Effects of Different Types of Clothing on Circadian Rhythms of Core Temperature and Urinary Catecholamines

Shin-Jung PARK and Hiromi TOKURA

Department of Environmental Health, Nara Women's University,
Nara, 630–8506 Japan

Abstract: This study investigated the effects of three different types of clothing on the circadian rhythms of core temperature and urinary catecholamines. One type of clothing consisted of long-sleeved shirts, full-length trousers, and socks (Type L, 1,042 g); the second type was of half-sleeved shirts and knee-length trousers (Type H, 747 g); the third type was of Type H during the daytime and Type L during night sleep (Type M). Six healthy females participated in this study where rectal temperature, skin temperatures, heart rate, and urinary catecholamines were continuously measured for 37.5 h at an ambient temperature of $23.8 \pm 0.2^\circ\text{C}$ and a relative humidity of $60 \pm 5\%$. The results were as follows: (1) The nocturnal minimum of rectal temperature decreased significantly in the sequence Type

L < Type M < Type H clothing, and 27.2 and 12.4% of the circadian amplitude were influenced by type of clothing during the daytime and the nighttime, respectively. (2) The rise of skin temperatures in the extremities increased significantly more after the subjects retired for sleep with Type M or Type H clothing than with Type L. (3) Urinary catecholamines decreased more in the evening and increased more in the morning with Type H and Type M clothing than with Type L. These results show that the circadian rhythm of core temperature, especially the nocturnal minimum value, was influenced by the type of clothing worn not only during the nighttime, but also during the daytime. [Japanese Journal of Physiology, 48, 149–156, 1998]

Key words: circadian rhythm, type of clothing, core temperature, skin temperatures, urinary catecholamines.

Recently, it has been reported that clothing acts as an important factor in modifying core temperature in humans [1–3]. In our previous study [1], it was suggested that different types of clothing could influence the circadian rhythm of core temperature and immune activity. In a thermally neutral environment ($24 \pm 0.5^\circ\text{C}$), core temperature was significantly lower and concentration of salivary immunoglobulin A significantly higher during nighttime sleep when half-sleeved shirts and knee-length trousers (Type H) were worn instead of long-sleeved shirts and full-length trousers (Type L). These results were hypothesized to be related to more relaxation in the sympathetic nervous system during nocturnal sleep with Type H

clothing. Fruhstorfer *et al.* [4] demonstrated that noise stress during the daytime caused a significant increase in plasma adrenaline during the first 6 h of exposure and lower values during the subsequent night sleep. This result suggests that higher daytime sympathetic activation leads to a lower level in the subsequent night. By analysis, therefore, it might be suggested that in the subjects wearing Type H clothing during the daytime, skin vasoconstriction in the extremities mediated by the sympathetic nervous system occurs more strongly with less insulation; i.e., it leads to a more excitable sympathetic nervous system during the daytime because of less thermal insulation. This results in a greater relaxation of the sympathetic ner-

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Correspondence should be addressed to: Hiromi Tokura, Department of Environmental Health, Nara Women's University, Nara, 630–8506 Japan. Tel: +81–742–20–3469, Fax: +81–742–20–3499, E-mail: tokura@cc.nara-wu.ac.jp

mattress to keep the subjects' entire bodies covered except for their faces. In the daytime, subjects sat on a sofa and were allowed to read a book, listen to music, or play a game, but they were not allowed to nap. Meals were served at 07:30, 12:00, and 18:30, and a light snack was served at 15:30. Subjects took in the same number of calories (1,600 kcal/d) in each part of the experiment. The intensity of light was controlled at 500 lx from 06:30 to 19:30 (by placing fluorescent lamps in front of the subjects) and at 100 lx from 19:30 to 22:30; it was totally dark during nighttime sleep.

Data from 06:30 on day 2 until 10:30 on day 3 (28 h) were used for analysis because the first night was treated as a time of adaptation to the experimental chamber.

Urine was collected into 6 N HCl at 4-h intervals; the volume was measured, and the urine was stored immediately at -80°C in a freezer for subsequent catecholamine analysis.

Measurements. Rectal temperature was measured by a thermistor probe (RE type, Grant Instruments Ltd., UK, accuracy $\pm 0.05^{\circ}\text{C}$) inserted 12 cm beyond the anal sphincter, and skin temperatures from seven sites (forehead, abdomen, arm, hand, thigh, leg, foot) by epoxy-coated copper thermistor probes (EU type, Grant Instruments Ltd., accuracy $\pm 0.05^{\circ}\text{C}$). Rectal and skin temperatures were stored every 10 min by a Squirrel Meter Logger (Grant Instruments Ltd.). Mean skin temperature was calculated by the method of Hardy and DuBois [8]. Heart rate was measured every min with a pulse watch (PE-3000, Sport Tester, Finland). Urine samples were analyzed for adrenaline and noradrenaline by High-Performance Liquid Chromatography with electrochemical detection (3000 series, EICOM Ltd., Japan). All samples from any single study were measured in the same assay.

Statistical analysis. The average patterns of rectal temperature, mean skin temperature, heart rate, and catecholamines were analyzed by a two-factor analysis of variance with repeated measures. (The main effects were type of clothing and time of day.) When a significant difference was obtained for clothing effect or the clothing $\times$ time interaction, the multiple comparisons procedure by Ryan's method [9] was used to identify specific differences. For rectal temperature and mean skin temperature, the statistical evaluation was carried out separately for the wake and sleep periods, and the values for the analysis were 30 min means. Cosinor analysis ($Z=24$) was used to determine circadian amplitude and acrophase of rectal temperature [10]. Friedman two-way analysis of vari-

Fig. 2. (a) The time course of average rectal temperature with three different types of clothing. (b) Temporal changes of mean skin temperature with three types of clothing. Results plotted from 06:30 on day 2 until 10:30 on day 3. Symbols ** and * represent statistically significant differences in the mean value at 1 and 5% levels, respectively: a, between Type L and Type H; b, between Type H and Type M; c, between Type L and Type M. Symbols of \$, #, and & indicate that the corresponding values differed significantly at the 5% level when the clothing $\times$ time of day interaction was significantly different: \$, between Type L and Type H; #, between Type H and Type M; &, between Type L and Type M.

ance by ranks was used to examine significant differences between the types of clothing of evening falls and morning rises in catecholamines, rectal temperature, and skin temperature in the extremities and the amplitude and acrophase in circadian rectal temperature.

RESULTS

Figure 2(a) shows the group mean rectal temperatures when Type L, Type H, and Type M clothing were worn. Rectal temperature during the sleep span was significantly different between the types of clothing, $F(2,10)=27.55$, $p<0.01$, and by time of day, $F(15,75)=17.79$, $p<0.01$. Moreover, the effect of clothing on rectal temperature differed by the time, $F(30,150)=1.706$, $p<0.05$. Further, multiple comparisons by Ryan's method showed that the mean level of rectal temperature was significantly lower with Type H than

Table 1. A comparison of cosinor analysis of circadian amplitude and acrophase of rectal temperature among three types of clothing.

Subjects	Amplitude (°C)			Acrophase (clock time; h)		
	Type L	Type H	Type M	Type L	Type H	Type M
S1	0.37	0.55	0.42	15.0	14.3	14.8
S2	0.34	0.47	0.38	16.7	15.3	16.0
S3	0.32	0.49	0.38	17.0	15.3	16.0
S4	0.56	0.83	0.69	14.7	14.3	14.7
S5	0.55	0.61	0.52	14.8	14.5	14.2
S6	0.31	0.43	0.35	15.0	14.3	15.3
Mean±SEM	0.41±0.047	0.56±0.059	0.46±0.053	15.5±0.38	14.7±0.19	15.2±0.27
Friedman's ANOVA		$p=0.0017$			$p<0.029$	

with Type L or Type M clothing ($p<0.01$ for both cases), and the temperature was significantly lower in the first half of sleep with Type M than with Type L clothing. On the other hand, the mean level of rectal temperature during the daytime was not significantly different for the three types of clothing. However, the time effect was significant, $F(40,200)=18.661$, $p<0.01$, and the interaction of time and clothing was also significant, $F(80,400)=3.623$, $p<0.01$. Rectal temperature started to fall more quickly in the evening in the sequence Type H>Type M>Type L (the difference between the mean values of 17:40–18:30 and 21:40–22:30, Friedman's ANOVA, $p=0.0055$). Rectal temperature also fell to a lower nocturnal minimum in the same sequence (the difference between the mean of 17:40–18:30 and 01:10–02:00, Friedman's ANOVA, $p<0.0017$). Finally, rectal temperature rose faster in the morning in this sequence (the difference between the mean values of 02:40–03:30 and 09:40–10:30, Friedman's ANOVA, $p=0.012$).

Table 1 compares the amplitude and the acrophase of the cosinor analysis of circadian rectal temperature between the three different types of clothing. As this table shows, the amplitude and the acrophase of rectal temperature were significantly greater and earlier, respectively, in the sequence Type H>Type M>Type L clothing. To determine to what extent the direct effects and aftereffects are responsible for the amplitude of the circadian rhythm of core temperature, the amplitudes of the circadian temperature rhythms with Type L, Type M, and Type H clothing were compared. Type L clothing had no direct effect or aftereffects at night; Type M had only aftereffects; and Type H had direct effects and aftereffects. Thus the amplitude of Type L clothing was treated as the baseline. The average percentages were 112.4 ± 4.0 and $139.6\pm6.2\%$ (mean±SEM) for Type M and Type H, respectively, compared with Type L. Therefore the aftereffects increased the

amplitude of circadian core temperature by 12.4% (the difference between Type L and Type M) and the direct effects by 27.2% (the difference between Type H and Type M).

Figure 2(b) shows the time course of mean skin temperature with the three different types of clothing. Statistical analysis indicated that mean skin temperature during the daytime was significantly affected by type of clothing, $F(2,10)=26.474$, $p<0.01$, and time of day, $F(10,40)=9.338$, $p<0.01$, but the interaction was not significant. Further analysis by Ryan's method showed that mean skin temperature was significantly higher with Type L than with Type H or Type M clothing during the daytime ($p<0.01$, for both). And during the sleep span, mean skin temperature was influenced by type of clothing, $F(2,10)=14.173$, $p<0.01$, and time of day, $F(15,75)=9.118$, $p<0.01$. The interaction was also significant, $F(30,150)=1.953$, $p<0.01$. The mean level was significantly lower with Type H than with Type L or Type M clothing during the nighttime ($p<0.01$, for both). As shown in multiple comparisons, during the first half of sleep mean skin temperature was significantly lower with Type M than with Type L clothing (even though the subjects wore the same types of clothing); and skin temperature with Type H and Type M clothing increased rapidly after sleep onset. The skin temperatures of the forearm, hand, leg, and foot especially were increased by large amounts on retiring for sleep. The mean increases of skin temperatures in the extremities after going to bed with the three types of clothing are compared in Table 2. The values are represented as the differences of the means for 4 h before and after retiring. The increases of skin temperatures in all sites were significantly greater with Type M and Type H than with Type L clothing (Friedman's ANOVA $p=0.052$, 0.0055, 0.0017, and 0.0055 for hand, forearm, leg, and foot, respectively). These were greater in

Table 2. A comparison of the changes of skin temperatures in the extremities after retiring for sleep among three types of clothing (values are mean $\pm$ SEM).

Type of clothing	Hand (°C)	Forearm (°C)	Leg (°C)	Foot (°C)
Type L	1.53 $\pm$ 0.34	0.43 $\pm$ 0.22	2.91 $\pm$ 0.33	4.92 $\pm$ 0.68
Type H	2.17 $\pm$ 0.23	1.89 $\pm$ 0.40	3.86 $\pm$ 0.33	6.51 $\pm$ 0.45
Type M	2.06 $\pm$ 0.25	2.04 $\pm$ 0.16	4.82 $\pm$ 0.33	6.44 $\pm$ 0.34
Friedman's ANOVA	$p=0.052$	$p=0.0055$	$p=0.0017$	$p=0.0055$

Fig. 3. The time course of average heart rate with three different types of clothing. Results shown from 10:30 on day 2 until 10:30 on day 3. Values are mean and SEM. Symbols ** and * represent statistically significant differences at 1 and 5% levels when the clothing $\times$ time of day interaction was significantly different.

the lower extremities than in the upper ones.

The temporal changes of mean heart rate when Type L, Type H, and Type M clothing were worn are shown in Fig. 3. The values are 4-h means (i.e., the average of 240 values). Statistical analysis indicated a significant interaction of type of clothing and time of day, $F(12,30)=2.989$, $p<0.01$. Heart rate with Type H or Type M clothing was significantly higher than with Type L clothing at 10:30 in the morning of day 3 ($p<0.05$ and $p<0.01$ for Type H and Type M, respectively), and it was significantly lower with Type H than with Type L or Type M clothing at 02:30 and 06:30 on day 2 ($p<0.05$ for both).

Figure 4, (a) and (b) compare mean urine adrenaline and noradrenaline excretion with three types of clothing. Mean excretion showed a time of day variation (i.e., it was greater during the waking period and less during nighttime). A two-way ANOVA showed that adrenaline and noradrenaline excretion were significantly different according to time of day, $F(6,30)=18.358$ and 46.180 , $p<0.01$, for both, and

Fig. 4. The urinary excretion of (a) adrenaline and (b) noradrenaline between 10:30 on day 2 and 10:30 on day 3. Values are mean and SEM. The statistical significance is indicated as in Fig. 3.

the effect of clothing on the excretion depended on the time, $F(12,60)=3.917$ and 2.502 , $p<0.01$, for both. Moreover, a multivariate analysis by Ryan's method showed that adrenaline excretion was significantly greater with Type H or Type M than with Type L clothing at 10:30 ($p<0.01$) and 14:30 ($p<0.05$), and significantly less with Type H or Type M than with Type L clothing at 22:30 and 02:30 ($p<0.05$, for all cases), but it was not significantly different at 18:30 and 06:30. Urinary noradrenaline excretion was significantly less with Type H than with Type L or Type M clothing at 02:30 ($p<0.05$ for both), and significantly greater with Type H or Type M than with Type L clothing at 10:30, especially in the next morning ($p<0.05$ and $p<0.01$ for Type H and Type M, respectively), but it was not so greatly different between the types of clothing in the afternoon. The evening decrease and the morning increase in adrenaline and noradrenaline excretion are compared in Table 3. The values were differences in rates of excretion from

Table 3. A comparison of evening decrease (18:30–22:30) and morning increase (06:30–10:30) of urinary catecholamine among three types of clothing (values are mean $\pm$ SEM).

Type of clothing	Adrenaline ($\mu\text{g} \cdot 4\text{h}^{-1}$)		Noradrenaline ($\mu\text{g} \cdot 4\text{h}^{-1}$)	
	Decrease	Increase	Decrease	Increase
Type L	0.154 ± 0.278	0.480 ± 0.181	0.201 ± 0.192	2.180 ± 0.328
Type H	0.738 ± 0.203	1.097 ± 0.326	0.804 ± 0.216	3.134 ± 0.321
Type M	0.650 ± 0.198	1.011 ± 0.221	0.665 ± 0.209	3.164 ± 0.328
Friedman's ANOVA	$p=0.029$	$p=0.029$	NS	$p=0.0081$

Fig. 5. The relationship between the fall of rectal temperature and the decrease of urinary adrenaline excretion in the evening.

18:30 to 22:30 and from 06:30 to 10:30. The evening decrease of adrenaline was significantly greater in the sequence Type H > Type M > Type L clothing (Friedman's ANOVA $p=0.029$), and the morning increases of adrenaline and noradrenaline were significantly greater with Type H and Type M than with Type L clothing (Friedman's ANOVA $p=0.029$ and $p=0.0081$, for adrenaline and noradrenaline, respectively). The decrease of noradrenaline excretion was not significantly affected by the type of clothing.

Figure 5 shows the relationship between the evening fall of rectal temperature (the difference between the mean values of 17:40–18:30 and 21:40–22:30) and the evening decrease of adrenaline (the difference from 18:30 to 22:30). Between these times there are no changes in the thermal insulation provided by clothing and bedclothes, so an opportunity is available to consider the relationship between sympathetic nervous system activity and rectal temperature

in the absence of this interference. The fall of rectal temperature was correlated positively and significantly with the decrease of adrenaline ($r=0.652$, $p<0.01$). However, no significant correlation was noted between the decreases of rectal temperature and noradrenaline.

The circadian pattern of heart rate was closer to that of noradrenaline than to that of adrenaline. The correlation coefficients between heart rate and adrenaline and between heart rate and noradrenaline were $r=0.418$ and 0.609 , respectively ($p<0.01$, for both).

DISCUSSION

The main result in this study is that the level of core temperature during nocturnal sleep was significantly lower in the sequence Type H < Type M < Type L clothing (Fig. 2(a)). It is interesting to note that the core temperature fell more during the nighttime with Type M than with Type L clothing, even though the same clothing was worn at this time. This suggests that the clothing type worn during the daytime could influence the nocturnal level of core temperature. Moreover, the minimum level of core temperature during sleep was significantly lower with Type H clothing. Therefore the nocturnal level of core temperature was determined by the type of clothing worn not only during the daytime, but also during the nighttime.

Furthermore, the circadian amplitude of the rhythm of core temperature was greater in the same sequence as the minimum value (Table 1). Moreover, the circadian amplitudes with Type H and Type M in comparison with Type L clothing were 139.6 and 112.4%, respectively. Thus 27.2% of circadian amplitude of core temperature might be affected in the addition by the elevated heat loss because of less insulation during nighttime sleep (direct effects), and its 12.4% by the more activated sympathetic nervous system during the daytime (aftereffects). Type H and Type M clothing induced an earlier fall of core temperature during the nighttime, resulting in a phase advance of the circadian core temperature (Table 1). However, it is not clear whether the phase changes observed in the present study represent an effect of clothing on the pacemaker driving the body temperature or only an effect of masking. A comparison of core temperatures between Type L and Type M clothing (which consisted of the same types of clothing during sleep) shows that the core temperature fell quicker and to a lower level during most of the sleep span with Type M clothing, but it became very similar to the temperature curve for Type L clothing late in the sleep period. Therefore these results indicate that clothing might change oscil-

lator amplitude, but that it will not affect the circadian pacemaker.

The reason that core temperature fell more deeply during the nighttime with Type M than with Type L clothing might be due to a higher increment of skin temperature and heat loss in the extremities soon after sleep onset (Table 2). In this study, heat loss was not measured directly. However, it is well documented that the circadian rhythm of skin temperature in the extremities is phased differently from that for rectal temperature, and that changes in heat loss from the extremities account for 75% of the circadian variation of core temperature [11,12]. Therefore we suggest that when wearing Type H or Type M clothing, the cutaneous tone was greater during the daytime to maintain core temperature, and that in the evening, when cutaneous vasoconstriction was reduced, a larger vasodilation caused the core temperature to decrease more [13]. The hands were not covered by any type of clothing; thus the time-course of hand skin temperature might be explained as reflecting only the changes of sympathetic nervous activity because different types of clothing were worn. The increment of hand skin temperature after retiring to sleep was significantly greater with Type H or Type M than with Type L clothing, suggesting a greater decrease in sympathetic tone with Type H or Type M than with Type L clothing.

Urinary adrenaline and noradrenaline excretions show a clear day-night variation, i.e., high values during the waking period and low during the nighttime (Fig. 4). These results are similar to the findings of many investigators [14–17]. Moreover, the levels of adrenaline and noradrenaline were significantly higher at 10:30 with Type H and Type M clothing compared with Type L clothing. This might also reflect differences in sympathetic nervous tone because of the need for stronger vasoconstriction in the extremities with less thermal insulation. This result is supported by previous findings that the more tense the subjects, in response to stressful stimuli, the higher the excretion of catecholamines [4, 14, 18, 19]. Moreover, the reason why urinary adrenaline and noradrenaline excretion differed in the morning between Type H or Type M clothing and Type L clothing might be a stronger cold sensation in the morning [20] because the extremities of the subjects with Type H and Type M clothing were directly exposed to the surrounding air. Moreover, the questionnaires about thermal sensation and comfort showed that in the morning, the subjects felt slightly cool with Type H and Type M clothing, but neutral with Type L clothing (data not shown). Furthermore, the rate of excretion of adrena-

line was less with Type H and Type M clothing than with Type L clothing, and noradrenaline excretion was less with Type H clothing than with Type L and Type M clothing at 02:30, even though no significant differences were found between the three types of clothing at 06:30. This result is supported by an investigation that showed that daytime stress induced a greater decrease of adrenaline during the sleep span [4]. The result also supports the hypothesis in our previous study [1] that the concentration of salivary IgA was higher with Type H clothing than with Type L clothing at 02:30 because of the decreased activity of the sympathetic nervous system at this time.

However, heart rate was not significantly lower with Type M clothing than with Type L clothing during the nighttime, although there was a significant difference in adrenaline excretion during the first half of sleep. This difference implies a dissociation of skin and cardiac sympathetic activity or, alternatively, by a simultaneous cardiac parasympathetic activation offsetting cardiac sympathetic activation [21]. We note also that heart rate was correlated more closely with noradrenaline excretion ($r=0.609$) than with adrenaline ($r=0.418$) excretion.

Furthermore, the quicker fall of rectal temperature with Type H and Type M clothing is accompanied by a greater decrease of urinary adrenaline excretion between the evening and the time of retiring, and there is a high correlation between the two variables (Fig. 5). This result is supported by the finding of Akerstedt and Froberg [16] that there is a close temporal covariation between urinary adrenaline excretion and rectal temperature.

Therefore it is concluded that the circadian rhythm of core temperature, especially the nocturnal minimum value, was modified by the type of clothing worn not only during the nighttime, but also during the daytime.

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REFERENCES

1. Park S-J and Tokura H: Effects of two types of clothing on the day-night variation of core temperature and salivary immunoglobulin A. *Chronobiol Int* 14: 607–617, 1997
2. Jeong WS and Tokura H: Circadian rhythm of rectal temperature in man with two different types of clothing. *Int Arch Occup Environ Health* 62: 295–298, 1990
3. Lee YH and Tokura H: Circadian rhythm of human rectal and skin temperatures under the influences of three different kinds of clothing. *J Interdiscipl Cycle Res* 24:

- 33–42, 1993
4. Fruhstorfer B, Pritsch MG, and Pritsch MB: Effects of daytime noise load on the sleep-wake cycle and endocrine patterns in man. III. 24 hours secretion of free and sulfate conjugated catecholamines. *Int J Neurosci* 43: 53–62, 1988
5. Kim HE and Tokura H: Influence of different light intensities during the daytime on evening dressing behavior in the cold. *Physiol Behav* 58: 779–783, 1995
6. Rutkowska D, Park S-J, Okazaki Y, and Tokura H: Effect of the different light intensities during the daytime on some physiological parameters in terms of circadian rhythm. *Appl Hum Sci* 15 (Suppl): 129, 1996
7. Tokura H, Yutani M, Morita T, and Murakami M: Effects of bright and dim light intensities during daytime upon circadian rhythms of core temperature in man. In: *Temperature Regulation*, ed. Milton AS, Birkäuser Verlag Co., Basel, pp 285–289, 1994
8. Hardy JD and DuBois EF: The technic of measuring radiation and convection. *J Nutr* 15: 461–475, 1938
9. Ramsey PH: Power of univariate pairwise multiple comparison procedures. *Psychol Bull* 90: 352–366, 1981
10. Halberg F, Tong YL, and Johnson EA: Circadian system phase—an aspect of temporal morphology; procedures and illustrative examples. In: *The Cellular Aspects of Biorhythms*, ed. von Mayersback H, Springer-Verlag, Berlin, Heidelberg, and New York, pp 20–48, 1967
11. Aschoff J and Heise A: Thermal conductance in man : its dependence on time of day and on ambient temperature. In: *Advances in Climatic Physiology*, ed. Itoh S, Ogata K, and Yoshimura H, Igaku Shoin, Tokyo, pp 334–348, 1972
12. Hilderbrandt G: Circadian variations of thermoregulatory response in man. In: *Chronobiology*, ed. Scheving LE, Halberg I, and Pauly JE, Igaku Shoin, Tokyo, pp 234–240, 1974
13. Waterhouse JM and Minors DS: The circadian rhythm of core temperature in humans. In: *Body Temperature and Metabolism*, ed. Nagasaka T and Milton AS, IPEC, Tokyo, pp 213–218, 1995
14. Fibiger W, Singer G, Miller AJ, Armstrong S, and Datar M: Cortisol and catecholamines changes as functions of time-of-day and self-reported mood. *Neurosci Biobehav Rev* 8: 523–530, 1984
15. Forsman L: Habitual catecholamine excretion and its relation to habitual distress. *Biol Psychol* 11: 83–97, 1980
16. Akerstedt T and Froberg JE: Sleep and stressor exposure in relation to circadian rhythms in catecholamine excretion. *Biol Psychol* 8: 69–80, 1979
17. Faucheux B, Kuchel O, Cuhe JL, Messerli FH, Buu NT, Barbeau A, and Genest J: Circadian variations of the urinary excretion of catecholamines and electrolytes. *Endocrinol Res Commun* 3: 256–272, 1976
18. Hjemdahl P, Freyschuss U, Juhlin-Dannfelt A, and Linde B: Differentiated sympathetic activation during mental stress evoked by the Stroop test. *Acta Physiol Scand* 527(Suppl): 25–29, 1984
19. Lundberg U and Frankenhaeuser M: Pituitary-adrenal and sympathetic-adrenal correlates of distress and effort. *J Psychosom Res* 24: 125–130, 1980
20. Kim HE and Tokura H: Effects of time of day on dressing behavior under the influence of ambient temperature fall from 30°C to 15°C. *Physiol Behav* 55: 645–650, 1994
21. Somers VK, Dyken ME, Mark AL, and Abboud FM: Sympathetic-nerve activity during sleep in normal subjects. *N Engl J Med* 328: 303–307, 1993