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Sleep of Andean high altitude natives

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Summary. The structure of sleep in lowland visitors to altitudes greater than 4000 m is grossly disturbed. There are no data on sleep in long-term residents of high altitudes. This paper describes an electroencephalographic study of sleep in high altitude dwellers who were born in and are permanent residents of Cerro de Pasco in the Peruvian Andes, situated at 4330 m. Eight healthy male volunteers aged between 18 and 69 years were studied. Sleep was measured on three consecutive nights for each subject. Electroencephalographs, submental electromyographs and electro-oculograms were recorded. Only data from the third night were used in the analysis. The sleep patterns of these subjects resembled the normal sleep patterns described by others in lowlanders at sea level. There were significant amounts of slow wave sleep in the younger subjects and rapid eye movement sleep seemed unimpaired.

Key words: Sleep - Electroencephalogram - High altitude natives - Andean physiology

Introduction

It is well known that many visitors on arrival at high altitude are unable to sleep well and this may persist. In a recent study we showed that at around 5000 m, the duration and efficiency of sleep are reduced, sleep onset time and amount of awake activity are increased and both slow wave sleep and rapid eye movement (REM) sleep are reduced (Nicholson et al. 1988). In contrast, little is known about the effects of prolonged hypoxia on sleep structure. Studies by Pappenheimer (1977, 1984) on rats chronically exposed to hypoxia simulating an altitude of 5500 m, showed that there was a 50% reduction in the proportion of time spent in slow wave sleep and REM sleep was virtually absent.

Clearly such major disturbances in sleep structure cannot normally occur in those people born and living permanently at high altitude. However, little is known about the electrophysiology of sleep in these people, although there is one report that at the relatively low altitude of 3500 m slow wave sleep is reduced (Selvamurthy et al. 1986). Many people are born and live at altitudes greater than this. How is slow wave sleep affected in such populations and what happens to REM sleep? It is with these questions that this paper is concerned. We report here the electroencephalographically recorded sleep patterns observed in eight subjects born and living at 4330 m in the Andes of Peru.

Methods

Eight healthy male volunteers aged between 18 and 31 years (five subjects) and 40 and 69 years (three subjects) were selected for the study on the basis of their answers to a sleep questionnaire which suggested that they were free of any sleep disorder. All the subjects were born and were permanent residents of Cerro de Pasco, which is a mining town situated 250 km north east of Lima, Peru in the Andes at an altitude of 4330 m. Sleep was measured for three consecutive nights for each subject.

Electroencephalographic (EEG) activity from C_3-C_z, C_4-C_z and O_2-C_z, the submental electromyogram (EMG) and bilateral electro-oculograms (EOG) were recorded on an Oxford 8-channel Medilog recorder. Each subject slept in a warm, quiet single room in the high altitude research laboratory. The subjects retired at their usual bedtime and were allowed to awaken naturally. Each morning following a sleep recording each subject answered a questionnaire which provided a subjective assessment of their quality of sleep, the sleeping conditions and how they felt at that precise time. To allow for adaptation to sleeping with electrodes, only data from the third night were used in the analysis. The participants were required to abstain from alcohol and caffeine-containing beverages from 6 h before lights out. The records were manually and independently scored by human staging (two analysts) of paper print outs into 30-s epochs according to conventional criteria (Rechtschaffen and Kales 1968).

The subjects were also divided into two age groups, those aged between 18 and 31 years (five subjects) and those aged between 40 and 69 years (three subjects). The age distribution of the samples (mean and SD) was as follows: young highlander 23.2 (5.54) years; old highlander: 58.3 (15.95) years.

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Results

Data for the eight Peruvian high altitude natives (HAN) are given in Tables 1 and 2. Examples of the sleep patterns of individuals are provided in Figs. 1-3. The HAN took quite a long time to get to sleep and woke quite early so that total sleep time was less than 400 min (Table 2). Their sleep was disturbed by periods of awake activity (Figs. 1, 2) which in the older subjects were marked so that mean sleep efficiency for the eight subjects was low (Table 2). The duration of stage 1 was greatly increased in those over 40 years whereas the duration of stage 2 sleep was similar in both young and old subjects (Table 1). There were significant amounts (74.6 min) of slow wave sleep (stages 3 and 4) in young Peruvians but this type of sleep was much reduced (9.7 min) in those over 40 years (Table 1). The amount (96.2 min) and percentage (25%) of REM sleep was quite large and did not differ between the two age groups. The onset of REM sleep occurred quite early in the night (mean 36.1 min) and this was particularly evident in the older subjects. In one elderly HAN (69 years, Fig. 3), REM onset occurred within the first 30 s.

Table 1. Duration (min) of sleep stages in high altitude natives

Sleep stage	Mean ($n=8$)	Under 40 years ($n=5$)	Over 40 years ($n=3$)
Awake	38.2 (30.7)	13.0 (3.4)	63.4 (57.3)
1	42.8 (22.9)	24.0 (8.3)	61.7 (19.3)
2	203.4 (41.5)	201.7 (48.3)	205.2 (36.8)
3	27.8 (23.5)	46.0 (17.6)	9.7 (8.1)
4	14.3 (22.6)	28.6 (22.7)	0.0 (0.0)
REM	96.2 (27.8)	94.0 (34.5)	98.3 (17.6)

Values given are the means (SD). REM, Rapid eye movement sleep

Table 2. Various measures of sleep in high altitude natives

Measure	Mean ($n=8$)	Under 40 years ($n=5$)	Over 40 years ($n=3$)
Total sleep time (min)	382.8 (57.9)	399.1 (67.9)	366.6 (43.1)
Sleep onset latency (min)	39.4 (15.3)	41.0 (17.7)	37.9 (13.2)
Sleep efficiency index	0.75 (0.09)	0.81 (0.03)	0.70 (0.12)
REM/NREM ratio	0.33 (0.08)	0.31 (0.10)	0.36 (0.05)
Latency (min) to stage 3 sleep	47.9 (78.1)	9.9 (2.7)	85.8 (126.2)
Latency (min) to REM sleep	36.1 (21.3)	60.2 (11.6)	12.1 (13.2)
Number of awakenings	15.9 (8.2)	8.2 (2.2)	23.7 (1.5)
Number of awakenings in the first 6 h of sleep	10.4 (5.7)	5.6 (3.5)	15.3 (0.6)

Values given are the means (SD). Sleep onset latency = time from going to bed to first appearance of stage 2 sleep. Sleep efficiency index = total sleep time/time in bed. REM/NREM = total REM/stage 1, 2, 3, 4

Discussion

The intriguing feature of this study on persons living at 4330 m is that despite the low ambient partial pressure of oxygen, sleep patterns closely resemble those reported in normal lowland populations sleeping at sea level (Agnew et al. 1967; Miles and Dement 1980; Tune 1969; Williams et al. 1964, 1974). It is quite different from the sleep of lowland visitors to similar altitudes (Nicholson et al. 1988) and shows none of the changes predicted by studies on rats chronically exposed to hypoxia albeit of slightly greater degree (Pappenheimer 1977, 1984). However, sleep efficiency was low and similar to that recorded in a group of lowlanders who had ascended to just below 5000 m (Nicholson et al. 1988).

The earlier onset of REM in HAN compared to that in lowlanders was particularly evident in subjects over 40 years of age. Although REM latency in healthy individuals decreases on average up to the fifth decade (Williams et al. 1974) very early onset of REM often indicates a depressive illness (Kupfer and Foster 1972).

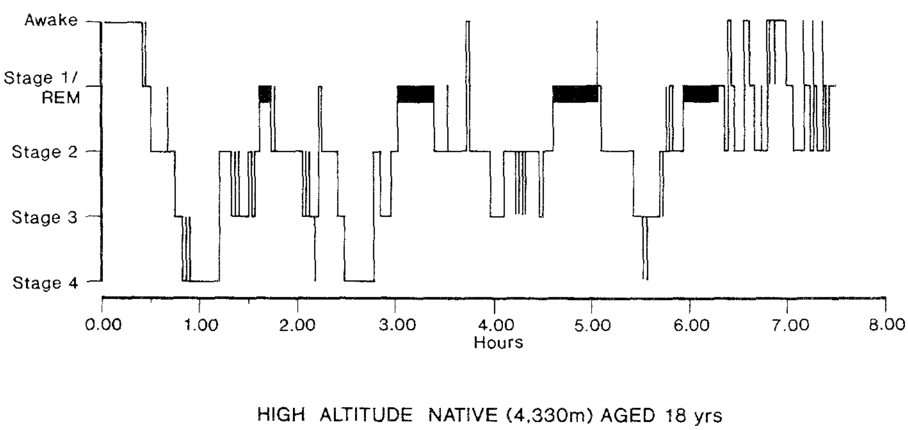

Fig. 1. Typical sleep pattern of a young Andean high altitude native sleeping at 4330 m

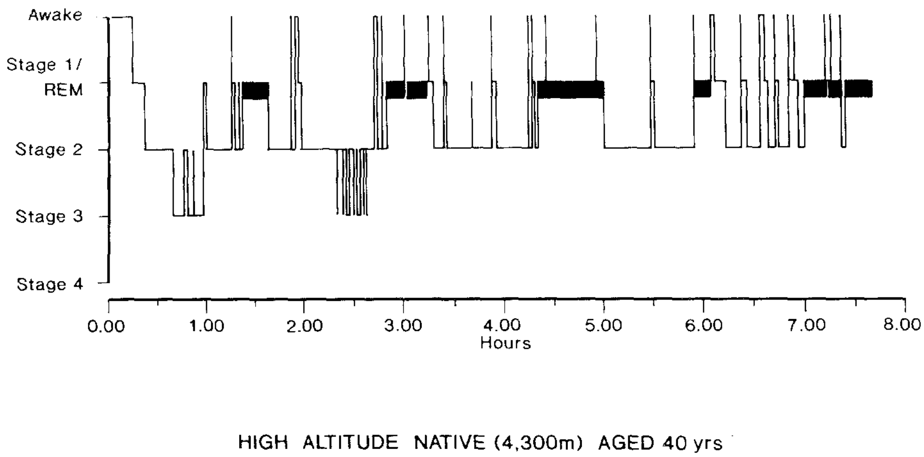

Fig. 2. Typical hypnogram of a middle-aged Andean high altitude native sleeping at 4330 m

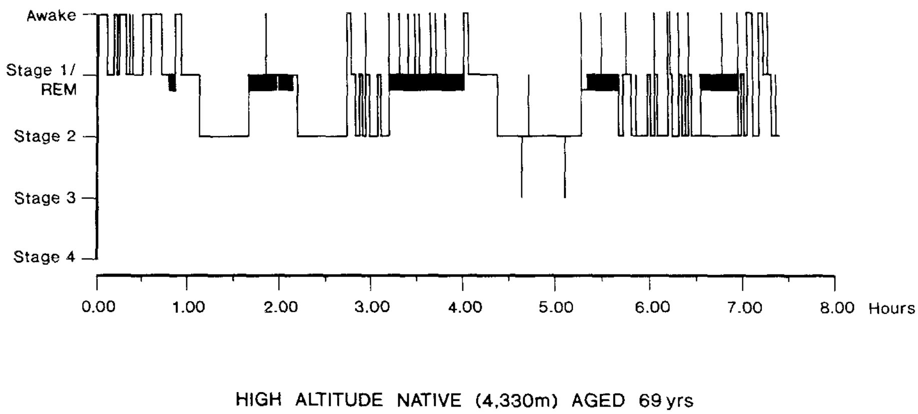

Fig. 3. Hypnogram of a 69-year-old Andean high altitude native sleeping at 4330 m

However, early onset of REM has been described in non-depressive elderly males living at sea level (Spiegel 1981) and the hypnogram from an elderly subject (69 years, Fig. 3) shows that this also occurs in Andean highlanders. Whether a shorter REM latency is a feature of sleep in Andean HAN remains to be investigated. An early onset of REM sleep has been described at around 5000 m in partially acclimatised mountaineers aged 33 (5) years (Goldenberg et al. 1985).

In the only other study of sleep in HAN (carried out in the Himalayas at 3500 m) it was reported that Ladakhis had less slow wave sleep than lowlanders (Selvamurthy et al. 1986). It was proposed that the curtailment of slow wave sleep at altitude is an adaptive feature of the sleep of HAN. However, our results do not support the generality of this hypothesis. Normal amounts of slow wave sleep were present in the Peruvians and they showed similar age-related changes to those described by others in lowland populations sleeping at sea level (Agnew et al. 1967; Tune 1969; Williams et al. 1964, 1974). Furthermore, the amount and percentage of REM sleep appears not to be curtailed by hypoxia in either the Peruvian (this study) or the Ladahki HAN (Selvamurthy et al. 1986). Since this is a period of sleep in which there is a relatively higher oxygen usage by the brain it is somewhat surprising that REM sleep is not impaired. One might speculate that in order to compensate for the lower oxygen content in the blood, these people would have large increases in cerebral blood flow. Whether this is the case or not awaits further study. Meanwhile, it is interesting to note that in Andean HAN, who respond to the hypoxia of altitude with an excessive polycythaemia, increases in cerebral blood flow are likely to be impaired since such an increase in blood flow is negatively related to the degree of polycythaemia (Winslow and Monge 1987; Severinghaus et al. 1966) and the Andean HAN show markedly disturbed sleep.

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