SLEEP AND WAKEFULNESS AT HIGH ALTITUDES

BY

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During the British North Greenland Expedition of 1952-4 studies were made (Lewis and Masterton, 1957) of the sleep pattern of men living as a partially organized community in an environment devoid of the diurnal cycle of light and darkness. It was demonstrated that the average total sleep taken per day was uninfluenced by the polar conditions but that the sleep/wakefulness pattern varied greatly from the usual pattern of the individuals studied. It was also shown that there was a seasonal change in the number of nights of broken sleep but that there was no correlation between the occurrence of such nights and the taking of naps.

The present study aims at demonstrating the effect of high mountaineering on these same characteristics of sleep rhythm. So far as I am aware no investigation of sleep similar to that carried out in North Greenland has previously been attempted during a mountaineering expedition.

Methods

The subjects of the investigation were three men aged 30-33 and a woman aged 26. Each was supplied with record cards identical with those described by Lewis and Masterton (1957), and records were kept for about two months of normal life and during an expedition to the Karakoram Mountains of West Pakistan. On these cards all periods of sleep were marked as a thick line, breaks in sleep appearing as breaks in the line. Naps taken during a waking period appeared as a very short line in an otherwise blank space. A "nap" was a sleep of not longer than three hours (usually much less) and separated from the termination of the main sleep by at least one hour.

Sleep/wakefulness diagrams were prepared following the method adopted by Kleitman and Engelmann (1953). Such a diagram is a rectangle, one side of which represents the number of days in a month normalized to unity (so that months of differing length can be directly compared), the other side representing the 24 hours in a day. The area of the rectangle therefore represents the number of hours in a month. The number of days on which the subject slept during any given hour of the day divided by the number of days in the month is the "sleep fraction" for that hour. This is shown in black in the diagram for each hour of the day, so that the pattern of sleep for the whole month can be seen at a glance.

The records were analysed in two parts: those relating to sleep habits below an arbitrary altitude of 10,000 ft. (3,050 m.), and those made during the time spent between 10,000 and 20,000 ft. (3,050 and 6,100 m.). The time spent above the 10,000 ft. level was in every case continuous, and much the greater part of this time was above 15,000 ft. (4,570 m.).

Results

The average sleep per day taken while living above 10,000 ft. was greater than the average while below this

TABLE I

Subject	Below 10 000 ft. (3,050 m.)			Above 10,000 ft. (3,050 m.)			Average Excess of Sleep when Above 10,000 ft.	Probability of this Excess Being Due to Chance
	Period in Days	Average Sleep per Day (hours)	Stand- ard Devi- ation	Period in Days	Average Sleep per Day (hours)	Stand- ard Devi- ation		
Female	71	6.827	1.615	50	7.784	1.739	0.957	Approx. 0.04
Male 1	72	6.964	1.671	50	7.645	1.619	0.681	Approx. 0.10
" 2	56	6.873	1.455	60	7.213	2.093	0.340	Approx. 0.45
" 3	62	7.483	1.338	60	8.488	1.613	1.005	< 0.01

level. This is shown in Table I. The probability of this difference being due to chance is shown in each case in the last column.

The sleep/wakefulness pattern became more coincident with the diurnal cycle of light and darkness as shown in Figs. 1 and 2.

The number of nights of interrupted sleep was greater above 10,000 ft. than during life in England, but the tendency to experience this showed a marked individual variation (Table II).

FIG. 1.—Sleep/wakefulness pattern for one month (June) of ordinary life and for one month (August) spent at an altitude above 15,000 ft. (4,570 m.). The blocked areas represent the fraction of the month spent in sleep. This individual was in the habit of taking naps, and the habit persisted at high altitudes.

FIG. 2.—Sleep/wakefulness patterns for an individual who took no naps either in ordinary life or in the mountains. Here, and in Fig. 1, is seen the tendency to advance the hour of going to sleep while at high altitudes.

TABLE II

Subject	Percentage of Nights when Sleep was Interrupted		Total Naps	No. of Times Naps Followed Period of Sleep < Average	No. of Times Broken Sleep Followed by Nap or Naps
	Above 10,000 ft.	In England			
Female..	22%	3%	7	7	0
Male 1..	24%	2%	13	10	0
" 2..	57%	4%	26	19	5
" 3..	28%	21%	71	36	18

There was no correlation between the incidence of nights of broken sleep and the taking of naps (Table II). The tendency to take naps appeared to be a personal idiosyncrasy, but naps were more often taken during the day following a night when the sleep had been less than the average for the individual concerned.

Discussion

It might be questioned whether the keeping of such a record as that described would itself have an effect upon the sleep pattern. In fact, the observer becomes quite used to noting the time frequently if there is delay in going to sleep, and in noting it immediately on waking. Accuracy to more than a few minutes in recording the onset of sleep is, of course, impossible.

The average sleep per day normally taken showed a wide individual variation. In three subjects the average was less than 7 hours, while in one subject it was almost 7.5 hours. The female member of the party in normal life took no more sleep than the male members.

During the time spent at high levels all four subjects took more sleep per day, but the difference in the mean value above and below 10,000 ft. was significant only in two cases, as seen in Table I. The sleep taken varied greatly from day to day, there being a wide spread of the sleep-frequency diagram (Fig. 3).

The change in the sleep/wakefulness pattern (Figs. 1 and 2) merely reflects the exigencies of mountaineering. The decrease in monthly sleep fraction in the early morning hours is accounted for by the necessity for

early morning starts whenever weather conditions permitted. Similarly, the increase in the sleep fraction for the hours before midnight is accounted for partly by the evening drop in temperature driving members of the expedition into their sleeping-bags, and partly as compensation for the usual early start of the working day.

Interrupted sleep was defined as a night's sleep with more than one break. The percentage of nights on which this occurred for each member of the expedition, compared with the percentage during normal life, is shown in Table II. Individual variations were again large, but there was a general increased tendency to interruption of nights during the time spent at a high altitude. The increase was least when the subject normally experienced frequent nights of interrupted sleep. In one case such interrupted nights were few in normal life but were 57% of all nights spent above 10,000 ft.

It is possible that this increased incidence of interrupted sleep is the factor which has given rise to the belief that climbers at high altitudes sleep less than at low levels. The man who wakes frequently gets the impression that he has slept little. At much higher altitudes than those at which this study was conducted sleep may well be severely curtailed by factors arising from the more marked anoxia, and lower temperatures, encountered.

The lack of correlation between broken sleep and the taking of naps agrees with the findings in the Arctic. The tendency for naps to be taken following a night where the total sleep was below the average for the particular individual confirms common experience, but, on the whole, the taking of naps appeared to be a personal idiosyncrasy.

One subject often took a nap when circumstances permitted, and this habit continued when he was living at high altitudes (Fig. 1). In contrast, another subject rarely took naps in normal life, and neither was it his habit to do so in the mountains (Fig. 2).

Summary

The sleep habits of three men and one woman were studied in normal life and during the time they spent as members of a Himalayan expedition.

The average number of hours' sleep per day while living between 10,000 and 20,000 ft. (3,050 and 6,100 m.) was greater than the average when below this level.

There was a tendency, imposed by the environment, for the diurnal sleep/wakefulness pattern to coincide with the diurnal light/darkness cycle.

The proportion of nights of broken sleep increased at the higher altitudes as compared with the incidence of broken sleep in normal life. The taking of naps was not correlated with broken sleep, but appeared to be an individual idiosyncrasy.

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REFERENCES

- Kleitman, N., and Engelmann, T. G. (1953). *J. appl. Physiol.*, 6, 269.
Lewis, H. E., and Masterton, J. P. (1957). *Lancet*, 1, 1262.

FIG. 3.—Typical frequency diagrams showing the wide spread in the number of hours' sleep taken per day by the same individual during 50 days of normal life and during 50 days at high altitudes.