PART 2. AUTONOMIC FUNCTIONS AND STATES OF SLEEP

Abstract

Five healthy male subjects, members of the Japanese wintering party, participated in the investigation of seasonal changes in autonomic functions during sleep, besides relationship between autonomic functions and states of sleep at Syowa Station, Antarctica.

Sleep polygraphic recordings including the indices of autonomic nervous system responses such as heart rate, respiratory rate, digital plethysmogram and skin potential reflex, were performed before the departure for Antarctica, in Antarctica and after returning to Japan.

Mean heart rate during the whole night tended to increase in early-term in Antarctica, whereas mean respiratory rate during the whole night tended to decrease in the same period. On the other hand, with respect to heart rate during a shift from sleep cycle 1 to 4, it tended to increase or at least tended not to decrease in the first period of sleep in the course of all night sleep in Antarctica, whereas it tended to decrease progressively from the onset of sleep until the final sleep cycle in Japan. Furthermore, heart rate during SWS in sleep cycle 1 showed a negative correlation with %S4 of total sleep time.

The results indicate that the sympathetic tone in the first period of sleep was enhanced by the low environmental temperature in Antarctica and suggest that proportion of SWS was modulated, at least in part, via the hypothalamus.

1. Introduction

Men living in the temperate zone are faced with many stressful factors when they winter over in Antarctica. Two main factors, low environmental temperature and daytime activity, were found to influence sleep patterns at Syowa Station (69°00′S, 39°35′E), Antarctica. The proportion of SWS reduced according to the lowering of atmospheric temperature and the proportion of REM sleep varied according to the changes in the energy expenditure with a positive correlation (see the preceding paper).

On the other hand, it is hypothesized by PARMEGGIANI and RABINI (1970) that a load imposed upon thermoregulatory mechanisms should markedly affect sleep processes; and that, conversely sleep in conditions of thermic stress should interfere with adequate thermoregulatory reactions. Therefore, of the two factors affecting sleep patterns, low environmental temperature is the most interesting one with respect to the relationship between autonomic functions and states of sleep.

The present work was intended to investigate on seasonal changes in several kinds of autonomic nervous system responses during sleep, besides the relationship between autonomic functions and states of sleep under the extremely cold environment at Syowa Station in the 16th Japanese Antarctic Research Expedition 1974–1976 (JARE-16).

2. Materials and Methods

Five healthy male subjects who had no experience of the wintering in Antarctica were chosen from 30 Japanese wintering members to participate in the study. Ages of these subjects ranged from 24 to 31 with a mean value of 27.8.

The investigations were performed 8 times. The first (TZ-1) was at Tokyo in October 1974, prior to departure from Japan. The investigations from the second (AT-1) through the seventh (AT-6) were carried out bimonthly, between February and December 1975 at Syowa Station. The eighth investigation (TZ-2) was at Tokyo in July 1976, 6 months after the subjects returned to Japan.

In each observation, three consecutive nights of all-night sleep polygraphic recordings including the indices of autonomic nervous system responses, such as heart rate (HR), respiratory rate (RR), digital plethysmogram (PLG) and skin potential reflex (SPR), were performed by using a Nihon Koden 9 channel multipurpose EEG machine (type 4109) with a paper speed of 1.5 cm per second. Reflection photoelectric plethysmogram was derived from the right index finger to evaluate the peripheral vasoconstriction responses (VCR). RR was picked up from the abdomen. SPR with a silver cup electrode was recorded between the right forearm (reference electrode) and the right palm (active electrode) with TC 0.3. The reference electrode was placed after skin was prepared by skin drilling technique (SHACKEL, 1959). A special circuit was placed between the subject and input box for recording SPR (Fig. 1), for the purpose of ATT (reducing actual signal to one tenth), high cut filter and elimination of the influence of skin resistance.

The subjects were not allowed naps, alcohol, coffee and drugs, but there were no restrictions as for their usual work in each of the experimental periods. They slept clothed and covered in usual sleeping manner from 11 p.m. until their usual awaking time in a darkened, semi-soundproof room at a temperature between 17° and 19°C.

Each epoch, which was classified according to the standardized criteria (RECHTSCHAFFEN and KALES, 1968) with respect to the third night's record, was summarized in each sleep cycle, for convenience sake, as follows: S1+2, S3+4 and SREM. The sleep cycle was presented until sleep cycle 4. The proportion of each sleep stage

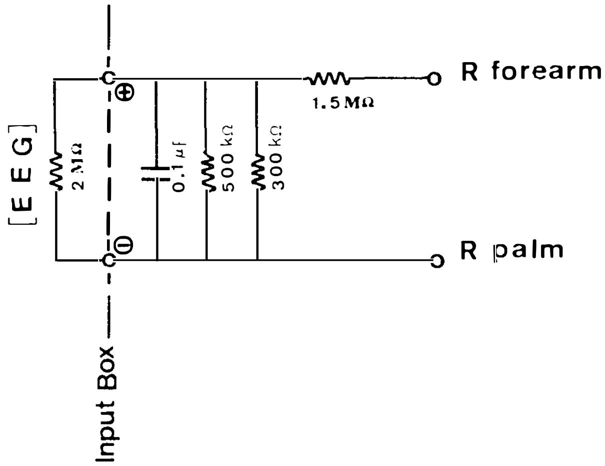

Fig. 1. Circuit placed between the subject and input box for recording skin potential reflex (SPR).

in each sleep cycle was obtained as follows: Number of epochs in each sleep stage in each sleep cycle/total number of epochs in the same sleep stage of total sleep time ×100. HR and RR were computed in regard to a mean value during the whole night, and a mean value of each sleep stage in each sleep cycle. Number of spontaneous VCR on PLG was calculated according to the manner of TAMURA (1967). SPR was presented by its frequency per minute in the course of all night sleep. When movement time or movement arousal was seen on the epoch in the sleep stage classification, its epoch and immediately before and after its epoch were excepted from the computation in HR, RR, VCR and SPR.

For the statistical evaluation of the results, t-test was used.

3. Results

As shown in Table 1 and Fig. 2, the profile of the appearance of each sleep stage during a shift from sleep cycle 1 to 4 showed, on the whole, little differences between the temperate zone and Antarctica. In the sessions except for AT-4 in Antarctica, however, the appearance of slow wave sleep (SWS; S3+4) in sleep cycle 1 tended to decrease, whereas that of SWS in sleep cycle 2 tended to increase. This fact indicates that the proportion of SWS showed a small migration from the first to the second sleep cycle. The same trend was seen as to stage 4 (S4). However, the migration was insignificant statistically as compared with the temperate zone value. On the other hand, the appearance of REM sleep (SREM) during the first period of sleep tended to be variable in contrast with SWS.

Seasonal changes in average HR and RR during the whole night are summarized in Table 2. In both NREM and REM sleep, HR tended to increase in early-term (AT-1 and AT-2) in Antarctica, whereas RR tended to decrease in the same period. The changes in HR during a shift from sleep cycle 1 to 4 in the eight sessions are shown in Table 3 and Fig. 3. Percent change in HR illustrated in Fig. 3 was presented in comparison with the base-line value of S1+2 in sleep cycle 1 in each of the eight sessions. As to HR during S1+2 in sleep cycle 1, no significant difference from TZ-1 was seen in any sessions. HR showed a progressive decrease from the base line during a shift from sleep cycle 1 to 4 in the temperate zone (both TZ-1 and TZ-2). However, HR during the first period of sleep tended to increase in early (AT-1 and AT-2)- and late-term (AT-5 and AT-6), or at least tended not to decrease in mid-term (AT-3 and AT-4) in Antarctica. Nevertheless the mean atmospheric temperature, which the present subjects have experienced, showed the lowest value during mid-term, the increase in HR during the first period of sleep was rather smaller in mid-term than in early- or late-term in Antarctica. The changes in RR during a shift from sleep cycle 1 to 4 in the eight sessions are shown in Table 4 and Fig. 4. RR during the first period of sleep did not show a remarkable difference between the temperate zone and Antarctica.

Peripheral VCR on PLG was seen most frequently during REM sleep, but no definite tendency was found during the course of experiments.

Table 1. Proportion of each sleep stage.

	Sleep cycle 1			Sleep cycle 2			Sleep cycle 3			Sleep cycle 4		
	S1+2	S3+4	SREM	S1+2	S3+4	SREM	S1+2	S3+4	SREM	S1+2	S3+4	SREM
TZ–1 (N=5)	16.10 ±2.27	65.64 ±21.94	6.95 ±4.93	21.36 ±3.12	16.13 ±19.15	22.94 ±14.99	21.46 ±2.54	10.29 ±6.76	19.16 ±10.89	19.12 ±3.96	4.03 ±4.08	29.13 ±15.89
AT–1 (N=5)	16.98 ±3.32	60.57 ±19.63	9.97 ±4.12	21.23 ±3.64	26.78 ±18.61	23.01 ±7.02	25.74 ±2.79	4.48 ±9.49	30.97 ±12.08	19.22 ±3.41	5.19 ±5.33	31.80 ±7.22
AT–2 (N=5)	17.37 ±3.99	59.81 ±20.77	19.74 ±18.09	22.55 ±4.96	23.84 ±19.67	21.62 ±8.69	24.32 ±3.32	6.43 ±6.99	29.07 ±13.40	17.73 ±1.58	8.20 ±8.55	24.57 ±1.21
AT–3 (N=5)	22.93 ±13.56	57.75 ±25.08	14.67 ±5.68	21.97 ±6.98	25.60 ±25.10	22.67 ±8.29	22.85 ±4.92	9.91 ±11.56	30.37 ±6.56	21.14 ±2.59	3.10 ±3.29	24.47 ±9.34
AT–4 (N=5)	15.97 ±3.81	77.93 ±16.74	9.47 ±4.97	28.04 ±4.66	13.78 ±14.47	28.00 ±15.94	23.42 ±1.94	5.55 ±6.80	28.82 ±27.73	20.36 ±2.61	2.53 ±2.58	27.81 ±12.22
AT–5 (N=5)	14.06 ±7.48	60.35 ±15.70	10.60 ±1.39	23.12 ±7.93	23.10 ±18.91	33.89 ±13.55	25.15 ±3.30	9.98 ±14.71	25.70 ±15.45	15.83 ±5.75	1.58 ±2.21	13.61 ±10.43
AT–6 (N=5)	16.17 ±5.16	66.16 ±21.72	15.05 ±9.98	24.33 ±4.76	24.56 ±25.44	26.39 ±7.24	24.34 ±6.59	6.49 ±12.10	17.00 ±7.23	19.66 ±2.60	2.01 ±2.91	26.91 ±13.20
TZ–2 (N=3)	11.17 ±1.84	70.02 ±15.73	13.35 ±5.09	26.17 ±9.55	17.73 ±14.48	35.71 ±18.62	22.65 ±4.35	10.81 ±14.98	13.67 ±8.44	19.28 ±6.88	0.43 ±0.74	18.94 ±10.72

Proportion of each sleep stage in each sleep cycle is presented in % of total number of epochs of the same sleep stage in total sleep time.

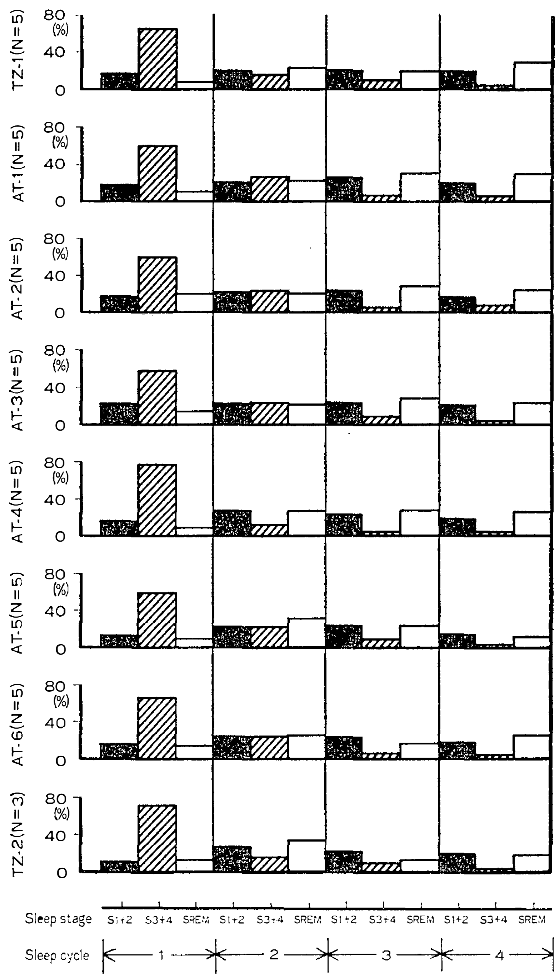

Fig. 2. The profile of the appearance of each sleep stage in each sleep cycle during a shift from sleep cycle 1 to 4 in each of the eight observations.

The appearance of SPR was also variable, especially personal differences were marked among the subjects. Histogram of all-night sleep polygraphic record including frequently appeared SPR is shown in Fig. 5.

Correlations between HR and states of sleep are illustrated in Figs. 6 and 7. The changes in HR during SWS in sleep cycle 1, showed a negative correlation with those in %S4 of total sleep time ($r=-0.3442$, $P<0.05$) as shown in Fig. 6. Although P value was at a level of 10%, higher coefficient of correlation was seen during the two observations, namely, TZ-1 and AT-1 ($r=-0.5994$, $P<0.1$) as illustrated in Fig. 7. On the other hand, no significant correlation between heart rate just before the onset of sleep, and the proportion of SREM in sleep cycle 1 was seen ($r=0.1412$, $P<0.4$). Neither was any correlation between heart rate during SREM in sleep cycle 1 and the proportion of SREM in sleep cycle 1 observed

Table 2. Changes in heart rates and respiratory rates.

	Whole night		NREM sleep		SW sleep		REM sleep	
	HR	RR	HR	RR	HR	RR	HR	RR
TZ–1 (N=5)	54.7 ±5.2	16.7 ±2.0	54.6 ±5.5	16.5 ±1.9	55.0 ±5.2	17.3 ±2.2	54.8 ±4.4	17.7 ±2.5
AT–1 (N=5)	56.6 ±7.1	16.1 ±1.7	56.7 ±7.5	15.9 ±1.6	58.1 ±7.0	16.7 ±1.9	56.4 ±6.0	16.9 ±2.6
AT–2 (N=5)	55.2 ±4.1	16.0* ±2.1	55.0 ±4.4	15.7* ±2.0	55.9 ±6.8	16.3* ±2.1	55.8 ±3.5	17.3 ±3.0
AT–3 (N=5)	55.0 ±4.7	16.3 ±1.8	55.0 ±4.9	16.1 ±1.6	55.7 ±4.5	17.1 ±2.0	54.8 ±4.6	17.0 ±2.7
AT–4 (N=5)	53.4 ±5.2	16.5 ±2.2	53.6 ±5.5	16.4 ±2.1	54.5 ±5.1	17.3 ±2.6	52.9 ±4.6	17.2 ±2.8
AT–5 (N=5)	54.7 ±4.9	16.4 ±2.0	54.8 ±5.2	16.1 ±1.8	56.7 ±5.9	17.1 ±2.2	54.5 ±4.5	17.6 ±3.0
AT–6 (N=5)	52.7 ±4.4	16.5 ±2.2	52.6 ±4.5	16.2 ±2.1	55.2 ±4.9	17.1 ±2.2	52.8 ±4.1	17.5 ±2.7
TZ–2 (N=3)	54.3 ±6.3	18.8 ±1.3	54.5 ±6.3	18.5 ±1.1	56.0 ±5.7	19.5 ±0.9	53.7 ±6.4	19.7 ±2.0

Mean heart rate (HR) and respiratory rate (RR) per minute are presented with standard deviation in each observation. Asterisk indicates a significant difference from TZ–1.

Table 3. Change in heart rate in each sleep stage.

	Sleep cycle 1			Sleep cycle 2			Sleep cycle 3			Sleep cycle 4		
	S1+2	S3+4	SREM	S1+2	S3+4	SREM	S1+2	S3+4	SREM	S1+2	S3+4	SREM
TZ–1 (N=5)	56.7 ±5.6	55.2 ±4.8	55.7 ±3.6	54.5 ±5.0	53.5* ±5.7	55.5 ±4.9	54.0 ±6.6	53.1 ±6.4	54.5 ±5.7	54.5* ±6.1	54.3 ±6.6	55.1 ±5.3
AT–1 (N=5)	57.6 ±6.6	58.2 ±6.3	59.9 ±7.1	58.3 ±8.1	57.9 ±8.5	57.4 ±6.4	54.9 ±8.1	49.8 ±6.0	54.8 ±6.4	55.7 ±8.2	59.5 ±5.9	55.7 ±6.4
AT–2 (N=5)	56.0 ±7.9	56.3 ±8.5	57.5 ±7.0	56.6 ±5.1	56.9 ±4.8	55.9 ±3.1	54.7 ±4.1	53.7 ±4.4	55.1 ±3.8	54.0 ±4.2	52.1 ±3.9	54.2 ±2.1
AT–3 (N=5)	56.9 ±5.2	56.7 ±4.7	57.3 ±5.4	55.3 ±4.5	56.8 ±3.6	53.7 ±5.0	53.6* ±5.0	51.7 ±5.9	54.6 ±5.0	53.8* ±4.8	55.7 ±2.3	54.1 ±4.1
AT–4 (N=5)	54.6 ±5.3	54.4 ±5.2	55.3 ±6.0	54.8 ±5.7	54.0 ±6.0	53.8 ±5.1	52.5 ±6.0	52.1 ±7.8	51.5 ±5.4	52.8 ±5.7	50.3 ±7.4	53.0 ±4.3
AT–5 (N=5)	57.6 ±6.9	58.3 ±7.1	57.4 ±5.5	56.2 ±4.8	56.0 ±5.2	55.7 ±5.6	53.8 ±5.6	53.6 ±5.7	53.3 ±4.0	52.7 ±4.8	54.0 ±3.0	53.9 ±5.7
AT–6 (N=5)	56.7 ±5.4	57.0 ±5.6	57.5 ±6.3	53.4* ±5.8	52.5* ±5.9	53.1 ±6.8	51.1* ±5.0	53.8 ±2.4	51.2* ±3.9	50.1* ±4.0	47.4 ±5.0	52.1 ±2.5
TZ–2 (N=3)	59.0 ±4.2	57.6 ±4.5	56.3 ±3.9	54.9 ±5.1	54.2* ±4.5	54.2 ±5.4	53.3 ±8.3	48.1 ±6.3	53.9 ±9.5	52.8 ±6.6	51.0 ±0.0	54.5 ±7.1

Mean heart rate per minute is presented with standard deviation. Asterisk indicates a significant difference ($P<0.05$) from a base-line value of heart rate during S1+2 in sleep cycle 1 in each observation.

(r=0.1257, P<0.5).

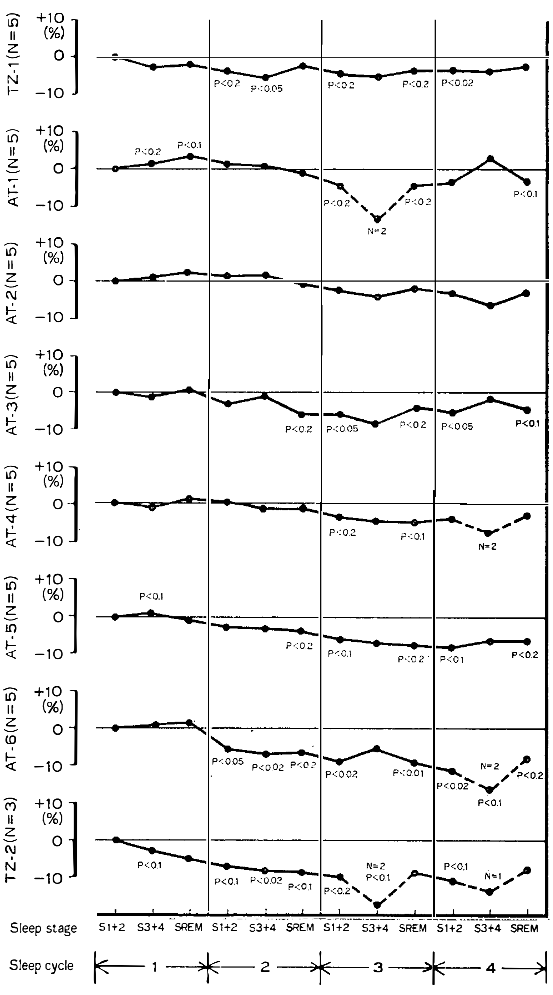

Fig. 3. Percent changes in heart rate during a shift from sleep cycle 1 to 4.

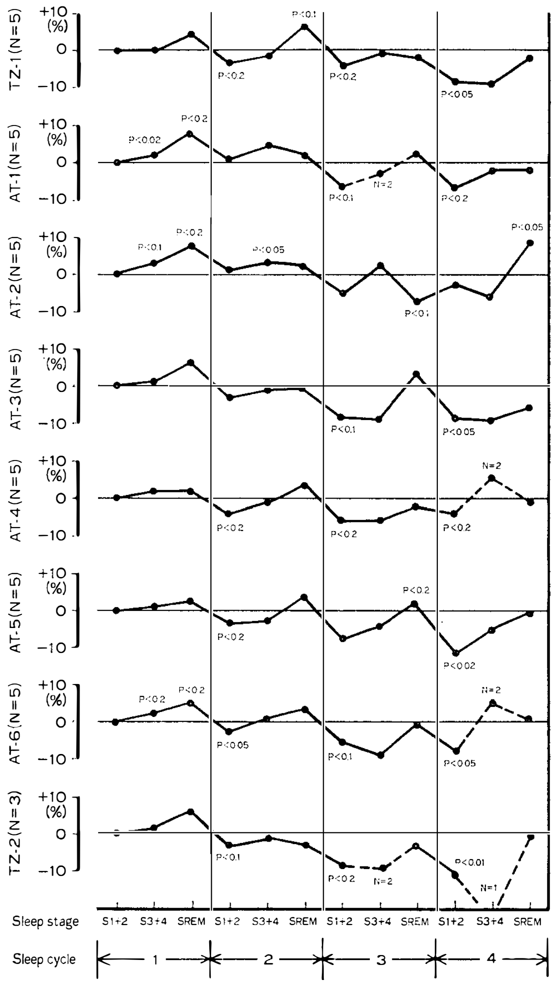

Fig. 4. Percent changes in respiratory rate during a shift from sleep cycle 1 to 4.

Table 4. Change in respiratory rate in each sleep stage.

	Sleep cycle 1			Sleep cycle 2			Sleep cycle 3			Sleep cycle 4		
	S1+2	S3+4	SREM	S1+2	S3+4	SREM	S1+2	S3+4	SREM	S1+2	S3+4	SREM
TZ-1 (N=5)	17.2 ±2.3	17.2 ±2.5	18.0 ±3.3	16.7 ±1.9	16.9 ±1.7	18.4 ±2.7	16.5 ±1.8	17.0 ±1.9	16.9 ±2.3	15.7* ±1.5	15.6 ±1.5	16.8 ±1.9
AT-1 (N=5)	16.4 ±1.9	16.7* ±2.0	17.7 ±2.9	16.4 ±2.0	17.2 ±2.1	16.7 ±2.4	15.4 ±1.3	15.8 ±1.2	16.8 ±2.6	15.2 ±1.2	16.1 ±2.2	16.7 ±2.9
AT-2 (N=5)	16.0 ±2.3	16.5 ±2.4	17.3 ±3.6	16.0 ±2.3	16.6* ±2.4	16.4 ±2.7	15.1 ±1.9	16.4 ±1.6	14.8 ±7.6	15.5 ±2.0	15.0 ±1.6	17.4* ±2.6
AT-3 (N=5)	17.0 ±2.4	17.2 ±2.3	18.1 ±3.1	16.4 ±1.7	16.9 ±1.9	16.9 ±1.7	15.6 ±1.4	15.5 ±1.3	17.6 ±2.3	15.5* ±1.4	15.4 ±0.8	16.0 ±4.7
AT-4 (N=5)	17.0 ±2.5	17.4 ±2.6	17.3 ±3.0	16.2 ±2.1	16.9 ±2.3	17.6 ±3.3	16.0 ±2.1	16.0 ±2.5	16.6 ±2.3	16.3 ±2.1	18.0 ±0.0	16.8 ±2.4
AT-5 (N=5)	17.1 ±2.1	17.3 ±2.3	17.6 ±2.9	16.6 ±2.0	16.7 ±1.8	17.8 ±3.2	15.7 ±1.7	16.4 ±1.1	17.5 ±2.4	15.2* ±1.4	16.3 ±1.6	17.0 ±4.0
AT-6 (N=5)	16.9 ±2.4	17.3 ±2.2	17.9 ±3.1	16.5* ±2.1	17.0 ±2.0	17.5 ±2.6	16.0 ±2.0	15.3 ±2.0	16.8 ±2.4	15.6* ±1.9	17.8 ±0.3	17.0 ±2.2
TZ-2 (N=3)	19.7 ±1.7	19.9 ±1.1	20.9 ±2.2	19.1 ±1.5	19.5 ±1.3	19.2 ±1.7	17.9 ±1.0	17.7 ±0.9	19.1 ±1.9	17.5* ±1.3	15.0 ±0.0	19.3 ±1.9

Mean respiratory rate per minute is presented with standard deviation. Asterisk indicates a significant difference ($P<0.05$) from a base-line value of respiratory rate during S1+2 in sleep cycle 1 in each observation.

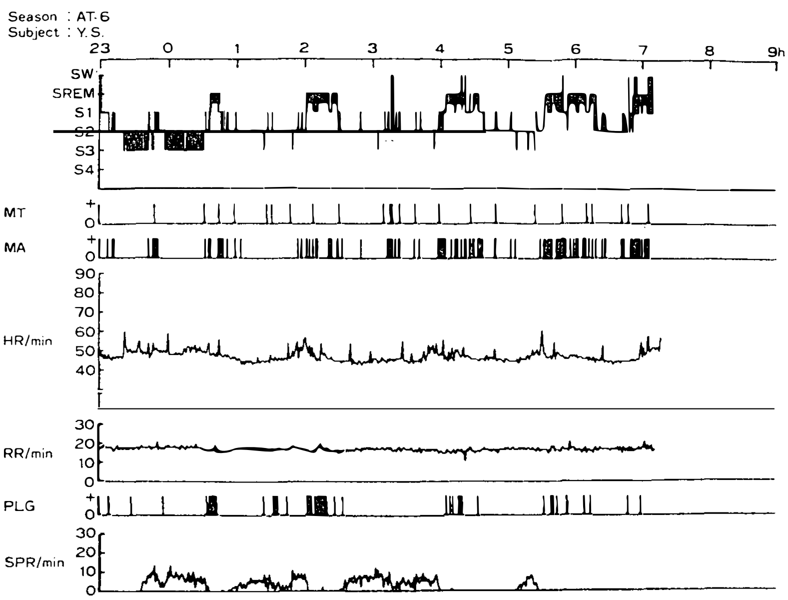

Fig. 5. Histogram of all-night sleep polygraphic record in Antarctica.

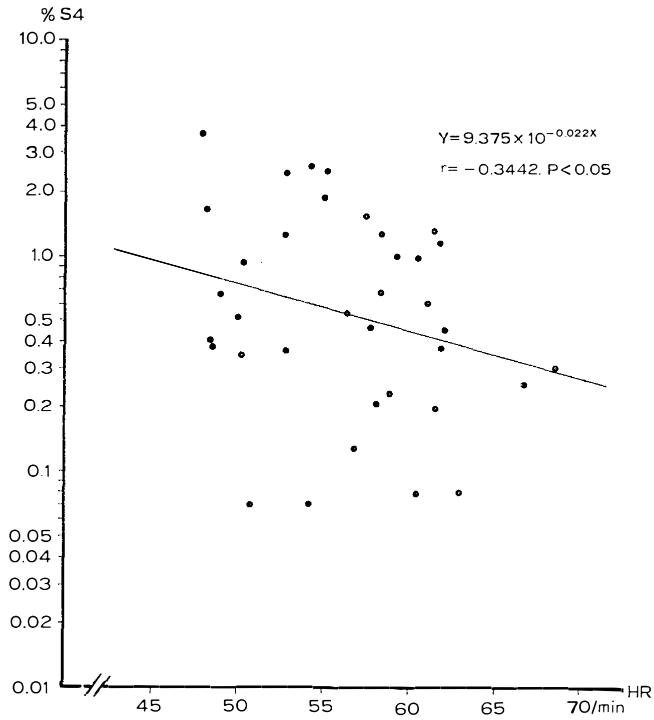

Fig. 6. Correlation between %S4 of total sleep time and heart rate during SWS in sleep cycle 1 (N=38). Considerable deviation from the regression line of this figure may be due to a decline response of the sympathetic nerve during mid-term in Antarctica.

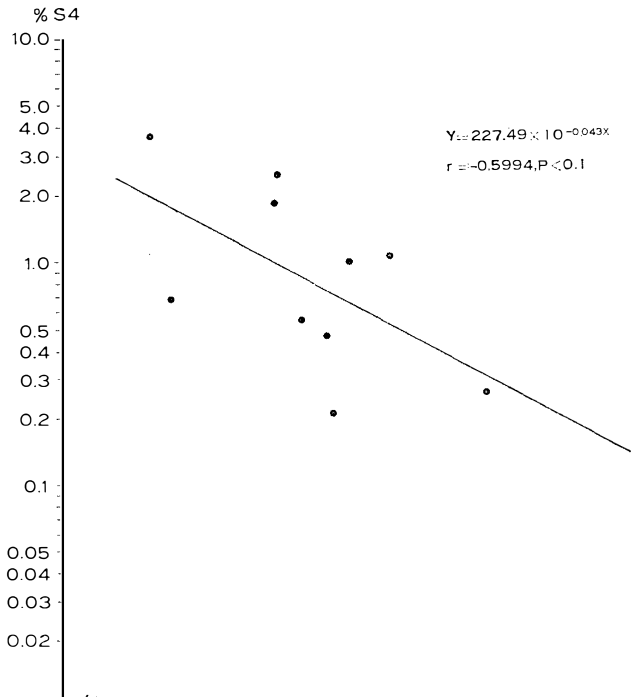

Fig. 7. Correlation between %S4 of total sleep time and heart rate during SWS in sleep cycle 1 (N=10) in the two sessions, TZ-1 and AT-1.

4. Discussion

Although the changes in several kinds of the indices of autonomic nervous system responses were investigated in relation to states of sleep before the departure for Antarctica, in Antarctica and after returning to Japan, no significant finding was seen in such indices, except heart rate. Therefore, the changes in heart rate related to states of sleep will be discussed below.

It is generally accepted that heart rate decreases progressively during a shift from the onset of sleep to the deeper stages of sleep during NREM sleep, whereas it increases during REM sleep in man as well as in animals (ASERINSKY and KLEITMAN, 1953; KHATRI and FREIS, 1967; MANCIA *et al.*, 1970; SNYDER *et al.*, 1964). The changes in heart rate associated with the different states of sleep, are antagonistically controlled by both the sympathetic and parasympathetic sections of the autonomic nervous system. Tonic fall in heart rate during a shift from wakefulness to synchronized sleep, is predominantly caused by an increase in the vagal tonus (BAUST and BOHNERT, 1969).

In the present study heart rate showed a progressive decrease during a shift from sleep cycle 1 to 4 in the temperate zone. However, heart rate during the first period of sleep tended to increase in early- and late-term and at least tended not to decrease in mid-term in Antarctica. It is enigmatic why heart rate does increase after the onset of sleep, but it is possible to say, at least, that the sympathetic activity has been enhanced, in other words, the parasympathetic activity has been inhibited during the first period of sleep in Antarctica.

On the other hand, a small migration of the proportion of SWS from sleep cycle 1 to 2 was seen in early- and late-term in Antarctica. Therefore, the increased sympathetic tone during the first period of sleep in early- and late-term in Antarctica, is likely to match a small shift of the proportion of SWS to the second sleep cycle.

It was already reported in the preceding paper, that a positive correlation was seen between %SWS of total sleep time and atmospheric temperature, and so far as %S4 is concerned, its coefficient of correlation was higher than that of %SWS. In addition, a negative correlation was seen between %S4 of total sleep time and heart rate during SWS in sleep cycle 1. It seems, therefore, that low atmospheric temperature is a possible factor increasing heart rate during SWS in sleep cycle 1 in Antarctica. It also has been reported in the preceding paper, that %SREM of total sleep time showed a positive correlation with the energy expenditure, calculated from daily activity patterns during experiments. It is reported by OKUDAIRA *et al.* (1979) that a positive correlation was seen between the total energy expenditure during exercise, and heart rate at the beginning of sleep polygraphic recording 90 minutes after exercise load. They also said that the appearance of SREM during the period between the onset of sleep and 120 minutes of continuous sleep, showed a positive correlation with heart rate.

In the present work, no significant correlation between heart rate just before the onset of sleep, and the proportion of SREM in sleep cycle 1 was seen. Neither was any correlation between heart rate during SREM in sleep cycle 1 and the proportion of SREM in sleep cycle 1 observed. In the present work, the sleep polygraphic recording started about 5 hours after finishing daily work, and the energy expenditure used in statistical analysis was a mean value during the three experimental days, so that these negative findings in the present results were probably due to a general effect of the energy expenditure on REM sleep during the whole night, but not specific in the first period of sleep.

Meanwhile, in the present work, the increase in heart rate in the first period of sleep was out of proportion to the lowering of atmospheric temperature in mid-term in Antarctica. It seems that this finding may be due to adaptation of the sympathetic nerve to the cold, because it is known that repeated sympathetic stimulation by the cold exposure in humans leads to a decline in response (LEBLANC, 1966). Considerable deviation from the regression line of Fig. 6 may be due to a decline response of the sympathetic nerve during mid-term in Antarctica. Furthermore, the inclination to the re-increase in heart rate in the first period of sleep during late-term in Antarctica may show a process of restration from adaptation according to the elevation of atmospheric temperature, since cold adaptation is rapidly lost on experimental animals, when animals are kept in neutral environment (LEBLANC, 1966).

So, there seems to exist an incompatibility between the evolution of SWS and the increase in heart rate, that is, the increase in the sympathetic activity, though the fact that, SWS showed the lowest value during mid-term when the sympathetic tone was supposed to be the lowest during the wintering over period, can not be explained adequately. This leads to the suggestion that another factor, changing SWS, is included.

The central mechanisms of the changes in SWS due to environmental temperature have not been directly studied in the present work. It is, however, suggested from the relationship among low environmental temperature, thermoregulatory activity and sleep pattern that the hypothalamus may play an important role to regulate sleep in animal studies (PARMEGGIANI *et al.*, 1969; SCHMIDEK *et al.*, 1972).

Indeed, the hypothalamus is the highest integration center for the autonomic nervous system, and there are much information in the literature about the structures which are related to both mechanism of synchronized sleep (McGinty and Sterman, 1968; Sterman and Clemente, 1962; Wada and Terao, 1970; Yamaguchi *et al.*, 1963), control of heart rate (Kabat *et al.*, 1935; Manning and Peiss, 1960; Rushmer *et al.*, 1959; Wang and Ranson, 1941) and thermoregulation (Benzinger *et al.*, 1961; Bligh, 1966; Feldberg and Myers, 1963; Hori and Nakayama, 1973) such as preoptic area, which is a telencephalic structure functionally related to the hypothalamus, and the hypothalamus.

Therefrom, even if brain stem mechanisms are responsible for SWS (Jouvet, 1972), it is suggested that the proportion of SWS was modulated, at least in part, via the hypothalamus.

5. Conclusion

The following facts have been confirmed from the long-term trial of all-night sleep polygraphic recordings including the indices of autonomic nervous system in five healthy male subjects, the members of JARE-16.

1) Average heart rate during the whole night tended to increase in early-term in Antarctica, whereas respiratory rate tended to decrease in the same period.

2) Heart rate during the first period of sleep tended to increase in early- and late-term and at least tended not to decrease in mid-term in Antarctica, though it tended to decrease progressively since the onset of sleep in the temperate zone.

3) The proportion of SWS showed a small migration from the first to the second sleep cycle except mid-term in Antarctica.

4) This migration of SWS is likely to match the increased heart rate during the first period of sleep in Antarctica.

5) Thus heart rate during SWS in sleep cycle 1 showed a negative correlation with %S4 of total sleep time.

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