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ELECTROENCEPHALOGRAPHIC ATTRIBUTES OF GOATS UNDER CONSCIOUS STATE

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Abstract : Electroencephalographic studies were undertaken in goats to correlate with normal behavioral states and physiological conditions. Duplicate EEG records from 4 adult female goats (8–12 months, 10±2 kg body wt), using bipolar scalp electrodes placed in occipital region, were obtained to evaluate electrical responses of brain during different postures and states of alertness. EEG recordings were obtained under comfortable conditions and after adequate training of animals. EEG frequency (Hz) during lying down posture was significantly ($P<0.05$) lower compared to standing posture (32.63±1.34 Vs 38.63±1.03), the individual values ranging between 29 to 42 Hz. EEG amplitudes however varied non significantly between two states with respective values of 5.75±0.25 and 6.11±0.26 μV. During light and deep drowsiness, the frequencies recorded were 21.63±0.94 and 13.00±0.68 Hz, whereas amplitudes were 12.45±0.55 and 19.96±0.68 μV, respectively and the differences being statistically significant ($P<0.05$). Mean EEG frequencies of the order of 7.13±1.14 and 3.25±0.49 Hz and amplitudes of 16.59±2.55 and 19.86±3.19 μV were recorded during light and deep sleep, respectively. General trend indicated that frequency decreased and amplitudes increased with onset of drowsiness and these changes were proportional to the state of consciousness.

Key words : behaviour brain functions consciousness EEG ethology goat

INTRODUCTION

Electroencephalography (EEG) records the electrical activities of brain graphically placing macroelectrodes on the scalp. Consciousness consists of different states such as alert, drowsy and sleep. Some basic EEG data had been provided during 1960–1970. EEG pattern of alert goats as low voltage high activity that was similar to the asynchronous pattern noted in other animals has been reported (1, 2). The drowsy state in adult goat was predominated over the sleep state (3). Ruminants like goats spend a substantial period of life in rumination actively during which they remain awake but drowsy. Recent studies indicated diagnosis of brain diseases through EEG (4) and some

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EEG changes associated with routine farm practices (5, 6) in calves and lambs. Importance of EEG has been emphasized in calves (7), kids (8), ewes (9) and even critical care human patients (10).

Ruminants rest briefly without true sleep and state of sleep is characterized by loss of vigilance which had been denoted by vague terms such as somnolence, drowsiness, transient drowsiness and transient sleeplike sleep. What is needed is specific functional definitions of various states related to resting behaviour during state of consciousness. The purpose of present study being to identify different states of consciousness in normal unrestrained goats and characterize their EEG pattern and to correlate them so as to utilize it for applied aspects.

MATERIALS AND METHODS

Four healthy crossbreds (local X Jamunapari) female goats (9–12 kg body weight) were included in this study. Each animal was fitted with a set of bipolar (RO-LO i.e. right occipital, left occipital) lead system in occipital region, while the earth lead was applied at the tip of the nostril as reported earlier (4). The site of placement of electrodes, selected after examination of saggital sections of skulls obtained from local slaughter house, was occipital region just 1 to 2 cm caudomedial from the base of the horn. This site overlaid occipital cortex consisting of most cortical neurons and had minimum distance between nervous tissue and electrodes. Earth lead was secured on dorsal aspect of nostril midway between external nostrils and eye. The attached leads were secured in place by using a modified band fabricated locally to suit animal's head. Local anaesthesia (xylocaine 2%) was injected subcutaneously into the underlying areas of skin immediately before lead placement to minimize the artifacts arising from adjacent skeletal muscles (11). Leads (silver disc electrodes) were applied on scalp using EEG paste (bentonite paste). Before application of the electrodes the sites were shaved, rubbed with ethanol to remove skin oils.

Single channel student physiograph (Biodevices, Ambala Cantt) was used for EEG recording. Calibration of physiograph was done by keeping amplifier sensitivity at 50 μV and calibration at 100 μV equal to 44 mm. Paper speed was adjusted to 50 mm/sec (1 mm equal to 0.02 s) and time constant was 0.03 s for EEG recording of goats.

All the animals were trained daily to the experimental conditions till consistent EEG recordings were obtained during different states of consciousness. Fifteen minutes before the actual recordings were taken, the animals were acclimatized to the recording condition with instrument put 'ON' position and all leads attached to the animal.

EEG recordings were made both in standing and lying down, during alert state, and in lying down posture, during drowsiness and sleep states. The EEG recordings for each state were taken after at least 30 minutes and each time tracings were obtained for 1–3 min duration or until a steady trace was obtained. The behavioural assessment was done by visual observations (12). At least two replicates recordings were made.

EEG tracings recorded were visually analyzed for rhythm. Frequencies were calculated by counting of all major and minor waves (13) and were expressed in number of waves per second (Hz). The amplitudes were calculated as the height of least and most waves in mm and then transformed to µV from calibration. The data for experiment recorded of EEG were analyzed statistically by analysis of variance (14).

RESULTS

Data on various EEG attributes during different states of consciousness in goats is presented in Table I.

Alert state

The frequency (Hz) of alert lying down state was significantly ($P<0.05$) lower (32.63±1.34) as compared to alert standing state (38.63±1.03). The frequencies of alert state ranged between 29 to 42 Hz in two different postures of alertness. The amplitude (µV) of alert lying down state stood non-significantly lower at 5.72±0.25 compared to standing posture amplitude of 6.11±0.26 while the values varied from 4.95 to 7.24 µV. The frequency of alert state depicted in Fig. 1 was found to be of β frequency band and corresponded to low voltage high frequency (LVFA).

TABLE I : Electroencephalographic recording (Mean±SE) in different states of consciousness in goats (n=8).

Experimental conditions	*Frequency (Hz)*	*Amplitude (µV)*
Alert		
Lying down	32.63±1.34[a] (29–39)	5.72±0.25 (4.95–6.90)
Standing	38.63±1.03[b] (35–42)	6.11±0.26 (5.24–7.24)
Drowsy		
Light drowsy	21.63±0.94[a] (18–26)	12.45±0.55[a] (10.35–14.95)
Deep drowsy	13.00±0.68[b] (11–15)	15.96±0.68[b] (13.80–19.17)
Sleep		
Light drowsy	7.13±1.14[a] (7–10)	16.59±2.55 (15.72–21.50)
Deep drowsy	3.25±0.49[b] (3–4)	19.86±3.19 (18.80–29.13)

Means with different superscripts along column within an experimental condition differ significant ($P<0.05$). Figures in parenthesis are range value.

Behavioural observations recorded in unrestrained goats in alert state indicated that animals preferred recumbent posture. Movements of head and ears were continuous to scan auditory and visual stimuli. During this state of alertness it was found that response to external stimuli (auditory, visual, tactile) was maximum and animals exhibited frequent vocalization and responded to auditory stimuli.

Drowsy state

The data indicated that there were two different stages of drowsiness, that is light and deep stages, the EEG pattern of which were significantly different from each another. The EEG pattern of light drowsy stage began with irregular high voltage slow activity interspersed with fast waves though this was not depicted by all the animals. Under favourable conditions, the light drowsy state was skipped to deep drowsy stage. The EEG patterns of deep drowsy stage showed high voltage slow activity (HVSA) and lasted only for one second or so in goats. The frequency (Hz) was significantly ($P<0.05$) higher as 21.63±0.94 in light drowsy compared to 13.00±0.68 in deep drowsy state. The frequencies ranged from 11 to 26 Hz in two different stages of drowsiness. The amplitude (µV) of drowsy state however stood significantly ($P<0.05$) lower in light drowsy state with 12.45±0.55 compared to 15.95±0.68 in deep drowsy. The amplitudes ranged from

10.35 to 19.17 μV for two different stages of drowsiness. The EEG pattern of light drowsy state (Fig. 1) was observed to be high voltage slow frequency (HVSA) with occasional spindle bursts. During deep drowsy state, the EEG tended to be of more regular nature without spindle discharge.

The behavioural observations in unrestrained drowsy goats indicated that animals preferred to remain recumbent. Goats usually went drowsy by taking a deep breath with relaxed posture. The head and ears started drooping towards the ground when it was recumbent or supported on nearby wall when sitting. The eyelids initially showed frequent movements of closing and opening, and partially closed. The thresholds of sensory stimuli started rising up and reached maximum thresholds during sleep state. Even rumination took place during drowsy state and such rumination cycles were of prolonged and regular nature.

Sleep state

The data recorded for sleep state is presented in Table I. The result indicated that there were two different stages of sleep state, that is light and deep sleep, which were significantly different from each other in terms of frequencies. The frequencies (Hz) of sleep state were significantly ($P<0.05$) higher with values of 7.13±1.14 compared to deep sleep 3.25±0.49. The frequencies of two different stages of sleep state ranged from 3 to 10 Hz. The amplitude (μV) of sleep state recorded was 16.59±2.55 (light sleep) and 19.86±3.19 (deep sleep), the differences being nonsignificant. The amplitude of two stages of sleep state ranged from 15.72 to 29.13

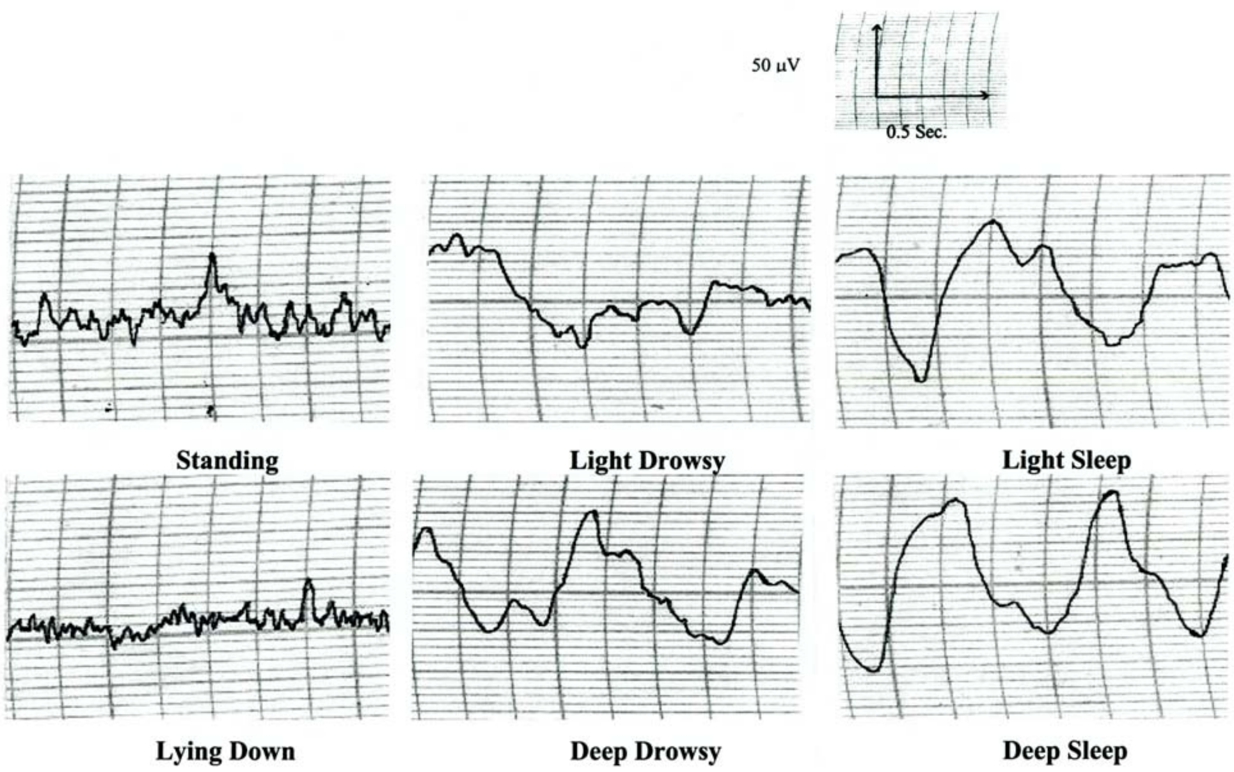

Fig. 1 : Electroencephalographic tracings of goats during resting period.

μV. The EEG patterns of sleep state and drowsy state were almost similar to that of high voltage slow frequency (HVSA), but without spindle burst and were of hyper-synchronous nature (Fig. 1). The light sleep showed mostly high voltage (HVSA) slow frequency alternating with low voltage high frequency (LVFA), whereas in deep sleep was dominant by brief spurts of HVSA for a maximum duration of one second. The frequency of sleep state was found to be in α and θ band for light sleep and δ band for deep sleep.

The behavioural observations during sleep indicated that head and ears were completely dropped sideways or down to the surface of the ground during recumbancy. Sleep state occurred with eyes partially closed and incomplete muscular relaxation. However, goats assumed sternal recumbency along with some loss of muscle tone allowing head and ears droop away. Sleep state followed drowsy state with restricted movements and relaxed posture. The threshold of sensory stimuli was increased, which was apparent from variable attitude towards environment due to rise in receptor threshold. During this state, rapid eye movement interfering with EEG pattern of sleep was often observed and salivation occurred due to unconscious state. The sleep state was also like drowsy state, it occurred depending upon the favourable environment and activation of its center.

DISCUSSION

EEG frequencies and amplitudes recorded in the present study compared well with those reported for goats (1) and other species (2, 15, 16). On the other hand EEG of alpha band (6–9 Hz) has been reported at two weeks of age, which changed to beta band by a seventh week of age in growing calves (7). Behavioural responses also corresponded well with earlier report (1, 2).

The state of alertness has been associated with activity of the ascending reticular formation of brain stem (17) and considering the asynchronous nature of the alert EEG in our study it appears that similar neural control mechanism applies in goats also. Data obtained during drowsy state compared well with earlier reports (1, 15). Higher amplitudes during drowsiness occurred due to better merging of electrical potentials from individual neurons when fire at lower frequency (18). The frequency of drowsiness state was found to be β band for light drowsy and α band for deep drowsy state. The behavioural observations during drowsy state are well supported by earlier reports (1, 19, 20). It has also been reported that ears droop down, tail or body movements were restricted or relaxed, and response to auditory and tactile stimuli initially increased which later decreased (20). Drowsy state is not confined to a particular period of the day and it occurred at any time depending on favourable environment and stimulation of its center. Drowsy state was found to cover maximum resting period as reported earlier (3) and was confirmed by animal's facial expression and head carriage. The EEG pattern of low frequency high amplitude with spindle bursts, which changed immediately to asynchronous form when the animal was disturbed has also been reported earlier (10).

Sleep pattern observed in these animals paralleled earlier observations (1, 21) however, the level of unconsciousness was lesser compared to other species. Alertness and somnolence (drowsy and sleep) have been shown to be associated with the level of nervous activity of the diencephalons and ascending reticular formation (22, 23).

It could be concluded that frequencies decreased and amplitudes increased with extent of drowsiness in goat. The EEG pattern of alert, drowsy and sleep states were LVFA, mixed LVFA and HVSA, HVSA dominant and frequencies were β, β and α, θ and δ. The EEG of alert goats is similar to the asynchronous pattern noted in other species. However, better spectral analysis of these frequency and amplitude patterns and their correlation with facial expressions can be done effectively with real time video recording in combination with wireless electrodes placed at multiple points on the scalp.

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