is a considerable risk of exposure to UV radiation. The welding process produces a radiation spectrum of 200–1400 nm. The radiation spectrum of UV light produced by welding has a wavelength of 200–400 nm.²⁵ The cornea will absorb maximum UV radiation from approximately 310–280 nm,²² and a welding arc can produce a very high UV radiation spectrum within the working distance with a short welding arc. This radiation can potentially damage the eye organ or risk causing photokeratitis.²⁶ Welding produces a broad spectrum of UV radiation within a short distance from the worker.¹ Photokerato conjunctivitis is suffered by workers who weld at very close distances. Exposure to UV radiation in welding can affect subjects' eyes if the welding distance is close.

The bias which may appear in this study was non-differential misclassification since each respondent was interviewed and measured using the same instruments. Such bias may result in an underestimation of risk magnitude. This cross-sectional study is identical to temporal ambiguity about exposure and outcome. Despite that, the study can be generalized to the population at large and external populations with the same characteristics as this study population. This study probably overestimates results where the adjusted odds ratio appears higher than the actual value. That is caused by a cross-sectional study with a high proportion of outcomes analyzed using logistic regression. Furthermore, chance seems to exist, possibly due to unmeasured risk factors (extraneous variables).

Conclusion

This study showed that UV radiation, more than TLV, is the primary risk factor of photokeratitis. The risk to in-

formal welding workers is higher than in formal or manufactured welding. The risk of photokeratitis complaints is influenced by education level variables, eye protection, safety knowledge, and welding distance.

Abbreviations

UV: Ultraviolet; Riskesdas: Riset Kesehatan Dasar (Indonesias' Basic Health Research); OHS: Occupational Health and Safety; TLV: Threshold Limit Value; AdjOR: Adjusted Odds Ratio; PPE: Personal Protective Equipment; SE: Standard Error; CI: Confidence Interval.

Ethics Approval and Consent to Participate

Ethics approval was obtained from the Health Research Ethics Commission, Universitas Pembangunan Nasional Veteran Jakarta (B/1899/5/2019/KEPK), on 10 May 2019. Written informed consent was obtained from the subject of both groups for voluntary participation.

Competing Interest

Author declares that there are no significant competing financial, professional, or personal interests that might have affected the performance or presentation of the work described in this manuscript.

Availability of Data and Materials

Data are not available due to the ethical restrictions of the research. Participants of this study did not agree for their data to be shared publicly.

Authors' Contribution

Maria KIJ Yustheresani, Fajaria Nurcandra, Azizah Musliha Fitri, Dyah Utari were involved in conceptualizing and designing the study. Maria KIJ Yustheresani, Fajaria Nurcandra, Azizah Musliha Fitri, Annisa Ika Putri searched the literature. Maria KIJ Yustheresani, Fajaria Nurcandra, AMF prepared the questionnaire and collected the data. Maria KIJ Yustheresani, Fajaria Nurcandra, Dyah Utari analyzed the data and prepared the manuscript. Fajaria Nurcandra, Dyah Utari, Annisa Ika Putri reviewed the manuscript. All authors read and approved the final manuscript.

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