Influences of Diurnal Bright or Dim Light Exposure on Urine Volume in Humans

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Abstract We investigated with eight healthy females if 8 hr diurnal (0700 to 1500 h) bright rather than dim light (5,000 vs. 80 lx) influenced urine volume. Environmental illuminance was made identical at all other times besides 07:00 to 15:00 h. The participants spent time at strictly regulated schedules in a bioclimatic chamber (26°C, relative humidity 60%) for 57 h. Blood was drawn (2 ml) just before lunch in order to calculate Creatinine clearance (Ccr). Urine volume was significantly higher during wakefulness and the 8-h sleep period with bright rather than dim light. Ccr was significantly higher after bright light. The results were discussed in terms of suppression of the sympathetic nerve system under the influence of diurnal bright light exposure. We also discussed these in terms of physiological polymorphisms. J Physiol Anthropol 25(2): 189–192, 2006 http://www.jstage.jst.go.jp/browse/jpa2 [DOI: 10.2114/jpa2.25.189]

Keywords: urine volume, creatinine clearance, bright light, dim light, renal circulation, physiological polymorphisms

Introduction

Tokura and his associates have found that bright light exposure for several hours during the daytime has profound influences on physiological variables (Tokura, 2005; Tokura and Kim, 2005). These include: a decrease of diurnal levels of tympanic temperature (Aizawa and Tokura, 1997); an improvement of digestion of carbohydrate in an evening meal (Sone et al., 2003); a decrease of blood pressure during the daytime (Kim and Tokura, 2000) and an increase of salivary secretion during the forenoon (Kanikowska et al., 2002), of melatonin excreting rate in urine (Aizawa and Tokura, 2000) and of parasympathetic nervous activity around midnight (Nishimura et al., 2003). These data suggest that bright light exposure for several hours during the daytime seems to inhibit the sympathetic and to enhance the parasympathetic nervous system. Therefore, there is a possibility that bright light exposure for several hours during the daytime may result in an increased amount of urine excretion under the influence of increased renal circulation due to an inhibition of the sympathetic nervous system relating to the kidney. Furthermore, we have often observed that subjects who spend time under bright light during the daytime in a bioclimatic chamber are apt to urinate more often. The present experiment was designed to test whether or not our hypothesis and observation were correct.

Materials and Methods

Participants

Eight young females 22.9±0.93 yrs (mean±SE) of age, 156.7±2.2 cm height, 51.1±2.2 kg body mass, participated. The purpose and risks of the experiment were explained to each participant beforehand, and all participants consented to the experiment, for which they were paid. The experiments were performed during the follicular phase of the subjects’ menstrual cycle. All the participants were university students. Therefore, they spent most of their time during the daytime inside the building to attend lectures before presenting themselves as participants.

Protocol

Subjects were studied in pairs. They entered a bioclimatic chamber (controlled at a room temperature of 26°C and a relative humidity of 60% with lighting of 80 lx) at 22:00 h on the first day, retired at 23:00 h, and slept in total darkness. They rose at 07:00 h on the second day and lived in dim light (80 lx) till 23:00 h, sitting quietly and mostly on a sofa (Dim condition). They rose at 07:00 h the on the third day and lived in bright light (5,000 lx) until 23:00 h and then in dim light until 23:00 h, again sitting quietly and mostly on a sofa (Bright condition). In order to investigate the order effect of dim and bright, a similar experiment was carried out except for light
exposure order, i.e. bright light condition on the second day and dim light condition on the third day. They were allowed to walk sometimes in a chamber during wakefulness on the 2nd and 3rd days. They were asked to gaze at the light source for one minute approximately every 10 min. They then slept in total darkness from 23:00 h until to 07:00 h the following morning, when the experiment ended. Meals were strictly controlled for calorie content, and were eaten at 08:00, 12:00 and 18:00 h. Distilled water (300 ml) was also provided three times per day, together with the meals.

The subjects emptied their bladders on retiring and again on awakening at 07:00 h. They also collected urine every 2 h when awake, and total 24-h urine volume was measured. Blood was drawn from median vein (2 ml) just before lunch, and was then centrifuged to get a serum sample. Urine and serum samples were frozen immediately for later analysis. Urine volume was measured by graduated cylinder. We asked the SRL laboratory (Tokyo, Japan) to analyze the samples for urine and serum Creatinine concentration. Ccr was calculated as: 

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\text{Ccr (L/day)} = U/P \times \text{Urine Volume (L/24 h)} \times 1.48/A, \text{where U is creatinine concentration in urine (mg/dl), P is creatinine concentration in serum (mg/dl), A is body surface area (m²) and 1.48 is the mean value for body surface area (m²) in Japanese subjects.}
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Statistics and calculation

The statistical significance of the differences between variables under the two conditions (bright light exposure and dim light exposure) was determined by Student's paired t-test. A p value of <0.05 was regarded as statistically significant.

Results

Figure 1a compares 2-h (07:00 to 23:00 h) or 8-h (23:00 to 07:00 h) urine volumes between the two light conditions. As seen in Fig.1a, the values were significantly higher with bright light at 11:00, 13:00, 15:00, 17:00, 21:00 and 07:00 h the next morning. It should be noticed that urine volume during the bright light condition increased about 4 h after the beginning of exposure to the bright light. Urine volume during the 8-h sleep period was significantly higher after bright light exposure. Figure 1b compares total urine volume during the 24 h. The value was significantly higher in the bright light condition (p<0.01).

Calculation of Ccr showed that the value was 140.04±10.741/day in the bright light condition and significantly less (130.48±9.15/day, p<0.05) in the dim light condition.

Discussion

What physiological mechanisms could account for the main finding that bright light increased urine volume significantly after about a 4-h delay in the conditions from dim to bright?
Since the content of meals and amount of water drunk were strictly controlled in our experiment, these factors can be presumed to be not responsible for any differences in urine volume. Posture change which could influence urine volume (Thomas, 1957) did not occur between dim and bright light exposure. Therefore, the factor of posture could be excluded for different urine volume.

Ccr increased in the bright light condition, suggesting that renal blood flow also increased then. Furthermore, Lee (2001) has found that the urinary excretion rate of vanillylmandelic acid (VMA), the main metabolites of noradrenaline, was significantly lower during the daytime and around midnight when there was exposure to bright light during the daytime, suggesting that sympathetic nerve activity had been suppressed by the bright light. The changes of other physiological variables (see Introduction) also suggest that bright light exposure during the daytime seems to inhibit an excitement of the body, being evidenced by the facts that blood pressure was significantly reduced (Kim and Tokura, 2000), salivary secretion increased significantly (Kanikowska et al., 2002) and digestive activity was improved (Sone et al., 2003) under the influence of diurnal bright light exposure. Therefore, the increase in urine volume observed in the present study might have been due to an increase in renal blood flow following an inhibition of the sympathetic nerves activity by innervating the kidney.

According to Saito et al. (1996) and Niijima et al. (1992), 20 min bright light exposure (5,000 lx) and 10 min bright light exposure enhanced the muscle sympathetic nerve activity in humans and the sympathetic nerve outflow suppressed the vagal outflow in rats, respectively. These results seem to be inconsistent with our present results. The reason for the discrepancies may be due to different duration of bright light exposure; 10–20 min in their case and 8 h in our case. It takes approximately 3 h until tympanic temperature begins to be lowered (Aizawa and Tokura, 1998), urinary melatonin to be higher (Aizawa and Tokura, 1999) and blood pressure to be decreased (Kim and Tokura, 2000) in humans under the influence of diurnal bright, compared with diurnal dim light exposure. Short bright light exposure could enhance sympathetic nerve activity, while long bright light exposure could suppress it. These two different responses to same bright light exposure, depending on the duration of bright light exposure, might have an adaptive and ecological significance in terms of survival value, because if the sympathetic nervous system continued to be excited for long hours under the influence of diurnal bright light exposure, the body may be easily fatigued. Physiological mechanisms to suppress sympathetic nervous activity were presumably established in the process of evolution.

Takasu et al. (2002) measured circadian core temperature in three Japanese macaques, Macaca fuscata fuscata continuously for three weeks, for the first week under diurnal dim light (180 lx), for the second week under diurnal bright light (3,500 lx) and for the third week again under diurnal dim light (180 lx). Nocturnal core temperature fell to a lower level soon after the light condition during daytime (06:00 to 18:00 h) was changed from 180 lx to 3,500 lx. However, when the light condition during daytime was changed from 3,500 lx to 180 lx, the nocturnal core temperature did not recover its value obtained during first dim light, but continued to keep the value during the second bright light for one week in two out of three animals, although the nocturnal value tended to recover itself to the first dim one in one out of the two monkeys. These findings suggest the “aftereffects” on core temperature by diurnal bright light may continue even during diurnal dim light in the third week. With these in mind, it was appropriate that dim to bright light conditions be applied as the present experimental protocol, because the probable occurrence of “aftereffects” on urine volume by bright light condition might have continued even during the following dim light condition, making the interpretation of the data complicated. In order to confirm our speculation, we carried out an additional experiment on urine volume changes under the influence of conditions from first day bright to second day dim light exposure. As expected, the urine volume during the daytime (between 09:00 and 19:00 h), obtained during first day dim light (from first day dim light to second day bright light exposure) and second day dim light conditions (from first day bright to second day dim light exposure) was 1.51±0.21 ml/2h/kg (mean±SE) and 3.04±0.61 ml/2h/kg, respectively (p<0.01). Thus, the urine volume was quite different even under the same dim light, suggesting the existence of “aftereffects” by first day bright light to the following day. However, the urine volume from 19:00 to 23:00 was 2.18±0.26 ml/2h/kg in the first day dim light and 2.96±0.41 ml/2h/kg in the second day dim light (p<0.01). The urine volume during 8 h sleep (23:00 to 07:00 h) was 7.97±1.37 ml/2h/kg in first day dim light (from first day dim light to second day bright light exposure) and 8.97±1.49 ml/2h/kg in second day dim light (from first day bright to second day light exposure) (p<0.01). These results suggest convincingly that although the “aftereffects” of first day diurnal bright light exposure on urine volume remains during the following daytime (09:00 to 19:00 h), they may disappear with a lapse of time and finally recover the expected higher urine volume under the influence of diurnal bright light exposure during the periods of 19:00 to 23:00 h and the sleep period. This interpretation seems reasonable. However, the situation remains to be studied more systematically concerning the “aftereffects” of diurnal/nocturnal bright light exposure on urine volume.

What is meant by our finding in terms of physiological anthropology? The present data suggest that different light conditions in various regions of the world might be one of several factors for explaining the cause of occurrence in physiological polymorphisms, because different light intensities during the daytime caused urine volume to differ in our present experiment. The seasonal pattern of breath hydrogen as an indicator of malabsorption is different between
Polish and Japanese people (Sone et al., unpublished). Breath hydrogen is greatly influenced by diurnal bright and dim light intensities (Sone et al., 2003). The melatonin secretion pattern is also quite different between Polish and Japanese people around the winter solstice (Blazejczyk et al., 2005). Melatonin secretion is influenced by diurnal light intensity (Park and Tokura, 1999). Poland and Japan have quite different light environments (Blazejczyk et al., 2005), which may be responsible for different physiological parameters such as breath hydrogen pattern and melatonin secretion. Such views have not been proposed up till now so as to interpret the causes for the occurrence of physiological polymorphisms. It is tempting to compare urine volume under natural illumination between Polish and Japanese people in daily life with strictly controlled food and water intake in order to confirm whether or not our speculation is correct.

Thus, it is concluded that bright light exposure during the daytime can enhance urine volume.

**Acknowledgement** The authors thank Prof. Jim Waterhouse in Liverpool, UK, for his help in correcting our English text and Prof. Takeshi Morita in Fukuoka for his critical reading of our paper.

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Received: July 22, 2005
Accepted: November 24, 2005
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