The Effects of Different Light Intensities during the Daytime on the Forearm Blood Flow and Mean Body Temperature in the Evening

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Summary: The subjects were exposed to bright or dim light during the daytime. Compared to dim light exposure, bright light exposure induced a steeper slope in the regression line between the skin blood flow of the forearm and mean body temperature under an external heat load in the evening. [Japanese Journal of Physiology, 46, 481–484, 1996]

Key words: forearm blood flow, mean body temperature, light intensities.

Tokura et al. [1] demonstrated that rectal temperature was maintained at a lower level throughout the day and night under bright light of 5,000 lx than under dim light of 60 lx. Kim and Tokura [2] found that most female subjects dressed more quickly and with thicker clothing in the evening in response to a cool environment when they had been exposed to dim light of 10 lx from 1000 to 1800 than to bright light of 4,000 lx. It is possible, therefore, that bright light reduces the setpoint of core temperature via melatonin. However, it remains to be investigated whether the effector mechanisms of autonomic thermoregulation in humans are also influenced by light intensity. Therefore, this study attempted to investigate the effects of different light intensities (4,000 and 100 lx) during the daytime on the forearm blood flow, skin temperature and tympanic temperature when the ambient temperature was gradually increased from 28 to 35°C in the evening.

Seven healthy, drug-free subjects, aged 19–23 years, including five females (S1, S2, S4, S5, S6), with normal menstrual cycles, and two males (S3, S7) participated in this study. The general purpose, procedures, and risks were carefully explained and informed consent was given by all subjects. All female subjects were tested in the follicular phase. All subjects refrained from heavy exercise and drinking alcoholic or caffeine-containing drinks at least 12 h before each experiment, and led well regulated lives for a week prior to participation. The subjects entered a climatic chamber at 0930, and spent time in the room sitting calmly without exercise or sleep, wearing cotton T-shirts and short pants. The light intensity was controlled, either at 4,000 lx for the bright light condition (Bright) or 100 lx for the dim light condition (Dim) from 0930 to 1800, and then kept at 100 lx until the end of the test (2120). Light exposure was obtained by placing many fluorescent tubes 1 m in front of the subjects. Each subject participated twice, once each for Bright and Dim, on separate days with at least 1 d between test sessions. Subjects received standardized meals (males: 850 kcal, females: 670 kcal) at 1200 and 1800. The ambient temperature \( T_a \) was maintained at 28°C from 0930 to 2020 and was then increased gradually to 35°C over approximately 1 h (rising speed: 0.12°C/min). Tympanic temperature \( T_{ty} \) was measured every minute by a thermistor probe (ST-21S, Sensor Technica Co. Inc., accuracy \( \pm 0.01°C \)) attached to the tympanic membrane. Skin temperatures were recorded at seven sites with thermistor probes (accuracy \( \pm 0.1°C \)) every minute, and mean skin temperature \( T_{sk} \) was computed every 10 min from the recordings according to the method of Hardy and DuBois [3]. The mean body temperature \( T_b \) was calculated every 10 min according to the following equation: \( T_b = 0.8T_{ty} + 0.2T_{sk} \).

The skin blood flow of the left forearm (BF) was measured at the lateral lower arm using a laser-
Doppler blood flow meter (Periflux System 4000, Perimed Co. Ltd.) at a depth of 1 mm every 10 s, and results were averaged over 10 min bins. All data were collected from 2000 till 2120.

All subjects showed a gradual increase in forearm skin blood flow as the ambient temperature was raised from 28 to 35°C. Linear regression analysis was applied to each subject to obtain a slope of the relation between BF vs. \( \bar{T}_b \). Figure 1 shows the slopes for each individual during bright and dim light exposure. All subjects showed a high correlation between BF and \( \bar{T}_b \). Most subjects, except S3, clearly showed steeper slopes in the Bright than the Dim. There was a statistical significant difference in the slopes of the regression lines between the two conditions for the group as a whole (Table 1, \( p<0.01 \), two tailed paired Student’s \( t \)-test). Our results showed that even a small increase in \( \bar{T}_b \), regarded as an indication of an input signal to the central thermoregulatory system, could produce more effective heat loss with cutaneous vasodilation in the Bright than the Dim, suggesting that bright light can increase the sensitivity of BF responses with the rise of \( \bar{T}_b \).

Why did the slopes of the line showing the relationship between BF vs. \( \bar{T}_b \) become steeper in bright light than dim light? One possible interpretation for this is that the setpoint of core temperature was reduced more in the bright light than in the dim light condition. Kim and Tokura [2] found that exposure to different light intensities during the daytime made dressing behavior different under the influence of reduced \( T_b \) in the evening and also changed the core temperature during night sleep. They suggested that the setpoint of core temperature differed during the evening and at night, depending on the light intensity that had existed during the daytime. Thus, the subjects dressed more slowly and with thinner clothing in response to a reduced \( T_b \) in the evening, and showed lower core temperatures at night when they had spent time in bright light during the daytime. These changes in thermoregulatory behaviour in the evening and core temperature at night can be interpreted as a reduced setpoint due to

![Fig. 1. Individual comparisons of regression lines for BF vs. \( \bar{T}_b \) between two different light intensities. Ordinate, BF; abscissa, \( \bar{T}_b \); closed circles, bright light; open circles, dim light.](image)

Table 1. Individual comparisons of a correlation equation between bright and dim light conditions.

<table>
<thead>
<tr>
<th></th>
<th>Bright</th>
<th>Dim</th>
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<tr>
<td></td>
<td>( y=ax+b )</td>
<td>( y=ax+b )</td>
</tr>
<tr>
<td>S1</td>
<td>( y=-9.6030x-331.35 )</td>
<td>( y=5.6524x-197.73 )</td>
</tr>
<tr>
<td>S2</td>
<td>( y=-16.558x-589.87 )</td>
<td>( y=15.787x-562.11 )</td>
</tr>
<tr>
<td>S3</td>
<td>( y=2.4505x-84.111 )</td>
<td>( y=8.3382x-295.68 )</td>
</tr>
<tr>
<td>S4</td>
<td>( y=9.0421x-318.32 )</td>
<td>( y=3.9236x-134.41 )</td>
</tr>
<tr>
<td>S5</td>
<td>( y=6.6103x-230.49 )</td>
<td>( y=2.5350x-84.961 )</td>
</tr>
<tr>
<td>S6</td>
<td>( y=18.904x-685.74 )</td>
<td>( y=6.9810x-245.52 )</td>
</tr>
<tr>
<td>S7</td>
<td>( y=14.085x-505.21 )</td>
<td>( y=9.4189x-335.57 )</td>
</tr>
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\( a; p<0.01 \).
daytime bright light. The findings we report here can be discussed in similar terms. Thus, if the setpoint of core temperature was reduced by daytime exposure to bright light, the BF should have increased more in response to the same heat load, which would enable the core temperature to approach its reduced setpoint by increasing dry heat loss. The blood pressure, heart rate, and rectal temperature were lower at night when the subjects spent time in bright light (5,000 lx) during the daytime than when they spent time in dim light (50 lx) [4]. This means that the sympathetic nervous system was released more strongly at night when the subjects were exposed to bright light during the daytime. If this were the case in this experiment, the steeper slope between the skin blood flow of the forearm and mean body temperature in bright light is possibly related to the stronger release of suppression mechanisms to vasomotor activity.

What physiological mechanisms could be responsible for the reduced setpoint of core temperature? There is some evidence that melatonin is a major regulator of the circadian rhythm of body temperature in various species including humans [5–8]. According to Cagnacci et al. [8], the circadian rhythms of plasma melatonin and core temperature are inversely related. On the other hand, Bojkowski et al. [9] reported that the magnitude of suppression of melatonin depends on the illumination levels, a finding which has been supported by others [7, 10–13]. Teramoto et al. [14] found that the level of urinary melatonin during the daytime was higher in bright (4,000 lx) than dim (200 lx) light conditions. Ishihara et al. [15] found also that plasma melatonin during the daytime was higher under bright (2,500 lx) than ordinary (500 lx) and dim (250 lx) light conditions. Compared with a placebo, the administration of melatonin during the daytime decreased core temperature markedly [8]. As Morita et al. [16] discussed fully elsewhere, the hypothalamus has receptors for melatonin [17, 18], and melatonin may be involved in the synthesis, secretion, and action of substances related to core-temperature control like prostaglandin E [18, 19]. Melatonin could have anapnyctic properties [5, 8]. Therefore, the possibility might exist that melatonin action on the hypothalamus is responsible for the reduced setpoint of core temperature.

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REFERENCES

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