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COURSE: NEUROPHYSIOLOGY

DEPARTMENT: MEDICINE AND SURGERY

ASSIGNMENT

1. Discuss the physiology of sleep
2. Discuss the role of basal ganglia in coordinating movement

ANSWERS

1) PHYSIOLOGY OF SLEEP

Sleep is defined as a natural decrease in the perception of the external environment that occurs periodically and reversibly but retaining a certain degree of reactivity towards the environment and autonomous functions. From a behavioural standpoint, sleep is a state of decreased awareness of environmental stimuli that is distinguished from states such as coma or hibernation by its relatively rapid reversibility. Sleep is considered an active process of biological, cyclical and, it is essential for survival. Most adults require an amount of sleep between 7 - 8 hours per day; however, there are individual variations regarding the schedule, duration, and internal structure of the dream.

Types of sleep

- Rapid eye movement (REM) sleep:

Rapid eye movement sleep is the type of sleep associated with rapid conjugate movements of the eyeballs, which occurs frequently. It is also referred to as paradoxical sleep because the electroencephalogram (EEG) during REM sleep is similar to that of waking. In infants, the equivalent of REM sleep is called active sleep because of prominent phasic muscle twitches. This type of sleep is less restful than slow-wave sleep and is associated with dreaming and bodily muscle movements. During REM sleep a person's threshold to be aroused by external stimuli is higher than during slow-wave sleep. Heart rate and breathing become irregular during REM sleep, a feature of the dream state. The brain is extremely active during REM sleep. The electroencephalogram shows patterns of brain wave activity similar to those that occur during the waking hours.

- Non-REM sleep or slow wave sleep.

Non-rapid eye movement (NREM) sleep is the type of sleep without the movements of eyeballs. It is also called slow wave sleep. Non-REM sleep is characterised by deep sleep. The duration of REM sleep episodes is longer earlier in the night when one is most tired. As one becomes more rested during the night, the duration of REM sleep episodes decreases. During non-REM sleep the blood pressure, breathing and metabolic rate are all depressed significantly. Bodily movements do not occur during non-REM sleep.

Non-REM sleep is also referred to as slow wave sleep as during this period the brain waves are very strong and of a very low frequency (i.e. slow).

Although slow-wave sleep is frequently called “dreamless sleep,” dreams and sometimes even nightmares do occur during slow-wave sleep. The difference between the dreams that occur in slow-wave sleep and those that occur in REM sleep is that those of REM sleep are associated with more bodily muscle activity. Also, the dreams of slow-wave sleep are usually not remembered because consolidation of the dreams in memory does not occur.

Stages of Sleep

Within REM and NREM sleep, there are further classifications called stages. The stages of sleep are characterised by typical patterns of electroencephalogram, 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. NREM sleep, which usually precedes REM sleep, is subdivided into four stages.

a) Stage 1(stage of drowsiness)

Sleep is usually entered through a transitional state, stage 1 sleep, characterized by loss of alpha activity and the appearance of a low voltage mixed frequency EEG pattern with prominent theta activity (3-7 cps) and occasional vertex sharp waves may also appear. Eye movements become slow and rolling, and skeletal muscle tone relaxes. Subjectively, stage 1 may not be perceived as sleep although there is a decreased awareness of sensory stimuli, particularly visual, and mental activity becomes more dream-like. Motor activity may persist for a number of seconds during stage 1. Occasionally individuals experience sudden muscle contractions, sometimes accompanied by a sense of falling and/or dreamlike imagery; these hypnic (hypnosis = mental state like sleep) jerks are generally benign and may be exacerbated by sleep deprivation.

b) Stage 2(stage of light sleep)

Stage 2 is the second stage of sleep and lasts for approximately 20 minutes. During stage 2 sleep: You become less aware of your surroundings, body temperature drops, breathing and heart rate become more regular. The brain begins to produce bursts of rapid, rhythmic brain wave activity known as sleep spindles. Body temperature starts to decrease, and heart rate begins to slow. According to the American Sleep Foundation, people spend approximately 50% of their total sleep in this stage.5

c) Stage 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 μV and 0.5–2 Hz) with stage 3 having between 20–50% and stage 4 more than 50% delta activity. Stage 3 and 4 are also referred to as slow wave sleep (SWS), delta sleep, or deep sleep, since arousal

threshold increases incrementally from stages 1 through 4. Eye movements cease during stages 2-4, and EMG activity decreases further.

d) REM stage

REM sleep is not subdivided into stages but is rather described in terms of tonic (persistent) and phasic (episodic) components. Tonic aspects of REM sleep include the activated EEG similar to that of stage 1, which may exhibit increased activity in the theta band (3-7 cps), and a generalized atonia of skeletal muscles except for the extraocular muscles and the diaphragm. Phasic features of REM include irregular bursts of rapid eye movements and muscle twitches.

Sequence of Sleep

It is important to realize that sleep does not progress through these stages in sequence. A healthy young Med 1 will typically spend about 5% of the sleep period in stage 1 sleep, about 50% in stage 2, and 20-25% in each of SWS (stages 3 and 4) and REM sleep. Sleep occurs in cycles of NREM-REM sleep, each lasting approximately 90- 110 minutes. SWS (stages 3 and 4) is most prominent early in the night, especially during the first NREM period, and diminishes as the night progresses. As SWS wanes, periods of REM sleep lengthen, while showing greater phasic activity and generally more intense dreaming later in the night.

Physiological Changes During 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.
- Respiratory system: Rate and force of respiration are decreased. Respiration becomes irregular and Cheyne-Stokes type of periodic breathing may develop.
- Renal system: The glomerular filtration rate and filtration fraction are reduced and ADH secretion is increased resulting in a low volume concentrated urine.
- 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.
- 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.

- 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.

Sleep Disorders

Sleep disorders are a group of conditions that affect the ability to sleep well on a regular basis. Common sleep disorders include:

a. Insomnia: Insomnia is the inability to get to sleep or sleep well at night, can be caused by stress, jet lag, a health condition, the medications you take, or even the amount of coffee you drink. Insomnia can also be caused by other sleep disorders or mood disorders such as anxiety and depression.
b. Sleep apnea: Sleep apnea is a common (and treatable) sleep disorder in which your breathing temporarily stops during sleep, awakening you frequently. If you have sleep apnea you may not remember these awakenings, but you'll likely feel exhausted during the day, irritable and depressed, or see a decrease in your productivity. Sleep apnea is a serious and potentially life-threatening sleep disorder, so see a doctor right away and learn how to help yourself.
c. Restless legs syndrome (RLS): Restless legs syndrome (RLS) is a sleep disorder that causes an almost irresistible urge to move your legs (or arms) at night. The urge to move occurs when you're resting or lying down and is usually due to uncomfortable, tingly, aching, or creeping sensations.
d. Narcolepsy: Narcolepsy is a sleep disorder that involves excessive, uncontrollable daytime sleepiness. It is caused by a dysfunction of the brain mechanism that controls sleeping and waking.
e. Circadian rhythm sleep disorders: Circadian rhythms have been linked to a variety of sleeping problems and sleep disorders, as well as depression, bipolar disorder, and seasonal affective disorder (the winter blues).
f. Shift work sleep disorder: Shift work sleep disorder occurs when your work schedule and your biological clock are out of sync. In our 24-hour society, many people have to work night shifts, early morning shifts, or rotating shifts. These schedules force you to work when your body is telling you to go to sleep, and sleep when your body is signaling you to wake.

2) ROLE OF BASAL GANGLIA IN COORDINATING MOVEMENT

The contributions of the basal ganglia to movement are complex and still not completely understood. In fact, the basal ganglia probably have multiple movement-related functions, ranging from choosing actions that are likely to lead to positive consequences to avoiding things that might be aversive. But the basal ganglia are most often linked to the initiation and execution of movements. One popular hypothesis suggests that the basal ganglia act to facilitate desired movements and inhibit unwanted and/or competing movements.

The intricacies of how basal ganglia activity leads to the facilitation of movement are still a bit unclear, but one popular hypothesis (Direct/Indirect model) suggests that there are different pathways in the basal ganglia that promote and inhibit movement, respectively.

According to the direct/indirect model, when a movement is desired, a signal to initiate the movement is sent from the cortex to the basal ganglia, typically arriving at the caudate or putamen (which are referred to collectively as the striatum). Then, the signal follows a circuit in the basal ganglia known as the direct pathway, which leads to the silencing of neurons in the globus pallidus and substantia nigra. This frees the thalamus from the inhibitory effects of the basal ganglia and allows movement to occur. There is also a circuit within the basal ganglia called the indirect pathway, which involves the subthalamic nucleus and leads to the increased suppression of unwanted movements. It is thought that a balance between activity in these two pathways may facilitate smooth movement.

We can see the importance of the basal ganglia to movement, however, when we look at cases where the basal ganglia have been damaged. In Parkinson's disease, for example, dopaminergic neurons of the substantia nigra degenerate. When this happens, the ability of the basal ganglia to inhibit contradictory movements is affected. This may cause individuals with Parkinson's disease to have difficulty initiating movements, resulting in some of the symptoms associated with Parkinson's disease like rigidity and slow movement.

On the other hand, in a disorder like Huntington's disease, degeneration of basal ganglia circuits causes the inhibitory capabilities of the basal ganglia to be diminished. This may lead to the excessive activation of movement-related circuits, causing the jerky and writhing involuntary movements seen in Huntington's disease.

A balance between the ability to inhibit and facilitate movement is critical to making normal, smooth movements, and the proper functioning of the basal ganglia is essential to maintaining that balance.