

## Sleep Deprivation

### Change in Rapid Eye Movement (REM) Sleep in Response to Exposure to All-Night Noise and Transient Noise<sup>7</sup>

#### Background

- Non-REM sleep, especially slow-wave sleep, is required for brain recovery from fatigue. Non-REM sleep stages are likely deeper as the stage number increases.
- REM sleep is need for physical recovery and is indispensable for the maintenance of quality sleep.

#### Findings

- Subjects were exposed to all night or transient noise (either pink noise or recorded road traffic noise)
  - Steady 60 dBA<sup>e</sup> pink noise<sup>f</sup>
    - Decrease %SREM<sup>b</sup>
    - Increased %S2<sup>c</sup>
  - Stead 40-60 dBA pink noise
    - Decreased %SREM
    - Increased %S2
  - Recorded passing-truck noise
    - %SREM significantly decreased (22.4-14.2% decrease)
    - Total sleep time significantly decreased
  - Road-traffic noise (field survey)
    - %SREM (in young males) significantly decreased in noisy environments
  - Recorded road-traffic noise (transient, following on nights of exposure)
    - REM sleep decreased
    - Number of awakenings increased significantly
    - Subjective quality of sleep worsened
- REM sleep began to decrease at a noise exposure of approximately 45 dBA
- Across subjects and conditions, wakefulness increased during noisy nights, and there was a tendency to spend less time in SREM.
- Subjects reported poorer sleep quality following noisy nights

## Effects of Insufficient Sleep on Circadian Rhythmicity and Expression Amplitude of the Human Blood Transcriptome<sup>3</sup>

### Background

- Insufficient sleep and circadian<sup>k</sup> rhythm disruption are associated with negative health outcomes, but the mechanisms are largely unexplored.
  - Outcomes include obesity, cardiovascular disease, and cognitive impairment.
  - 26 participants were exposed to 1 week of insufficient sleep ( $t_{\text{sleep}} = 5.70$  hrs,  $\sigma = 0.03$  sleep per 24 hrs) and 1 week of sufficient sleep ( $t_{\text{sleep}} = 8.50$  hrs,  $\sigma = .11$ )
    - Insufficient is defined as inadequate or mistimed sleep
  - Immediately following each condition, 10 whole blood RNA<sup>i</sup> samples were collected from each participant (effects of lights, activity, and food were controlled for).

### Findings

- Transcriptome<sup>j</sup> analysis revealed that 711 genes were up- or down-regulated by insufficient sleep.
  - 444 down-regulated
  - 267 up-regulated
- Insufficient sleep also reduced the number of genes with a circadian expression profile from 1,855 to 1,481, reduced the circadian amplitude of these genes, and led to an increase in the number of genes that responded to subsequent total sleep deprivation from 122 to 856.
- Genes affected by insufficient sleep:
  - Circadian Rhythms – PER1, PER2, PER3, CRY2, CLOCK, NR1D1, NR1D2, RORA, DEC1, CSNK1E
  - Sleep Homeostasis – IL6, STAT3, KCNV2, CAMK2D
  - Oxidative Stress – PRDX2, PRDX5
  - Metabolism – SLC2A3, SLC2A5, GHRL, ABCA1
- Biological processes affected:
  - Chromatin Modification
  - Gene-expression Regulation
  - Macromolecular Metabolism
  - Inflammatory Response
  - Immune Response
  - Stress Response
- During period of insufficient sleep ( $t_{\text{sleep}} = 5.7$  hrs), it was observed that the sleep obtained was not sufficient enough to maintain alertness and performance.
  - By the last day of sleep restriction, participants were significantly more sleepy (Karolinska Sleepiness Scale) and had more lapses of attention in the Psychomotor Vigilance Task
- Melatonin Rhythm<sup>l</sup> was affected by sleep restriction such that the midpoint occurred significantly later after sleep restriction (0501 hrs +/- 19 mins versus 0415 +/- 19 mins).

- Duration of melatonin secretion was not significantly reduced.
- Study demonstrates that insufficient sleep to an extent frequently or chronically experienced by many individuals in industrialized societies alters temporal organization of the human blood transcriptome, including circadian regulation and response to acute total sleep loss.
- History of sleep and wakefulness affects the dynamics of transcriptome, the data show robust effects of sleep restriction on humans in a comparable fashion to other animal studies.
- Data suggest several pathways by which sleep restriction and circadian rhythmicity may be linked to negative outcomes associated with insufficient sleep. Baseline circadian data underscore pronounced variation in classic circadian genes, as well as the genes implicated in metabolism, sleep homeostasis, and immune function.

## Effects of 24 hrs+ of Sleep Deprivation on Waking Human Regional Brain Activity<sup>6</sup>

### Background

- Short periods of total sleep deprivation (24 hrs) typically occur in instances where individuals or groups undergo extended wakefulness to meet deadlines. Longer periods (>40 hrs) can occur during atypical sustained work conditions.
- Decrements in cognitive performance, often independent of loss of alertness or lapses in attention, are also produced by both short and long term sleep deprivation

### Findings

- After 24 hrs sleep deprivation, global CMRglu<sup>a</sup> decreased by 7.76%
  - Objective and subjective alertness declined but mood remained constant
  - Significant reduction in cognitive performance (Serial Addition/Subtraction task)
    - Accuracy: -3%
    - Speed: - 13%
    - Speed-accuracy product, index of overall productivity: -16%
- Relative regional CMRglu indicates areas more deactivated than the global decrease (3-7% more deactivated)
  - Thalamus: Alertness and Attention
  - Prefrontal Cortex: High Order Cognitive Processes
  - Posterior Parietal Lobes: High Order analysis and Integration of sensory motor information and cognition
    - Prefrontal and Posterior Parietal Cortices are recruited during tasks requiring visual verbal working memory and arithmetic calculations
- One night of sleep deprivation in humans diminishes waking regional brain activity predominantly in a bilateral prefrontal-posterior parietal-thalamic network mediating alertness, attention, and high order cognitive process.

## Trait Hostility, Perceived Stress, and Sleep Quality in a Sample of Normal Sleepers<sup>5</sup>

### Background

- Individual with heightened trait hostility<sup>b</sup> demonstrate similar patterns of reactivity to perceived stressors as is often reported by poor sleepers.
  - Relationship between trait hostility and sleep quality remains unexplored despite empirical indications that individuals with increased hostility experience more stress, which is a factor known to degrade sleep quality.
- Trait hostility construct is organized into three major components:
  - Cognitive – cynicism, hostile attribution bias<sup>h</sup>.
  - Affective – tendency to experience negative emotions such as anger, annoyance, resentment, disgust, and contempt.
  - Behavioral – tendency to act aggressively.
- Individuals who report higher levels of trait hostility are highly reactive to and slow to recover from interpersonal stress.
- 73 undergraduate psychology students recruited
  - 26 male, 47 female
  - 56 Caucasian, 3 African American, 4 Hispanic, 4 Asian, 3 Mixed Ethnicity, 3 Other Ethnicity
  - Study excluded those who took medications that interfered with stress reactivity or who used drugs/alcohol daily.
  - 7 individuals failed to complete minimum of 10 daily surveys over the course of the two week period and were excluded from analysis due to lack of data.
  - 92.4% of participants completed 12 or more surveys out of a possible 14.
  - Final sample consisted of 66 participants

### Findings

- Significantly negative correlations were found between cognitive hostility and sleep quality such that increased hostility related to decreases in both retrospective sleep quality and prospectively measured sleep quality
  - Behavioral hostility showed no meaningful association with sleep quality variables
- Positive correlation between trait cognitive hostility prospectively measured perceived stress as well as retrospective perceived stress.
  - No relationship found between cognitive hostility and number of stress events per day
  - No relationship found between behavioral hostility and stress measures
- Strong negative correlation between sleep quality and perceived stress such that poorer sleep was associated with more perceived stress. Also a moderate associate between tendency to rate stress events more severely.
  - No significant relationship between perceived stress and the number of stress events per day

- Increased trait hostility is associated with decreased sleep quality and the relationship is significant mediated by one's response to stress. Only the cognitive component of hostility was associated with heightened stress and sleep quality.
  - Individuals scoring high on cognitive hostility reported more daily and retrospective perceived stress compared to participants who scored lower.
  - While hostility was unrelated to stress event frequency, high hostility subjects reported heightened reactivity to their stressors and rated their stress as more severe than low hostile participants.
  - Note that there was no correlation between number of stress events experienced in one day and the quality of sleep. Data does support the indication that higher levels of perceived stress following a stressor are associated with poorer subjective sleep quality.
- Possible explanations for findings:
  - High cognitively hostile individuals attend to and ruminate more on their internal responses to stress. The cognitive model of insomnia prioritizes this type of repetitive, negatively toned cognitive activity as a major pathway through which sleep can be disrupted. The typed of behaviors can result in stronger cognitive and somatic responses to stress and heightened pre-sleep arousal, reducing sleep quality.
  - While behavioral components of trait hostility were unrelated to sleep quality, cognitive hostility was associated with subject sleep quality. This supports findings from previous studies.
- Finding support the hypothesis that heightened trait hostility acts as a risk factor for poor sleep. This study does not establish causality and cannot be directly addressed, only correlation is established.

## Psychomotor Performance of Medical Students: Effect of 24 Hours of Sleep Deprivation<sup>2</sup>

### Background

- Study was conducted on 30 medical undergraduate students in the age group of 18 – 25 years (21.08 +/- 2.15 years).
- Participants had no current illness, no history of drug intake during the last two weeks (including smoking and alcohol).
  - Subjects also asked to refrain from caffeine or any other stimulant intake for at least 12 hrs prior to the study
- Testing occurred following a restful overnight sleep on days when no examination was scheduled, subjects were called a day before actual testing to familiarize them with the tests:
  - Digit Symbol Substitution: Test of visuomotor coordination, sustained attention, and response speed. Test consisted of numbers 1 – 9 arranged randomly in 4 rows of 25 squares each. Subjects were asked to substitute each number with a symbol given in the key. Completion time was recorded.
  - Digit Vigilance Test: Measures sustained attention. Consists of numbers 1- 9 arranged randomly in rows, 30 digits per row and 50 digits per sheet. Subjects asked to cancel out

digits 6 and 9, time to complete test along with number correct and number incorrect was noted.

- Letter Cancellation Tasks: One-letter and three-letter cancellation tasks were used. Subjects had to cancel “A” in one-letter test and “A,” “Q,” and “T” in three-letter version. Total number of correct responses and number of errors were noted in addition to completion time.
- Subjects tested at 8 AM, 1 PM, 5 PM, 10 PM, 1 AM, and 8 AM. At no time during the day were subjects allowed to sleep or have any stimulants.
- Time of testing was kept in accordance to the daily activity of students attending lectures, practical, and clinics.
- On the test day, subjects were accompanied at all times with one of the investigators, eliminating the possibility for unobserved sleep.
  - Subjects experience sleepiness were kept awake by means of verbal communication

## Findings

- Digit Symbol Substitution Results:
  - Significant progressive increase in time taken to complete the test was observed (with 24 hrs being the maximum)
- Digit Vigilance Test Results:
  - Non-significant increase in time required for test completion
  - No significant change in number of correct responses on the test
  - Number of errors increased significantly with time, with the maximum amount of errors occurring after 24 hrs.
- Letter Cancellation Test Results:
  - No significant difference in time required to complete one-letter and three-letter cancellation tasks.
  - In both tests, there was an observed progressive increase in time required to complete the test.
  - Number of correct responses decreased significantly when compared to the baseline.
  - Number of errors increased significantly more with sleep deprivation
- Findings suggest that tasks requiring sustained attention were affected by sleep deprivation.
  - The effect was more on judgment ability that response speeds.
- Findings also suggest that complex tasks suffer more than simple ones by means of increasing the probability of errors.
  - This particularly affects performance of students, especially in situations such as multiple-choice questions where students must choose and respond often to similar appearing responses.

## Effects of Caffeine and Caffeine Withdrawal on Mood and Cognitive Performance Degraded by Sleep Restriction<sup>4</sup>

### Background

- Caffeine is widely regarded as a useful psychostimulant, although consumers also recognize that caffeine can disrupt sleep and caffeine withdrawal is associated with adverse symptoms.
- Significant fatigues results from even overnight caffeine withdrawal (ONW ~6 – 8 hrs) versus long term withdrawal (LTW ~3 weeks)

### Findings

- ONW participants reported finding tasks (impulsivity [inhibition], reasoning, focus of attention, long duration variable foreperiod simple reaction time<sup>d</sup>, memory, two finger speed tapping, hand steadiness) more tiring and difficult. ONW participants reported higher feelings of tension, light-headedness, and jitteriness, more headache, and lower clear-headedness and energy than LTW participants
  - Caffeine treatments prevented decrease in performance for ONW participants, but did not affect the performance of LTW participants on any cognitive tasks.
  - Weak effects of caffeine on mood occurred for both ONW and LTW participants (decrease in light headedness, increase in clear-headedness [marginally significant], and increase in jitteriness [marginally significant]) were observed.
  - Caffeine treatments improved finger tapping performance, but tended to impair hand steadiness and it increased blood pressure.
- No pre-treatment difference between the two cohorts.
- Clear finding that acute caffeine withdrawal (overnight) was associated with negative effects including:
  - *Impaired cognitive tasks*
  - *Perception that cognitive tasks were more difficult/tiring to perform*
  - *Greater headache occurrence*
  - *Reduced alertness*
  - *Reduced clear-headedness*
  - *Increased feeling of light-headedness*
  - *Increased feelings of tension and jitteriness*
- Caffeine consumption failed to benefit the performance of participants who were free of the negative effects of acute caffeine withdrawal, even in the context of low alertness induced by sleep restriction
  - This contradicts suggestions that caffeine is especially beneficial for performance when alertness is low
- Caffeine affected the cognitive performance of ONW participants, but only insofar as to prevent yet further deterioration in their poorer pre-treatment performance.

## Behavioral and Physiological Consequences of Sleep Restriction (Review Article)<sup>1</sup>

### Background

- Adequate sleep is essential for general healthy functioning. Restricting sleep below an individual's optimal time in bed can cause a range of neurobehavioral deficits, including lapses in attention, slowed working memory, reduced cognitive throughput, depressed mood, and preservation of thought.

### Neurobehavioral Consequences of Sleep Restriction

- Neurobehavioral deficits accumulate across days of partial sleep loss to levels equivalent to those found after 1 to 3 nights of total sleep loss.
  - Recent experiments reveal that following days of chronic restriction of sleep duration below 7 hours per night significant daytime cognitive dysfunction accumulates to levels comparable to that found after severe acute total sleep deprivation.
    - Partial sleep deprivation occurs in 3 ways:
      - Preventing sleep from being physiologically consolidated (sleep fragmentation)
      - Loss of specific physiological sleep stages (selective sleep stage deprivation)
      - Sleep restriction, which is characterized by reduced sleep duration (sleep debt)
      - Sleep restriction alters sleep architecture, but it does not affect all sleep stages equally.
    - Depending on timing and duration of sleep, some aspects of sleep are conserved, occur sooner, or intensify, while other aspects of sleep time are diminished.
    - Restricting sleep from 8 hrs to 4 hrs led to adults falling asleep more quickly and decreased time in non-REM stage 2 sleep and REM sleep, but no decrease in non-REM slow wave sleep or slow wave sleep activity

### *Experimental Control of Wakefulness in Sleep Restriction Experiments*

- Early experimental research (pre-1965) on waking neurobehavioral effects of prolonged sleep restriction bordered on the anecdotal and lacked adequate sample sizes and control groups
- Subsequent experiments (1970-1995) on cognitive and subjective effects of sleep restricted to 4 – 6 hrs per night often failed to ensure subjects maintained the assigned sleep-wake schedules, used infrequent, confounded and/or insensitive measures of sleep and waking, lacked sophisticated time series analyses; and general drew conclusions not substantiated by the quantitative results.

- These methodological inadequacies and small sample sizes have prompted 3 widely repeated conclusions:
  - Reducing nightly sleep to between 4 – 6 hrs had little adverse effects on daily functions.
  - Only “core sleep” duration of 4 – 6 hrs was physiologically essential, and that any additional sleep was optional and reflected residual capacity.
  - An individual could adapt to a reduced amount of sleep with few neurobehavioral consequences.
- These claims have subsequently been shown to be incorrect.

### *Physiological Sleep Propensity During Sleep Restriction*

- Tendency to fall asleep is among the most well validated measures of sleepiness. It is based on the assumption that sleepiness is a physiologic need state that leads to an increased tendency to fall asleep, and It is operationalized as the speed of falling asleep in both sleep-conducive and non-conductive conditions.
- Effects of chronic sleep restriction on daytime physiological sleep propensity have been evaluated using the multiple sleep latency test (MLST) and the maintenance of wakefulness test (MWT).
  - Subjects instructed to close eyes and try to fall asleep while lying in a supine position for 20 minute periods, two hours apart, four to five times throughout the day while polysomnography<sup>m</sup> recordings (PSG) were made. (MLST)
  - Same procedure repeated, but with subjects in an upright position. (MWT)
  - Persons reporting >7.5 hrs of sleep had significantly less probability of falling asleep that those reporting between 6.75 to 7.5 hrs per night (27% risk).
  - Persons reporting <6.75 hrs of sleep per night had a much higher probability of falling asleep (73%).
- Sleep loss has also been found to affect oculomotor responses. Eyelid closure and slow rolling eye movements are part of the initial transition from wake to drowsiness and light sleep (stage 1 sleep).

### *Effects of Sleep Reduction on Behavioral Alertness and Cognitive Performance*

- Performance on psychomotor vigilance tasks requiring vigilant attention is very sensitive to sleep loss in general and sleep restriction in particular.
- It has been hypothesized that lapses in attention produced by sleep loss may originate in sleep-initiating subcortical systems (hypothalamus, thalamus, and brainstem).

- Behavioral Alertness (as measured by psychomotor vigilance testing) deteriorated steadily across days when nightly sleep duration was between 3 and 7 hrs, with deterioration being more rapid as time allowed for sleep was reduced.
- These findings are consistent with those on the effects of sleep restriction on physiological sleep propensity.
  - Collectively they suggest there is a neurobiological integrator that either accumulates homeostatic sleep drive or the neurobiological consequence of excess wakefulness.

### *Sleep Restriction Effect on Subjective Reports of Sleepiness and Mood*

- Subjective sleepiness responses during chronic sleep restriction show a different dynamic profile than those found for total sleep deprivation.
  - Total deprivation results in immediate increases in feelings of sleepiness, fatigue, and cognitive confusion, with concomitant decreases in vigor and alertness
  - Chronic sleep restriction yields much smaller in these psychometric ratings of internal state. Thus, ratings of sleepiness repeatedly made by subjects (with <8 hrs sleep) did not parallel performance deficits. As a result, after 1 – 2 weeks of sleep restriction, subjects were markedly impaired and less alert, but rated themselves subjectively as only moderately sleepy.
- This suggests a frequent underestimation of the cognitive impact of sleep restriction and overestimation of performance readiness when sleep restricted.

### *Physiological Consequences of Sleep Restriction*

- Relatively long (>8 hrs of sleep per day) and relatively short sleepers (<7 hrs sleep per day) have increased risks of all-cause mortality.

### *Endocrine Responses*

- Comparison of sleep restriction (4hrs/night for 6 nights) to sleep extension (12 hrs/night for 6 nights) in healthy young adults revealed an elevation in evening cortisol<sup>n</sup>, increased sympathetic activation<sup>o</sup>, decreased thyrotropin<sup>p</sup> activity, and decreased glucose tolerance in the restricted versus extended sleep condition.
- Extended sleep restriction (10 days) corresponded to shifts in morning peak cortisol so that the relationship between sleep termination and cortisol acrophase<sup>q</sup> was maintained. In the same protocol, there was a significant delay in melatonin onset and the timing of the peak in growth hormone was found.
- Restricted sleep also corresponded to a decrease in leptin<sup>r</sup> levels and an increase in ghrelin<sup>s</sup> levels, similar to the effects reported for total sleep deprivation. This in turn increases the possibility of a causal relationship between sleep restriction/deprivation and obesity.

- This conclusion has also been suggested by the findings of a large longitudinal study (n = 1,024) of sleep disorders.
  - Participants underwent nocturnal polysomnography and reported sleep habits through questionnaires and sleep diaries. Blood samples were taken in the morning (before consumption of food).
  - A positive correlation existed between sleep restricted/deprived and increased BMI. Short sleep was associated with low leptin and high ghrelin independent of BMI.

### *Cardiovascular Responses*

- An increase in cardiovascular events and cardiovascular morbidity associated with reduced sleep durations has been reported in a number of epidemiological studies and in a case-control study examining insufficient sleep due to work demands.
- A study of nurse's health showed an increase risk in coronary events for female subjects obtaining  $\leq 7$  hrs of sleep per compared to those averaging 8 hrs.
- Another study found a 2 – 3 –fold increase in risk of cardiovascular events for subjects with an average sleep duration of  $\leq 5$  hrs per night (or chronically having  $< 5$  hrs of sleep per night at least twice per week). Similar findings were observed in studies examining cardiovascular health in shift workers.

### *Concluding Remarks*

- Restrictive sleep time – particularly when chronic, can cause significant and cumulative neurobehavioral deficits and physiological changes, some of which may account for epidemiological findings that reduced sleep durations are associated with the following:
  - Obesity
  - Cardiovascular Morbidity
  - Traffic Accidents
  - Death
- Recent careful controlled experiments in healthy adults revealed that as sleep was restricted to less than  $< 7$  hrs per night, significant daytime cognitive dysfunction accumulated as a restriction continued to levels comparable to those found after severe acute total sleep deprivation.
- These studies strongly suggest the existence of a neurobiological integrator in the that instantiates either the need for sleep across days or the accumulation of excess wakefulness.
- Studies also show high individual variability in cognitive vulnerabilities to sleep restriction, which suggest a trait-like (possible genetic) basis for the response.
- Research also demonstrates that experimentally induced chronic sleep restriction results in several adverse physiologic consequences, including:
  - Reduced Glucose Tolerance
  - Increased Blood Pressure

- Decreased Leptin Levels
  - Increased Ghrelin Levels
  - These findings are consistent with those of self-reported sleep duration, implying that sleep restriction is associated with obesity, heart disease, and mortality.
- Current research on the effects of sleep restriction on neurobehavioral and physiological functioning suggest that adequate sleep duration (7 – 8 hrs per night) is vital.

## CITATIONS

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## APPENDIX

- a. CMRglu (Cerebral Metabolic Rate for Glucose utilization) – Glucose is used to fuel brain cells, but neurons cannot store glucose. Brain cells depend on the bloodstream to deliver a constant supply of fuel. These cells require two times more energy than other since they are always in a state of metabolic activity. A lack of glucose affects the ability to think and remember.
- b. %SREM – Percentage of total sleep time spent in the Rapid Eye Movement stage. 20 – 25% of sleep time is spent in Stage REM. Breathing rate increases, as well as heart rate and blood pressure. Eyes move rapidly and muscles become immobile. This is also the stage of sleep in which dreaming occurs.
- c. %S2 – Percentage of total sleep time spent in the 2<sup>nd</sup> stage. 45 – 55% of sleep time is spent in Stage 2. Breathing rate and hear rate slows down, and body temperature decreases slightly. Brain waves become slower, but there are also brief bursts of rapid brain activity known as sleep spindles.
- d. Long Duration Variable Foreperiod Simple Reaction Time – Foreperiod corresponds to the time interval between a warning signal and the presentation of a stimulus to which the subject is to respond. Duration and predictability of the foreperiod greatly influences reaction time.
- e. dBA – Decibels (dB, named after Alexander Graham Bell) are a logarithmic method of measuring sound intensity as a function of the threshold of human hearing ( $I_0 = 10^{-12} \frac{\text{watts}}{\text{m}^2}$  for intensity, corresponds to a sound pressure of  $P_0 = 2 * 10^{-12} Pa$ ). A sound that is  $10^4$  times more intense  $I_0$  is recorded as 40 dB. The most common sound level filter is the A filter, which is less sensitive to very high and very low frequencies. Measurements on this scale are expressed as dbA.
- f. Pink Noise – Pink noise is a sound signal with a frequency spectrum such that the power spectral density is inversely proportional to the frequency. Each octave carries an equal amount of noise power. Pink noise gets its name from the pink appearance of visible light that has the same power spectrum. This is different from white noise, which is characterized by a frequency spectrum with a power spectral density that is proportional to the frequency. In white noise, every frequency carries an equal amount of noise power.
- g. Trait Hostility – How likely a person is to react in an emotionally charged (not always violent) way as a function of predisposition. For someone with high trait hostility, they are likely to react in a hostile manner in a wide range of scenarios because that is the natural method of reaction. Likewise, someone with low trait hostility is generally well mannered and more likely to react with hostility in isolated circumstances due to external factors.
- h. Hostile Attribution Bias – The tendency for an individual to believe antagonistic behaviors of others are expressly directed at the self.

- i. RNA –Stands for ribonucleic acid, which is a family of large biological molecules that perform vital roles in the coding, decoding, regulation, and expression of genes. RNA is one of the three macromolecules essential for life.
- j. Transcriptome – Set of all RNA molecules, including mRNA, rRNA, tRNA, and other non-coding RNA produced in one cell or a population of cells.
- k. Circadian – Processes are described as circadian if they exhibit a periodicity of 24 hrs.
- l. Melatonin Rhythm – Melatonin is a naturally occurring compound which is produced by the pineal gland in humans. Melatonin signals help regulate the sleep-wake cycle by chemically causing drowsiness and lowering the body temperature.
- m. Polysomnography – A multi-parametric test used in the study of sleep and as a diagnostic tool in sleep medicine. This test makes use of other tools such as the electroencephalograph (EEG), electrooculography (EOG), and electromyography (EMG).
- n. Cortisol – Also known as hydrocortisone, cortisol is a steroid hormone produced in the adrenal cortex as a response to stress. Its primary functions are to increase blood sugar, suppress the immune system, and aid in fat, protein, and carbohydrate metabolism. It also decreases bone formation.
- o. Sympathetic Activation – Generally occurs in reaction to stress to trigger the sympathico-adrenal response, more commonly known as the “fight or flight response.” It acts primarily on the cardiovascular system to accelerate heart rhythm and raise blood pressure, though it also decreases the movements of the intestine and widens bronchial passages.
- p. Thyrotropin – A thyroid-stimulating hormone that stimulates the metabolism of almost every tissue in the body.
- q. Acrophase – The time period in a cycle during which the cycle peaks, used especially when in reference to the local maximum of a sine wave fitted to a circadian pattern or other biological rhythm.
- r. Leptin – A protein hormone produced in adipose tissue which suppresses appetite.
- s. Ghrelin – A peptide hormone secreted in the stomach that increases appetite.