

NAME: DARA SANCTUS

MATRIC NO: 17/MHS01/096

PHYSIOLOGY ASSIGNMENT

QUESTION

- 1. DISCUSS THE PHYSIOLOGY OF SLEEP**
- 2. DISCUSS THE ROLE OF BASAL GANGLIA IN COORDINATING MOVEMENT**

. Sleep is a physiological behavior that is common in all animal species. It forms around one third of a human life. It is not known clearly the exact functions of sleep but it seems to be essential for survival as prolonged sleep deprivation leads to severe physical impairment followed by cognitive loss and eventually death.

Sleep disturbances are important clinically as they are indicators of almost all types of psychiatric ailments.

1. We are functionally blind during sleep with no response to visual stimuli and a decreased threshold of response to auditory stimuli. Babies have been exposed to sound of up to 100 dB, which is above the legal limit for ear protection for employees, without waking up. In adults, the process is selective demonstrating continuing cortical function. For example, a sleeping mother is woken by her crying baby but not by other louder noises.

Sleep is distinguished from unconsciousness and anaesthesia by a characteristic cycle of sleep with specific EEG patterns and physiological changes. Natural sleep is divided into two distinctive states: non-rapid eye movement (NREM) and rapid eye movement (REM) sleep. NREM sleep is then further divided into 4 stages where stage 1 is the lightest and stage 4 the deepest level of sleep. REM sleep is divided into phasic and tonic phases. The two distinctive states follow a regular pattern called a sleep cycle which, in an adult, lasts about 90 min and comprises a period of NREM sleep followed by REM sleep. The cycles may be separated by

a period of wakefulness and are repeated 3–6 times each night and are typically displayed as an hypnogram . The majority of deep (stage 4) NREM sleep occurs in the first and second cycles. As the night progresses, the proportion of REM sleep in a cycle increases and the NREM element is of lighter stage 2 sleep.

Functions of sleep

The functions of sleep are still poorly understood. However, the observation that sleep (or, at least, an activity–inactivity cycle) is present in all species and has been preserved throughout evolution and that sleep deprivation leads to a drastic deterioration in cognitive function and eventually to mental and physical morbidity proves its importance. It has been suggested that sleep might conserve energy by reducing core temperature slightly and lowering metabolic rate by 10% compared with quiet wakefulness. Sleep would prevent perpetual activity as a response to environmental stimuli leading to excessive energy consumption. However, sleep is a state of starvation and there is no evidence that sleep is important for tissue repair. Sleep has been implicated as an important factor in storage of long-term memory. Facts learned during the day are usually better remembered the next morning whereas facts learned shortly before going to sleep are often poorly recalled.

Electrophysiological characteristics of sleep

The stages of sleep are characterised by typical patterns of electroencephalogram (EEG), electro-myogram (EMG) and electro-oculogram (EOG) activity. Wakefulness with open eyes is characterised by an EEG with dominant low amplitude, high frequency beta activity of 16–25 Hz. Muscle tone is usually high with high-to-moderate EMG activity.

Stage 1

Sleep is usually initiated by a transition from wakefulness to a state of drowsiness with closed eyes and a shift from EEG beta activity to alpha activity of 8–12 Hz passing to Stage 1 NREM sleep with a mixed frequency EEG-pattern with low amplitude theta waves of 3–7 Hz accompanied by slow rolling eye movements. Involuntary muscle clonus occurs frequently, resulting in jerky movement of the whole body (hypnic jerks) and EMG activity is moderate-to-low. This stage lasts typically only 5–10 min, during which time minor auditory stimuli will cause arousal.

Stage 2

Stage 2 is characterised by short bursts of high frequency activity (12–15 Hz – sleep spindles) and K-complexes (large amplitude biphasic waves). Bodily movements continue and the EMG activity is low-to-moderate. This stage is generally short (10–20 min) in the first 1–2 cycles but predominates in later cycles. It is the most abundant sleep stage in adults accounting for up to 50% of TST.

Stages 3 and 4

Deep NREM sleep stages 3 and 4, sometimes combined as slow wave sleep (SWS) are characterized by high amplitude low frequency delta waves ($> 75 \mu\text{V}$ and 0.5–2 Hz) with stage 3 having between 20–50% and stage 4 more than 50% delta activity. EMG activity is low and eye movements are rare. Arousal through auditory stimuli from this stage of sleep is difficult and, if awakened, the individual is often disorientated and slow to react. Return to sleep is easy and short arousals ($< 30 \text{ sec}$) are rarely remembered.

REM sleep

NREM sleep is followed by REM sleep, the proportion increasing with each cycle. REM sleep is characterised by a fast mixed frequency low voltage EEG with saw-tooth waves and rapid eye movements on the EOG. During the tonic phases of REM sleep, there is marked reduction of muscle tone and EMG activity in skeletal muscles. The tonic phases of REM sleep are interrupted by short episodes of phasic REM sleep with increased EMG activity and limb twitches. The atonia of REM sleep affects all skeletal muscles, except the diaphragm and the upper airway muscles, and is associated with hyperpolarisation of the α -motor neurones. The purpose of this may be to prevent the acting out of dreams. About 10% of the population have experienced sleep paralysis (*i.e.* wakening from sleep and finding that the atonia has persisted into wakefulness). It can be frightening but is entirely harmless. Natural wakening usually occurs from REM sleep. Subjects woken from REM sleep are much more likely to recall dream content than those awakened from NREM sleep. NREM dreams are generally vague and formless in contrast to REM dreams.

Physiological changes during sleep

Respiratory system

During NREM sleep, there is a decrease in respiratory drive and a reduction in the muscle tone of the upper airway leading to a 25% decrease in minute volume and alveolar ventilation and a doubling of airway resistance accompanied by a small (0.5 kPa) increase in PaCO_2 and decrease in PaO_2 . Hypercarbic and hypoxic ventilator drives are

reduced compared with wakefulness. The breathing pattern is regular except at the transition from wakefulness into sleep when brief central apnoeas are common. During REM sleep there is a further decrease in hypercarbic and, particularly, hypoxic ventilatory drives. The breathing pattern is irregular especially during phasic REM sleep. The loss of skeletal muscle tone in REM sleep affects the intercostal and other muscles which stabilise the chest wall during inspiration. In infants, this may be seen as paradoxical movement of the rib cage and abdomen. In adults, there may be maldistribution of ventilation and impaired ventilation–perfusion matching with consequent arterial hypoxaemia. In normal subjects, this is unimportant but it may be very important in patients with chronic lung disease or abnormalities of the thoracic (*e.g.* kyphoscoliosis). The great majority of patients with impaired respiratory function will be at their worst during REM sleep.

Cardiovascular system

Blood pressure decreases during NREM and tonic REM sleep but may increase above waking values during phasic REM sleep. Cardiac output is generally decreased during all sleep phases. Systemic vascular resistance (SVR) and the heart rate are both reduced during NREM and tonic REM sleep and increased during phasic REM sleep.

Central nervous system

Cerebral blood flow (CBF) increases by 50–100% above the level of resting wakefulness during tonic REM sleep and is even greater during phasic REM sleep. Cerebral metabolic rate, oxygen consumption and neuronal discharge rate are reduced during NREM sleep but increased above resting values during REM sleep. The autonomic nervous system shows a general decrease in sympathetic tone and an increase in parasympathetic tone, except in phasic REM sleep.

Renal system

The glomerular filtration rate and filtration fraction are reduced and ADH secretion is increased resulting in a low volume concentrated urine.

Endocrine system

The secretion of several hormones is directly linked to the sleep/wake cycle. Melatonin is released from the pineal gland under the control of the supra-chiasmatic nuclei (SCN) in a 4–5h pulse, usually beginning at the onset of darkness (~9 pm). The pulse is inhibited or delayed by exposure to bright light in the evening. It is best regarded as being permissive of

sleep ('opening the gate to sleep') rather than as an hypnotic, as it is possible to maintain wakefulness during this period. Growth hormone is mostly secreted during the first episode of SWS, particularly during puberty. Prolactin concentrations also increase shortly after sleep onset and decrease with wakefulness. Sleep phase delay delays secretion of both of these hormones. The secretion of cortisol decreases with the onset of sleep and reaches a trough in the early hours of the morning and a peak just after waking.

Temperature control

In contrast to anaesthesia, thermoregulation is maintained during sleep. However, the shivering threshold is decreased and body core temperature decreases by about 0.5°C in humans and 2°C in hibernating mammals. Body temperature is linked to the circadian rhythm and reaches its nadir at about 3 am. Thermoregulation is quite good in human infants compared with other species.

2.

Regulation of Voluntary Movements

Movements during voluntary motor activity are initiated by cerebral cortex. However, these movements are controlled by basal ganglia, which are in close association with cerebral cortex. During lesions of basal ganglia, the control mechanism is lost and so the movements become inaccurate and awkward. Basal ganglia control the motor activities because of the nervous (neuronal) circuits between basal ganglia and other parts of the brain involved in motor activity. Neuronal circuits arise from three areas of the cerebral cortex:

- a. Premotor area
- b. Primary motor area
- c. Supplementary motor area

All these nerve fibers from cerebral cortex reach the caudate nucleus. From here, the fibers go to putamen. Some of the fibers from cerebral cortex go directly to putamen also. Putamen sends fibers to globus pallidus. Fibers from here run towards the thalamus, subthalamic nucleus of Luys and substantia nigra. Subthalamic nucleus and substantia nigra are in turn, projected into thalamus. Now, the fibers from thalamus are projected back into primary motor area and other two motor areas, premotor area and supplementary motor area.

Regulation of Conscious Movements

Fibers between cerebral cortex and caudate nucleus are concerned with regulation of conscious movements. This function of basal ganglia is also known as the cognitive control of activity. For example, when a stray dog barks at a man, immediately the person, understands the situation, turns away and starts running.

Regulation of Subconscious Movements

Cortical fibers reaching putamen are directly concerned with regulation of some subconscious movements, which take place during trained motor activities, i.e. skilled activities such as writing the learnt alphabet, paper cutting, nail hammering, etc.

CONTROL OF REFLEX

MUSCULAR ACTIVITY

Some reflex muscular activities, particularly visual and labyrinthine reflexes are important in maintaining the posture. Basal ganglia are responsible for the coordination and integration of impulses for these reflex activities. During lesion of basal ganglia, the postural movements, especially the visual and labyrinthine reflexes become abnormal. These abnormal movements are associated with rigidity. Rigidity is because of the loss of inhibitory influence from the cerebral cortex on spinal cord via basal ganglia.

CONTROL OF AUTOMATIC

ASSOCIATED MOVEMENTS

Automatic associated movements are the movements in the body, which take place along with some motor activities. Examples are the swing of the arms while walking, appropriate facial expressions while talking or doing any work. Basal ganglia are responsible for the automatic associated movements. Lesion in basal ganglia causes absence of these automatic associated movements, resulting in poverty of movements. Face without appropriate expressions while doing any work is called mask-like face. Body without associated movements is called statue-like body.