

Sleep Physiology - Sleep is the greatest gift of God to the mankind.

Normal human sleep can probably be described as “a reversible behavioural state of perceptual disengagement and unresponsiveness to the environment”. Sleep is vital for our good health. Most of us know that when we do not sleep well we feel tired and irritable.^{1,2} Some of the more well-recognized results of poor sleep are:

- impaired thinking
- reduced learning ability
- decreased libido^{1,2}

Most of the complex problems get solved if we “sleep over it”, However, many of us do not realize that poor sleep also affects our cardiovascular and metabolic health,

and that chronic poor sleep is now associated with an increased risk for:

- obesity
- hypertension and heart disease
- type 2 diabetes³⁻⁷

Poor sleep may be a result of not giving yourself enough time to sleep. But if you do sleep long enough, it may be that your quality of the sleep is poor due to an undiagnosed sleep disorder. Either way, it is likely that you may have adverse health outcomes including impaired cognitive or mental processing and functioning.⁴⁻⁶

Conversely, a good night’s sleep allows you to awake refreshed and energized, ready to take on all the challenges of the day—both mentally and physically. In short, good sleep improves your quality of life.⁸⁻¹⁰

Sleep structure changes from night to night depending on the sleeper’s physical and psychological state and environmental conditions. For most people, sleep is composed of two very distinct types of sleep:

- non-rapid eye movement (NREM)
- rapid eye movement (REM)¹¹⁻¹²

At the beginning of sleep, sleepers may fluctuate between Stage W (wakefulness) and Stage N1 of NREM sleep. During Stage W, the patient may range from full alertness through to the early stages of drowsiness.

Table 1: Stages of NREM sleep	
Stage	Characteristics
N1	Transitional stage from wakefulness to sleep. Brain and body begin to relax; muscle jerking/twitching is fairly common. Most people without sleep disorders spend just a few minutes in stage N1.
N2	As the body further relaxes, breathing and heart rate slow down and become regular. Most adults spend about 50% of their total sleep time (TST) in this stage. Sleep spindles (bursts of brain activity to keep sleep tranquil) and K complexes (brain responses to stimuli), are two commonly observed traits.
N3	May be referred to as deep sleep or slow wave sleep (SWS) due to the types of brain waves seen during a sleep study. Deepest of all sleep stages, revealing the slowest breathing and heart rate of the night. The sleeper is very difficult to arouse; there are no noticeable eye movements. As people age, this stage decreases. Because of the restorative physiological processes that occur during N3, this may explain why older adults report a lack of the same restorative benefits during sleep as when they were younger.

Table 2: REM sleep	
Stage	Characteristics
REM	Most dreams take place during this stage. Heart rate and breathing become more irregular. Sleeper experiences almost total muscle paralysis except for the diaphragm. Occurs roughly every 90 minutes and progressively increases in duration over the course of the night. Occurs after stage N3 in the first part of the night and occasionally after stage N2 as sleep progresses. First cycle lasts approximately 10 minutes and can progress up to 25 minutes. Typically accounts for 20–25% of TST.

370 After Stage W, the sleeper begins NREM sleep with the following stages (Table 1):¹¹⁻¹⁴

The following Table 2 describes what happens during REM sleep^{11,13,12,15}

PHYSIOLOGICAL CHANGES DURING SLEEP

During sleep, many of our biological functions undergo change. Sleep is an inactive state for most of our systems, thereby allowing our mind and body to rest and perform essential activities. For example:

During sleep there is less need to be vigilant, and as a result, there is a generalized decrease in our central nervous system activity, allowing our nervous system time to rest and restore.^{4,11,13,16}

Our heart rate and blood pressure decrease allowing for rest and repair of the heart and vascular system.^{6,9,11}

As our metabolic needs are not as great in sleep, our breathing rate decreases giving our respiratory system a time to rest and repair.^{11,13,17}

While most of our bodily functions undergo rest during sleep, our hormonal production system is very active. It is during sleep, particularly stage N3, that our growth hormones, essential to our good health and good metabolism, are produced. Without sufficient sleep we have an imbalance in these hormones and our metabolic health is adversely affected.^{4,12,14,18}

SLEEP DEPRIVATION

The effects of sleep deprivation are the results of not allowing either our body or mind sufficient time to rest and to carry out the vital functions that can only occur during sleep. When we get insufficient sleep, we do not get to rest, restore or conserve energy adequately which adversely affects our cognitive, cardiovascular and metabolic health.^{4,10,19}

The accumulation of lost sleep is like monetary debt, which needs to be paid back eventually. Consequences of sleeplessness include:^{12,10,6,8,17}

- deficiency in alertness and attentiveness
- increase in irritability, lethargy and other mood problems
- lack of concentration and judgment
- difficulty in conducting simple tasks
- decline in productivity
- higher risks for developing anxiety or depression
- increased risk of developing coronary disease
- lack of control over sleepiness and unintentionally falling asleep
- physical symptoms of sleep deprivation, including headaches, gastrointestinal problems and more.

SLEEP DISORDERS

There are over 80 documented sleep disorders which

affect either the quality or quantity of sleep. Many of these disorders have the potential to seriously disrupt sleep and have long-term ill-effects on our health. Therefore, it is important to diagnose and treat them quickly.¹⁰

Insomnia

Insomnia is defined as trouble falling or staying asleep. If you suffer from insomnia, it affects both your waking and sleeping hours.¹⁰ Insomnia may be:

- transient—a few nights
- short term—two or three weeks
- chronic—poor sleep every night or most nights.

Insomnia afflicts people of all ages and it is estimated that up 35% of adults suffer from insomnia at some time during their life.

Insomnia has many possible causes and may be a result of:

- internal factors—such as depression or a tumor
- external factors—primarily those factors surrounding good sleep hygiene.

Many cases of insomnia can be improved with the implementation of good sleep hygiene, including developing relaxation methods for coping with stress and improving the sleeping environment.^{12,10,19}

Sleep Deprivation as a Fashion –Many teen agers as well as young adults deliberately sleep less, as it is considered as IN THING to sleep less, many young executives who are working for American companies sitting in India work at American time and keep up whole night can never get 8 hrs of good sleep. Many teen agers keep up and sleep late not for studies but to be playing on their computers or mobiles on what'sup. Frequent fliers fly out of India at odd hrs and rarely sleep well on board. Most flights leave India at late night to suit European and American airports which close down at nights unlike ours and it is fashionable for a dynamic CEO of a company to fly overnight and come to the work next morning before the rest of the staff just to show off his or her dedication and fitness! All these eventually has a toll on their health of both body and mind. The average sleeping time over a period of last 20 years has reduced from 8 hrs to 5 hrs or fragmented sleep of a period from 2 to 3 hrs.

Learned insomnia, a result of a period of insomnia causing an ongoing fear of the insomnia repeating itself, is often improved by cognitive behavioural therapy.¹

NARCOLEPSY

Narcolepsy is a neurological disorder that causes uncontrollable daytime sleepiness. It affects the part of the brain that regulates sleep and wakefulness, resulting in the sudden onset of REM sleep. Symptoms typically begin between puberty and age 25, developing slowly over months or years.^{10,9,2} Narcolepsy usually goes undiagnosed for many years.

Narcolepsy is characterized by:

Table 3: Symptoms of Narcolepsy

Symptom	Description
Excessive daytime sleepiness	Episodes of falling asleep at inappropriate times. Usually the earliest sign of narcolepsy.
Cataplexy	Abrupt loss of strength brought on by strong emotions like surprise, joy, anger or fear.
Hypnagogic hallucinations	Auditory, visual and tactile hallucinations that take place at sleep onset.
Atonia	Paralysis occurring between waking and sleeping.

- a frequent and irresistible need for sleep
- occasional paralysis and hallucinations
- sudden and uncontrollable attacks of deep sleep that are often brief, lasting from a few seconds to 30 minutes or more.

The following Table 3 lists the four primary symptoms of narcolepsy. Only 25% of people with narcolepsy have all four symptoms, though all experience excessive daytime sleepiness (EDS), with sudden episodes of sleep onset at inappropriate times.^{2,9,10,12,19}

Narcoleptics may take anywhere from 1–6 naps/day. Currently no cure exists, but its symptoms can be controlled through lifestyle management and medications such as stimulants and antidepressants.^{2,10}

PARASOMNIAS

Parasomnias are a category of sleep disorders that involve abnormal movements, behaviours, emotions and perceptions that occur while:

- falling asleep
- during sleep
- arousal from sleep.^{10,12,19}

Parasomnias are classified according to the sleep state in which they occur, either NREM or REM.

NREM PARASOMNIAS (TABLE 4)

The following parasomnias typically occur during NREM sleep:

REM PARASOMNIAS (TABLE 5)

The following parasomnias typically occur during REM sleep:

Sleep Disordered Breathing (SDB) (TABLE 6)

Sleep Disordered Breathing (SDB) is the general term used to describe any sleep related breathing abnormalities. SDB describes a number of clinical disorders including:

- Obstructive sleep apnoea syndrome (OSA)



Note: In this illustration, the size of the disorder indicates the relative frequency of occurrence. OSA is the largest because it is the most common SDB.

Fig. 1: Sleep Disordered Breathing

- Central sleep apnoea syndrome (CSA)
- Cheyne-Stokes Respiration (CSR)
- Nocturnal hypoventilation (NH)^{16,17,19}

The Figure 1 below shows the different disorders that fall under the umbrella of SDB.

SDB describes a number of different disorders that affect breathing during sleep. The following Table 4 lists and describes these disorders:

Obstructive Sleep Apnea (OSA)

Obstructive sleep apnoea (OSA) is a sleep disorder that involves cessation or significant decrease in airflow in the presence of breathing effort. It is the most common type of sleep-disordered breathing and is characterized by recurrent episodes of upper airway collapse during sleep. These episodes are associated with recurrent oxyhaemoglobin desaturations and arousals from sleep.^{5,6,10,11,13,16,17}

Prevalence

Various studies indicate the prevalence of OSA in India is between 4-21 percent in males and between 2.5-7.4% in females. Here is a list of studies in India which have been done on OSA (Table 7).

These figures closely match global figures – the study by Peppard et al²¹ in US studied 1520 participants concluded that the prevalence of OSA is 14% in males and 5% in females. Similarly, the study by Young et al²² puts the prevalence at 24% of men and 9% of women, between 30 and 60 years old with average BMI from 25 to 28.

SIGNS AND SYMPTOMS

Adults

Diurnal

- Excessive daytime sleepiness
- Hypertension
- Depression, irritability
- Fatigue, lack of energy
- Morning headaches

Table 4: NREM Parasomnias

Disorder	Description
Restless leg syndrome (RLS)	<p>This disorder often appears in otherwise healthy people. RLS affects primarily the legs, but is seen in the arms as well. People experiencing restless legs all describe it as a very unpleasant “creepy, crawly” sensation that occurs in the legs when they are sitting or lying still.</p> <p>Symptoms occur primarily when awake, and they may also be present during sleep.</p> <p>The constant need to stretch or move the legs often prevents a person with RLS from achieving and maintaining sleep.</p> <p>RLS affects 5–10% of the population, and is more common in older individuals.^{10,19}</p>
Disorder Description Periodic limb movement disorder (PLMD)	<p>While the movements of RLS are a voluntary response to uncomfortable feelings, the movements of PLMD only occur when a person is asleep and are involuntary.</p> <p>Periodic limb movements usually occur in the legs but can also affect the arms. The movements occur at periodic intervals, typically every 30 seconds.</p> <p>The incidence of PLMD increases with age and men and women are equally at risk.</p> <p>The cause of PLMD is unclear, but it is more common in people who have kidney disease or narcolepsy.</p> <p>Some antidepressant medications can also increase the frequency of limb movements.^{10,12,19}</p>
Night terrors and sleepwalking	<p>Both night terrors and sleepwalking arise during NREM sleep and occur mostly in children between the ages of three and five.</p> <p>Treatment is rarely needed and these parasomnias usually do not indicate any underlying medical or psychological problems.</p> <p>Children generally outgrow them.¹⁹</p>
Bruxism	<p>This is one of the most common sleep disorders.</p> <p>It is characterized by the grinding of teeth and the clenching of the jaw. In its more severe form, if left untreated, it can cause major health issues.^{19,20}</p>

Table 5: REM Parasomnias

Disorder	Description
REM behaviour disorder	<p>This is the ability to act out your dreams.</p> <p>Ordinarily all body muscles, with the exception of those used in breathing, are usually paralysed during REM sleep.</p> <p>However, in some cases this paralysis is incomplete or absent, thus allowing dreams to be acted out.</p> <p>u such as this can be violent and result in serious injuries to the victim and bed-partner.</p> <p>After awakening, the sleeper is usually able to recall vivid dreaming.^{2,12,19}</p>
Nightmares	<p>Nightmares are frightening dreams that arise during REM sleep.</p> <p>They can be caused by stress, anxiety, and some drugs.</p> <p>When nightmares frequently interfere with sleep, treatment with cognitive behavioural interventions is sometimes undertaken.¹⁹</p>

Table 6: Sleep Disordered Breathing	
Type	Description
Obstructive sleep apnea (OSA)	<p>Also known as OSA or in some cases simply referred to as SDB.</p> <p>This syndrome is characterized by repeated episodes of the collapse and the reopening of the upper airway during sleep occurring at a rate of five or more per hour.</p> <p>Some symptoms of the disease are:</p> <ul style="list-style-type: none"> • snoring • witnessed apnoeas • restless sleep • daytime sleepiness^{2,15-17}
Central Sleep Apnea (CSA)	<p>CSA is characterized by no effort and no airflow for periods of 10 seconds or more.</p> <p>This syndrome is characterized by CSAs occurring at a rate of five or more per hour during sleep.</p> <p>In contrast to OSA, in CSA there is no snoring and the person is frequently unaware that they have SDB. However, symptoms may include:</p> <ul style="list-style-type: none"> • excessive daytime sleepiness/daytime fatigue • insomnia • frequent arousals. <p>CSA is categorized according to the patient's blood CO₂ level:</p> <ul style="list-style-type: none"> • Hypercapnic CSA: When the CSA is associated with high levels of CO₂ it is referred to as hypercapnic CSA. This type of CSA is discussed in depth in the section on Nocturnal Hypoventilation. • Non-hypercapnic CSA: When CSA is associated with normal/low levels of CO₂, it is referred to as non-hypercapnic CSA. This includes Cheyne-Stokes respiration (CSR) and Complex Sleep Apnoea (CompSA).^{5,10,12,16}
Cheyne-Stokes Respiration (CSR)	<p>This is a type of CSA and is often seen in patients with heart failure and in some patients after a stroke.</p> <ul style="list-style-type: none"> • CSR is often under-diagnosed as it is a silent disorder. • CSR is a breathing pattern characterized by a period of apnea lasting approximately 20 seconds followed by a gradually increasing of depth and frequency of depth, and frequency of respirations. it is also known as a waxing and waning pattern alternating with either apnoeas or hypo apnoeas. • CSR is common in patients with congestive heart failure and is detrimental to sleep quality and the general health of these patients. Statistically it leads to increased morbidity and mortality.^{5,10,12,16,19}
Nocturnal Hypoventilation (NH)	<p>Nocturnal hypoventilation, or NH, is a reduced rate and depth of breathing.</p> <ul style="list-style-type: none"> • It occurs due to the loss of muscle tone during sleep, especially during REM sleep. • Nocturnal hypoventilation often occurs in patients with: <ul style="list-style-type: none"> - chronic obstructive pulmonary disease (COPD) - neurological impairments - restrictive diseases (eg, scoliosis) - obesity^{11,19}

- Concentration and memory problems
- Mood Swings
- Diabetes

Nocturnal

- Snoring
- Partner-witnessed apnoeas
- Irregular breathing during sleep

Table 7: Studies of Obstructive Sleep Apnea

Author	Sample Size		OSA Percentage		
	Questionnaire	Sleep Study	Overall	Males	Females
Udwadia Et Al, 2004	658	250	NA	19.5	NA
Sharma Et Al, 2006	2150	150	13.7	19.7	7.4
Viiayan Et Al, 2006	7975	47	3,5	4.4	2.5
Reddy Et Al, 2009	2505	365	9,3	13.5	5.6

- Nocturia
- Sexual dysfunction
- Cardiac arrhythmias
- Night sweats^{10,16,17,23}

Children

Although this so-called “hypersomnolence” (excessive sleepiness) may also occur in children, it is not at all typical of young children with sleep apnoea. Toddlers and young children with severe OSA instead ordinarily behave as if “over-tired” or “hyperactive.” Adults and children with very severe OSA also differ in typical body habitus. Adults are generally heavy, with particularly short and heavy necks. Young children, on the other hand, are generally not only thin, but may have “failure to thrive”, where growth is reduced. Poor growth occurs for two reasons: the work of breathing is intense enough that calories are burned at high rates even at rest, and the nose and throat are so obstructed that eating is both tasteless and physically uncomfortable. OSA in children, unlike adults, is often caused by obstructive tonsils and adenoids and may sometimes be cured with tonsillectomy and adenoidectomy.

This problem can also be caused by excessive weight in children. In this case, the symptoms are more like the symptoms adults feel: restlessness, exhaustion, etc.

Children with OSA may experience learning and memory deficits and OSA has also been linked to lowered childhood IQ scores.^{16,17,23}

COMPLICATIONS^{3,6,15,17,23-27}

Screening and diagnosis

The screening of OSA is done based on clinical evaluation, and through the help of various standard questionnaires like the Epworth Sleepiness Score, the Berlin Questionnaire or the STOP-BANG questionnaire.^{15,15,23,17,24}

In certain cases, overnight oximetry may also be used for screening OSA.

The diagnosis is done through a sleep study, which may either be done at home, or in a hospital. There are various types of sleep studies - as follows:

Type 1 device: Full Polysomnography (PSG)

In-lab study including audio-visual.

Over 24 channels, including EEG, EOG, EMG, ECG, thermistors and pressure transducer, respiratory effort, SaO₂, body position, limb movement. While this is the gold

standard, it is usually expensive and should be reserved for diagnosing sleep disorders other than OSA, or for patients having OSA and significant comorbidities.^{15,17,20}

Type 2 device: Ambulatory PSG

In-lab or in-home, with cut down version of PSG and usually without audio-visual. Indications are similar to type 1.²³

Type 3 device: Polygraphy (PG)

Studies using at least four channels at home or hospital, including pressure transducer, snore, respiratory effort and SpO₂. This is usually adequate for diagnosis for OSA – unless there are significant comorbid conditions.²³

Type 4 device

Screening devices - Usually one/two channels

These devices measure the AHI – or the apnoea hypopnea Index – which is the diagnostic measure of OSA.

The Apnoea-Hypopnea Index or Apnoea-Hypopnoea Index (AHI) is an index used to indicate the severity of sleep apnoea. It is represented by the number of apnoea and hypopnea events per hour of sleep. The apnoeas (pauses in breathing) must last for at least 10 seconds and be associated with a decrease in blood oxygenation. Combining AHI and oxygen desaturation gives an overall sleep apnoea severity score that evaluates both the number of sleep disruptions and the degree of oxygen desaturation (low blood level).^{5,6,10,17,23,28}

The AHI is calculated by dividing the number of apnoea events by the number of hours of sleep. The AHI values are categorized as:

Normal: 0-4

Mild sleep apnoea: 5-14

Moderate sleep apnoea: 15-29

Severe sleep apnoea: 30 or more

Treatment

In mild cases, avoiding alcohol and smoking is recommended, as is avoiding medications that relax the central nervous system (for example, sedatives and muscle relaxants). Weight loss is recommended in those who are overweight. Continuous positive airway pressure and mandibular advancement devices are often used. Physical training, even without weight loss, improves sleep apnoea.^{6,3,9,10,16,17,23,24,29,26}

For moderate to severe cases, the most widely used current



Fig. 2: OSA Related Medical Problems

therapeutic intervention is positive airway pressure whereby a breathing machine pumps a controlled stream of air through a mask worn over the nose, mouth, or both. The additional pressure holds open the relaxed muscles.^{6,7,10,12,16,17,20,24} There are several variants:

Continuous positive airway pressure (CPAP) is effective for both moderate and severe disease.

(APAP), or automatic positive airway pressure, also known as “Auto CPAP”, is the newest form of such treatment. An APAP machine incorporates pressure sensors and a computer which continuously monitors the patient’s breathing performance.^{26,27}

CPAP and APAP are gold standard treatment for obstructive sleep apnoea.

(VPAP), or variable positive airway pressure, also known as bilevel or BiPAP, uses an electronic circuit to monitor the patient’s breathing, and provides two different pressures, a higher one during inhalation and a lower pressure during exhalation. This system is more expensive, and is sometimes used with patients who have other coexisting respiratory problems and/or who find breathing out against an increased pressure to be uncomfortable or disruptive to their sleep.^{10,17,26}

Oral appliances or splints may be tried in mild to moderate cases, but are not as effective as CPAP and need to be individually tailored for them to be effective.^{9,10,12,17,23,24,26,29}

Surgical treatments to modify airway anatomy, known as sleep surgery, are varied and work only in selected patients with obvious anatomical abnormalities.^{6,15,17,23,24,26}

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Table 8: Complications of sleep disorders

Metabolic	Cardiovascular
• Insulin resistance (type 2 diabetes)	• Hypertension
• Metabolic syndrome	• Rhythmic problems
• Weight gain	• Cerebrovascular events
• Nocturia	• Myocardial infarction
• Sexual dysfunction	• Heart failure
Behavioural	Others
• Cognitive and memory problems	• Excessive daytime sleepiness
• Irritability	• Fatigue-related accident
• Concentration difficulties	• Headaches
• Premature aging	
• Depression	

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