Circadian Periodicity of Plasma Cortisol Levels in Members of Japanese Antarctic Research Expedition in Antarctic Region

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南極圏における日本南極地域観測隊員の血中コルチゾール日内リズムについての研究

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要旨: 血中コルチゾールの日内リズムの変化を，昭和基地に居住する隊員について調査した.

年4回(3月，6月，9月，12月)，昼夜時間の異なる時期を選び，1日4回(8時，12時，18時，22時)採血し，血中コルチゾールを測定した. 日内リズムの乱れは，暗期の6月に得られ，他の3時期は，正常のリズムであった. さらに，個々のリズムとそれらの睡眠覚醒時間を合わせて考慮すると，血中コルチゾールの日内リズムは，睡眠覚醒の周期に合い，ピークは，ほぼ，覚醒時に得られた.

6月，12月に行った睡眠覚醒の変化に伴うリズムの変化，夜勤者から得られた各時期の一定したリズムから，昼夜の変化より，睡眠覚醒周期が，血中コルチゾールの日内リズムの重要な因子の一つであろうと考えられた.

Abstract: With collaboration of the members of the 14th Japanese Antarctic Research Expedition (JARE), circadian rhythm of plasma cortisol levels was studied in 4 different seasons during a year.

Blood specimens were obtained from 30 members at 22:00, 08:00, 12:00, 18:00 on each experimental day. Time-study was performed on the same days for all members. They had arbitrary daily schedules and sleeping times, except for several members in charge of machine maintenance, 3 weathermen and 2 correspondents, who followed their own fixed schedules.

"Normal" circadian rhythm was observed on the days in March and September which have the same day-night cycles as in Japan.

The rhythm was disturbed in June, the month of darkness throughout the day. In December, the season of midnight sun, the nyctohemeral rhythm was maintained although plasma cortisol levels were slightly elevated. The

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members of the machine maintenance group had "normal" rhythm at every period. The nightworkers had inverse rhythm at 4 different period.

The circadian rhythm reexamined 4 days after changing the sleep-wake cycle showed the time shift according to the new sleep-wake period.

These results suggest that the circadian rhythm of plasma cortisol levels depends on the sleep-wake cycle rather than on the day-night cycle.

1. Introduction

The existence of circadian rhythmicity in plasma cortisol levels is well documented (PINCUS, 1943; TYLER *et al.*, 1954; PERKOFF *et al.*, 1959; NEY *et al.*, 1963). This is known to be dependent upon the rhythm of ACTH secretion maintained under CNS control (SLUSTER, 1964; DEMURA *et al.*, 1966; HIROSHIGE *et al.*, 1970; TAKEBE *et al.*, 1972).

Alternation in this pattern is reported to occur with reversal of the sleep-wake cycle in normal subjects. This suggests the important role of sleep-wake rhythmicity in the timing of the cortisol cycle (ORTH *et al.*, 1967, 1969; KRIEGER *et al.*, 1969, 1971b).

On the other hand, light is known to be an important factor in the initiation and/or maintenance of many biological rhythms (MIGEON, 1956; SHARP, 1960; KRIEGER *et al.*, 1971a, 1971c).

Some investigators emphasized the role of the light-dark cycle in the control of the circadian rhythmicity in plasma cortisol levels in man. The present study was undertaken to elucidate the circadian rhythm of plasma cortisol levels in the members of the Japanese Antarctic Research Expedition in 4 seasons with different light-dark cycles.

2. Materials and Methods

Syowa Station, the main station of the JARE, was set up on East Ongul Island located in long. 39°E and lat. 69°S facing the Indian Ocean of Antarctica. It is 5 km distant from the main Antarctic land. Members of the JARE-14 consisted of 30 healthy men, aged 20 to 39, with the average age of 30.0, and stayed there for a year from 10th February 1973 to 10th February 1974.

The outdoor temperature of the station in that year was 6.2°C at maximum and −39.5°C at minimum (KOZUMA *et al.*, 1974). There are seasonal changes in the expected duration of sunshine (Fig. 1).

The residential houses were air-conditioned with the temperature around 18°C and were lighted by electricity constantly all day long through the year. Although meal times were fixed throughout the year, most of the members were able to have arbitrary daily schedule and sleeping hours. However, the members of the machine maintenance group had to wake up at 08:00 and go to bed at

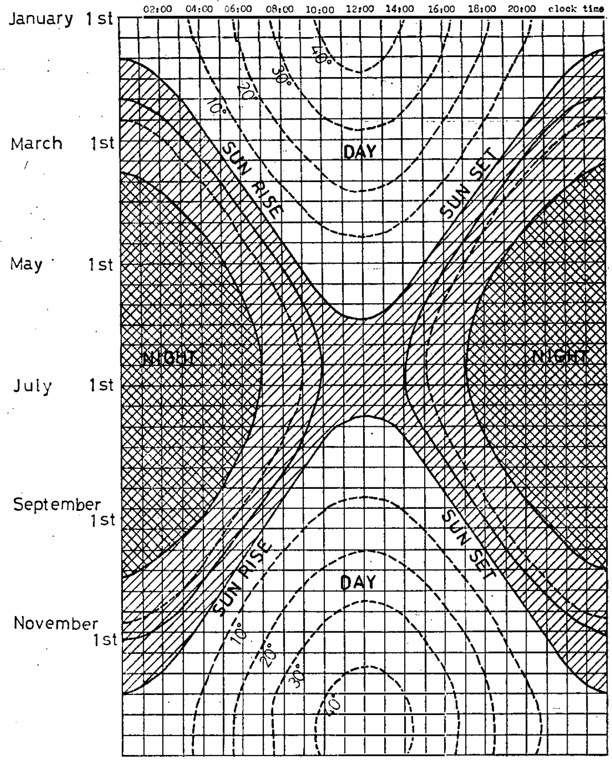

Fig. 1. Day and night at Syowa Station in Antarctica (Masaki FURUHATA, *Tokyo Astronomical Observatory). Syowa Station is located in long. 39°E, lat. 69°S. Shadow: night. 10, 20, 30, 40: solar altitude.*

23:00-24:00. Three weathermen and two correspondents made their own fixed schedules including nightwork.

Blood specimens from these men were taken at night duty time when they woke up at 11:00-13:00 and went to bed at 04:00-06:00. Blood specimens from all members were taken on 16th March, 25th June, 11th September and 23rd December at 22:00 (of the preceding day), 08:00, 12:00, 18:00. In June and December, the dark and light season, blood sampling was performed before and 4 days after the 12 hours time-shift of the sleep-wake periods.

Blood samples were taken into heparinized syringes. Plasma was separated by centrifugation and kept at −20°C until assayed. Plasma cortisol was determined at Syowa Station by a fluorometric method of DEMOOR *et al.* (1960) and the same samples were reexamined by competitive protein binding assay (CERESA *et al.*, 1970) at Kobe University in Japan.

3. Result

Representative results obtained from 10 members are shown in Fig. 2.

The maximum levels of plasma cortisol were observed around the awaking

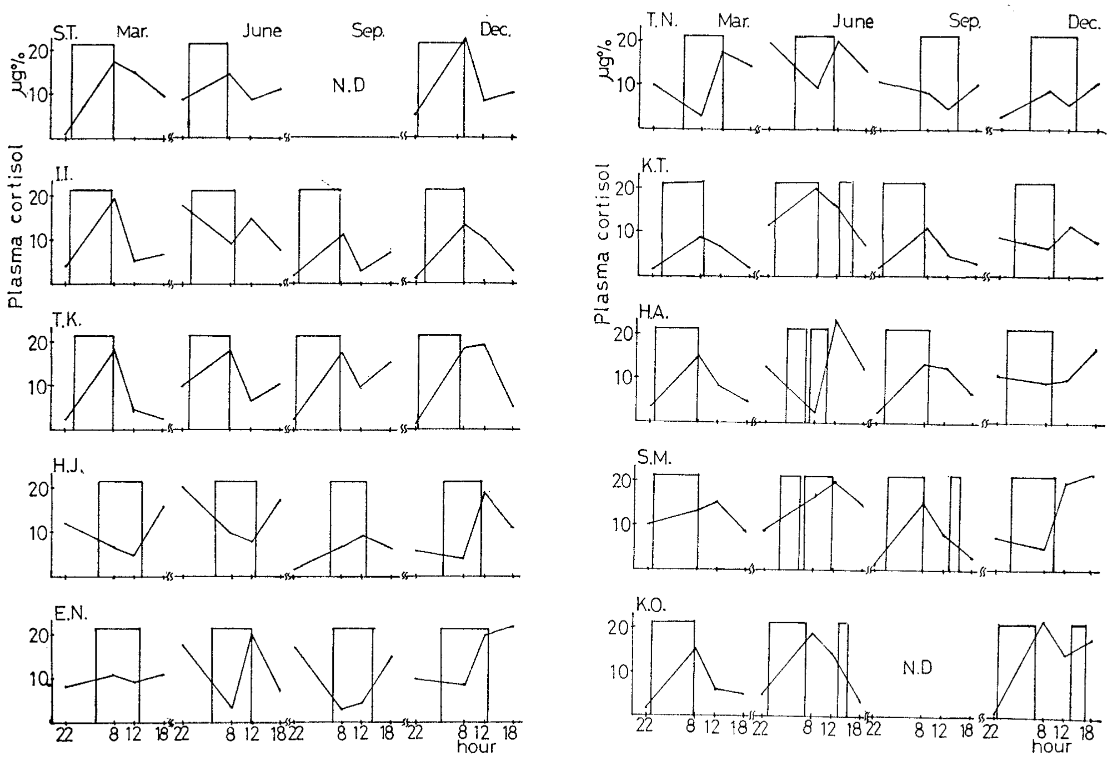

Fig. 2. Sleeping time and plasma cortisol levels of 10 members in 4 periods (March, June, September, December). Symbols of S.T., I.I. etc. are the initials of the subjects. S.T., I.I. and T.K. are the members of the machine maintenance group with the fixed sleep-wake schedule. H.J., E.N. and T.N. are nightworkers. Four others are researcher with a free schedule. Most peaks of cortisol levels occurred at the time of awaking. White column: sleeping hours. N.D.: data were not obtained.

time in most of the cases. In S. T., I. I. and T. K. who belong to the machine maintenance group with the fixed sleep-wake schedule, the peaks occurred at 08:00 in each of the 4 periods. On the other hand, H. J., E. N. and T. N. who were nightworkers had the peaks at 12:00, the time of awaking.

Fig. 3 shows the circadian rhythm of plasma cortisol with the day-night cycle. The normal rhythm was observed on 16th March, when all members took almost the same sleep-wake period except nightworkers. In this figure the data of nightworkers are not included.

On 25th June, disturbance of the rhythm was observed in nearly a half of the subjects studied. Some individuals living in polar regions suffer from insomnia during this period. One could not have the regular sleep-wake cycle and sleep was light and intermittent. On 11th September, the rhythm was almost the same as in March.

On 23th December, the normal rhythm was observed with slightly elevated

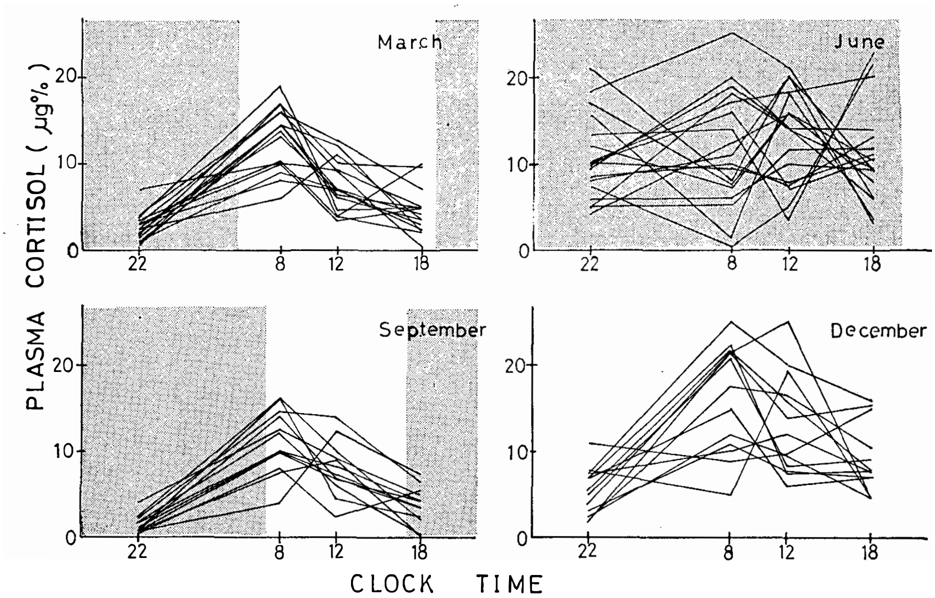

Fig. 3. The circadian rhythms of plasma cortisol levels and day-night cycles in 4 periods (March, June, September, December). The data of nightworkers are not included. The normal rhythms were observed in March, September and December. The disturbance of the rhythm was observed in June in nearly are half of the subjects. Shadow: night.

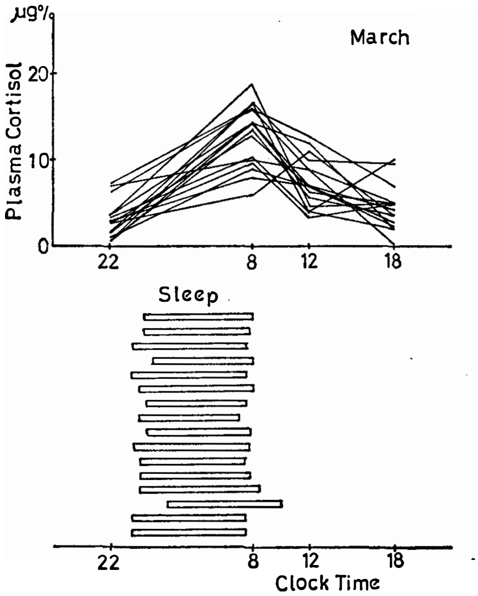

Fig. 4. Sleeping time and plasma cortisol levels in individual subjects in March. The peaks of the rhythms were observed at the time of awaking. White column: sleeping hours.

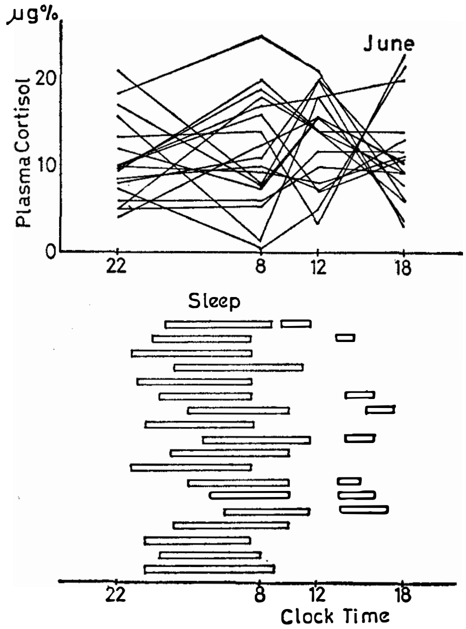

Fig. 5. Sleeping time and plasma cortisol levels in individual subjects in June when the rhythm was disturbed. White column: sleeping hours.

plasma cortisol levels ($p<0.05$). One had a longer time of outdoor working because of the midnight sun.

Figs. 4 and 5 illustrate sleeping time and plasma cortisol levels in individual subjects in March and June, respectively. Irregular circadian rhythms of plasma cortisol levels were observed in June in some subjects whose sleep-wake cycle was disturbed. Those who had regular periods of awaking and sleep even in this dark season showed normal circadian rhythmicity as shown in Fig. 6. Fig. 7

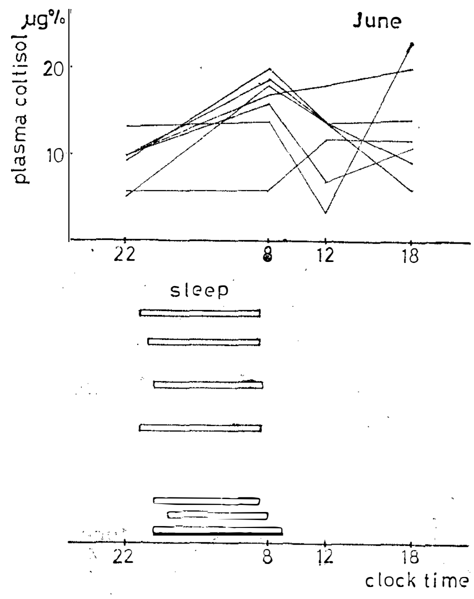

Fig. 6. Sleeping time and plasma cortisol levels in selected members who got up at about 08:00 in June. Most of the peaks were observed at that time. White column: sleeping hours.

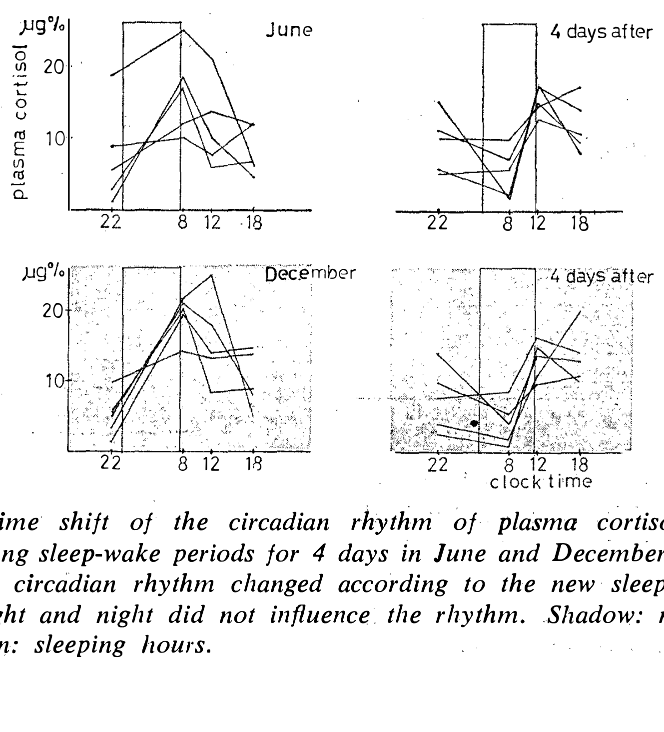

Fig. 7. The time shift of the circadian rhythm of plasma cortisol levels by changing sleep-wake periods for 4 days in June and December. The peaks of the circadian rhythm changed according to the new sleep-wake cycle. Daylight and night did not influence the rhythm. Shadow: night. White column: sleeping hours.

shows the time shift of the circadian rhythmicity of plasma cortisol levels by changing the sleep-wake period for 4 days studied in June and December.

4. Discussion

It is generally recognized that the dark-light cycle or the photo period is the major external synchronizer of biological circadian rhythm in animals other than man. Because man could create darkness and light artificially in the buildings, he would be much less influenced than the animals by the periodicity of natural light.

Nevertheless, it is known that with the onset of the polar day and night, when natural light comes to differ sharply from the accustomed pattern, certain individuals living in polar regions suffer from insomnia and sleep disturbance (YOSHIMURA, 1973; BUNDZEN, 1969; SIMPSON, 1967; ODA, 1972), which suggests the influence of natural light.

It is also known that, in human, the circadian rise in plasma cortisol levels occurs during the transition from darkness to light, usually in the latter part of sleep. It has been shown that light is the most common and most important synchronizing agent for circadian rhythms no matter they are of endogenous or exogenous origin.

ORTH *et al.* (1967) observed the alternation in the circadian pattern of plasma 11-OHCS levels in subjects with artificial sleep-wake cycles of 12, 19 or 33h (one-third of each cycle spent in sleep), respectively. In their studies, the major peak of plasma cortisol was observed during the latter part of sleep, which was also the period of dark-light transition.

Recent studies have revealed that plasma cortisol level fluctuates considerably due to episodicity in secretory activities (ORTH *et al.*, 1967; KRIEGER *et al.*, 1971a). Frequent sampling is required, therefore, to follow exact circadian variations of plasma cortisol levels.

However, frequent sampling was not performed in the present experiments it was difficult to collect samples more than four times a day. Other plasma cortisol peaks than those in the morning which were observed on some occasions may represent episodic rise of plasma cortisol observed by chance. Nevertheless, most of the subjects showed a regular circadian rhythm in March, September and December.

Disturbed rhythm of plasma cortisol in June can be ascribed either to irregular sleep-wake cycle or to dark season; the cause seems more important, because those with the regular sleep-wake cycle retained a regular plasma cortisol pattern even during the dark season. KRIEGER (1974) observed the shift in the time of the circadian peak of plasma corticosterone level in rats with food restriction, and discussed that the disruption of the sleep-wake pattern, induced by food restriction, may be the major factor responsible for the changes observed.

The change of food intake by the shifted sleep-wake cycle may be concerned with plasma cortisol level.

The fact that shifted sleep-wake period in five men resulted in the reversal of circadian rhythmicity of plasma cortisol level within 4 days during the dark period may also indicate the importance of sleep-wake cycle as a synchronizer of the circadian rhythmicity.

Acknowledgments

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