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17/MHS01/266

PHYSIOLOGY ASSIGNMENT

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1 Discuss the Physiology of Sleep

Sleep is defined as unconsciousness from which a person can be aroused by sensory or other stimuli. It is a state of reduced awareness and responsiveness associated with reduced movement. It is distinguished from coma in that a person asleep can be aroused or woken. There are multiple stages of sleep from very light sleep to very deep sleep. There are two types or major phases of sleep; Rapid eye movement (REM) sleep and Non-Rapid eye Movement (slow wave sleep)

Rapid eye movement sleep (REM) is characterised by the presence of rapid eye movements during sleep. This type of sleep is less restful than slow-wave sleep and is associated with dreaming and bodily muscle movement. It occurs in episodes that occupy about 25 percent of sleep time in young adults. Each episode normally occurs or recurs about every 90 minutes and lasts for about 5 to 30 minutes. During this type of sleep a person's threshold to be aroused by external stimuli is higher than during slow-wave sleep and heart rate and breathing becomes irregular (a feature of the dream state). This means the person in REM sleep is more difficult to arouse by sensory stimuli than N-REM sleep. When a person is extremely sleep, each bout of REM sleep is short and may be absent, while as ~~well rested person~~ a person becomes well rested through the night, the durations of the REM bouts increase.

The brain is extremely active during this type of sleep and overall brain metabolism may be increased as much as 20 percent. The ElectroEncephaloGRAm (EEG) of REM sleep shows patterns of brain wave activity similar to those that occur during the waking hours. Muscle tone throughout the body is depressed (indicating strong inhibition of spinal muscle control areas) but irregular muscle movements do occur in addition to rapid movements of eyes (despite extreme inhibition of peripheral muscles) in REM sleep. It is also Called Paradoxical sleep because it is a paradox that during REM sleep the brain is quite active but the person is not fully aware of his or her surroundings and therefore he or she is truly asleep

Non-Rapid Eye Movement (Non-REM) Sleep is characterised by deep sleep. This sleep is exceedingly restful and is associated with decreases in both peripheral vascular tone and many other vegetative functions of the body. During Non-REM sleep there is 10 to 30 percent decrease in blood pressure, respiratory rate and basal metabolic rate. Bodily movements do not occur during non-REM sleep. It is referred to as Slow-wave sleep as during this period brain waves are very strong and are of very low frequency. It is also referred to as dreamless sleep but dreams and nightmares can occur during this sleep. The difference between these dreams and those of REM are that there is no bodily muscle activity and are not remembered as they are not consolidated to memory during this sleep phase.

The functions of sleep are still poorly understood but it is absolutely important to sleep. Sleep causes two major physiological effects; effects on nervous system and on other functional systems of the body. Nervous system effects seem to be more important as lack of sleep is often associated with progressive malfunction of thought processes, abnormal behavioural activities, increased sluggishness of thought and the person might become irritable or even psychotic. Sleep in multiple ways restores normal levels of brain activities, normal balance among different functions of central nervous system, functions in neural maturation, facilitation of learning or memory, cognition, clearance of metabolic waste products generated by neural activity in the awake brain and conservation of metabolic energy (by reducing core temperature slightly and lowering metabolic rate by 10% compared to quiet wakefulness).

The functions of sleep both REM and non-REM can be classified into biochemical, physiological, neurological and psychological.

i. Biochemical function: Some hormones are secreted during sleep eg growth hormone and so growth occurs during sleep, metabolic rate falls during non-REM sleep, energy is conserved, body temperature drops, protein synthesis and production of complex molecules increase. Intracellular glycogen stores are also refilled.

ii Physiological functions: Cell division is more rapid and sleep has an effect on immune system as well as prepares the body for next episode of wakefulness by acting as a restorative or recovery phase.

iii Neurological functions: Sleep may have a role in development of brain cells and neurogenesis. Neurons formation is also done during sleep and the Cerebral Cortex is open to sensory inputs and forms loose associations.

iv Psychological function: Consolidation and maintenance of memory is done during sleep. It is known that learning of visual information is improved during the first night of sleep and sleep deprivation impairs recall of information

Sleep Cycles

REM sleep occurs at about 90 minute interval and there are usually 4 to 6 cycles of REM and non-REM sleep each night. Later into the night REM episodes become longer and non-REM sleep becomes shorter and lighter. REM sleep is divided into phasic and tonic phases while NREM sleep is divided into 4 stages. Sleep cycle is a regular pattern in which a period of NREM sleep is followed by a period of REM sleep. The cycles may be separated by a period of wakefulness and are repeated 3-6 times each night. Each cycle as mentioned before is 90 minutes.

Age has a major effect on duration of sleep cycle and ratio of NREM/REM sleep: Neonates sleep 16-18 hours with REM sleep accounting for 50 %, 2 year old & children sleep 10 hours per day with REM sleep accounting for 20-25 % of Total Sleep Time (TST) and Adults sleep 6-8 hours per day with 15-20 % REM sleep. Total sleep Time changes as sleep is more fragmented with less REM sleep and lighter NREM sleep.

The stages of sleep are characterised by typical patterns of electroencephalogram (EEG), electromyogram (EMG) and Electro-oculogram (EOG) activity. NREM is divided into 4 stages with Stage 1 being the lightest and Stage 4 the deepest level of sleep. Stage 1 and 2 are called Light sleep while stage 3 and 4 are called deep sleep, slow-wave sleep or delta sleep.

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Stages of NREM are

I Stage 1 : It is 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 NREM sleep with a mixed frequency EEG-pattern with low amplitude theta waves of 3-7 Hz accompanied by slow rolling eyes. This stage lasts for only 5-10 minutes during which minor auditory stimuli causes awakening. Involuntary jerky movement of the whole body (hypnic jerks) occurs and EMG activity is moderate-to-low.

II Stage II ; It is characterised by short bursts of high frequency activity (12-15 Hz - sleep spindles), bodily movements and EMG activity is low-to-moderate. This stage is short (10-20 min) in the first 1-2 cycles but predominates in later cycles and is the most abundant sleep stage in adults accounting for up to 50% of Total sleeping Time.

III Stage 3 and 4 ; These are the deep sleep stages combined sometimes as slow wave sleep. They 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. EMG is low and eye movements are rare. Arousal through auditory stimuli from this stage of sleep is difficult and when awakened, the person is often disoriented and slow to react. Return to sleep is easy and short arousals are rarely remembered (< 30 sec).

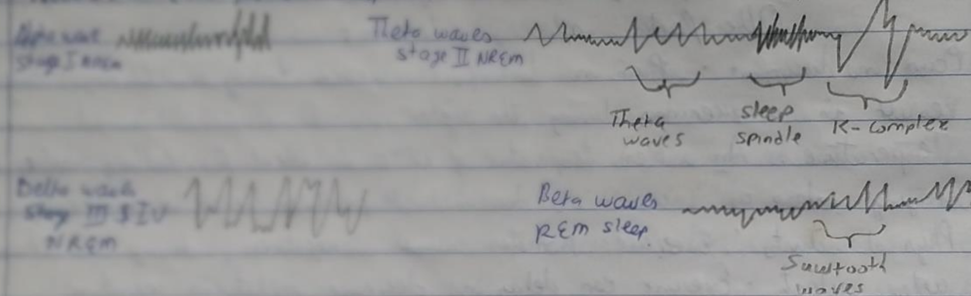
REM sleep ; NREM sleep is followed by REM sleep, the proportion increasing with each cycle. It is characterised by a fast mixed frequency low voltage EEG with saw-tooth waves and rapid eye movements on the EOG. It has two phases, tonic phase and Phasic phase. The tonic phases are characterised by marked reduction of muscle tone and EMG-activity in skeletal muscles. The tonic phases of REM sleep are interrupted by short episodes of phasic REM with increased EMG-activity and limb twitches. The atonia of REM sleep affects all skeletal muscles except diaphragm and the upper airway muscles. It is associated with hyperpolarization of the [illegible] motor neurons and all this may be to prevent the acting out of dreams. Natural wakening usually occurs from REM sleep but about 10% population experience sleep paralysis when they awaken. Dream content from REM sleep are more likely to be recalled and NREM dreams are generally vague and [illegible] formless in contrast to REM dreams.

The first NREM-REM sleep cycle is about 70-100minutes while the second and later cycles are longer lasting (approximately 90 to 120 minutes).

~~Sleep-Wake Regulation~~

~~The sleep-wake system is regulated by two processes,~~

~~i Process S (It promotes sleep) It is the homeostatic drive for sleep. The need~~



Sleep-Wake Regulation

This is done by two processes;

i Process S (It promotes sleep) It is the homeostatic drive for sleep. The need for sleep accumulates across the day and peaks just before bedtime at night and dissipates throughout the night. It is regulated by neurons in preoptic area of hypothalamus.

ii Process C (one that maintains wakefulness): It is wake promoting and is regulated by the circadian system. It promotes alertness and begins to decline at bedtime serving to enhance sleep consolidation. It is generated by an ascending arousal system from the brainstem that activates forebrain structures.

Other ~~reg~~ ~~most~~ important things to note are that the propensity to fall asleep varies throughout the day and depends on both circadian factors (process C) and time since last sleep period (process S). The longer the time since last sleep period, the greater will be process S. Its propensity is modulated by process C. This processes and regulation is also called the

Circadian rhythm: It is called the biological clock and is modulated by various external stimuli. This rhythm occur in 24 hour cycles and it prompts sleep at night and at between 2 and 4pm. Sleep, temperature and hormonal circadian rhythms are synchronised so that they all act together to drive a state of sleep or wakefulness. External stimuli ensures that the internal clock (circadian rhythm) is in sync with the external environment. This rhythm is mediated by the suprachiasmatic nuclei (SCN). Cells in the retina provide input to SCN which influences melatonin secretion from the pineal gland (melatonin is synthesized from tryptophan). Melatonin secretion causes sleep while its inhibition causes wakefulness. Regimented times for going to bed, going to sleep, waking and getting up are important for reinforcing circadian rhythm. Serotonin is associated with sleep production.

Other factors affecting sleep are

i Pain and discomfort: Pain and discomfort increases tossing and turnings that result in awakenings during the night

ii Temperature: An ambient temperature of 18°C is ideal for falling asleep and staying asleep as increased and decreased temperatures result in awakenings

iii Physical activity: Exercise promotes ~~awak~~ wakefulness during and 3 hours after activity. Exercise can delay and decrease melatonin secretion

iv Sexual activity: Sexual intercourse promotes falling asleep

v Noise: Noisy environments impair sleep but the level that leads to arousal from sleep varies with age and people

vi Hunger: Hunger causes wakefulness. Carbohydrate, milk, bananas, peanuts and figs encourage or increase melatonin production but high protein foods rich in tyrosine and large meals cause wakefulness

vii Light exposure: Seasonal changes in daylight affect sleep. Light can result in arousal from non-REM sleep and increases alertness as well as decreases melatonin secretion.

Physiology During sleep

There are various physiological changes during sleep and they include

1 Respiratory system: ~~vent~~ During NREM sleep there is a decrease in respiratory

drive and breathing pattern is regular except at transition from wakefulness into sleep. During REM sleep, breathing is irregular and there is further decrease in hypoxic ventilatory drives

2 Cardiovascular System: Blood pressure decreases during NREM and tonic REM but may increase during phasic REM sleep. Cardiac output is decreased as well as systemic vascular resistance and heart rate are also reduced but only in NREM and tonic REM. Systemic vascular resistance and heart rate increases during phasic REM sleep

3 Central Nervous System: Cerebral blood flow increases by 50-100% during tonic REM sleep and is greater during phasic REM. There is increase in parasympathetic tone and decrease in sympathetic tone except in phasic REM. Cerebral metabolic rate, oxygen consumption, and neuronal discharge rate are reduced in NREM but increased in REM sleep

4 Renal system: Glomerular Filtration Rate and Filtration fraction are reduced while Anti-Diuretic Hormone secretion is increased

5 Endocrine system: Melatonin is increased at beginning at onset of darkness and is inhibited by exposure to bright light. Growth hormone and Prolactin increase during sleep while cortisol secretion decreases with onset of sleep and reaches a trough in early hours of morning and a peak just after waking

6 Temperature Control: Thermoregulation is maintained, shivering threshold is decreased and body core temperature decreases by about 0.5°C in humans and 2°C in hibernating animals. Thermoregulation is not maintained in sleep due to anaesthesia

2 Discuss the role of Basal ganglia in Coordinating movement.

Role of Basal Ganglia in Coordinating Movement

Basal ganglia or basal nuclei are a group of subcortical nuclei of varied origin in brain of vertebrates which are situated at the base of the forebrain and top of the midbrain. They are a group of structures found deep within the cerebral hemispheres. They include the caudate, Putamen and globus pallidus in the cerebrum, the substantia nigra in the midbrain and the subthalamic nucleus in the diencephalon. The contributions of the basal ganglia to movement are complex and are still not completely understood. The separate nuclei of the basal ganglia all have extensive roles of their own in the brain but they are also interconnected with one another to form a network that is thought to be involved in a variety of cognitive, emotional and movement-related functions. The basal ganglia however are best known for their role in movement.

The basal ganglia's primary function is to control and regulate activities of the motor and premotor cortical areas so that voluntary movements can be performed smoothly. It does this by exerting an inhibitory influence on a number of motor systems and that a release of this inhibition permits a motor system to become active. This "behavioural switching takes place in basal ganglia which is influenced by the prefrontal cortex. The main components of basal ganglia are the striatum [divided into Dorsal striatum (caudate nucleus and putamen) and ventral striatum (nucleus accumbens and olfactory tubercle)], the globus pallidus, the ventral pallidum, the substantia nigra and the subthalamic nucleus.

The striatum receives input from many brain areas beyond the basal ganglia but only sends output to other parts of basal ganglia including the pallidum which receives input from striatum and sends inhibitory output to a number of motor-related areas. The substantia nigra sends input of dopamine (neurotransmitter) to the striatum while the subthalamic nucleus receives input from striatum and cerebral cortex and projects it to the globus pallidus.

The globus pallidus and substantia nigra form neuronal synapse with thalamic neurons which in turn project to the motor cortex (where many voluntary movements originate from) and can stimulate movement through these connections. The basal ganglia continuously inhibit the thalamic neurons thereby inhibiting movement.

When a movement is desired, a signal is sent from the cerebral cortex to basal ganglia (at specifically the dorsum striatum). The signal follows a circuit known as direct pathway in the basal ganglia which leads to silencing of neurons in the globus pallidus and substantia nigra and freeing of the thalamus from inhibitory effects of the basal ganglia. This allows movement to occur.

Another circuit in the basal ganglia called the indirect pathway involves the subthalamic nucleus and leads to increased suppression of unwanted movements. This circuit balances the activity of direct pathway and thereby facilitate smooth movements

Clinical Physiology

i. Tourette syndrome: It is a disease of the basal ganglia characterized by multiple movement tics and at least one vocal (phonic) tic. These tics include blinking, coughing, throat clearing, sniffing and facial movements. There is no cure.

ii. Wilson's disease: It is a genetic disorder in which excess copper builds up in the body.

iii. Huntington's disease: This is degeneration of basal ganglia circuits causing inhibitory capabilities of the basal ganglia to be diminished. It causes jerky and writhing involuntary movements

iv. Parkinson's disease: Here the dopaminergic neurons of substantia nigra degenerates causing ~~the~~ the basal ganglia's ability to inhibit contradictory movements to be affected.

Other clinical conditions are Obsessive-Compulsive Disorder, Addiction, Chorea, Fahr's disease, Lesch-Nyhan syndrome, Stuttering, Spasmodic dysphonia, Kernicterus, Dystonia, Cerebral palsy, bruxism, Athetosis etc.