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Influence of Different Wavelengths of Evening Indoor Lighting on Salivary Secretion and Cutaneous Temperature of the Feet

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A B S T R A C T

The experiment investigated the effect of light wavelength upon salivary secretion and cutaneous temperature of the foot in humans. Seven healthy young female students served as participants. They spent three nights in a bioclimatic chamber controlled at 26 °C and 60%. Participants were exposed to two different wavelengths of light from 1800 to 2400 h on second day and third day: 1) Fluorescent light (FL) with short wavelengths and a high color temperature (6,500 K); 2) Incandescent light (IL) with long wavelengths and a low color temperature (3,000 K). Light intensity was 400 lx in both conditions. Saliva was collected every 10 min from 2100 to 2200 h, and from 2300 to 2400 h on the second and third days, by a Lashley cup fixed to the parotid gland. The mean salivary secretion rate between 2100 and 2200 h was 15.27±2.86 g/h (Mean±SEM, N=7) in the IL condition and 10.80±2.97 g/h in the FL condition ($p<0.011$) and, between 2300 and 2400 h, 14.98±3.80 g/h in the IL condition and 11.55±2.60 g/h in the FL condition ($p<0.057$). Foot skin temperature was significantly higher in IL than FL during the period 1800–2400 h. These findings suggest that the parasympathetic nervous system, which is responsible for serous saliva flow, is less suppressed by IL condition, and that the sympathetic nervous system, which is responsible for vasoconstriction of foot skin vessels, is less activated by IL.

***Key words**: salivary secretion, cutaneous skin temperature of the foot, parasympathetic nervous system, light wavelength, evening light*

Introduction

Several studies have investigated the effect of light wavelength on the autonomic nerve system. For example, Sato and his group suggested that lights with different temperatures influenced the CNS[1], blood pressure[2] and heart rate variability[3]. Also, Morita and his group[4] found that, compared to red light, green and blue light could suppress the evening fall of core temperature and rise of urinary melatonin. Morita and Tokura[5] showed that, compared with fluorescent light (FL, with a short wavelength and high color temperature, 6,500 K), incandescent light (IL, with a long wavelength and low color temperature, 3,000 K), was less effective at reducing the nocturnal rise of melatonin and fall of core temperature.

Salivary secretion is controlled by activity of the autonomic nervous system[6,7]. Recently, Kanikowska and her colleagues[8] found that the amount of saliva secreted in the morning was significantly greater under bright rather than dim light exposure, while secretion in the evening was less in bright light. However, it is not known if light wavelength affects other physiological parameters. In the present study, we have investigated if salivary secretion and foot cutaneous temperature are influenced by light wavelength.

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Materials and Methods

Participants

Seven healthy young female students served as participants. Their physical characteristics were as follows: age, 21.1±0.6 (X±SEM) yrs (range 20–23); stature, 1.56±0.02 m (range 1.50–1.63); body mass, 48.9±2.7 kg (range 40–62); body mass index, calculated by weight/height^2, 20.08±0.80 kg/m^2 (range 17.31–23.34); and body surface area, from the expression weight$^{0.444}$ ×height$^{0.663}$×88.83 cm/kg, weight in kg and height in cm, 1.42±0.04 m^2 (range 1.28–1.63). They were studied when they were in the follicular phase of the menstrual cycles. No participant had any sleep disorders, at least during the month prior to the experiment.

All participants wore loose half-sleeved shirts and knee-length trousers. Isocaloric meals were provided at 0800, 1200 and 1800 h, and a light snack was served at 1430.

The purpose and risk of the experiment were fully explained to all participants. All of them agreed with their attendance by signature as participants. The experimental design was approved by the Ethics Committee of Nara Women's University.

Protocol

The participants spent three consecutive days and nights in a bioclimatic chamber (size; 7.3 m long, 3.8 m wide, 2.6 m high), which was controlled at 26±1 °C and 60±3%. They were exposed to dim light (50 lx) from 0900 to 2400 h on first day. On the second and third days, participants were exposed to bright fluorescent light (3,000 lx) from 0800 to 1500 h, and to twilight (1,000 lx) from 1500 to 1800 h. From 1800 to 2400 h on these two days, exposure was to one of two types of light: 1) On day 2, fluorescent light, FL, with a short wavelength and high color temperature, 6,500 K; 2) On day 3, incandescent light, IL, with a long wavelength and low color temperature, 3,000 K. Both light intensities were 400 lx (Figure 1). Light intensities were measured at eye level by a photometer (T-1H, Minolta Camera co., Ltd, Japan).

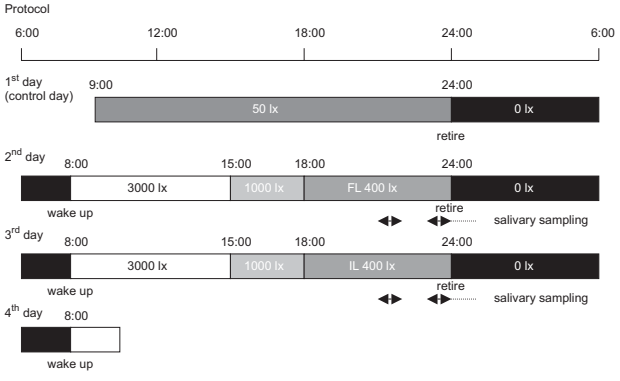

Fig. 1. Experimental protocol.

Saliva samples were collected on the second and third days every 10 min from 2100 to 2200 h and from 2300 to 2400 h by a Lashley cup fixed to the parotid gland. Saliva flow was stimulated by yogurt-flavored candy. The temperature of the skin of the foot was measured every five minutes by a logger (LT-8A, Gram, Japan) using a thermistor sensor (LT-ST08-12, accuracy ±0.01 °C, Gram, Japan) fixed to the skin surface of right instep of the foot with thin, air-permeable adhesive surgical tape.

The experiment was carried out in the Heart-ful Living R&D Institute, Sekisui House, Ltd., Kyoto/Japan from August to September, 2001.

Statistics

Temporal changes of the cutaneous temperature of the foot were compared during the two lighting conditions by two-way analysis of variance (ANOVA). Values for salivary secretion were compared by paired Student t-tests. Data were generally expressed as X±SEM. Statistical significance was accepted as $p<0.05$, and marginal significance when $0.05<p<0.10$.

Results

Figure 2a (top) compares mean salivary secretion rate in FL and IL from 2100 to 2200 h (left) and from 2300 to 2400 h (right). As seen in this Figure, salivary secretion rate was significantly higher ($p<0.05$) in IL from 2100 to 2200 h, and tended to be higher from 2300

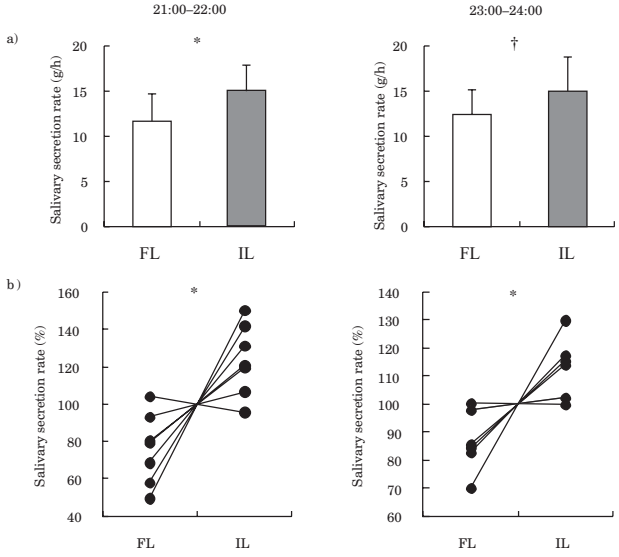

*Fig. 2. a) Top: Salivary secretion rates at 2100 and 2200 h (left) and 2300 and 2400 h (right) under the influence of FL (fluorescent light, white column) and IL (incandescent light, hatched column). b) Bottom: Individual salivary secretion rates in FL and IL, where 100% represents the mean of the values obtained under FL and IL. *p<0.05, †0.05<p<0.1. N=7.*

to 2400 h. Figure 2b (bottom) compares individuals' salivary secretion rates. As seen in the graph, most participants showed significantly higher salivary secretion rate in IL ($p<0.05$).

Mean salivary secretion rate between 2100 and 2200 h was 15.27±2.86 g/h (X±SEM, N=7) in the IL condition and 10.80±2.97 g/h in the FL condition ($p<0.011$); between 2300 and 2400 h, it was 14.98±3.80 g/h in the IL condition and 11.55±2.60 g/h in the FL condition ($p<0.057$).

Figure 3 compares temporal changes of foot cutaneous temperatures between the FL and IL conditions from 1800 to 2400 h. As seen in this Figure, temperatures were significantly higher in IL than FL during this time interval ($p<0.01$).

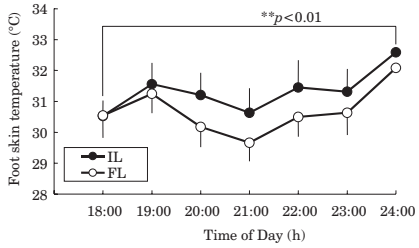

*Fig. 3. Temporal changes of foot cutaneous temperatures between 1800 and 2400 h under the influence of fluorescent (FL) and incandescent (IL) light. **p<0.01. N=7*

Discussion

The present findings suggest that the parasympathetic nervous system, which is responsible for serous saliva flow[9], is less suppressed by IL exposure, and that the sympathetic nervous system, which is responsible for vasoconstriction of the cutaneous blood vessels of the foot[9], is less activated by IL. Thus, physiological functions such as salivary secretion and skin vessels are influenced differently by changing the wavelength of light to which the participants are exposed.

These findings suggest that it is advantageous to have dinner under IL and dim light[8], because salivary secretion is accelerated under these conditions and higher rates of saliva secretion are better for efficient digestion[9].

IL exposure in the evening is also better for preparing the body for sleep, because higher skin temperatures of the extremities, including the feet, could accelerate the fall of core temperature in the late evening, and this is important for inducing deeper sleep. Recent studies indicate that manipulation of skin temperature not only promotes sleep[10,11] but also improves vigilance[12].

Salivary secretion rate was significantly higher with bright rather than dim light exposure in hours before noon, while it was significantly lower under bright rather than dim light in the evening[8]. In the present experiments, IL increases salivary secretion in the evening. It would be interesting to know how salivary secretion is influenced by exposure to FL or IL in the morning.

The detailed physiological mechanisms by which FL and IL cause different physiological responses remain to be studied systematically. It is concluded that exposure to IL in the evening can promote salivary secretion and raise the cutaneous temperature of the foot more than FL, and that light exposure can thus be applied to alter sleep- and vigilance-regulating systems[13].

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REFERENCES

1. DEGUCHI T, SATO M, Ann Physiol Anthropol, 11 (1992) 37. — 2. KOBAYASHI H, SATO M, Ann Physiol Anthropol, 11 (1992) 45. — 3. MUKAE H, SATO M, Ann Physiol Anthropol, 11 (1992) 533. — 4. MORITA T, TERAMOTO Y, TOKURA H, Jpn J Physiol, 45 (1995) 667. — 5. MORITA T, TOKURA H, Appl Human Sci, 15 (1996) 243. — 6. GARRETT JR, J Dent Res, 66 (1987) 387. — 7. EKSTROM J, Proc Finn Dent Soc, 85 (1989) 323. — 8. KANIKOWSKA D, YAMABAYASHI Y, TSUCHIDA K, HYUN KJ, TOKURA H, GOTOH K, KONDO M, AKIMOTO T, Biol Rhythm Res, 33 (2002) 129. — 9. GANONG WF, Review of Medical Physiology (Maruzen, Tokyo, 1987). — 10. RAYMANN R JEM, SWAAB DF, VAN SOMEREN EJW, Am J Physiol, 288 (2005) R1589. — 11. RAYMANN RJEM, SWAAB DF, VAN SOMEREN EJW, Physiol Behav, 90 (2007) 257. — 12. RAYMANN RJEM, VAN SOMEREN EJW, Sleep, 30 (2007) 96. — 13. VAN SOMEREN EJW, RIEMERSMA RF, SWAAB DF, Prog Brain Res, 138 (2002) 205.

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UTJECAJ RAZLIČITIH VALNIH DULJINA, UMJETNE RASVJETE NA SEKRECIJU SLINOVNICA I TEMPERATURU KOŽE NA STOPALIMA

S A Ž E T A K

Eksperiment je proučavao utjecaj valnih duljina rasvjete na sekreciju slinovnica i temperaturu kože na stopalima. Istraživanje je izvršeno na sedam zdravih studentica.

Studentice su provele tri noći u bioklimatiziranoj sobi kontroliranoj na 26 °C. Ispitanici su bili izloženi dvjema različitim valnim duljinama od 18.00 do 24.00 h drugog i trećeg dana. Ispitanici su bili izloženi: 1) Fluorescentnom svijetlu (FL), sa kratkom valnom duljinom i visokom temperatutom boje (6500 K); 2) Užarenim svijetlom (IL), sa dugom valnom duljinom i niskom temperaturom boje (3000 K). Intenzitet svijetla bio je 400 lx u oba uvjetima. Slina je bila skupljanja u Lashleyeve posude pričvršćene na parotidnu žlijezdu svakih 10 minuta na određenim valnim duljinama u periodu između 21.00 i 22.00 h i u periodu između od 23.00 do 24.00 h. Najveća stopa sekrecija sline bila između 21.00 i 23.00 h na 15.27±2.86 g/h (vrijednost±SEM N=7) u IL uvijetima i 10.80±2.97 g/h u FL uvijetima ($p<0.011$), a između 23.00 i 24.00 h na 14.98±3.80 g/h u IL uvijetima i 11.55±2,6 g/h u FL uvijetima ($p<0.057$). Temperatura kože na stopalima bila je značajno viša u IL uvijetima nego u FL uvijetima tijekom perioda 18.00-24.00 h. Ovi nalazi sugeriraju da je parasimpatički nervi sustav odgovoran za sekreciju sline, te aktivniji pri IL uvijetima. Simpatički nervni sustav odgovoran za funkcioniranje krvnih žila na koži stopala je manje aktivan kod IL svijetla.