Blue Light Promotes Heart Rate Recovery After Exercise

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ABSTRACT

Today, various sports and competitions are performed under artificial lighting, whether indoors or outdoors. We studied if the color of the lighting affects athletic ability. Comparing orange light that did not contain melanopsin-stimulating component, blue light rich in melanopsin-stimulating components prompted heart rate (HR) recovery after submaximal exercise.

1 INTRODUCTION

Light has different physiological effects depending on its color [1-4]. Physiological effects of light include not only those forming images but also those that do not form images. The latter involves intrinsically photosensitive retinal ganglion cells (ipRGC) [5-9]. The ipRGC responds to light with the light-sensitive pigment melanopsin, which has a specific sensitivity to light with a blue wavelength around 480 nm. In a previous study using color-rendering organic light-emitting diode (OLED) lighting, we observed that blue light rich in melanopsin-stimulating components has the effect of maintaining autonomic and psychomotor arousal levels over green, red, and white light [10, 11].

Today, various sports and competitions are performed under artificial lighting, both indoors and outdoors. However, there are few studies that objectively examined the effects of lighting, particularly the light color and components, on the physiological responses associated with sports and exercise. In this study, we investigated the effects of blue light rich in melanopsin-stimulating components and orange light without melanopsin-stimulating components on HR recovery after exercise [12-15].

2 METHODS

2.1 Subjects

Eleven healthy adults (age 27 ± 7 years, 2 women) were studied. This study was conducted according to a protocol (No. 60-16-0164) approved by the Research Ethics Review Committee of Nagoya City University Graduate School of Medicine and Nagoya City University Hospital.

2.2 Protocol

The experiment was conducted in the morning in a laboratory conditioned at 24 ± 2 ° C. The room equipped with a ceiling light system consisting of 120 OLED panels (55 x 55 mm square VELVE OLED Lighting Module, Mitsubishi Chemical Pioneer OLED Lighting Corporation, Tokyo, Japan) with adjustable red, green and blue colors and brightness (Fig. 1).

Fig. 1. Exercise test laboratory under blue and orange OLED lighting

After 5-min sitting rest for equilibrium, the subject walked on a treadmill for 5 min at a speed of 4 km/h as a warm-up. Subsequently, the treadmill speed was increased by 1 km/h per min until the average HR for 15 seconds reached 60% of the difference between (220-age [y])/min and the resting HR. After maintaining the above HR for 1 minute, the treadmill speed was reduced to 4 km/h. After walking for 1 minute as a cool-down, they rested in the supine position for 5 minutes.

In all subjects, the exercise test was conducted under blue and orange OLED illumination with equal illumination. The order of the light color was counter balanced among subjects. Exercise test under different illumination colors were performed at intervals of 24 h or more.

2.3 Measurement and Data Analysis

Throughout the experiment, electrocardiograms were continuously recorded with a Holter electrocardiograph (Cardy 303 pico +, Suzuken Corporation, Nagoya). The electrocardiogram data was transferred to a Holter electrocardiogram analyzer (Cardy Analyzer 5, Suzuken Co., Ltd., Nagoya), and all QRS waves were detected to obtain a time series of R-R intervals.

As indices of HR recovery, (1) the %HR decrease from the peak value 1 min after the HR reached the target and finished the exercise load and (2) the time required for the HR to return from the peak to 50% of the increase due to exercise (half time) were determined.

2.4 Statistical Analysis

For statistical analyses, we used Statistical Analysis System (SAS version 9.4, Cary, NC, USA). The mixed procedure was used for evaluating the lighting color as a fixed effect and the subject as a random effect. *P* <0.05 was used as a criterion for statistical significance.

3 RESULTS

Fig. 2 and Table 1 show the results of photo-spectroscopic analysis of the lights measured at the eye position of the subject under blue and orange illumination. As shown in the absorption spectrum of melanopsin in Fig. 1, blue light contained a large amount of melanopsin stimulating components, whereas orange light contained only a small amount of melanopsin stimulating components. As Table 2 shows, the illuminance of blue light was slightly darker than that of orange light, but the photon flux density was almost the same, and the total amount of light stimulation was almost the same. According to the result of spectroscopic analysis, the ratio of the melanopsin stimulating component in the entire photon flux density was 35.2% for blue light and 1.1% for orange light.

The %HR decrease at 1 minute after exercise was about 40% under orange light, but was about 50% under blue light with a statistically significant difference (*P* = 0.02; Fig. 4). On the other hand, the half-life of HR decrease from the peak also was shorter under blue light, but the difference was not statistically significant.

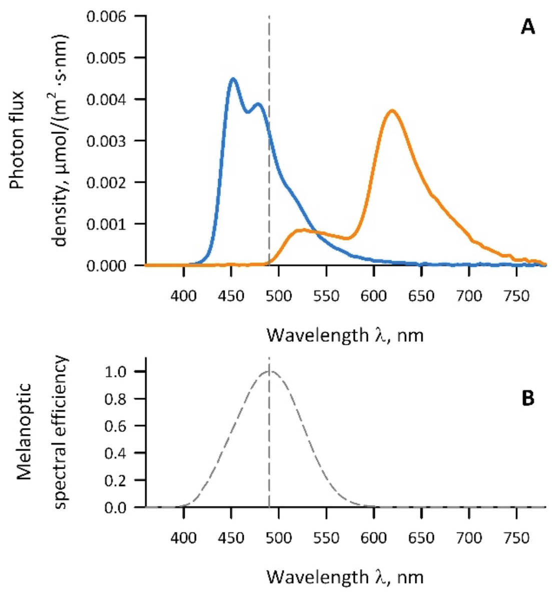

Fig. 2. Photo spectrum in blue and orange illumination (A) and absorbance spectrum of melanopsin (B) from literature [16]

Table 1. Results of photo-spectroscopic analysis

	Blue	Orange
Illuminance, lx	60	76
Irradiance, W/m^2	0.372	0.270
Chromaticity (x,y)	0.146,0.167	0.554,0.427
Wavelength, nm	479	589
PFD, μmol/m^2/s	1.50	1.40
MSPFD, μmol/m^2/s	0.527	0.016
Relative MSPFD,%	35.2	1.1

PFD=photon flux density, MSPFD = melanopsin-stimulating PFD.

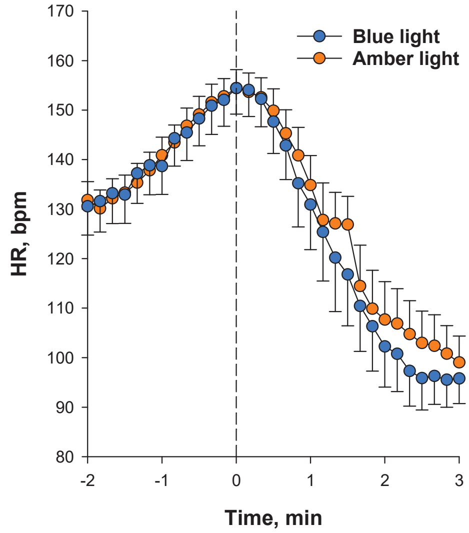

Fig. 3. Exercise response of heart rate (HR) and recovery under blue and orange lights

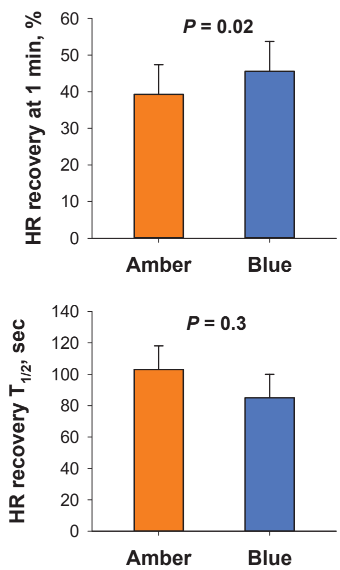

Fig. 4. HR recovery under blue and orange lights

4 DISCUSSIONS AND CONCLUSIONS

By treadmill exercise under color-rendering OLED ceiling illumination, we demonstrated that %HR recovery after exercise was greater and the half time of HR recovery was shorter under blue light than orange light. Because HR recovery after exercise is known to be mediated by cardiac vagal activation [12,13], our observations suggests that blue light containing a melanopsin stimulating component may be associated with the greater and prompt activation of cardiac vagus after finishing exercise.

In previous studies, we observed that blue light suppresses cardiac vagal activity assessed by high frequency component of HR variability than green, red, and white lights [10,11]. Apparently, the present observation is opposite to previous ones, but the previous studies were performed in the supine position while the present subjects were standing during 1 min after the end of exercise. Recently, we also observed that the vagal effect of blue light may depend on the angle of incidence on the eye; i.e., blue light from below suppresses vagal activity, while that from above stimulates it. Further studies are necessary to clarify the effect of incidence angle of blue light on the HR recovery.

5 CONCLUSIONS

Treadmill exercise and recovery under blue ceiling light rich in melanopsin-stimulating components may be associated with enhanced reflex cardiac parasympathetic autonomic activation after exercise.

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