Effect of Light Intensity On Eye Fatigue

Restu Kurniawati
Faculty of Sports Sciences
State University of Malang
Malang, Indonesia
restukurniawati.ikm@gmail.com

Mr. Mardji
Faculty of Engineering
State University of Malang
Malang, Indonesia
mardji.ft@um.ac.id

Agung Kurniawan
Public Health Department
Faculty of Sports Sciences
State University of Malang
Malang, Indonesia
kurniawan1974agung@gmail.com

Abstract—The improper light intensity can cause eye fatigue in a person. Based on preliminary observation in the Technical Implementation Unit of Job Training (UPTPK) Singosari-Malang, it was known that the light intensity in the welding room at UPTPK Singosari-Malang was ranging from 101.25 lux to 102.97 lux. According to the International Labor Organization (ILO), the ideal light intensity for metal work or welding is 200 lux. This study aimed to determine the effect of room light intensity on eye fatigue in the welding students at the Technical Implementation Unit of Job Training (UPTPK) Singosari-Malang. This research used the method of Quasi-experimental. Samples in this research were all the welding students at UPTPK Singosari-Malang, and the sampling technique was Total sampling. Research data were statistically analyzed by using Mann-Whitney analysis. Based on the results, it can be stated that there was a significant difference on the eye fatigue experienced by the welding students in accordance with the treatment of decreasing and increasing the light intensity of the room.

Keywords—Light Intensity, Eye Fatigue, Welding

I. INTRODUCTION

Eye fatigue is the eye problem that occurs when the eyes are focused on close objects for relatively a long time. This happens since the eye muscles work harder to be able to focus on close objects, especially when this condition is worsened by inadequate lighting. Eye fatigue is influenced by labor and environmental factors. Labor factors include age and eyes abnormalities, meanwhile, the environmental factor is mainly the lighting [1]. Welding is a kind of work that requires good lighting. Welding is a process of metal connection that is widely used in the manufacturing industry, thus it requires a high level of accuracy [2]. Technical Implementation Unit of Job Training (UPTPK) Singosari-Malang is a governmental agency that provides jobs training, including welding competency.

A preliminary survey conducted in the welding department at UPTPK on November 15th, 2013 and November 10th 2017 revealed that there were 21 welding students at UPTPK Singosari-Malang. Researcher measured the intensity of light using lux meter in the welding room at 10 AM in nine spots. The result indicated that the average light intensity in the welding room was ranging from 101.25 to 102.97 lux. This was not in accordance with the standard from the [3], the standard of average light intensity for metal work or welding is 200 lux.

Therefore, it is important to study conduct an investigation on the difference in eye fatigue at the time of decreasing and increasing light intensity. Measurement of eyestrain was done by performing eye exhaustion test using eyestrain questionnaire.

II. LIGHT INTENSITY AND EYE FATIGUE

A. Welding

Welding is one of the two permanent metal connection using heat [4]. According to [3] the minimum and average light intensity on different types of metal work (welds) is 200 lux.

B. Light Intensity

The lighting arrangement depends on the energy efficiency, the type of lamp and the point of measurement of the light intensity of the room. According to the [5], the determination of measurement points of light intensity of a room is generally based on the size of the room. General illumination is the point of horizontal line length and width of the room at any given distance of one meter from the floor. The room size and distance of measurement according to [5] are: The room area is less than 10m², the cutting point of horizontal length and width of the room at a distance of every meter, the space of less than 10m²- 100m², the horizontal stripe length and width of the room at a distance of every three meters, the area of the room is more than 100m², the cutting point of horizontal line length and width of the room at a distance of every six meters.

C. Eye Fatigue

The light that illuminated the eye will meet the outer protector of the cornea. Most of the image focusing is deflected on the surface of the cornea. However, the cornea can not filter light with such high intensity that the vision system requires a mechanism to maximize the incoming light during low light conditions, and minimize the light intensity. This function is governed by the iris and pupils [6].

The size of the pupil is adaptive in accordance with light intensity and the light changes. Sensitivity is the ability to detect objects in dim light, and acuity is the ability to see objects detaily [7]. Light is passed to the lens after the pupil. The lens can focus on the light coming from the near or far objects by the accommodation process [6]. After passing through the lens, light arrives at the retina which is the coating of the photoreceptors and nerve cells located at the back of the eye [6]. There are two types of receptors in the retina, namely the rods and the cones, and from this comes the theory of duplexity. Duplexity is the theory about the ability of cones and rods in mediating different types of vision [7], including:
a. Phototropic vision (mediated by cone).

b. Scotopic vision (mediated by rod).

When rhodopsin is exposed to intense light continuously, the pigment loses its color, as well as the ability of rods to absorb light, but when in dim condition, the rods regain red and boost the capacity to absorb the light [7]. Rhodopsin is a G-protein receptor that responds to the light. At the bright situation, rhodopsin is broken continuously, thus it will be exhausted or absent. Meanwhile, in the dark condition, rhodopsin is not broken and getting accumulated [7].

If a person transferred from a light condition to dark, the sensitivity of the retina will gradually increase and become maximum after 20 minutes. That is when it takes to stock up enough rhodopsin [7]. Conversely, if a person goes from dark to light, the eyes will be dazzled for a while (5 minutes) as the cone is full of rhodopsin and it takes time to reach another level of balance between production and decomposition [7]. If a person is in bright light for a long time, most of the photochemical substances in the rod and cone have been reduced to retinal and opsins, where most retinal stems and cones have been converted into vitamin A [8]. In bright light, all the existing rhodopsin will be broken down rapidly and only slightly left to form a potential action in the stem cell. This is called the light adaptation [9].

If the retina sensitivity is large enough, all objects will stimulate the rods (rods on the retina used at night) to the maximum. Hence, even dark objects will be visible (bright white). But if the retina's sensitivity is very weak, when entering into a dark room there is no bright shadow that stimulates the rod so the objects are invisible. Changes in retinal sensitivity are known as light and dark adjustment phenomena [10].

Eye fatigue or asthenopia is a subjective complaint that includes a sense of discomfort in the eyes, muscle pain around the eyes [11]. Eye fatigue is eye strain caused by visual impairment in work that requires the ability to see for long periods of time. This usually accompanied by the inadequacy of the lighting condition [12]. Asthenopia, commonly known as eyestrain (eye fatigue) is mainly caused by the continuous work that causes eye fatigue [13]. Symptoms of asthenopia are including blurred vision, diplopia (double vision), difficulty in performing jobs in poor lighting, headache, eye pain and eyestrain [14]. More specific symptoms include photophobia, blur, double vision, itching, tearing, dryness and sensations of the presence of foreign objects [15].

III. METHOD

This research used the experimental method and the design of pseudo-experiments. The population in this study was welding students at UPTPK Singosari-Malang, by the total of 21 people. The technique of sampling implemented was Total Sampling by taking all the welding students at UPTPK Singosari-Malang period of December 2017 - January 2018. This is followed by the filling of informed consent.

The instruments of this study were including rollmeter, lux meter and eyestrain questionnaire. Eye fatigue tests were performed using an eye fatigue questionnaire. Most studies measure eye fatigue using a questionnaire that not only measures emotional fatigue but also emotionally on each subject [15]. Data will be analyzed by using the method of Mann-Whitney analysis.

IV. RESULT

The welding room at UPTPK Singosari is L-shaped. The measurement process of the light intensity of the room was divided into two rooms; the first room and the second room. The first room has an area of 5.81 m x 12.42 m = 72.16 m². On the other hand, the second room has an area of 5.86 m x 16.94 m = 99.27 m². Hence, it can be stated that both rooms have less than 100 m² of space. The measurement spot of light intensity was the horizontal intersection between length and width every 3 m². Therefore, the total spot of measurement of the light intensity of the room was nine spots.

The welding room in UPTPK Singosari has nine spots of light sources. The lamp used was a mercury lamp with 250 watts of power as much as 7 pieces and 2 mercury lamps with 500 watts.

In the treatment of decreasing the light intensity in the welding room, the researcher did the blackout in the first room by turning off five lamps since the lamp in the welding room has two fuses which control the lamp current in the welding room. The first switch regulates the current connection of five lamps in the first room and the second fuse regulates the current of four lamps in the second room.

In the treatment of increasing the light intensity of the room, the researcher replaced five 250-watt mercury lamps with 500-watt mercury lamps. Replacement of five lights was aimed to manage the different light intensity between the rooms, significantly.

A. The Result of Light Intensity Measurement

The data of light intensity measurement are presented in this following table:

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>THE RESULT OF LIGHT INTENSITY MEASUREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room</td>
<td>Light Intensity</td>
</tr>
<tr>
<td></td>
<td>Decrease</td>
</tr>
<tr>
<td>1</td>
<td>37.55</td>
</tr>
<tr>
<td>2</td>
<td>84.75</td>
</tr>
</tbody>
</table>

Based on the data, it can be seen that the light intensity of the room generated in the treatment of decreasing the intensity was ranging from 37.55-84.75 lux. On the other hand, the light intensity obtained from the treatment of increasing the intensity was ranging from 157.09-174.75 lux.

<table>
<thead>
<tr>
<th>TABLE II</th>
<th>SUMMARY OF DATA MEASUREMENT OF LIGHT INTENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room</td>
<td>Measurement Spot</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>37</td>
</tr>
<tr>
<td>3</td>
<td>28</td>
</tr>
</tbody>
</table>
In the treatment of decreasing the light intensity of the first room, the highest light intensity was generated at the measurement spot 4 (65 lux). In addition, the lowest light intensity in the first room was at the measurement spot 1 (20.2 lux). The highest intensity of light in the second room in the treatment of decreasing the light intensity was at the measurement spot 8 (99.25 lux). Moreover, the lowest light intensity was at the measurement spot 5 (60 lux).

In the treatment of increasing the light intensity of the first room, the highest light intensity was produced at the measurement spot 4 (199.1 lux). Meanwhile, the lowest light intensity was at the measurement spot 1 (119.4 lux). The highest light intensity in the second room in the treatment of increasing the intensity was at the measurement spot 5 (188.8 lux). Finally, the lowest light intensity was generated at the measurement spot 9 (114.25 lux).

### B. Statistical Analysis (Mann-Whitney Test)

<table>
<thead>
<tr>
<th>Room</th>
<th>Measurement Spot</th>
<th>Light Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Decrease</td>
<td>Increase</td>
</tr>
<tr>
<td>5</td>
<td>60</td>
<td>188.8</td>
</tr>
<tr>
<td>6</td>
<td>97.5</td>
<td>172.2</td>
</tr>
<tr>
<td>7</td>
<td>95</td>
<td>155</td>
</tr>
<tr>
<td>8</td>
<td>99.25</td>
<td>153.2</td>
</tr>
<tr>
<td>9</td>
<td>72</td>
<td>114.25</td>
</tr>
</tbody>
</table>

The result of Mann-Whitney analysis on eye fatigue data based on the treatment of decreasing and increasing the light intensity of the room demonstrated the p-value of 0.00 (< 0.05). This means that there was a significant difference in eye fatigue at the time of decreasing and increasing the light intensity of the welding room at UPTPK Singosari-Malang.

When the light is absorbed by the rhodopsin, the rhodopsin will be decomposed soon. This is due to a photo of electron activation in the retinal rhodopsin part causing an immediate change from the cis-retinal to a trans-retinal. The chemical structure is still the same as cis form but has a different physical structure, which is a straight molecule instead of a bent one [8].

As the three-dimensional orientation of the all the trans-retinal reactive venue is no longer matches the orientation of the reactive spot of the skotopsin protein, rhodopsin begins to move beyond skotopsin. Its proximate product is batorhodopsin (also called prelumirhodopsin), which is a partial breakdown of the combination of total trans-retinal and skotopsin. However, batorhodopsin is a highly unstable and then begin crumbling into the second small part called lumirhodopsin, then transformed to metarhodopsin I, metarhodopsin II, and then partially split to form scotopsin and total trans-retinal. During the surgery, the arousal and signaling stems are sent into a central nervous system [8].

The re-formation of rhodopsin begins by transforming the all-trans-retinal into 11-cis-retinal. This process is catalyzed by the retinal isomerase enzyme. However, this process also requires the return of other cell functions by rods and cones. When 11-cis retinal has been formed, it will automatically be re-joined with skotopsin to reproduce rhodopsin, an exergonic process (releasing energy). Finally, rhodopsin is formed as a stable compound in the dark but its decomposition can be reestablished by energy absorption [8].

When the rhodopsin in the outer segment of the stem cells is exposed to the light and begins to decompose, it lowers the entry of sodium into the inside of the stem even though sodium is still pumped out. Thus, there is a net loss of sodium from the stem, it increases the negative state of the membrane. Thus, the greater the amount of light energy that concerns the rod, the greater the electronegative. This process is called hyperpolarization [8].

Both types of retinal can be converted to the corresponding retinyl ester and retinol. Instead, they can be
converted back into two retinal types. Thus, these two retinal types are in a dynamic balance with vitamin A. Most retinal vitamins are stored in the retinal pigment layer rather than inside the stem cells themselves, but this vitamin A is readily available to the stem [8].

Other important properties of retinal changes to vitamin A or vice versa, vitamin A changes to retinal, is that this process takes a much longer time to achieve balance than the time required for retinal changes and skotopsin to rhodopsin or for change (in light strong) rhodopsin to retinal and skotopsin. Therefore, all reactions last several minutes (some in less than a second) compared to the slower retinal and vitamin A interconversions (occurring minutes to hours) [8].

In contrast, during total darkness, all retinents in the stem cells are essentially converted into rhodopsin which decreases the retinal concentration to almost zero. This allows a lot of vitamin A to be converted into retinents that also become rhodopsin within the next few minutes. Hence, during the perfect darkness, it is not only almost all retinal stem cells are converted to rhodopsin but also many vitamin A deposited in the pigment layer of the retina are absorbed by stem cells and converted into rhodopsin [8].

In eye fatigue, eye fatigue is also affected by the mechanism of accommodation. The mechanism of accommodation is a mechanism that focuses on eye lens systems that are important for high-grade vision acuity. Accommodation is due to the contraction or relaxation of ciliary muscles, in which the contraction causes increased lens system strength and relaxation leading to a reduction in lens strength [8].

Accommodation is the process of increasing the curvature of the lens. In the resting state, the tension of the lens is maintained by the pull of the lens ligament. Because the lens material is easily shaped and the lens capability of the capsule is quite high, the lens can be pulled into a sprawl [18].

When the view is directed to a close body, the ciliary muscle will contract. This reduces the distance between the edges of the ciliary body and releases the lens ligament so that the lens constricts to form a more convexed object. The laxity of the lens ligament due to ciliary muscle contractions is partly due to the cordular muscle fibers of the ciliary bodies which are like sphincters and partly by the contraction of longitudinal muscle fibers attached to the anterior, near the boundary of the cornea and sclera. When these fibers contract, the entire body is drawn forward and inwards. This movement causes the edges of the ciliary corpus to close together [18].

VI. CONCLUSIONS

Generally, the study in UPTPK Singosari-Malang showed that there was a significant difference in eye fatigue when the light intensity was decreased and increased.

REFERENCES


